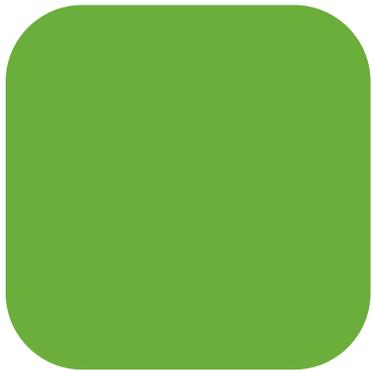
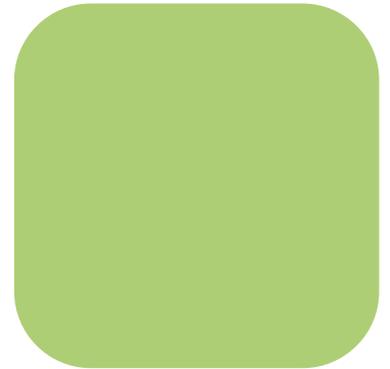




Department of Natural and Environmental Resources
Commonwealth of Puerto Rico



Puerto Rico Forest Action Plan



Puerto Rico Forest Action Plan



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Under direction provided on February 6, 2015 by a joint Memorandum from the Deputy Chief of State and Private Forestry of the United States Forest Service, James E. Hubbard and National Association of State Foresters President James Karels titled *State Forest Action Plan- Five-Year Review and Future Updates*, state forestry agencies were required to prepare a new National Priorities Section to be added to existing State Forest Action Plans. State Forest Action Plans were originally completed in 2010 and they were formerly known as *State Assessment and Strategies for Forest Resources*. The purpose of adding this new section to State Forest Action Plans is to grant states and territories with flexibility to describe actions and success stories contributing to three (3) National Priorities identified in the 2008 Farm Bill:

- Conserve and Manage Working Forest Landscapes for Multiple Values and Uses
- Protect Forests from Threats
- Enhance Public Benefits from Trees and Forests

The Memorandum provided for the new section to be incorporated into the State Forest Action Plan as a new section or as a separate addendum (section of new material that is added after the first edition or first printing of a book) to the document. The Department of Natural and Environmental Resources, through funding provided by a grant from the USFS, hired Estudios Técnicos to complete this new section, which constitutes Addendum 1 and is placed at end of this new edition.

Under the aforementioned Memorandum, state forestry agencies were also compelled to either review or update their existing State Forest Action Plans at this time if significant changes such as changes in priority areas, re-writes of complete sections or the addition of new strategies were needed, although State Forest Action Plan updates are required at least every ten (10) years. In the case of the Puerto Rico Forest Action Plan, a full revision was conducted at this five (5) year mark.

We want to gratefully acknowledge those that have contributed to this final edition of the Puerto Rico Forest Action Plan. Once again the efforts of our collaborators have resulted in a comprehensive, forward- looking strategy to keep Puerto Rico's forests as healthy natural resources and thriving into the future. As we previously recognized those whose help was instrumental in our first edition of the Puerto Rico Forest Action, we want to distinguish those whose contribution was vital to this present edition:

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Acronyms

AFP (Auxiliary Forests Program)

CCP (Centro para la Conservación del Paisaje)

CFP (Community Forest and Open Space Conservation Program)

CRP (Conservation Reserve Program)

CSP (Conservation Stewardship Program)

CWA's (Critical Wildlife Areas)

CRMCP (Coral Reef Management and Conservation Program)

CSCOR (Center for Sponsored Coastal Ocean Research)

DBH (Diameter Breast Height)

DNER (Department of Natural and Environmental Resources)

DNERFSB (Department of Natural and Environmental Resources Forest Service Bureau)

EPA (Environmental Protection Agency)

EQIP (Environmental Quality Incentives Program)

FEMA (Federal Emergency Management Agency)

FIA (Forest Inventory Analysis)

FLAP (Forest Landscape Analysis Project)

FLP (Forest Legacy Program)

FSP (Forest Stewardship Program)

HFRP (Healthy Forests Reserve Program)

IPCC (Intergovernmental Panel on Climate Change)

IUCN (International Union for the Conservation of Nature)

NASF (National Association of State Foresters)

NGO's (Non-Governmental Organizations)

NOAA (National Oceanic and Atmospheric Administration)

NRCS (Natural Resources Conservation Service)

PFW (Partners for Fish and Wildlife)

PR (Puerto Rico)

PRCCC (Puerto Rico Climate Change Council)

PR-GAP (Puerto Rico Gap Analysis Program)

PRFD (Puerto Rico Fire Department)

PRIDCO (Puerto Rico Industrial Development Company)

PRSWAP (Puerto Rico Sate Wildlife Action Plan)

RCPP (Regional Conservation Partnership Program)

SFLA (Southern Forest Land Assessment)

S&PF (State and Private Forestry)

U&CF (Urban and Community Forestry)

UNEP (United Nations Environmental Program)

UPR (University of Puerto Rico)

USA (United States of America)

USFS (United States Forest Service)

USDA (United States Department of Agriculture)

USFWS (United States Fish and Wildlife Service)

I. INTRODUCTION

In 2008 the Congress of the United States of America (USA) enacted the Food, Conservation, and Energy Act (2008 Farm Bill), which amended the Cooperative Forestry Assistance Act of 1978 to require each State and Territory to provide a Statewide Assessment of Forest Resources and a Statewide Forest Resources Strategy to the Secretary of Agriculture. These reports are a prerequisite to participation in the United States Department of Agriculture (USDA) Forest Service cooperative technical and financial assistance programs. The existing Forest Legacy Assessment of Need was evaluated for currency and is incorporated into the document in its entirety (Appendix A).

The Farm Bill established national goals for forest conservation. Statewide strategies are expected to contribute to the national goals. Each year state and territorial requests for program funding will be evaluated against their contribution to progress on these national goals:

1. **Conserve working forest landscapes**- conserve and manage the functional areas of the forest for multiple uses and values.
2. **Protect forests from harm** - identify, manage and reduce threats to the forest, such as storms, floods, insects, diseases, invasive species and fire.
3. **Enhance benefits from trees and forests** - implement conservation and management actions that contribute to the continuous enjoyment of benefits such as air and water quality, soil conservation, biodiversity, carbon storage, maintain and promote the economic benefits of forest through planned use of forest products, and renewable energy production, and others.

Requirements of the statewide assessment are as follows:

1. describe forest conditions on all ownerships in the state or territory;
2. identify forest-related benefits and services;
3. identify threats to the forest resources;
4. highlight issues and trends of concern;
5. delineate high priority forest landscapes.

The strategic component will ensure United States Forest Service (USFS) cooperative programs can provide an efficient and effective allocation of resources to meet the national goals. It considers other plans such as the Comprehensive Wildlife Conservation Strategy in order to maximize the leverage of information and implementation resources among agencies, organizations, and individual stakeholders.

II. PUERTO RICO STATE-WIDE ASSESSMENT

a. CURRENT CONDITIONS AND BENEFITS OF FORESTS

i. Current Conditions

1. Geography

Puerto Rico (PR) is an unincorporated territory of the USA since 1898. Population is estimated at 3.5 million people (U.S. Census Bureau 2015). The capital and largest city, San Juan, is home to over 400,000 people. Puerto Rico is part of the Antillean archipelago (Figure 1) located between the Caribbean Sea and the Atlantic Ocean and consists of the main island of Puerto Rico and a variety of keys and islands such as Culebra and Vieques to the east, and Mona, Monito and Desecheo to the west (Figure 2). The main and largest island is about one hundred and sixty km (160 km) long, sixty km (60 km) wide, and approximately nine thousand square km (9,000 km²) of land area.

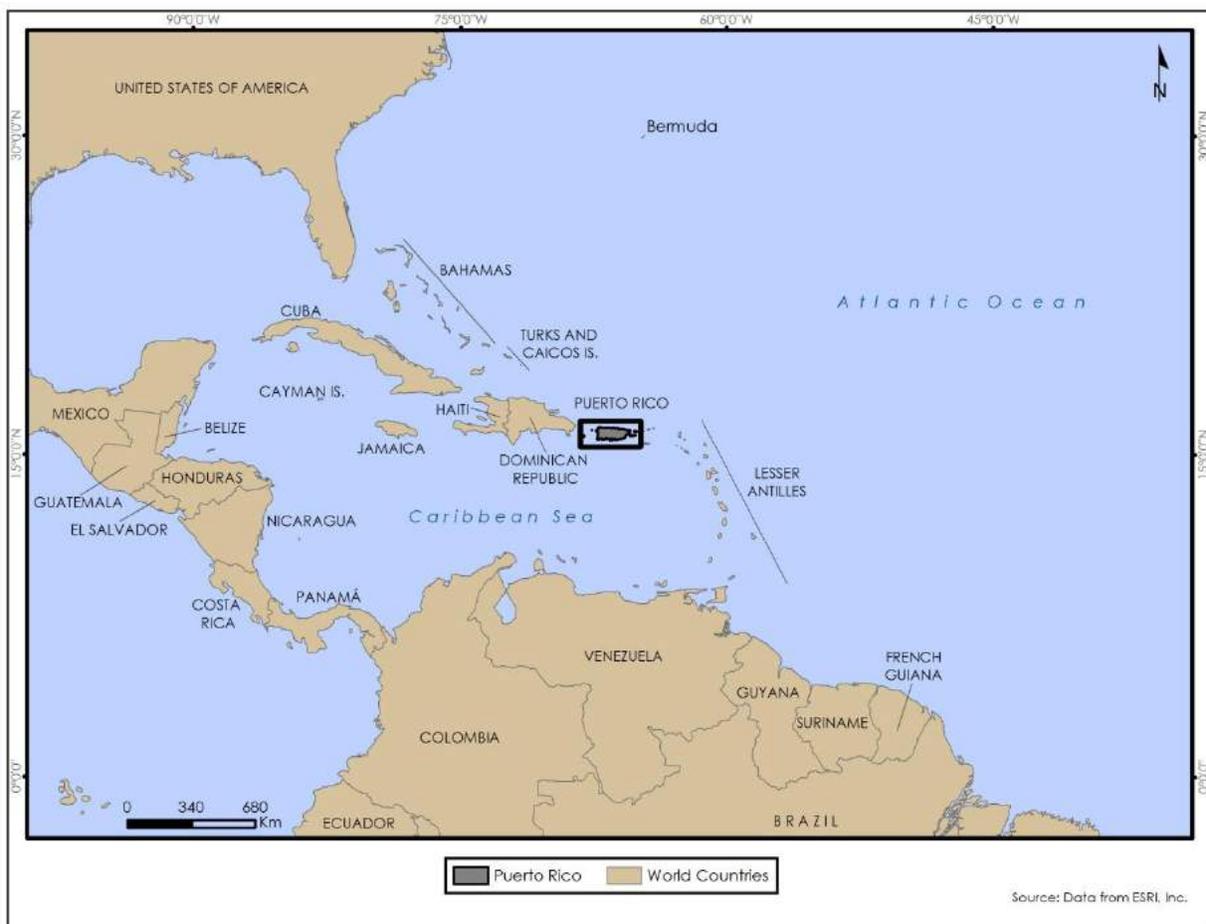


Figure 1. Location of Puerto Rico

Puerto Rico, centered at 18° 15' north, 66° 30' west has wide variations in elevation, climate zones and soil types. The geographical regions and its geological primary substrates are divided into: Coastal Plains, Limestone Regions, and the Mountainous Interior that is composed of three main volcanic ranges; and the Plutonic batholiths and

associated ranges. Fifty-three percent (53%) of the island is mountainous, twenty-five percent (25%) is plains, twenty percent (20%) is hilly, one percent (1%) is plateaus, and one percent (1%) is composed of rivers, lakes and reservoirs.



Figure 2. Puerto Rico and main islands.

2. Land use and land cover

According to Gould et al. (2008) land cover in Puerto Rico today consists of 53% forest, woodland and shrub land vegetation; 32% dry and wet grasslands and pasture; 3% herbaceous agriculture, 4% saline and freshwater wetlands, 1% barren land, 1% fresh water, and 10% developed land. The history of land use is typical of most Caribbean islands.

Puerto Rico was almost completely forested for centuries, if not millennia. The area was originally inhabited by the indigenous Taíno people. The influence that indigenous peoples had on the landscape is now believed to be much greater than previously assumed, but is still understood to be limited to alteration of tree species composition in the forest rather than changes in the extent of forest cover (Mann 2006).

Christopher Columbus first visited the Island in 1493 and Spain ruled the island for four centuries. As a colony of Spain, the economy was initially based on extraction of timber and gold, but eventually moved into organized and widespread land clearing and drainage for agriculture. Forest cover dropped precipitously from roughly 65% in 1828 to 20% by 1899 (Wadsworth 1950). Mangroves were drained and filled for agriculture and other uses.

The land use pattern during these several centuries of agricultural development was similar to that of other tropical countries. The lowlands were used more intensively as cropland for sugarcane while the uplands were used less intensively to produce products such as shade-grown coffee. Land distant from population centers or possessing steep slopes or lower quality soils were used for shorter time periods and less intensively (Mather 1992). Population increases were accompanied by deforestation (Mather and Needle 1998). In the early 1990's, at the height of agricultural production, forest cover was as low

as 6% (Birdsey and Weaver 1987). By 1940 a 45% reduction in mangrove forest was observed (Martinuzzi et al. 2009).

Puerto Rico became part of the United States in 1898 as a result of the Spanish-American war. The island retained a land-intensive agricultural economy until after World War II when wide-spread industrialization began under a program called Operation Bootstrap. Industrialization precipitated a migration of population to urban centers as did the simultaneous abandonment of agricultural land. The result was an island-wide regeneration of secondary forests, starting in the lowest-quality agricultural sites (Grau et al. 2003).

The most recent estimates of forest cover on mainland Puerto Rico are shown in Figure 3. Forest cover remained relatively constant between the 1980 and 1990 inventories and then increased dramatically between the 1990 and 2003 inventories from 32 to 57% (Birdsey and Weaver 1982, Franco et al. 1997, Brandeis et al. 2007). A 25% increase is substantial even after a portion of this increase is attributed to changes in inventory methods and definitions. However, from 2004 to 2009 the change was of a 1.9% increase, suggesting that the rate of forest cover increase on mainland Puerto Rico has slowed since the forest inventory began in 1980 (Brandeis and Turner 2013). Forestland is defined in the 2013 inventory as any area that is at least ten percent (10%) stocked by forest trees of any size, and is not currently developed for a nonforest use. This is, intentionally, a more encompassing definition of forest than used previously. It is intended to capture forests developing on old farm fields and pastures. Forest covered 74 percent of Vieques, and 90 percent of Culebra (Brandeis and Turner 2013). The spatial distribution of forest cover is shown in Figure 4.



Figure 3. Forest area of mainland Puerto Rico as measured by forest inventories in 1980, 1985, 1990, 2004, and 2009 (Brandeis and Turner 2013)



Figure 4. Forest cover in Puerto Rico, Vieques, Culebra, and Mona Island (Gould et al. 2008)

3. Forest composition, structure and function

The Holdridge life zone model is used to facilitate comparisons of ecological information around the world (Holdridge 1967). Life zones are broad bioclimatic units of land that can be further subdivided into associations based on the combination of soils, vegetation, and microclimates within them. There are six Subtropical Holdridge Life Zones present in Puerto Rico (Figure 5) (Ewell and Whitmore 1973). At 62%, the Subtropical moist forest life zone contains the most land in mainland Puerto Rico. (Brandeis et al. 2007). The Lower montane wet forest and the Lower montane rain forest zones combined are only slightly over 1%. Land area in the dry forest zone is almost 14%, and the combined wet forest and rain forest zones account for about 23%.

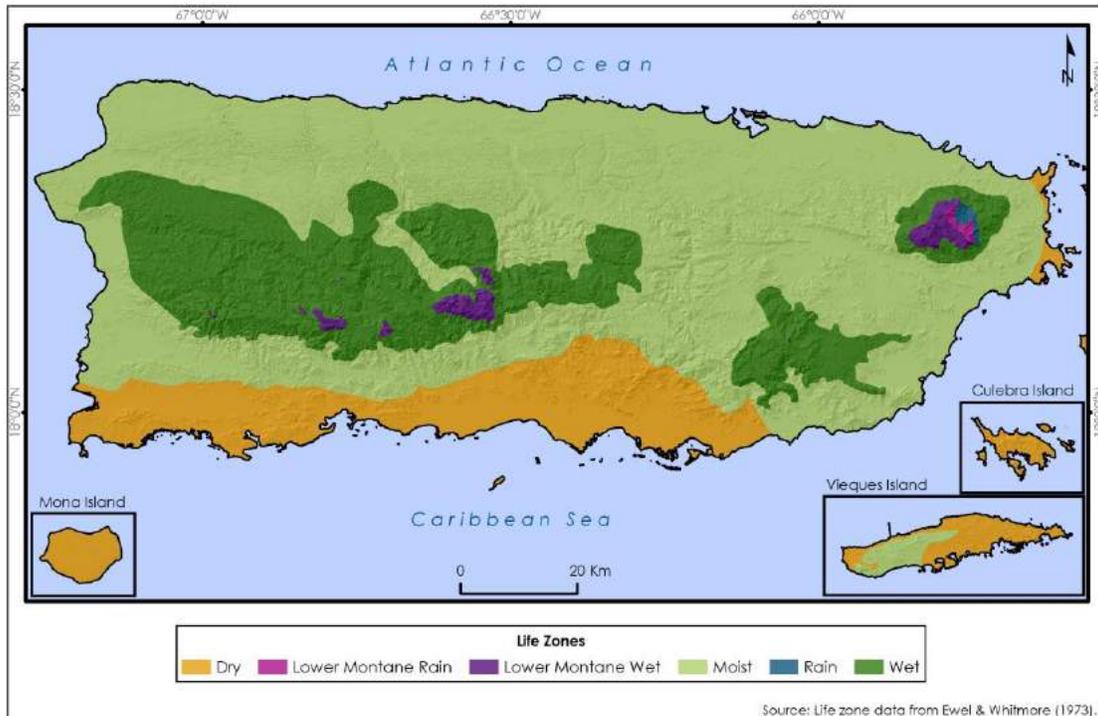


Figure 5. Land distribution among the Subtropical forest life zones of Puerto Rico, Vieques, Culebra, and Mona Islans (Brandeis et al. 2007)

Forest species predominate in “forest” life zones. However other classes of species, human activities, barren landscapes, and natural disturbances can lead to less than complete forest cover with a zone. Figure 6 depicts the percent of forested acres by stand-size class and forest-type group (Brandeis and Turner 2013). Small diameter stands predominate in the subtropical dry forests while lower montane wet and rain forests are principally made-up of larger diameter stands (Brandeis and Turner 2013), but as indicated in Figure 5 above, both lower montane wet and rain forests have the smallest land areas. The moist and dry forest zones together account for three quarters of the land area in Puerto Rico, but each has less than 50% of larger diameter stands in their forest cover.

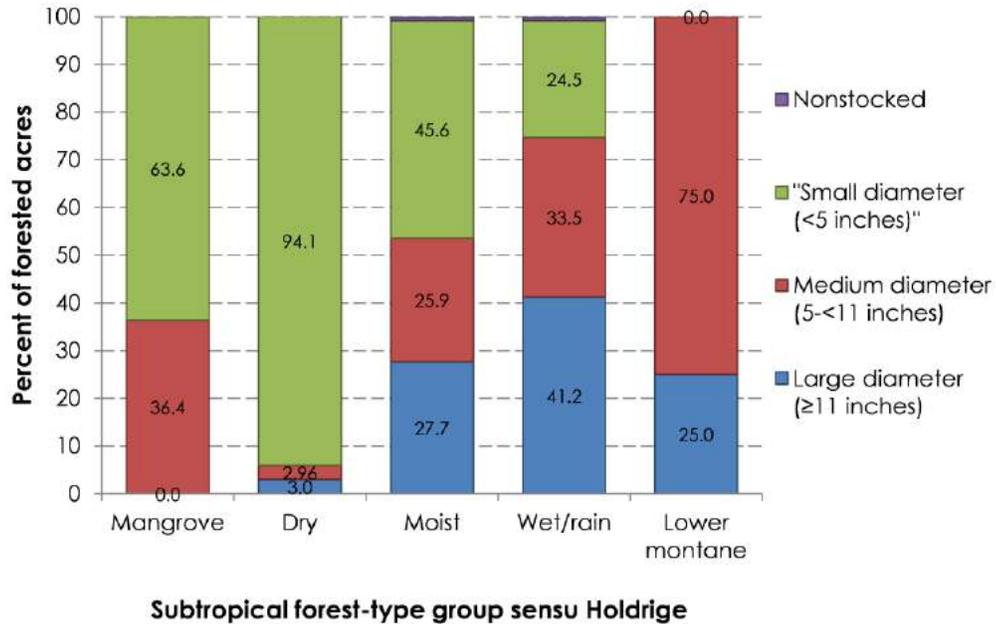


Figure 6. Percent of forested acres by stand-size class and forest-type group, Puerto Rico, 2009 (Brandeis and Turner 2013)

Succession is a natural ecological process in which one plant community replaces another over an extended period of time. Secondary succession is the re-establishment of the same or a different plant community in an area where a (natural or man-made) disturbance has occurred. The term “secondary forest” is derived from this concept of succession. Information on stocking, and canopy closure in Puerto Rico shows a predominance of secondary forests with early and mid-successional tree species that are not stocked to their full potential (Brandeis et al. 2007). An estimated 68% of Puerto Rico is in young secondary forest, 12% is in mature forest; and land reverting to forest accounts for 18% of total forest cover. Subtropical moist forest had the most land in the reversion category. The lower montane group had no reverting forest; the wet and rain forest had 30.4%; and dry forest had 12.5%.

Brandeis and Turner (2013) collected size class information data on stands with at least 10% stocking by live trees. Small diameter stands were made-up of trees with a diameter breast height (d.b.h) <5.0 inches, medium diameter stands had trees mostly 5-10 inches d.b.h., and and large diameter stands were those with trees predominately ≥11.0 inches d.b.h, nonstocked stands were those that had <10 percent tree cover (Brandeis and Turner 2013). When comparing the 2004 and 2009 data we see that there have been minor changes in the distribution of stand sizes, with a slight tendency toward increasingly larger diameter stands (Figure 7). Slow growth is common in stressful environments so a given species growing at high elevations, on barren land, or in drought prone areas does not accumulate girth as rapidly as the same species in more hospitable environments.

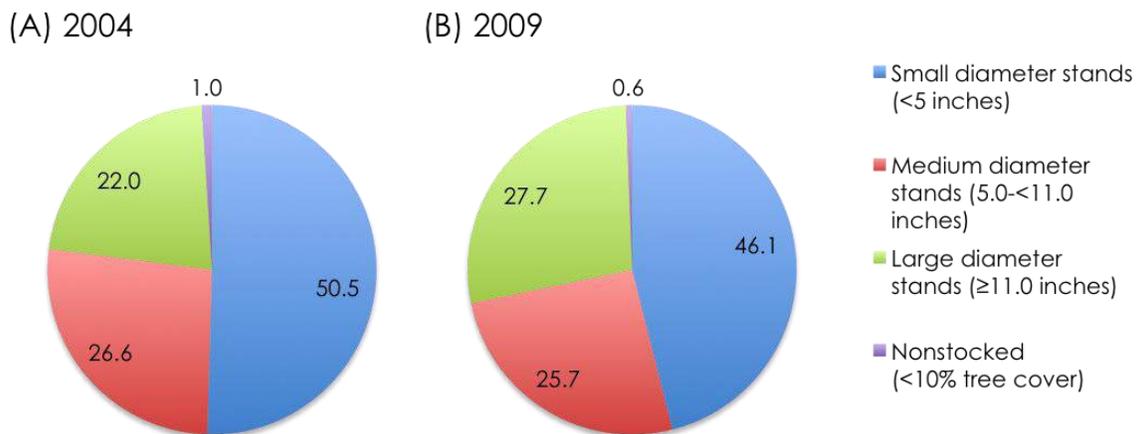


Figure 7. Percentage of stand-size class distribution, Puerto Rico, (A) 2004 and (B) 2009 (percentages may not sum to 100 due to rounding). (Brandeis and Turner 2013)

Plant species composition, dominance and importance in today's regenerating forests are different from forests that were present before the island was deforested (Lugo and Helmer 2004). A total of 298 tree species were identified among trees with d.b.h. >5 inches on the 2006-09 forest inventory (Brandeis and Turner 2013). The exotic African tulip tree (*Spathodea campanulata*) is the single most abundant tree species on the island, with the greatest measured sum total basal area (Brandeis and Turner 2013). The natives guaraguao (*Guarea guidonia*) and yagrumo (*Cecropia schreberiana*) are very common trees in Puerto Rico's subtropical wet and rain forests (Brandeis and Turner 2013).

The mixes of native and non-native naturalized species are creating novel plant and animal communities. Many of today's forests are far from maturity, so definitive successional pathways, and the ultimate composition and structure of future forests is conjecture. We are gathering evidence that these novel forests provide public benefits. They support wildlife, mitigate species extinctions, and provide natural functions such as soil stabilization, temperature regulation, nutrient transformation, and water and carbon cycling (Lugo 2004). For example, the African tulip tree is a pioneer species that colonizes abandoned lands and facilitates the establishment of native tree species under its canopy (Lugo and Helmer 2004; Brandeis 2006).

There is no field inventory of forest vegetation communities in Puerto Rico but some general taxonomic principles are informing remote sensing inventories such as the worked produced by Kennaway and Helmer (2007) in Table 1.

Table 1. Satellite image mapping zones in Puerto Rico and associated vegetation formations (Kennaway and Helmer 2007)

Satellite image mapping zone ^{1, 2}	Woody vegetation formations ²
Dry forest-Alluvial	Lowland dry semi-deciduous forest or woodland/shrubland Tidally and semi-permanently flooded evergreen sclerophyllous forest
Dry forest ³ -Volcanic, Sedimentary, Limestone	Lowland dry semi-deciduous forest or woodland/shrubland Lowland dry mixed evergreen drought-deciduous shrubland with succulents
Dry and moist forests –Serpentine	Lowland dry and moist, mixed seasonal evergreen sclerophyllous forest with succulents
Moist forest-Alluvial	Lowland moist evergreen hemi-sclerophyllous shrubland Lowland moist seasonal evergreen forest or forest/shrub Lowland moist coconut palm forest Seasonally flooded evergreen forest Tidally and semi-permanently flooded evergreen sclerophyllous forest
Moist forest-Volcanic and Sedimentary	Lowland moist seasonal evergreen forest or forest shrub Lowland moist semi deciduous forest ⁴
Moist forest with rainfall<1500 mm yr ⁻¹ Northern Limestone ⁵	Lowland moist semi-deciduous forest or forest/shrub
Moist forest with rainfall>1500 mm yr ⁻¹ - Northern Limestone ⁵	Lowland moist and wet, seasonal evergreen and semi-deciduous forest and forest/shrub

¹ Aggregated from Geoclimatic Zones in Figueroa Colón (1996), which overlay Holdridge life zone (Ewel and Whitmore 1973) onto generalized geology (Krushensky, unpubl.). Volcanic refers to intrusive/plutonic and extrusive/volcanoclastic geology.

² Forest are subtropical sensu Holdridge (1967) and broadleaf unless otherwise indicated; lowland refers to forests from 0 to 400 m elevation. Both forest/shrub and woodland/shrubland refer to stands with a) 25-60% covers of trees with distinct canopies and an under story of shrubs, seedlings, or saplings, or b) dense shrubs, seedlings or saplings, as indicated by a matrix of woody vegetation or a smooth canopy.

³ The Dry Volcanic/Sedimentary/Limestone Zone included southern limestone areas in the drier part of the moist forest zone.

⁴ Coastal areas in southeastern Puerto Rico

⁵ Northern Limestone refers to limestone areas north of the Central Cordillera with well-developed karst topography and areas at the Cordillera's southern edge.

Wet and lower montane wet forest-Serpentine	Submontane and lower montane wet evergreen sclerophyllous forest or forest/shrub ⁶
Wet and rain forest, lower montane wet and rain forest-Volcanic, Sedimentary and Alluvial	<p>Submontane wet evergreen forest</p> <p>Active sun/shad coffee, submontane/lower montane wet evergreen forest/shrub, other agriculture</p> <p>Submontane/lower montane wet evergreen forest/shrub, active/abandoned shade coffee</p> <p>Lower montane wet evergreen forest⁷-tall cloud forest</p> <p>Lower montane wet evergreen forest⁷-palm and elfin cloud forest</p> <p>Lower montane wet evergreen forest-elfin cloud forest</p>

4. Riparian forests

Riparian areas are the lands adjacent to a body of water, stream, river, marsh, or shoreline. These areas form the transition between the aquatic and the terrestrial environment. A riparian area may include several riparian ecosystems. Riparian ecosystems include the soil, surface structure (woody debris, rocks, depressions), and the plant and animal communities. Because of their position in the landscape, riparian areas interact with the flow of surface and groundwater from upland areas, and play an important role in filtering runoff, reducing excess nutrients and other pollutants, and providing critical ecological values such as shade, food, and structural habitat. Species abundance and richness tend to be greater in riparian ecosystems than in adjacent uplands (Odum 1979). Although healthy riparian vegetation of any kind is desirable, forests provide the greatest number of benefits and highest potential for reaching both water quality and living resource goals. As functional ecosystems, they have large energy, nutrient, and biotic interchanges with aquatic systems on one side and with upland terrestrial ecosystems on the other. Their linear nature and high edge-to-area ratios contribute to this functionality, which is why riparian areas are best evaluated and managed as parts of larger landscapes.

Streamside forests are important riparian areas. Under natural conditions these forests would protect most of the rivers and streams in our Nation, but deforestation associated with agricultural and urban expansion has drastically reduced their extent. In agricultural areas, many floodplain forests have been reduced to isolated fragments no longer capable of supplying the river with essential woody debris or an adequate organic food supply for healthy fisheries. The linkage between streamside forests and the health of fish stocks may stretch to ocean fisheries where the natural process of delivering

⁶ Includes forest in the rain forest zone sensu Holdridge (1967).

⁷ Includes forest in the lower montane rain forest zone sensu Holdridge (1967).

large quantities of wood from the watershed to the sea has essentially been severed (Maser and Sedell 1994).

Riparian forests can help remove or ameliorate the effects of pollutants in runoff, and increase the biological diversity and productivity of aquatic communities by improving habitat and adding to the organic food base. Riparian forests can also play a large role in buffering urban and agricultural development. When conserved and managed as buffers, riparian forests can dramatically reduce the impacts of land use activities (Welsch 1991). In fact, studies show dramatic reductions from 30 to 98 percent in nutrients, sediments, pesticides, and other pollutants in surface and groundwater after passing through a riparian forest buffer (Lowrance et al. 1984). Streamside forests are important riparian areas (Figure 8). Agricultural runoff is one type of nonpoint pollution that can be reduced by using streamside forests as buffers.

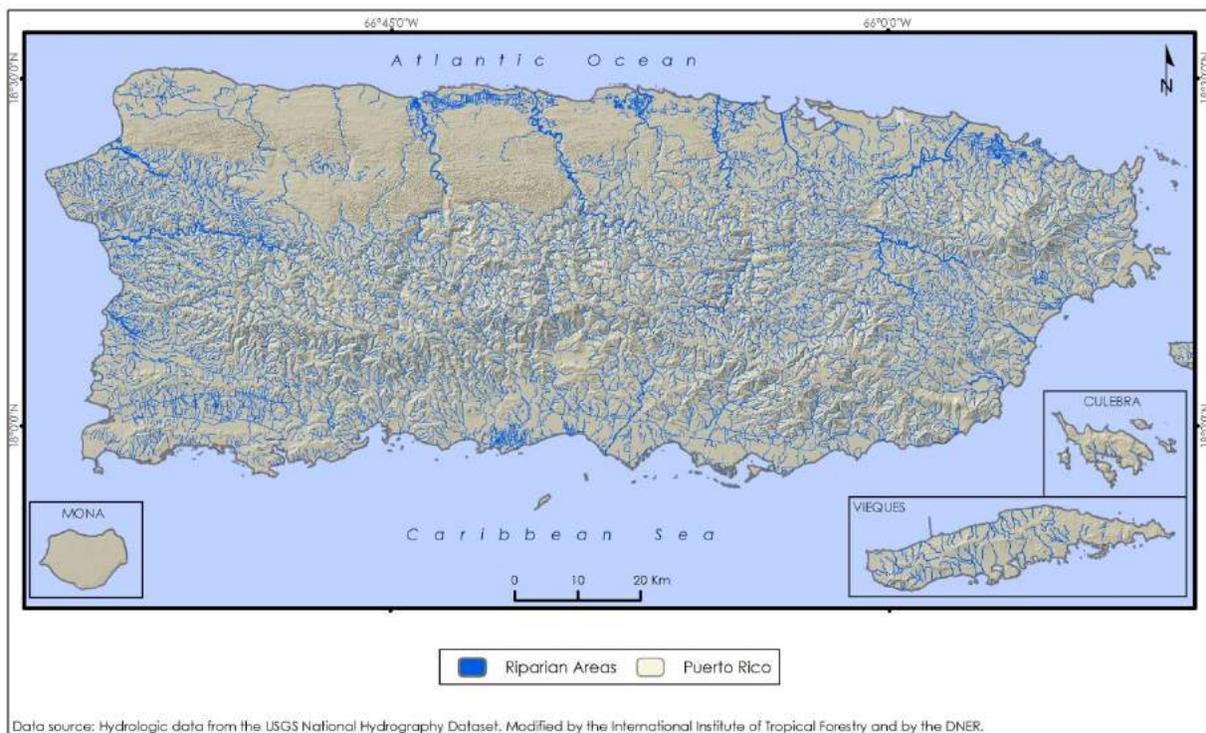


Figure 8. Overview of riparian areas in Puerto Rico, Vieques and Culebra

The presence or absence of trees adjacent to stream channels may be the single most important factor altered by humans that affects the structure and function of the stream macro-invertebrate community on which many aquatic species depend. Restoring streamside forests may be a necessary prerequisite to restoring a disturbed stream system to a natural or quasi-natural state (Sweeney 1993); however, few natural riparian zones remain to serve as models (Naiman et al. 1993).

5. Urban forests

Urban forests are forested ecosystems characterized by a high concentration of human influences (Dwyer et al. 2000). The types of trees and plant associations in urban forests vary with regional and local environmental conditions and human activities. Native, exotic and naturalized plants and animals, ground cover, buildings, and human activities affect the character and values associated with an urban forest. Vegetation within urban environments is important in providing wildlife habitat, environmental services related to water, heat control, air quality, temperature regulation, and carbon storage. They provide oxygen, shade, food, and attributes important to human well-being. Recent studies reveal the psychological benefits of trees helping people adjust to their societies (Kuo and Sullivan 2001). In addition properties and neighborhoods with well-developed tree cover are appraised higher.

Martinuzzi et al. (2007) estimated developed land, land use, and urban sprawl across the Puerto Rico landscape and explained important distinctions among urban land classification schemes (Table 2). Depending on the classification, between 11 and 50% of Puerto Rico could be called “urban”. They found that most urban areas exist on the coastal plains, lower hills, and valleys, and that urban sprawl is occurring at low elevations, over flat topography, and close to roads and existing urbanized areas.

Table 2. Definitions of urban and related classifications and the percentage of land in each class in Puerto Rico (Martinuzzi et al. 2007)

Classification	% in class	Definition
Urban/built-up cover or developed land	11%	Developed and non-vegetated surface that results from human activity (built structures, concrete, asphalt, buildings, barrens, roads, some of which occur in rural areas.)
Urban use setting	16%	Includes development and undeveloped lands that are part of the urban landscape and excludes development that is part of a non-urban setting. (Urban centers, exurban agglomerations, industrial areas, large isolated residential complexes, port, airports, parklands and urban forests)
Census Bureau Urban area	50%	Census block with a population density of at least 1000 people/ mi ² (390 people/ km ²) plus surrounding census blocks with at least 500 people/mi ² (195 people/km ²)
Urban sprawl	40%	Low-density construction and areas with significant land consumption.

Source: US Census Bureau (2010). Urban and rural classification.

Undeveloped lands in urban areas form green infrastructure in the same way that roads, water mains, electric lines, and sewers form grey infrastructure. For example,

a forest patch can provide habitat for feeding and nesting birds, while a green corridor can ease dispersal if populations become too large or recruitment if they are too small. Connecting open spaces in urban settings creates value (Pirnat 2000; Rudd et al. 2002; Melles et al. 2003). Green infrastructure connects forest and other vegetated land in settings such as wetlands, parks, farms, shorelines, cemeteries, and utility corridors. Urban forests capture significant levels of carbon and represent important economic benefits including tourism, nursery production, food production, and pharmaceuticals for research as well as some wood and non-wood products (NUCFAC2008).

Many vegetated patches in urban areas are of low quality when evaluated based on tree health, species diversity, and ecosystem processes. More data is needed on the extent, composition, health, and restoration of urban forests. Ruiz-Jaen and Aide (2005) demonstrated ecological value added from a forest restoration along a grass covered riparian area in Puerto Rico. Communications and tactical exchange of information as a best management practice is essential for tropical urban forestry viability (NUCFAC 2008).

6. Wildlife

Forest cover provides wildlife habitat to many vertebrate and invertebrate species. Individual trees are important in wildland and urban settings as they can provide reproductive, foraging and perching habitat. Wildlife interacts with and has an effect upon the ecosystem where it resides. Even dead trees have life as their tree cavities are used for nesting and downed woody debris provides habitat and substrate for a variety of species in aquatic and terrestrial settings. Closed canopies and large contiguous forest conditions are necessary for some species to maintain viable populations. Forested corridors are an important means of connecting fragmented habitat into a more unified whole.

A significant proportion of the biota in Puerto Rico are found nowhere else in the world, thus the loss of a species locally represents a reduction of the biological diversity of the planet. Gould et al. (2007) conducted an analysis of conservation status on 177 mostly native species that are regularly found on the island. Non-native species evaluated include those that affect the distribution or density of native species and those valued as game species. Of these, 18 are amphibians, 98 are birds, 14 are mammals, and 47 are reptiles. The analysis indicates that the highest levels of habitat heterogeneity and resulting biodiversity are in the coastal areas with a mix of wetlands, grassland, and forested coastal hills.

The status of many native wildlife species has yet to be documented. In 2001 the US Congress directed the development of a Comprehensive Wildlife Conservation Strategy (CWCS), which includes information on conservation of game and non-game species (DNER 2005). By the end of 2015 the Department of Natural and Environmental Resources (DNER) will publish an update of the CWCS titled Puerto Rico State Wildlife Action Plan: Ten Year Review (PRSWAP). According to the data published in the preliminary version of the PRSWAP around 5,847 native wildland species have documented occurrences in Puerto Rico (DNER 2015). Of these, 51 are reptiles (Rivero 1998), 18 amphibians (Rivero 1998), 5,573 are insects (Torres and Medina-Gaud 1998), 190 are birds (Raffaele 1989), and 15 are mammals (DNER 2015).

The law *Wildlife of Puerto Rico* (Law No. 241 of August 15, 1999) provides the legal framework that empowers the DNER to protect the wildlife resources of Puerto Rico (DNER 2005). The DNER adapted the following categories from the International Union for the Conservation of Nature Red List (1994) to classify species according to risk of extinction (DNER 2005). Table 3 presents the status of species identified at the Commonwealth level as species of priority. The list includes the species identified as federally threatened or endangered. Criteria include information on the rate of decline, population size, and geographic area. The coding “data deficient” (DD) means there is not enough information for a direct or indirect assessment of its risk of extinction based on distribution and/or population status.

Table 3. Number of species of greatest conservation by taxon included in the PRSWAP (DNER 2015)

Taxon	CR	EN	VU	DD	LR	Total
Amphibians	4	1	4	6	0	15
Birds	5	6	16	45	9	81
Reptiles	3	5	4	8	0	20
Marine Mammals	0	2	0	2	0	4
Terrestrial Mammals	0	1	5	6	1	13
Fresh Water Fishes	0	0	0	9	6	16
Salt Water Fishes	1	1	5	57	0	64
Invertebrates	3	0	13	19	8	43
Plants	32	26	3	0	0	61
Total	48	42	50	152	24	317

CR - Critically Endangered, EN - Endangered, VU - Vulnerable, LR - Low Risk, DD - Data Deficient. International Union for the Conservation of Nature (IUCN) Red List (1994).

The coastal zones in Puerto Rico make a substantial contribution to the islands terrestrial and marine biological diversity. Wetland reduction has resulted in the fragmentation of what once was an extensive and continuous coastal corridor. Wetlands in the eastern Caribbean region are small relative, rare, and severely degraded ecosystems, which make them vulnerable to destruction (Martínez et al. 1979; Lugo and Brown 1988b). Due to the land use history in Puerto Rico, most of the remaining coastal wetlands are marginal habitat for most water birds.

The coastal area is also extremely vulnerable to development and the coastal plain and coastal hills are largely unprotected. Development is prohibited in the wetlands, but development adjacent to them affects hydrologic patterns and alters species and

landscape biodiversity. Figure 9 shows coastal areas identified as Critical Wildlife Areas (CWA's). There are eighty-seven (87) CWA's in Puerto Rico identified by the PRSWAP (DNER 2015). These were delineated by identifying areas within Puerto Rico that are "necessary" to perpetuate the existence of species of special interest.

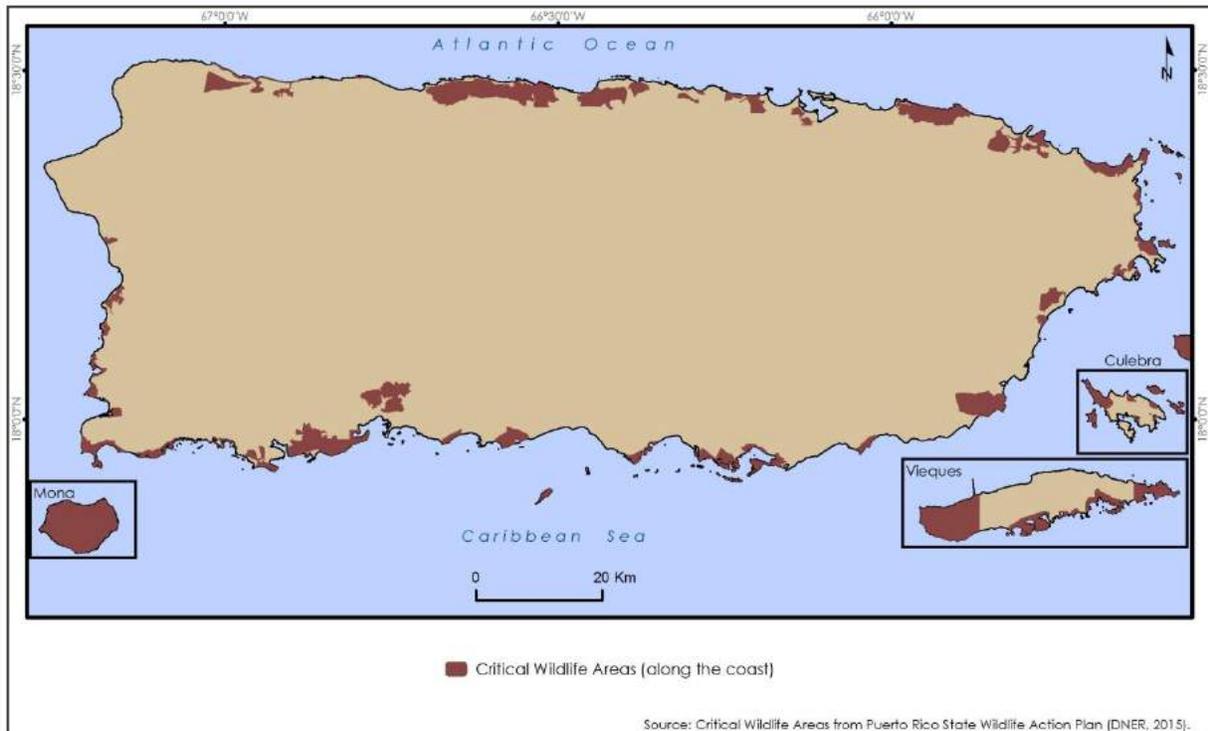


Figure 9. CWA's along the coast (DNER 2015)

To date, dense stands of invasive vegetation (e.g., *Typha dominguensis*) have developed after sugarcane production ceased in coastal plains. That densely overgrown vegetation may limit access by water birds, either for feeding or nesting (Weller and Fredrickson 1974; Kaminski et al. 1985). Puerto Rico native freshwater fish are threatened by habitat modification, pollution, and overfishing. Considerable habitat loss for freshwater fishes and invertebrates has resulted from water withdrawal from streams for domestic and industrial purposes, river channelization, and dam construction. Recent periods of severe water shortage have already highlighted the potential impact of increased water demand on fish and wildlife (Lugo et al. 2004).

7. Water resources

Water resources include the physical features, habitat, and inhabitants of aquatic ecosystems as well as the water itself. Puerto Rico has a great diversity of freshwater and salt-water resources including rivers, streams, freshwater and saltwater wetlands, estuaries, and a variety of aquifer types. There are numerous rivers and streams on mainland Puerto Rico. There are reservoirs but no freshwater inland lakes. Seventy eight percent of water in Puerto Rico comes from surface sources and 22

percent comes from groundwater sources. Fifty-five (55) rivers discharge directly into the sea.

Water resource quality is often assessed on a watershed basis. A watershed is a geographic land area within which water flows to a common point. Watersheds are bounded by ridges that catch rain and drain into a marsh, stream, lake, estuary, or groundwater aquifer. Small watersheds nest within larger watersheds or basins. Large watersheds contain a stream network. Water usually enters a watershed through precipitation and leaves as streamflow, groundwater discharge, evaporation, or transpiration. Soil, vegetation, topography, climate, land use, and wildlife are important factors that affect watershed functions, water quality, streamflow, flooding, and aquatic life. Functional catchment and drainage areas are shown in Figure 10. The area portrayed as no drainage is the northern Karst zone consists primarily of subterranean drainage.

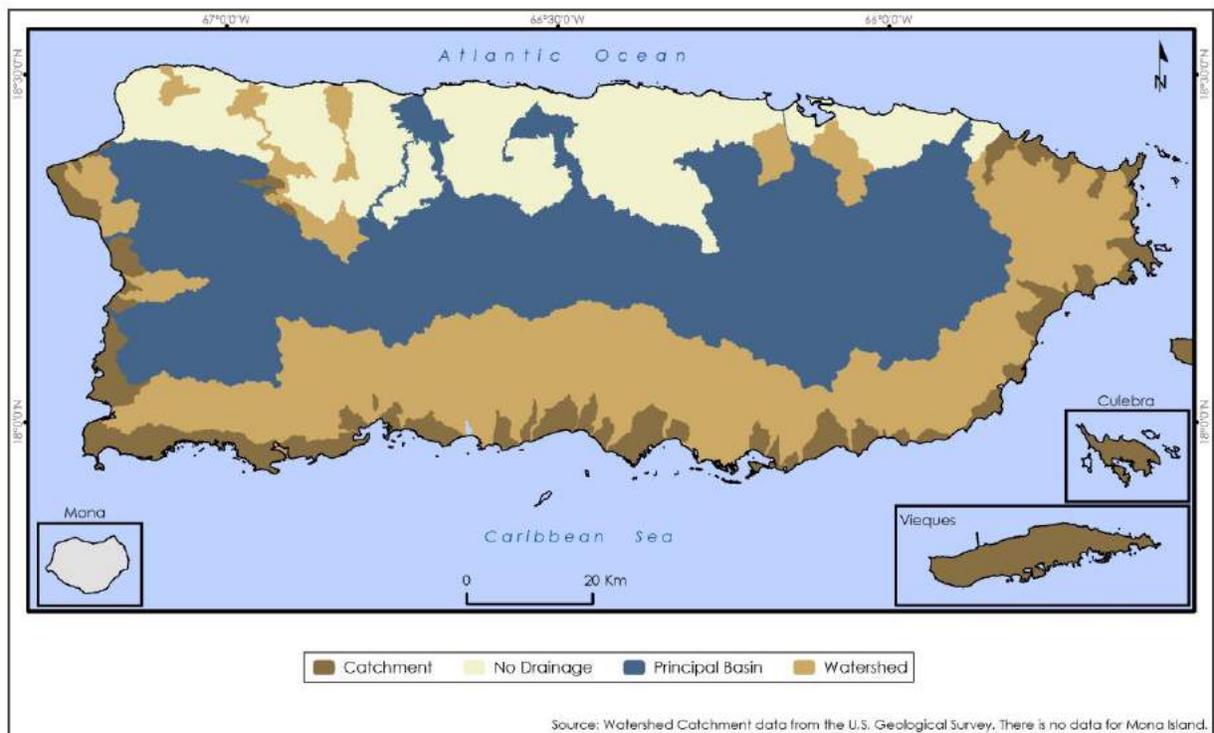


Figure 10. Surface catchment and drainage areas in Puerto Rico, Vieques, and Culebra.

Forests play an important role in the regulation of surface and groundwater flow and quality. Forested watersheds are important for storing water and providing for its long-term release and groundwater recharge. Forests help sustain watershed functions. Trees and forests help reduce stormwater runoff; filter and buffer pollutants from air and water; store water and nutrients; protect soils, floodplains, and streambanks; clean and cool air and water; protect municipal water supplies; reduce flooding; recharge groundwater aquifers; and provide critical fish habitat. Forests adjacent to bodies of water buffer the movement of pollutants from upslope land use activities and support aquatic health through regulation of temperature, additions to the food web, and provision of habitat structure. The amount, location, and management of forestland

in a watershed are important to the quantity and quality of water in streams, lakes, wetlands, and groundwater aquifers. Clean water is one of the most important forest products. Figure 11 indicates the location of water bodies relative to high medium and low priority forest areas based upon an analysis of the existing values associated with the resource through the Southern Forest Lands Assessment (SFLA) (Appendix B).

a. Surface Water Quality

In Puerto Rico, surface water quality is poor in most of the water bodies in Puerto Rico (DNER 2008-a). The main problems are nutrient pollution, suspended sediments, and the presence of fecal-origin bacteria (Figure 12). Water must be properly treated in order to be used as a potable water source. In isolated mountain areas and in protected forest reserve lands, surface water quality is not affected by high levels of these pollutants (DNER 2008-a). When it rains for a long time or the rain is intense, landslides and sedimentation are likely to occur, while bacteria and nutrient concentrations may diminish in the short term due to dilution.

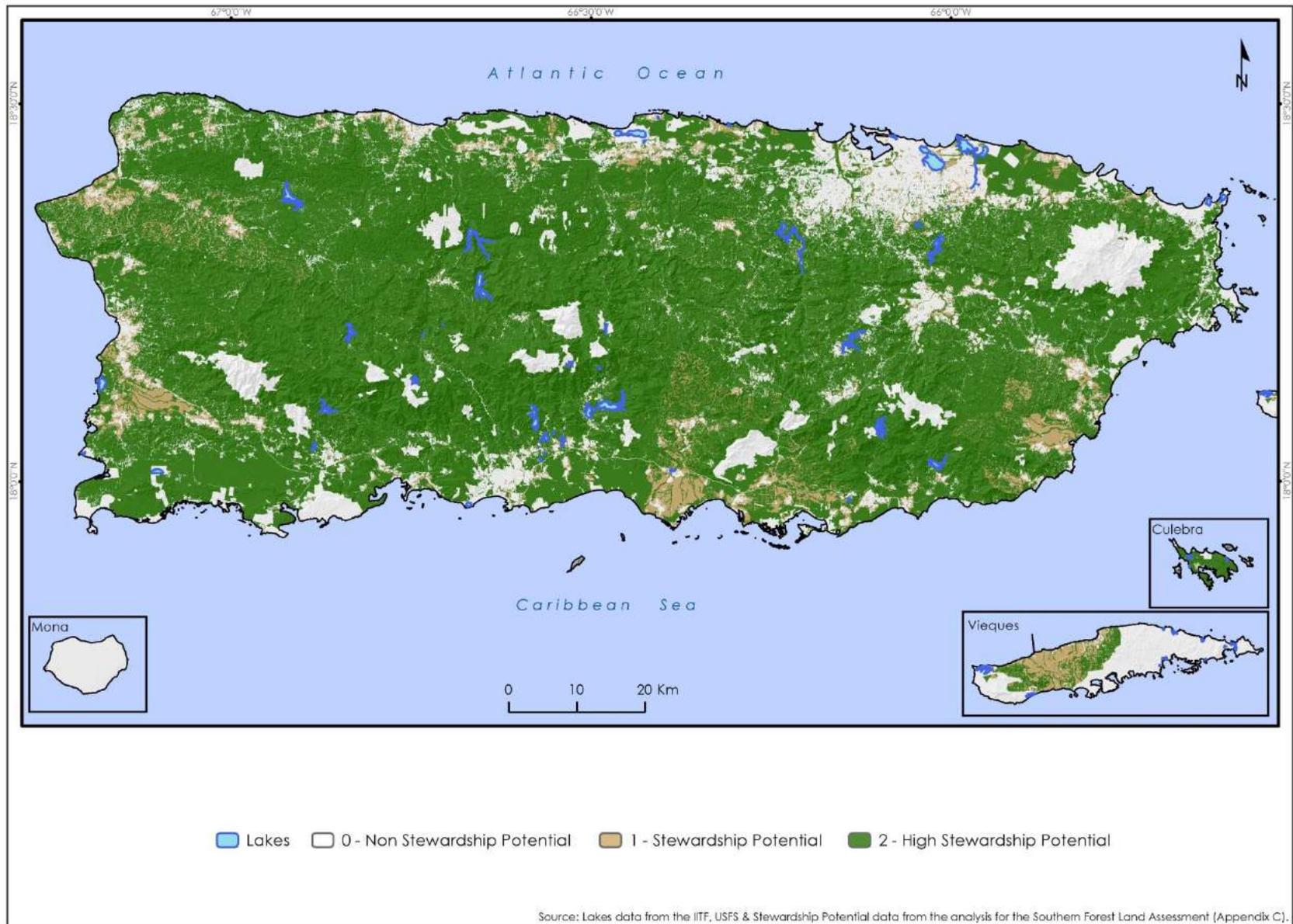


Figure 11. Water bodies in Puerto Rico, Vieques, and Culebra and their relationship to Forest Stewardship Potential.

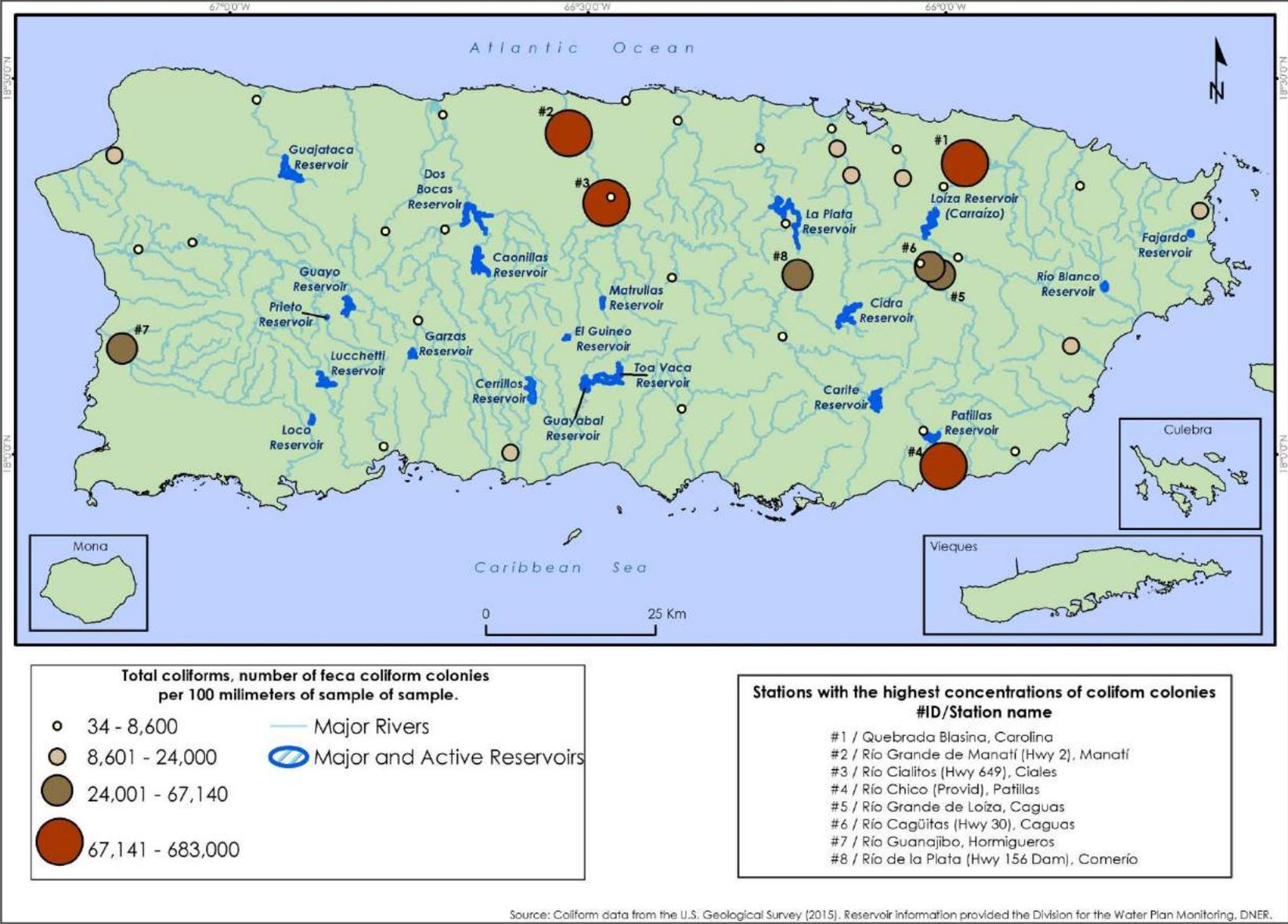


Figure 12. Concentration of fecal-origin bacteria in rivers, reservoirs, and lagoons in Puerto Rico (2015)

b. Reservoirs

There are fifteen (15) major dams providing water and electricity on the island. Figure 13 shows the associated reservoirs for these dams, which are the main surface water source in Puerto Rico (DNER 2008-a). During 2010, reservoirs provided 328.39 mgd of waters for domestic use and over 15.73 mgd for agricultural purposes. Jointly, reservoirs account for 56 percent of fresh water extraction on the island. Thus, preservation of reservoir capacity is an important management objective. The potential for loss of storage capacity in reservoirs is very real as the combination of steep soils, intense rains, and extensive land use in Puerto Rico contribute to high erosion and sedimentation rates (DNER 2008-a). Rivers transport dislodged sediments to the reservoirs. There is a large variation in sedimentation rates from one reservoir to the next. The most forested watersheds among them show significantly lower sedimentation and run-off of non-point sources of pollution (DNER 2008-a).

According to the Division for the Water Plan Monitoring at DNER, since late 2013 there has been a decrease in precipitation leading to drought. Currently, there is a rainfall deficit of twenty (20) to thirty (30) inches. So far, this drought has impacted more severely the east of the island, breaking historical record flows from mid-April of 2015 in the major rivers and reservoirs of the east such as Carraízo, La Plata, Fajardo, Blanco, and Patillas. Because it has not significantly affected the west of the island, the rivers and reservoirs of the zone such as Guajataca, Dos Bocas, and Caonillas are still in healthy conditions.



Figure 13. Overview of the reservoirs of Puerto Rico

c. Aquifers

An aquifer is a geological formation saturated with water, the volume and permeability of which is enough to sustain the extraction of a significant amount of fresh water. Puerto Rico hosts a diversity of geological formations functioning as aquifers, which can be grouped in three fundamental types: Alluvial deposits, limestone (karst), and igneous rock. Classification and location of the different aquifers in the island are presented in Figure 14.

Water in aquifers naturally comes from rainwater that initially percolates through the soils. In general, development activities increase the proportion of impermeable surfaces within a watershed. This causes an increase in the proportion of rainwater that runs directly into streams rather than infiltrating into the soil and recharging groundwater aquifers. In Puerto Rico some aquifer recharge is enhanced through manipulation. Recharge in the Karst region is slightly different, in that increases in impermeable surfaces may increase water to subterranean drainage, even though the quality of the infiltrating water is not desirable.

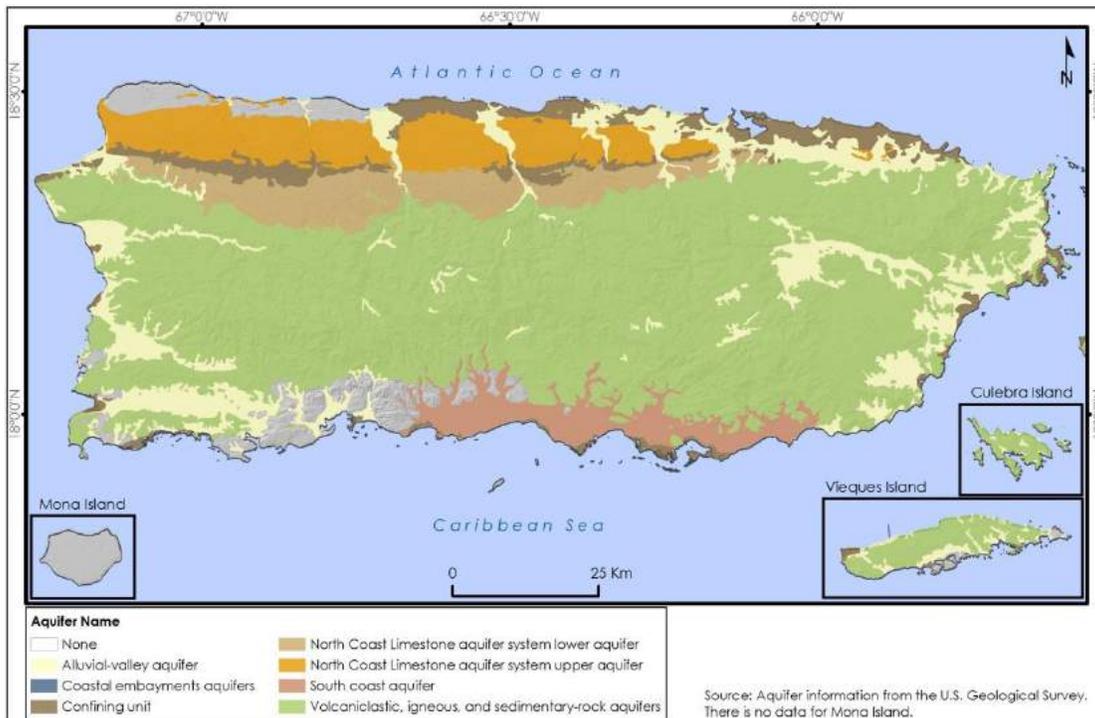


Figure 14. Classification and location of the aquifers in Puerto Rico, Vieques, and Culebra.

The main aquifers in the island include those formed of limestone and alluvium on the North Coast; the alluvial aquifers in the inland valleys of Caguas, Cayey, and Cidra; and minor aquifers in the river valleys in the west and east of the island (Figure 14). Forest cover plays an important role in areas that serve as recharge cores particularly the one on the north coast: the central north and northwest karstic region. This karstic zone must be oriented to the preservation of the lush forested areas, particularly in locations

where there are other benefits such as biological diversity protection and the potential for ecotourism development (DNER 2008-a).

8. Wetlands

Wetlands are natural areas defined by their hydrology, soil and vegetation (Cowardin et al. 1979). Wetlands have important functions and economic, social and scientific value. They help control floods, provide water and recharge areas for aquifers, feed springs, modify climate, improve water quality, maintain the salt balance needed for estuarine life, and stabilize and protect coasts. In the economic area, wetlands are a highly productive resource by being a source of food, wood, energy, aesthetics, and recreational opportunities. Wetlands influence the quality and ecological status of associated water bodies and moderate peak stream flows during storm events. They are also important nurseries for aquatic life.

The area of wetlands in Puerto Rico has decreased substantially over the past centuries. Technology factors and government incentives led to the progressive destruction of wetlands in the first decades of the twentieth century through dredging, drainage, and deposition of landfill as well as other undesirable activities. In Puerto Rico, coastal wetlands have been the most impacted. The wetlands in the East part of the Island have been impacted by tourism, urban, residential and commercial developments. Meanwhile, the Northern Area has been most at risk of losing natural wetlands as evidenced by the high incidence of mitigation requests filed through the Joint Permits Application process under the Section 404 of the Clean Water Act, and the no net loss of wetlands policy (Perez, 2003).

The perception of wetlands as a system with little value has changed in recent decades. This has led to the enactment of various laws and statutes, both local and federal. However, even with the existence of laws and regulations aimed at protecting wetlands, certain practices continue that reduce and alter these ecosystems.

Inventories of wetlands in Puerto Rico mainly cover the coastal zone (Figure 15). Through a National Oceanic and Atmospheric Administration (NOAA) initiative, in 2004 approximately 160,000 ha of benthic niches in the territorial waters of Puerto Rico were mapped. Approximately 87,578 ha of wetlands were inventoried (Table 4). It is estimated that 25% of them are found within marine protected areas (Lopez, 2007). Marine protected areas can be natural reserves, marine reserves, coastal state forests, national estuarine research reserves or seasonal fishing closures.

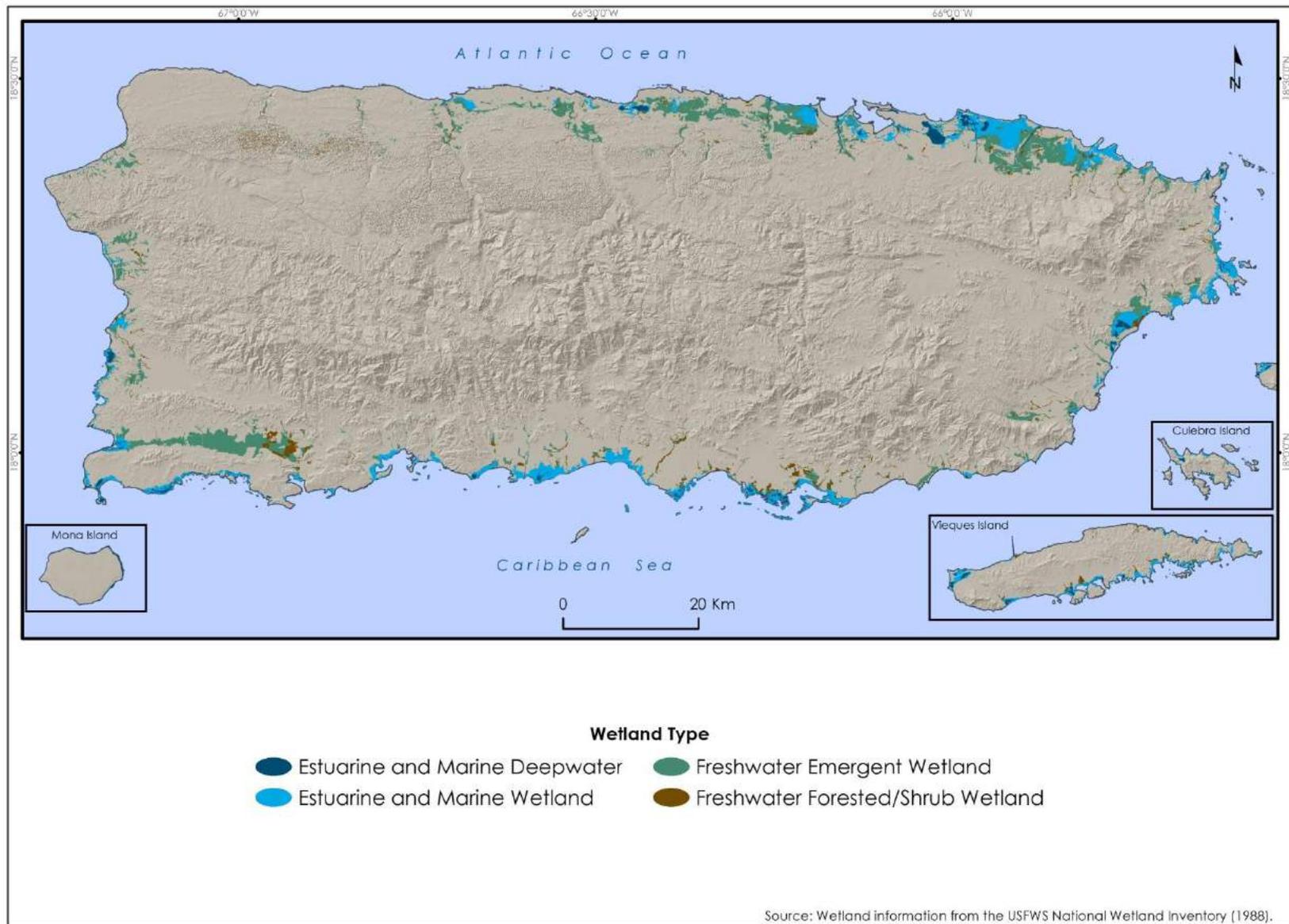


Figure 15. Overview of coastal wetlands in Puerto Rico (National Wetlands Inventory 1988)

Table 4. Area of coastal wetland types (Lopez 2007)

System	Definition	Hectares
Marine	Area exposed to sea waves and sea currents with water salinity greater than 30-35 parts per thousand (e.g. coral reefs seagrass beds).	23,642
Estuarine	Area affected by the tide with low energy waves, where the water salinity is greater than 0.5 parts per million (e.g. saltpeter beds, mangroves and coastal rivers).	31,947
Palustrine	Areas in freshwater that may be subject to the ebb and flow of tides. Persistent trees, shrubs, and herbaceous plants. Upright and entrenched, submerged and/or floating plants predominate in them. (e.g. swamps, marshes, wet meadows, shallow ponds).	31,555
Total		87,144

According to the *Puerto Rico Gap Analysis Project (PR-GAP)*, Puerto Rico has 34,000 ha (4%) of coastal wetlands, of which 42% are saline wetlands and 58% are freshwater wetlands. Among the freshwater wetlands, 74% (25,100 ha) are dominated by herbaceous vegetation and 92% (23,000 ha) are seasonally flooded. Of herbaceous wetlands, 77% (19,300 ha) are not saline and 23% (58,000 ha) are salty. Forested coastal wetlands cover approximately 1% of the Commonwealth's territory, of which 6,700 ha are mangroves and 300 ha are bloodwood swamps also known as *Pterocarpus* forests (Gould et al. 2007).

a. Mangrove forests

Mangroves are particularly important coastal forests due to the variety of functions and benefits they provide (DNER 2010). Mangroves are composed of tree species with accessory organs for respiration, which allow them to colonize wet and inundated lands. Their physiology allows them to tolerate high salinity levels. They have aerial roots, floating seeds, and specialized structures called lenticels and pneumatophores that allow the entrance of oxygen and the exit of carbon dioxide.

Mangroves are found along the coast of Puerto Rico in wetlands subject to salt-water intrusion (Figure 16). They provide many benefits such as buffering coastlines against the onslaught of wind caused by weather events; serving as wildlife refuges, fisheries, and nurseries for marine life; and they serve as sources and natural filters to purify water. These characteristics distinguish mangroves as coastal systems of high ecologic and economic value. Between 70% and 90% of marine life of commercial or recreational value uses mangroves for at least part of their respective life cycles (DNER 2003).

Mangroves are also part of the habitat for native and migratory birds, including birds that are on the federal list of endangered species.

Four (4) mangrove species are reported in Puerto Rico. These species are red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), button mangrove (*Conocarpus erectus*), and white mangrove (*Laguncularia racemosa*). In the first inventory of mangroves, mandated by the 1870 "Land Act", some 11,790 ha were counted. An inventory done in 1972 found that the mangrove population had been reduced to 7,074 ha. Two years later, in 1974, the mangrove population was reduced to 6,485 ha (DNER 2003). According to Martinuzzi et al. (2009), between 1977 and 2002 the mangrove cover of Puerto Rico increased by 12% mainly in rural and urban/rural sites. Meanwhile, a more recent study analyzing land coverage using satellite images from 1999 to 2003 reflected 6,700 ha of mangroves (Gould 2007).⁸

⁸ The coverage of mangroves varies depending on the methodology used for the analysis. For example, the study "The Status of Puerto Rico's Forests 2003" reported that mangrove forests occupy approximately 7,920 ha of the coastal areas in Puerto Rico (Brandeis 2007). In this case, the estimated area for the mangrove forests is based on a soil coverage map and forest formations produced by Kennaway and Helmer (2006) in 2000. Said map classified mangrove forest with 82% precision.

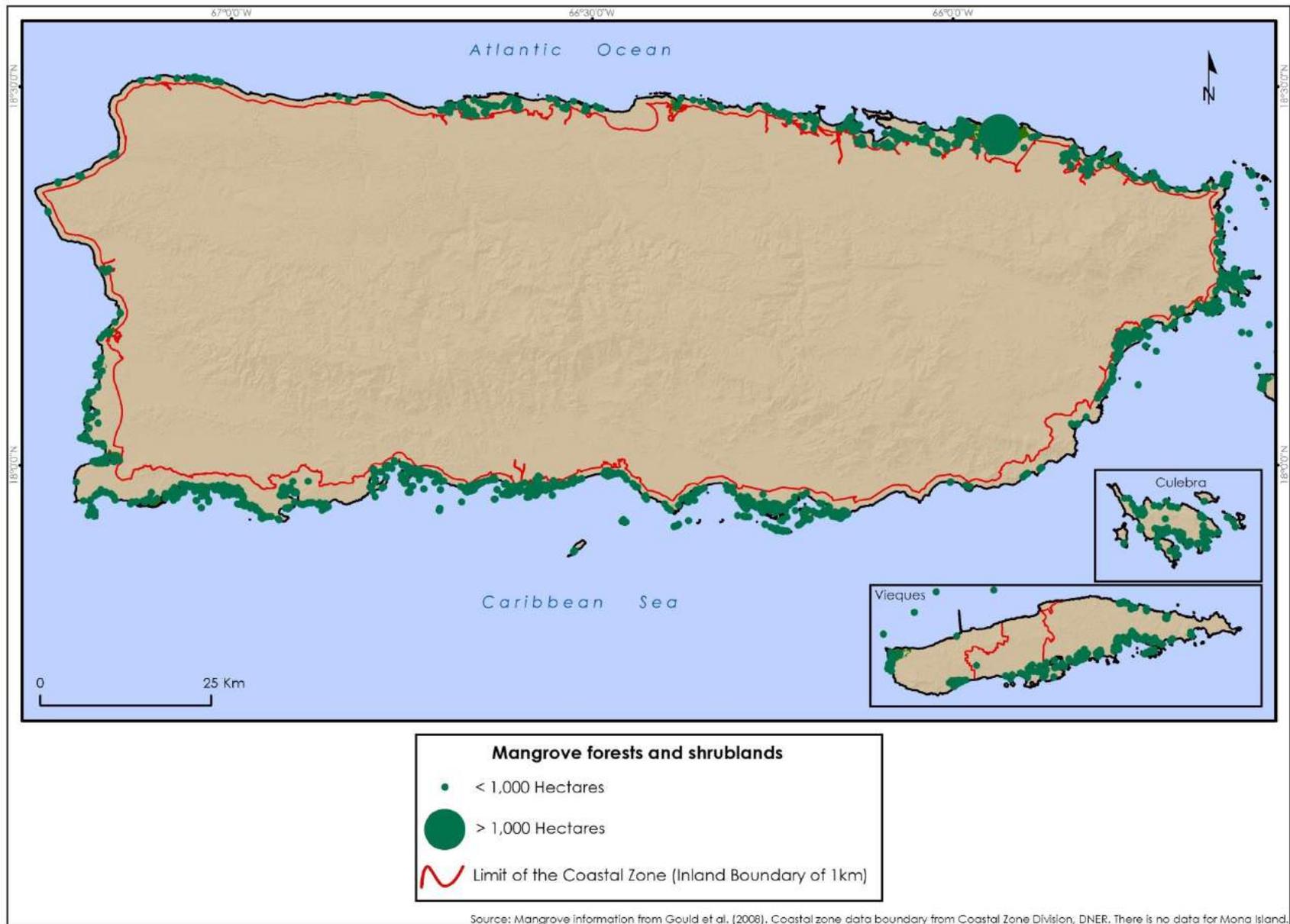


Figure 16. Location of mangrove forests in Puerto Rico, Vieques, and Culebra.

Historically, mangroves were perceived as areas of low economic productivity providing mainly wood and charcoal and the filling of mangroves was encouraged as a means to combat malaria. However, modern medicine has provided alternatives to control this disease and today the ecologic and economic values of these systems are recognized. Mangroves can be degraded or destroyed by activities such as drainage, dredging, filling, sedimentation, and oil spills. The filling of mangroves and adjacent land, which affects hydrology, is the most serious threat to them today. Despite the massive destruction of these systems in the first decades of the 20th century, mangrove coverage is increasing due to new legal protections (Figure 17).

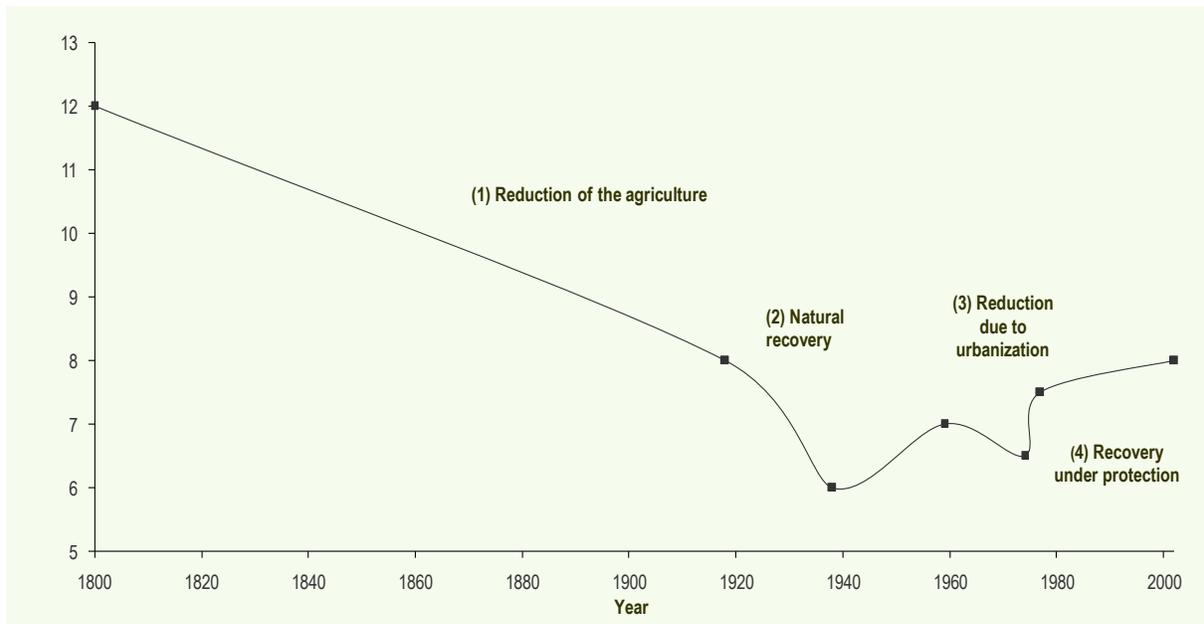


Figure 17. Changes in mangrove forest cover in Puerto Rico over the last 200 years. (Martinuzzi et al. 2009)

9. Coral Reefs

Coral reefs and rock reef communities are productive marine systems. They provide habitat for a large number and variety of fish and invertebrates. Coral reefs protect coastlines from wave action. They are a primary source of carbonate sand. They promote the deposition of sand on beaches as well as the formation of sea grass beds and mangroves. They serve as buffers against coastal erosion.

Approximately 500,000 ha of easy access coral reefs (reefs less than 20 meters deep) surround Puerto Rico (CSCOR 2005). Some 228 species of corals have been identified in the territorial waters, including: 117 scleractinian corals (rocky), 99 antipatharia corals (black or spiny), 13 corallimorpharia (fungi type coral), three (3) fire corals and five (5)

hydrocorals (DNER 2000). Mainly three types of structures form these coral reefs: fringing or marginal reefs (which are the most common), bank reefs, and barrier reefs.

Living coral reefs are present around Puerto Rico and a large number are degraded, largely because of increased sediment and nutrient discharge resulting from anthropogenic modifications of the densely populated island. These modifications are associated with intensive land clearing, agricultural and industrial development that accompany a steady increase in the standard of living (Goenaga and Cintrón 1979; Morelock et al. 1980, 1983, 1985; Rogers 1990; Acevedo and Morelock 1988; Acevedo et al. 1989; Clark and Wilcock 2000; Larsen 2000; Larsen and Santiago-Román 2001; Torres and Morelock 2002; Weil 2004; Warne et al. 2005).

ii. Economic benefits from forests

In 1995 there were nearly 4,000 ha of forests planted on both public and private lands for timber purposes (Francis 1995). Species included mahogany (*Swietenia spp.*), teak (*Tectona grandis*), eucalyptus (*Eucalyptus spp.*), Caribbean pine (*Pinus caribea*), María (*Calophyllum antillanum*), and mahoe (*Hibiscus elatus*). In 2003 commercially designated forest covered about 400,000 ha (988,420 ac) or 45 percent of the Island (Brandeis et al 2007). Gross merchantable volume is only estimated for trees with d.b.h. ≥ 5 inches (Brandeis and Turner 2013). The preponderance of small diameter trees on the island limits the potential for commercial wood production. Even though larger diameter trees make up a relatively small percentage of the total number of trees in the forest, they provide most of the merchantable volume; particularly in the subtropical moist and subtropical lower montane wet and rain forests. According to the 2009 Forest Inventory Analysis (FIA), there are 1.28 billion cubic feet of merchantable wood in Puerto Rico's forests, 86 percent of which is on unreserved, private lands (Brandeis and Turner 2013).

In a recent study by Forero-Montaña (2015) encountered that there are four (4) tree species that together account for more than 50 percent of the net volume of growing stock trees. These species are *Spathodea campanulata*; *Calophyllum antillanum*; *Guarea Guidonia*; and *Cecropia schreberiana*, being *S. campanulata* the most abundant tree species in Puerto Rico according to the last two FIA inventories. The majority of the growing stock tree species were hardwoods with sound wood properties suitable for a variety of uses including construction, joinery, furniture, crates and boxes, flooring, fuel, poles, and turning (Forero-Montaña, 2015)

During 2005-2013, Puerto Rico imported more than 2.5 billion dollars of a wide variety of solid wood products from 83 countries and six territories, being furniture the most important item accounting for more than 55 percent of the transactions with an annual average value greater than 156 million dollars (Forero-Montaña, 2015). However, the production and sale of wood products is important to individuals and can serve as an inducement for forest landowners to conserve and/or manage their forests. During 2005-2013 Puerto Rico also exported wood and manufactured wood products to 72 countries and 15 territories for an annual average value of more than 24 million dollars (Forero-Montaña, 2015), representing a small fraction of the amount of wood products that were imported. According to Forero-Montaña (2015), in terms of annual volume increment the island could cover almost its total current demand for imported sawn-wood (149,222 m³) using local wood, which accounts for 11 percent of the transactions

with an average annual value of U.S. \$30 million. There is a need for more information on existing and potential wood product markets. Potential sources of this information include local craftsmen, oral tradition, available inventories in governmental agencies, updated sawmill information, and commercial suppliers of wood and non-wood materials used for arts and crafts. Currently some local artisans are using native wood and other locally grown wood to produce musical instruments, carvings and other crafts. Inventories could help link landowners with desirable trees to those who would use them.

Potential agro-forestry approaches may have commercial benefits for communities. In addition, the identification and development of non-wood products may be similarly useful. This includes items such as medicinal plants, arts and crafts materials, food, animal forage, resins, and oils.

The acreage of land dedicated to nursery production of trees and palms has increased since 1992. In 2008, approximately 897 acres were dedicated to this purpose (Mendoza 2010). Of these, 127 acres were used to grow trees and 769 acres for palm production. The combined income in 2008 was \$10,934 million of which \$2,264 million was generated from ornamental trees and \$8,670 million from palms. The municipality of Aibonito is distinguished as the leader in this industry with close to 16 tree producers and 19 palm producers.

The economic value of Puerto Rico's forests should consider the economic benefits to society. For example, reduction of sediment to extend reservoir life through reforestation is more cost effective than continual dredging or construction of new reservoirs; and protection of the rivers and reefs indirectly supports fishing and water recreation activities. In 2007, the DNER's Coral Reef Management and Conservation Program commissioned a study to determine the economic value of coral reefs in Eastern Puerto Rico, specifically in Fajardo, Arrecifes La Cordillera, Vieques and Culebra. The study also included the value of associated resources such as beaches, bays, mangroves, seagrass beds, saltpeter bed, and coastal lagoons. The combined value came to \$1.6 billion, with tourism and recreation the activities providing the largest share. In a recent case study, the municipality of Caguas calculated that retaining tree cover saved them from spending \$63,486,739 on runoff control infrastructure like culverts, sewer lines, etc (Glogiewicz et al. 2008).

Additional economic opportunities for forest conservation could arise through various payments for environmental services or through emerging markets in carbon, water, and biodiversity. Incentives for providing watershed services, including water purification, ground water and surface flow regulation, erosion control, and streambank stabilization, may be an important area to explore. In particular, the 2008 Puerto Rico Integrated Water Resources Plan (DNER 2008-a) recommends developing incentives for reforestation on private lands in upper watersheds and exploring ways to decrease sedimentation of reservoirs. There may also be incentives for reforestation and associated carbon sequestration through the voluntary carbon market. Carbon credit trading is one way that private landowners may participate and prosper while contributing to mitigation efforts. At present there is no active market for carbon on the island. There is a need to educate the public about the multiple benefits and economic value provided by forestry resources in Puerto Rico.

b. THREATS TO FOREST RESOURCES

i. Development and forest fragmentation

Humans depend on natural systems for survival. The primary impact of development is that built up areas displace forests and other vegetation with inert materials that do not provide the environmental, economic, and social benefits discussed in the sections above (Martinuzzi et al 2007). Eleven percent (11%) (95,342 ha) of Puerto Rico is composed of urban/built-up surface, which is distributed throughout the island, but tends to concentrate in coastal plains and valleys and follows transportation routes to the very interior of the island. Over time, the concurrent impacts of resource demand and limited supply can result in significant management challenges and affect the amount and quality of the goods and services available in the future. In Puerto Rico one-quarter of the rich soils suitable for agriculture have already been developed. The distribution of plant and animal communities across an unaltered landscape will reflect differences in soil, climate, moisture, slope, aspect, and disturbance regime. For this reason, landscapes naturally exhibit variations in the amount, type, and distribution of forests. The distribution of the people of Puerto Rico is also heterogeneous. More than half of the population lives in the San Juan Metropolitan Area (PRCCC 2013a). Sixteen percent (16%) of the Island is in urban use and supports 2.3 million people (PRCCC 2013a); 35% of the land is densely populated; rural areas support 0.8 million people; and sparsely populated land covers 48% of the landscape and hosts less than 300,000 people (Figure 18) (Martinuzzi et al. 2007). The least populated parts of the landscape correspond to agricultural fields, higher elevations, protected lands or rugged topography. Compact construction in urban centers encompasses 60% of total development while the other 40% is more dispersed.

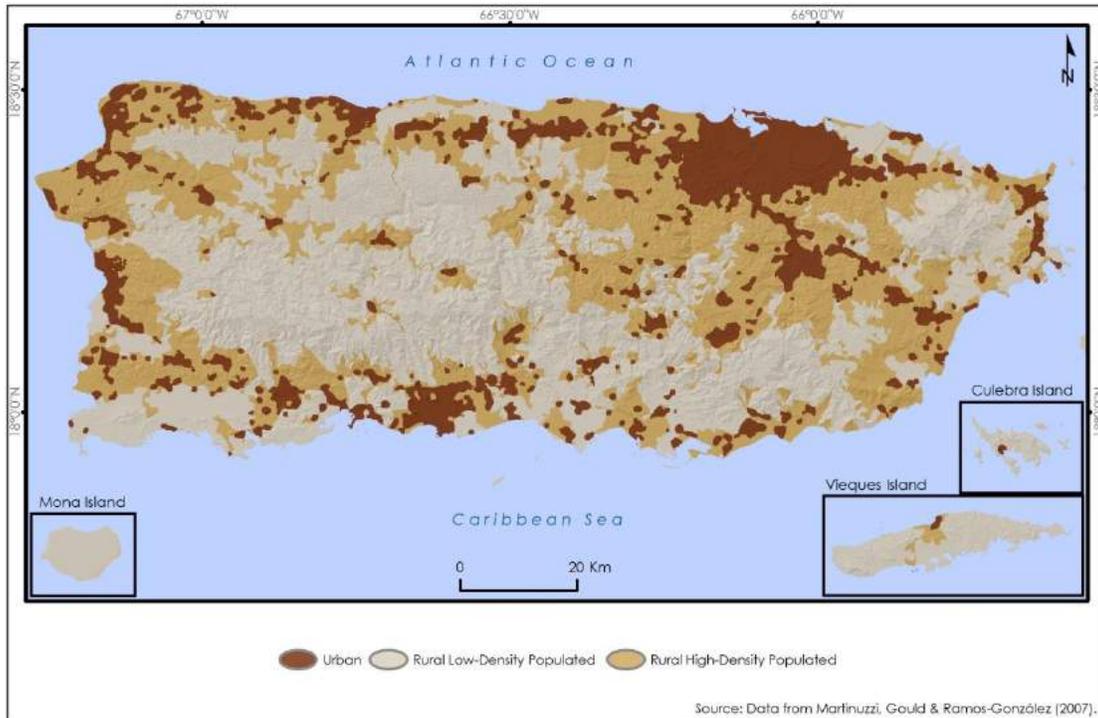


Figure 18. Distribution of population across Puerto Rico (Martinuzzi et al. 2007)

Fragmentation is the breaking up of large and continuous ecosystems, natural communities, and habitats into smaller areas surrounded by altered habitat, developed land, disturbed land, or aquatic substrate. A reference to a forest fragment may refer to either a patch of forest land or, in a different context, a forest patch of a certain age or structure that provides some aspect of a species' habitat. Fragmentation due to development has negative impacts on forests. It decreases forest health and diversity, the viability of forests as an economic unit, stream stability, health and water quality, habitat for interior dwelling wildlife species, and limits recreation use. Forest fragmentation can involve a simultaneous decrease in the average size of habitat patches, an increase in the average distance between patches, and an increase in edge effects. As a general rule, large fragments have more wildlife species and can sustain larger wildlife populations than small fragments (Hunter 1996). As the amount of fragmentation increases, species populations may become isolated, and the migration of individuals and populations between areas of suitable habitat becomes more difficult.

The overall effects of habitat fragmentation on wildlife may be difficult to sort out at first, because tradeoffs are inherent among species with varying life strategies, and wildlife populations fluctuate naturally over time. Some species of forest songbirds thrive only on very large patches of mature forest habitat, whereas others flourish in younger, more fragmented habitats. Physical changes in microclimates can occur as fragmentation affects physical fluxes of solar radiation, wind, and water (Saunders et al. 1991). Increases

in soil temperature and modified hydrology after harvest can affect habitat for species such as salamanders. Edge effects occur at the interface of two or more habitat types; they can be beneficial for some species and detrimental for others. A large amount of edge can result in increased competition, predation, and parasitism among others.

The intense growth pattern in land use has impacted a significant amount of geographic zones associated to the recharge areas of the main aquifers in Puerto Rico and has the direct consequences of soil erosion and sedimentation of water bodies and reservoirs (DRNA 2008-a). Likewise, it affects the quality of the resource and contributes to the deterioration of the environmental conditions necessary to sustain the aquatic biodiversity. There is also a consequence in the increased costs incurred to process water for human consumption. Site location consultations filed at the Puerto Rico Planning Board show the trend for *urban sprawl*, with urban activities dominating the territory and threatening watershed functions that support mainly the Río Grande de Loíza, Río La Plata, Río Piedras-Río Puerto Nuevo, Río Guaynabo-Río Bayamón, Río Cibuco, Río Grande de Manatí, Río Grande de Arecibo, and Río Guanajibo basins (Figure 19).

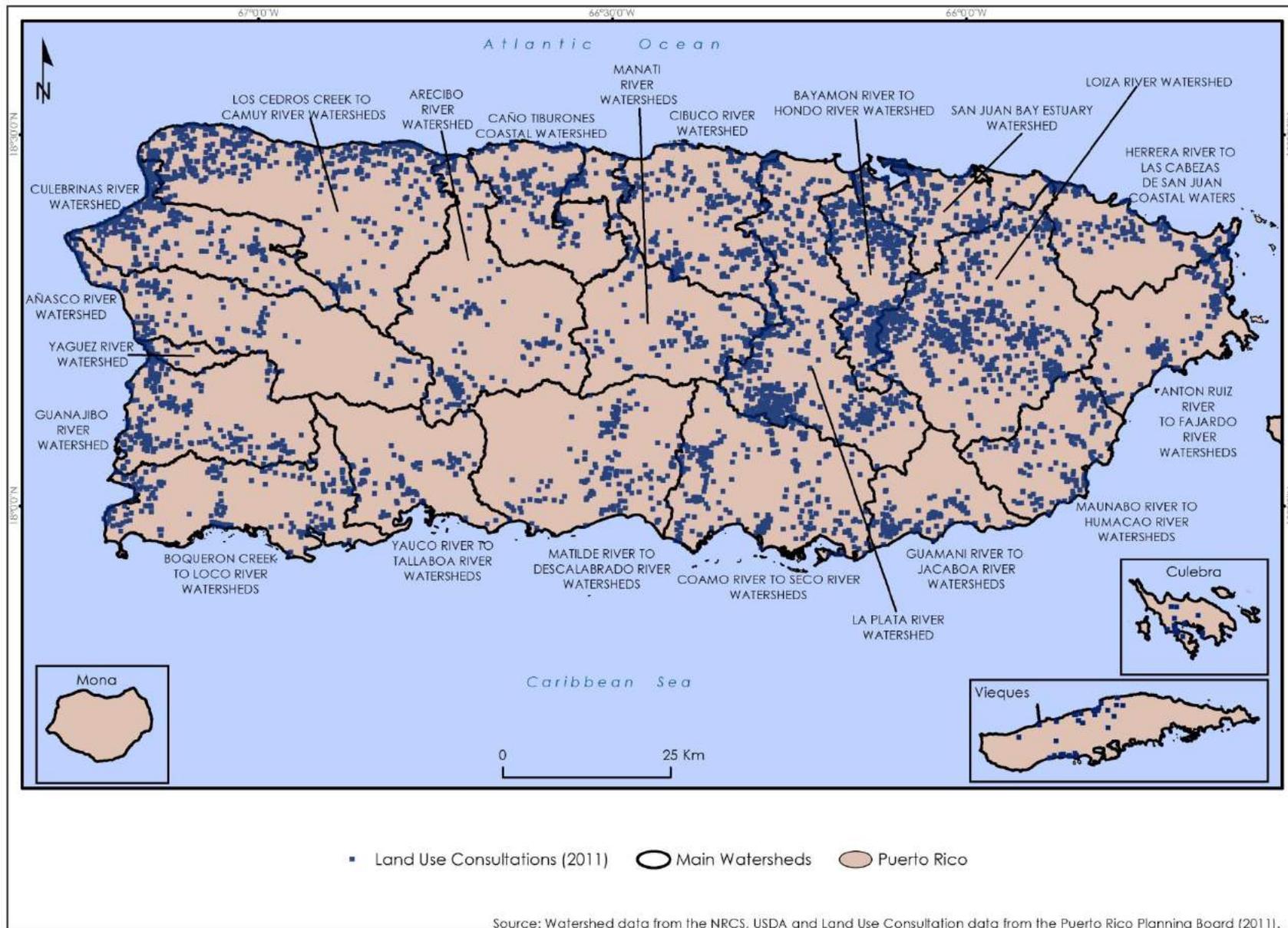


Figure 19. Locations of consultations related to commercial, industrial, residential, and other development in Puerto Rico.

The increase of population densities in rural land puts pressure on the young forests and open space on the urban fringe (Martinuzzi et al. 2007). A majority of new development inquiries in the non-zoned areas of Puerto Rico are occurring in the land use designation "Common Rustic Land" (Figure 20). This land use zoning designation is the most permissive classification of the Municipal Territorial Plans. An additional overlay of this zoning with the wildland urban interface areas shows that a large portion of the open space on the island is facing development pressure or that the concerned land has not been yet designated under specific land use zoning. These areas shall be considered priorities, particularly those portions overlapping Forest priorities (high, medium or low) areas according to the SFLA.

ii. Wildfires.

Managing wildfires is an important global and local issue given interactions among people, fire, and wild lands. While studies have shown fire has effects on ecosystem structure and functioning, uncertainties prevail on the particular effects to ecosystem services due to feedback loops involving multiple factors such as land cover, invasive species, and climate change (Gould 2008).

Understanding the ecological and social consequences of wildfires in Puerto Rican natural ecosystems is fundamental and key for important conservation and management actions to be planned. Fire prevention efforts need to reach private forest owners and others, as the majority of fires in Puerto Rico are set by people (Gould 2008). Research and monitoring of fires in our region has not been a high priority. Most fires and the highest potential for fires occur in the dry forest zones. Climate change, extended drought, and human-induced landscape fragmentation have the potential to greatly expand fire-prone areas to moist and wet tropical forests and even non-forested landscapes traditionally fire-free (Gould 2008). The Caribbean Fire Ecology and Management Symposium held in San Juan, Puerto Rico in 2007 sent a clear message that in the New World Tropics human activities and fires are intricately linked; at the same time, forest fragmentation will increase the likelihood of fires.



Figure 20. Intersection of wildland urban interface and "Common Rustic Lands" zoning according to Puerto Rico

iii. Hurricanes

Tropical forests are shaped by natural disturbances of varying forces and frequency (Hartshorn 1978; Lugo 2000). Flooding and landslides are secondary disturbances associated with hurricanes. Hurricanes are one of several natural disturbances that contribute to the dynamics, structure, and function of forest ecosystems (Borman and Likens 1979a,b; Pickett and White 1985).

Known effects of hurricanes on Caribbean forests include: defoliation, tree mortality, falling of trees by uprooting and snapping, variation of food supplies for animal populations and direct damage to a proportion of their individuals, modification of microclimate and of seeds and seedling banks dynamics (Tanner et al. 1991). The effects vary based on environmental gradients, topographic location, stand characteristics, tree size, and species characteristics such as wood density (Tanner et al. 1991; Basnet et al. 1992). Hurricanes are an important factor controlling species composition and important aspects of ecosystem dynamics in our region (Tanner et al.; 1991; Lugo 2000; Flynn et al. 2010). Their effects have been theorized as a major determinant of distribution patterns of tree species on tropical forest affected along their pathways (Basnet et al. 1992).

A strategy in urban areas is to establish green infrastructure with the goal mitigating the potential for wind damage, flooding, and mass wasting (Lugo 2000). Decades are required for both urban and natural systems to recover from the passage of a single category 4 or 5 hurricane. Hurricane Hugo in 1989 and Georges in 1998 passed through the natural forested regions of Puerto Rico with various effects. They removed foliage and caused tree mortality over hundreds of acres of forested land on subtropical wet and moist, lower montane wet, and rain forest life zones. Urban forest resources were not exempt as trees fell onto power lines, houses, vehicles, and roads.

Habitat loss and fragmentation has increased the threat that stochastic events like hurricanes and tropical storms pose to plants and animals on the island (Wiley and Wunderle 1993). For example, half the population of the Puerto Rican Parrot (*Amazona vittata*) (ca. 35 individuals) disappeared when Hurricane Hugo struck the island in 1989 (Wiley and Vilella 1998). In fact, about half of the wild parrot population disappeared when hurricane Hugo struck the Luquillo forest in 1989 (Vilella and García 1995).

iv. Climate change

The most general definition of climate change is a change in the statistical properties of the climate system when considered over periods of decades or longer, regardless of cause (Houghton 2001). The effects of climate change have the potential to be devastating in many areas of the world, including islands with substantial portions of its coastal plain composed of lowlands close to current sea level. The predicted intensity of change and the time frame over which change will occur depends on the model; however, most of these agree that climate change will affect forests along the coastlines.

The expected changes, presented so far by the United Nations Environmental Program (UNEP 2008) include:

- deteriorating coastal conditions as, for example, beach erosion and coral bleaching, affecting fisheries and touristic coastal scenarios;
- floods, storm surge, erosion and other coastal hazards, exacerbated by sea-level rise, threatening fundamental infrastructure, settlements and facilities that support the livelihood of island communities;
- reduction in freshwater resources to the point where they cannot meet demand during drought periods;
- increased invasion by non-native species as result of higher temperatures, particularly on middle and high latitude islands;
- economic losses from reduced agricultural yields (shortening of the growing seasons and droughts)
- loss of mangrove forests and coral reefs as a consequence of sea level rise;
- coral bleaching and acidification of the ocean;
- damage to terrestrial forests caused by extreme events;
- reduction of the size of freshwater aquifers or lenses and of general water resource availability due to decreased rainfall and salt water intrusion;
- inundation on coastal settlements and arable land on the coast;
- reduction in tourism due to increased frequency and extreme severe weather;
- hurricanes and tropical storm winds can reach more than 170 miles per hour and can devastate the landscape (Reilly 1991).

The Puerto Rico Climate Change Council (PRCCC, 2013a) identified four major climate change stressors that are likely to affect Puerto Rico's forests:

- Sea level rise
- Increased severity of tropical storms
- Decreased precipitation / increased drought / increased seasonality
- Increased irradiation / increased mean temperature and extremes

These stressors will likely alter the flowering and fruiting phenology of all forests types, and the establishment and survival of seedlings, which would lead to changes in species composition, distribution and abundance (PRCCC 2013a). Also, the PRCCC has stated that the delivery and flow of important forest ecosystem services may be compromised by climate-induced alterations, with potentially detrimental effects for the human communities that depend on them (PRCCC 2013b). Table 5 presents a summary of outcomes/consequences of climate change stressors on Puerto Rico's dominant forest types prepared by the PRCCC.

Climate models suggest that there will be a decrease in the frequency of hurricanes in the Caribbean, although an increase is also expected in the frequency of more intense events (PRCCC 2013a). The PRCCC (2013a) recommends increasing standards of preparation for more intense hurricanes. However the information on the effects and outcomes of past hurricanes and tropical storms, as described above, can be used to anticipate possible effects of either increasing or decreasing hurricane frequency and intensity (Lugo 2000).

Table 5. Summary of outcomes/consequences of climate change stressors on Puerto Rico's dominant forest types prepared by the PRCCC.

Forest Type	Stressors					Biophysical Outcomes					Societal Consequences
	Sea level rise	Increased storm severity	Decreased precipitation/increased drought	Increased solar irradiation/temperature	Salt water intrusion	Increased seasonality/changes in flowering & fruiting phenology, seedling establishment	Increased wildfires	Elevated cloud condensation level	Changes in species composition, distribution, and abundance	Novel plant and animal assemblages with unique structure and function	
Pterocarpus forests	√	√	√		√	√			√	√	√
Lowland moist forest & woodlands	√		√		√	√			√	√	√
Dry forests	√	√	√	√	√	√	√		√	√	√
Karst forests		√	√	√		√	√		√	√	√
Lower montane forests	√	√	√	√		√		√	√	√	√

The expected sea level rise is another issue that will significantly affect certain forests in Puerto Rico, mainly within the coastal zone. A rise in sea level of just one foot could have a detrimental effect on coastal forest areas, including mangrove systems and other coastal swamps characteristic of lower saline intrusion such as bloodwood swamps (*Pterocarpus officinalis*) and pond apple swamps (*Annona glabra*). All these coastal forests act as nurseries for fish, habitat for other wildlife, and sediment filters for runoff. Research conducted on *Pterocarpus* forests has shown that increased soil and water salinity affects litter, flower, and fruit production and that salinities above fourteen percent (14%) can kill populations of these trees (Eusse and Aide 1999; Rivera-Ocasio et al. 2007). Available data suggests that under current conditions sea level could rise from 48 cm (1.3') (Pfeffer and O'Neel 2008) to as much as 880 cm (27.7') (Carlson et al. 2008) over the next hundred years. The more conservative numbers from the Intergovernmental Panel on Climate Change (IPCC) estimate 40 to 102 cm over the next 100 years. Sea level rise could have a domino effect if the Federal Emergency Management Agency (FEMA) flood zones push development back into the central volcanic parts of lower montane forests or karstic zones of Puerto Rico.

Climate change is likely to exacerbate many of the existing threats to forest ecosystems. Climate warming, droughts, and the increase of invasive species will make forests more vulnerable to wildfires. Evidence of this is already being seen in the Island where wildfires are increasing in frequency and occurring in areas where such fires have never been recorded before (Robbins et al. 2009).

The World Bank has identified Puerto Rico among nations with higher carbon dioxide emissions per person in Latin America and the Caribbean compared to world average emissions (Figure 22). Climate warming is mainly caused by increasing CO₂ emissions in the atmosphere. According to the Environmental Protection Agency (EPA), 26 large facilities reported a total of 16,342,726 metric tons of CO₂ emissions in 2014 (EPA 2015). Carbon sequestration by forests is one way to mitigate ambient greenhouse gases, such as CO₂, by offsetting losses through removal and storage of carbon (USDA Forest Service 2015-a). According to recent estimates of net annual storage, these indicate that forests are an important carbon sink, removing more carbon from the atmosphere than they are emitting (Pan et al. 2011). The USDA Forest Service (2015-a) recommends to enhance rates of net carbon sequestration through management strategies that retain and protect forest land from conversion to non-forest uses, restore and maintain resilient forests that are better adapted to a changing climate and other stressors, and reforest lands disturbed by catastrophic wildfires and other natural events.

Climate change can be regarded as a process of long-term change that requires a monitoring mechanism or protocol to categorize management applications and setting priorities can focus on adapting to the climate change process. Given the importance role forests play in sequestering carbon, expanding forest cover is a logical response to climate change. Carbon credit trading is one way that private landowners may participate and prosper while contributing to mitigation efforts. At present there is no active market for carbon on the island.

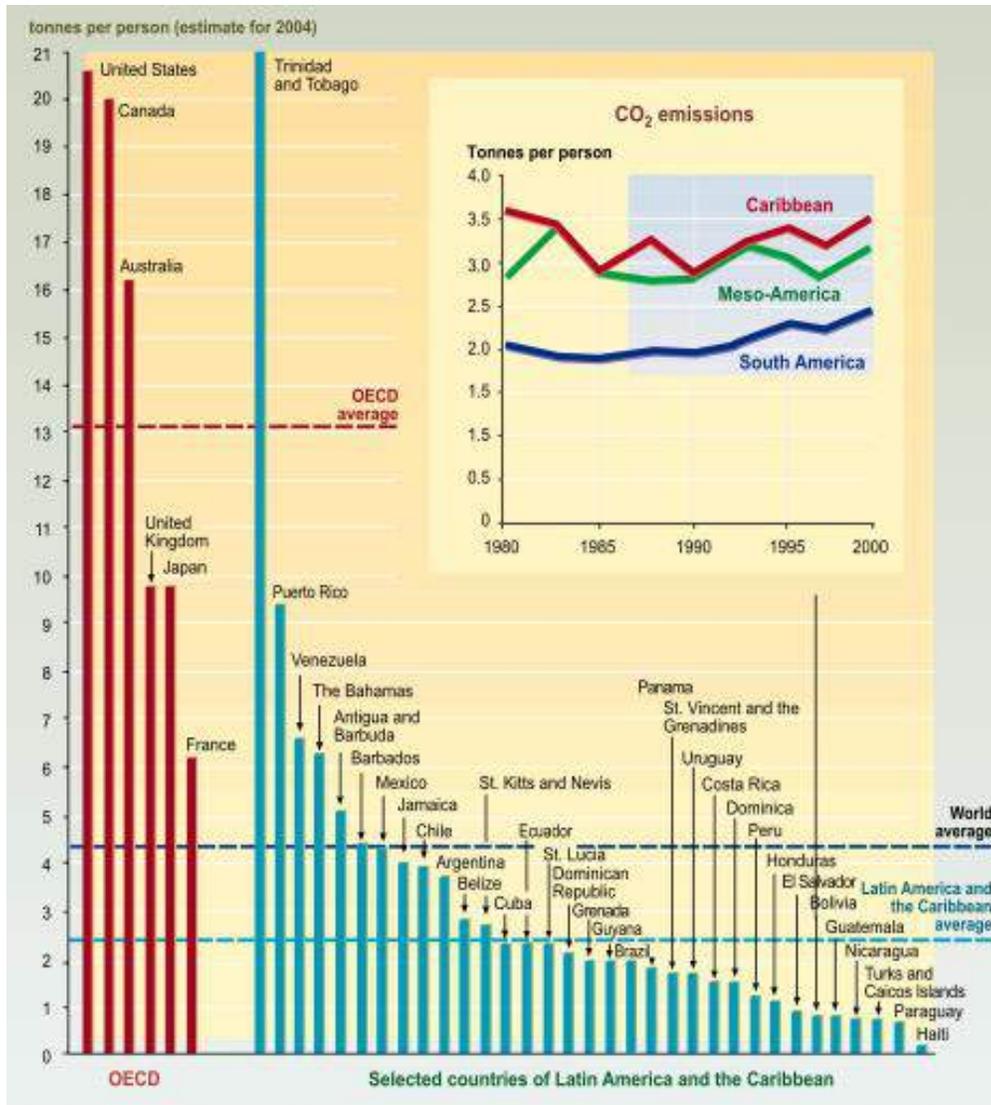


Figure 21. CO₂ emissions per person in Latin America and the Caribbean and average emissions of Organization for Economic Cooperation and Development (OECD). Obtained from World Bank's Development Indicators of year 2008 and US Energy Information Administration.

v. Invasive species

In 1999, Executive Order Num. 13112 was signed by President Bill Clinton, with the purpose of preventing the introduction of invasive plant and animal species, providing resources for their control, and diminishing their main economic and ecological impact. Under this Executive Order, federal agencies could not authorize, nor provide funding or accomplish any action considered capable of causing or promoting the introduction or dispersion of invasive species to the USA, unless all reasonable measures that diminish risks are considered first. This Order is applicable to Puerto Rico and requires action by several federal or Commonwealth agencies.

These following terms are commonly used when discussing exotic organisms and invasive species.

- Native – Organisms found within what is considered their natural range.
- Endemic – Similar to native but usually refers to a more specific geographic range.
- Exotic – Exotic species are any organism taken from their natural range and transported to a new area. This only pertains to organisms moved by humans, such as in cargo ships or planes. It does not include natural migrations like birds or fish that travel great distances.
- Naturalized – An organism that is able to reproduce itself unassisted in their new habitat is considered naturalized.
- Invasive – An organism that grows or spread aggressively in its new environment and causes environmental and/or economic harm. Lists showing exotic agricultural pests invasive species in Puerto Rico detected are shown in Table 6.

Table 6. Puerto Rico Exotic Agricultural Pests Invasive Species

Common Name	Scientific Name
Chili Thrips; Yellow Tea Thrip	<i>Scirtothrips dorsalis</i>
Citrus Greening Huanglobing (Asian)	<i>Candidatus Liberibacter asiaticus</i>
Hibiscus Erineum Mite	<i>Aceria hibisci</i>
Lobate Lac Scale	<i>Parachatardina pseudolobata</i>
Old World Bollworm	<i>Helicoverpa armigera</i>
Passionvine Mealybug	<i>Planococcus minor</i>
Red Palm Mite	<i>Raoiella indica</i>
Mealybug	<i>Hypogeocus pungens</i>
Oak Thrip	<i>Holopothrips tabebuiae</i>
Hempel	<i>Crypticerya genistae</i>
Pine Tortoise Scale	<i>Toumeyella parvicornis</i>
Weeping Fig Thrip	<i>Gunaicothrips uzeli</i>

Islands have long been considered to be particularly vulnerable to biotic invasions. Usual predictions concerning the number of invasive plant species per island group are based on factors such as: area and isolation, habitat diversity and human development. Comprehensive data set to date on the global distribution of invasive plant species in natural areas of oceanic islands have shown that island area, latitude, isolation from continents, number of present non native species with known invasion history, and native species richness do not seem to retained as significant factors in the multivariate models (Kueffer et al. 2009).

In Puerto Rico, close to 60 species of exotic vascular plants, of different growth forms, are being considered preliminarily as invasive species by a local inter agency committee under the leadership of the Commonwealth Transportation and Highway Authority. This committee started working during year 2000 in response to the implied requirement settled by the Executive Order 13112. Although this list has not acquired official status yet, some of the species included, detected at sensitive wetlands of the Island, have been subjected to technical research concerning aspects of its distribution, population biology, and biological control in Puerto Rico (Pratt et al. 2005; 2006).

Contributions from field of population biology hold promise for understanding invasiveness and recognizing when management could be effective (Sakai et al. 2001). However, the effects of invasive, non-indigenous species on ecosystem processes are still to be studied and debated (Coluatti and Maclsaac 2004; Lugo 1990; 1992; Rudel et al. 2001; Lugo and Helmer 2004; Lugo 2004).

Attempts to redefine commonly used terminology have proven difficult because authors are often partial to particular definitions. Some authors propose invasive species do alter properties of the ecosystems at several scales including geomorphology, hydrology, biogeochemistry, and disturbance (Gordon 1998) based on anecdotal observations. Predatory and competitive impacts of biological invasions are well documented; same as success of invading exotics do to having escaped their natural enemies and not because of novel interactions with their new neighbors (Callaway and Aschehoug 2000; Jenkins and Pimm 2003). Plant diversity patterns, plant community structure and forest regeneration patterns have been interpreted as strongly affected in the Luquillo Mountains of Puerto Rico due an invasive tropical tree species introduced over 180 years ago into the Island (Brown et al 2006). In contrast, perspectives and paradigms based on such data seem to be threatened by new concepts and observations. Searches through recent ecological literature found that facilitative interactions between invasive and native species occur in a wide range of habitats, can have cascading effects across trophic levels, can restructure communities, and can lead to evolutionary changes; recent evidence suggest several mechanisms that exemplify how exotic species can facilitate native species (Rodriguez 2006), having important implications for management, eradication, and restoration. The change in species composition taking place due to invasiveness might not be seen as chaotic process, instead a directed process responding to fundamental changes the conditions of the planet (Lugo 2004).

vi. Pests and diseases.

The Agricultural Extension Service of the University of Puerto Rico in Mayagüez has been able compile a long time a list of native and non native insect species that, at certain life-cycle stages, affect adversely particular organs of native or naturalized tree or shrub species occurring on forested ecosystems or urban forest system (Martorell 1945; Almodovar 2008). Table 7 shows a list of the concerned species considered pests in Puerto Rico forests and their host woody plants (Martorell 1982).

Table 7. Natives and non natives insect species detected in Puerto Rico considered harmful to local tree or shrub species

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
<i>Apate monacha</i>	the apate borer/ "escarabajo taladrador del tallo"	<i>Bixa orellana</i> ; <i>Bucida buceras</i> ; <i>Casuarina equisetifolia</i> ; <i>Delonix regia</i> ; <i>Inga vera</i> ; <i>Eugenia jambos</i> ; <i>Linociera domingensis</i> ; <i>Melia azedarach</i> ; <i>Persea americana</i> ; <i>Picramnia pentandra</i> ; <i>Salix chilensis</i> ;
<i>Aphis gossypii</i>	"áfido"	no information available
<i>Aspidotus destructor</i>	the coconut scale/ "la queresa del coco"	<i>Cocos nucifera</i> ; <i>Annona glabra</i> / <i>Barringtonia speciosa</i> ; <i>Grevillea robusta</i> ; <i>Mammea americana</i> ; <i>Persea americana</i> ; <i>Phoenix dactylifera</i> ; <i>Psidium guajava</i> ; <i>Terminalia catappa</i>
<i>Chlorida festiva</i>	the mango borer/ "el barrenador del mangó"	<i>Albizzia lebbbeck</i> ; <i>Casuarina equisetifolia</i> ; <i>Mangifera indica</i> ; <i>Stahlia monosperma</i>
<i>Chrysomphalus aonidum</i>	the Florida red scale	no information available
<i>Diaprepes abbreviatus</i>	sugarcane weevil/ "vaquita de la caña"	<i>Albizzia lebbbeck</i> ; <i>Andira jamaicensis</i> ; <i>Byrsonima spicata</i> ; <i>Cedrela mejiicana</i> ; <i>Cedrela odorata</i> ; <i>Ceiba pentandra</i> ; <i>Chrysophyllum cainito</i> ; <i>Coccoloba uvifera</i> ; <i>Cordia alliodora</i> ; <i>Delonix regia</i> ; <i>Ficus stahlia</i> ; <i>Guaicaum officinale</i> ; <i>Inga vera</i> ; <i>Lagerstromia speciosa</i> ; <i>Melicocca bijugata</i> ;

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
		<i>Thespesia grandiflora</i> ; <i>Persea americana</i> ; <i>Psidium guajava</i> ; <i>Swietenia macrophylla</i> ; <i>Swietenia mahogani</i> ; <i>Tamarindus indica</i> ; <i>Terminalia catappa</i>
<i>Eulepte concordalis</i>	the roble leaf-webber/ "tejedor de la hoja del roble"	<i>Tabebuia argentea</i> ; <i>Tabebuia heterophylla</i> ; <i>Tabebuia lucida</i> ; <i>Tabebuia rigida</i> ; <i>Tabebuia schumaniana</i> ; <i>Crescentia cujete</i> ; <i>Spathodea campanulata</i>
<i>Exophthalmus roseipes</i>	the green bug/ "la vaquita verde"	<i>Andira inermis</i> ; <i>Chrysobalanus icaco</i> ; <i>Coccoloba uvifera</i> ; <i>Conocarpus erectus</i> ; <i>Dalbergia ecastophyllum</i> ; <i>Elaeodendrum xylocarpum</i> ; <i>Hymenaea courbaril</i> ; <i>Inga vera</i> ; <i>Inga laurina</i> ; <i>Terminalia catappa</i>
<i>Homaledra sabalella</i>	the palm leaf-webber/ "tejedor de las hojas de las palmas"	<i>Cocos nucifera</i> ; <i>Prestoea montana</i>
<i>Iceria montserratensis</i>	no official common name; at first glance it looks as the cottony cushion scale ("queresa algodonsa")	<i>Byrsonima spicata</i> ; <i>Callophyllum calaba</i> ; <i>Casuarina sylvestris</i> ; <i>Casuarina equisetifolia</i> ; <i>Chrysophyllum argenteum</i> ; <i>Cocos nucifera</i> ; <i>Ficus nifida</i> ; <i>Inga vera</i> ; <i>Inga laurina</i> ; <i>Mammea americana</i> ; <i>Psidium guajava</i> ; <i>Samanea saman</i>
<i>Iceria purchasii</i>	the cottony cushion scale / "queresa algodonsa"	<i>Casuarina equisetifolia</i> ; <i>Erythrina glauca</i> ; <i>Senna emarginata</i> ; <i>Prosopis juliflora</i> ; <i>Pithecelobium dulce</i>
<i>Ischnaspis longirostris</i>	the black red scale	no information available
<i>Megalopyge krugii</i>	flannel moth/ "la plumilla"	<i>Andira inermis</i> ; <i>Byrsonima spicata</i> ; <i>Cocos nucifera</i> ; <i>Delonix regia</i> ; <i>Erythrina glauca</i> ; <i>Ficus laevigata</i> ; <i>Guaiacum officinale</i> ; <i>Guarea trichiloides</i> ; <i>Guazuma ulmifolia</i> ; <i>Inga</i>

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
		<i>vera</i> ; <i>Inga laurina</i> ; <i>Nectandra sintenisii</i> ; <i>Ormosia krugii</i> ; <i>Psidium guajaba</i> ; <i>Rhizophora mangle</i> ; <i>Sciacassia siamea</i> ; <i>Spondias purpurea</i> ; <i>Terminalia catappa</i> ; <i>Triplaris caracasana</i>
<i>Nasutitermes costalis</i>	common termite/ "comején"	<i>Albizia lebbeck</i> ; <i>Albizia procera</i> ; <i>Andira inermis</i> ; <i>Artocarpus communis</i> ; <i>Bucida buceras</i> ; <i>Bursera simarouba</i> ; <i>Callophyllum calaba</i> ; <i>Canagium odorata</i> ; <i>Capparis portoricensis</i> ; <i>Casuarina equisetifolia</i> ; <i>Cecropia peltata</i> ; <i>Cedrelaodorata</i> ; <i>Ceiba pentandra</i> ; <i>Coccoloba uvifera</i> ; <i>Cocos nucifera</i> ; <i>Colubrina arborescens</i> ; <i>Crescentia cujete</i> ; <i>Delonix regia</i> ; <i>Eucalyptus robusta</i> ; <i>Ficus elástica</i> ; <i>Inga vera</i> ; <i>Petitia domingensis</i> ; <i>Prestoea montana</i> ; <i>Roystonea borinquena</i> ; <i>Swietenia mahogani</i> ; <i>Terminalia catappa</i>
<i>Oiketicus kirbyi</i>	bagworm/ "oruga de casucha"	<i>Casuarina equisetifolia</i> ; <i>Casearia sylvestris</i> ; <i>Ceiba pentandra</i> ; <i>Chrysophyllum cainito</i> ; <i>Cordia alliodora</i> ; <i>Cupania americana</i> ; <i>Guazuma ulmifolia</i> ; <i>Thespesia populnea</i> ; <i>Ochroma pyramidale</i> ; <i>Petitia domingensis</i> ; <i>Persea americana</i> ; <i>Pisonea aculeata</i> ; <i>Randia portoricensis</i> ; <i>Terminallia catappa</i> ; <i>Thuja orientalis</i> ; <i>Tabebuia</i> spp.
<i>Pachylia ficus</i>	the ficus sphinx	<i>Ficus nitida</i> ; <i>Castilla elastica</i>
<i>Pectynophora gossypiella</i>	the pink bollworm	<i>Thespesia grandiflora</i> ; <i>Thespesia populnea</i>
<i>Phyllophaga portoricensis</i>	may beetle/ "caculo de mayo"	<i>Coccoloba uvifeera</i> ; <i>Schefflera morototoni</i> ; <i>Lagerstromia speciosa</i> ; <i>Bucida buceras</i> ; <i>Cordia alliodora</i> ; <i>Cordia sebestena</i> ; <i>Grevillea</i>

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
		<i>robusta</i> ; <i>Sterculia apétala</i> ; <i>Sterculia foetida</i> ; <i>Swietenia mahogani</i> ; <i>Swietenia macrophylla</i> ; <i>Terminalia catappa</i>
<i>Pseudalcapasis pentagona</i>	west indian peach scale	<i>Calatropis procera</i> ; <i>Clibadium erosum</i> ; <i>Erythrina poeppigiana</i> ; <i>Fraxinus sp.</i> ; <i>Gleditsia triacanthos</i> ; <i>Mammea americana</i> ; <i>Mangifera inindica</i> ; <i>Thespessia grandiflora</i> ; <i>Hibiscus tiliaceum</i> ; <i>Salix chilensis</i> ; <i>Trema lamarkiana</i> ; <i>Trema micrantha</i>
<i>Pseudococcus adonidum</i>	mealybug/ "chinche harinosa"	<i>Barringtonia speciosa</i> ; <i>Callophyllum calaba</i> ; <i>Erythrina glauca</i> ; <i>Hibiscus tiliaceus</i>
<i>Psychonoctua personalys</i>	mangrove stem-borer/ "barrenador del mangle"	<i>Eugenia jambos</i> ; <i>Laguncularia racemosa</i> ; <i>Rhizophora mangle</i>
<i>Saissetia oleae</i>	black sacale/ "la queresa negra"	<i>Andira inermis</i> ; <i>Annona muricata</i> ; <i>Cedrela mejicana</i> ; <i>Cordia alliodora</i> ; <i>Cordia sulfata</i> ; <i>Crescentia cujete</i> ; <i>Erythrina berteroa</i> ; <i>Erythrina glauca</i> ; <i>Erythrina poeppigiana</i> ; <i>Ficus laevigata</i> ; <i>Ficus nitida</i> ; <i>Gleditsia triacanthos</i> ; <i>Guarea trichiloides</i> ; <i>Guazuma ulmifolia</i> ; <i>Isandrina emarginata</i> ; <i>Eugenia jambos</i> ; <i>Lagerstromia speciosa</i> ; <i>Manilkara bidentata</i> ; <i>Thespessia grandiflora</i> ; <i>Ocotea portoricensis</i> ; <i>Petitia domingensis</i> ; <i>Psidium guajava</i> ; <i>Sciacia siamea</i> ; <i>Sideroxylon foetidissimum</i> ; <i>Spathodea campanulata</i> ; <i>Spondias dulcis</i> ; <i>Sterculia apétala</i> ; <i>Swietenia mahogani</i> ; <i>tamarindus indicus</i> ; <i>Tectona grandis</i> ; <i>Terminalia catappa</i> ; <i>Trema lamarckiana</i> ;

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
		<i>Trema micrantha</i> ; <i>Zanthoxylum flavum</i>
<i>Selenothrips rubrocinctus</i>	cacao thrips/ "candelilla del cacao"	<i>Anacardium ; occidentale</i> ; <i>Bixa Orellana</i> ; <i>Chrysobalanus icaco</i> ; <i>Coccoloba laurifolia</i> ; <i>Mangifera indica</i> ; <i>Psidium guajava</i> ; <i>Spondias bombim</i> ; <i>Terminalia catappa</i> ; <i>Zanthoxylum monophyllum</i>
<i>Sericocerina krugii</i>	sea grape wasp/ "avispa de la uva de playa"	<i>Coccoloba uvifera</i> ; other <i>Coccolobba spp</i> ; <i>Triplaris surinamensis</i>
<i>Spodoptera frugiperda</i>	the fall armyworm/ "el gusano de ejército de otoño"	Seedlings of <i>Eucaliptus robusta</i>
<i>Xyloborus affinis</i>	ambrosia beetle	<i>Albizzia lebeck</i> ; <i>Cocos nucifera</i> ; <i>Inga vera</i> ; <i>Inga laurina</i>

C. LAND CONSERVATION AND MANAGEMENT IN PUERTO RICO

Spain recognized the importance of forests and forest products. During the last quarter of the 19th century, various forest areas and forest types on the Island were identified as resources of special value to be protected for the benefit of the public. Management plans were developed and implemented under a jurisdiction called the Puerto Rico Forest Inspection ("Inspección de Montes"). Wet montane and coastal tidal forest types were among those types recognized for their special value.

The importance of forest resource conservation was reinforced in US policy. Several public forests were proclaimed and managed for conservation by the insular civilian government of Puerto Rico during the 1910s, 1920s, 1930s and 1940s. Today many of these areas form the core of lands designated in the State Forest system and are under the administration of the Department of Natural and Environmental Resources Forest Service Bureau (DNERFSB). The Insular government also managed areas in the Luquillo Mountains until the President Theodore Roosevelt established the Caribbean National Forest. The USFS now manages this National Forest, which, as of April 2007, is called El Yunque National Forest to reflect island culture and history.

Land protection is an important conservation tool today. The PR-GAP Analysis Project (2008) conducted an inventory of protected areas and an evaluation of the degree of their management for conservation purposes using information from federal and state agencies, the Conservation Trust of Puerto Rico and the Puerto Rico Planning Board (Gould et al. 2008). The project identified 90 stewardship⁹ areas of which 77 have some type of management for conservation. Among these, 59% of the stewardship areas are managed by commonwealth agencies, 30% by federal agencies, and 11 % by non-government agencies. Another key finding was that management plans for many areas either do not exist or have not been updated to provide direction for today's conditions (e.g. reduced timber production, focus on forest restoration, and increased development pressures (Figure 23).

⁹ The PR-GAP Analysis Project (2008) uses the term "stewardship" in place of "ownership" in recognition that legal ownership does not necessarily equate to the entity charges with management of the resource.

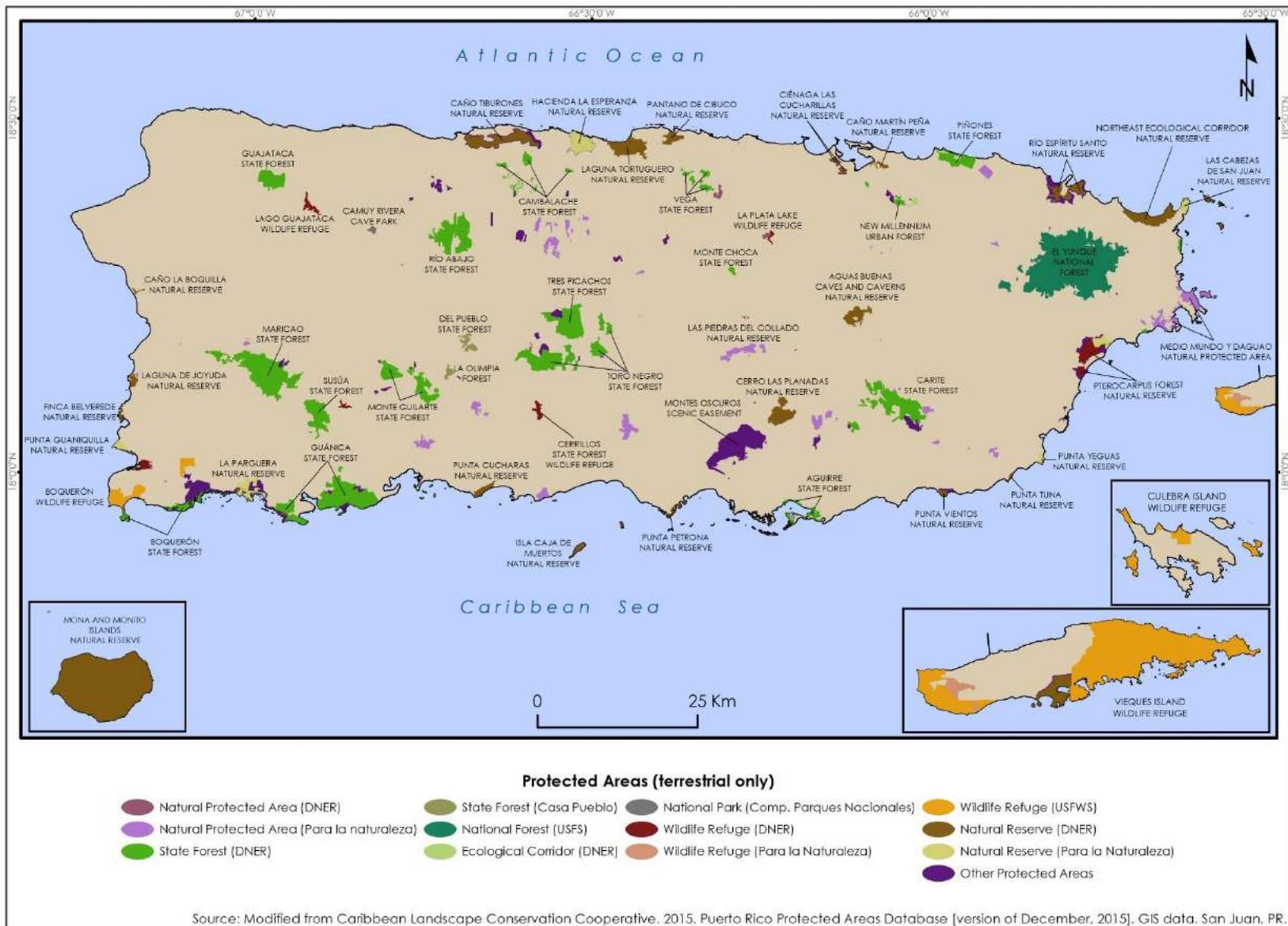


Figure 22. Location of land currently protected by Federal or Commonwealth designation, legislation, or proclamation or as private reserves of NGO's

- i. Financial assistance programs for management and conservation
 - 1. USDA Forest Service Cooperative Programs

USFS has a number of programs to provide technical and financial assistance to non-industrial private landowners and communities (Table 8). The DNERFSB is the primary state administrator for most USFS Cooperative programs, with one exception; the Puerto Rico Fire Service is designated as the primary agency responsible for implementation of the State Fire Assistance and Volunteer Fire Assistance Program.

Table 8. USDA Forest Service Cooperative Programs available in Puerto Rico

Program	Purpose
<p>Forest Stewardship Program, FSP</p>	<ul style="list-style-type: none"> -Provides technical assistance, through State forestry agency partners, to nonindustrial private forest owners to encourage and enable active long-term forest management. A primary focus of the Program is the development of comprehensive, multi-resource management plans that provide landowners with the information they need to manage their forests for a variety of products and services. -Promotes the conservation of soil, water, flora and fauna through the protection and effective management of private forest land. -Promotes greater participation of owners in the programs. -Develops projects that are aimed at improving water quality through the protection and conservation of watersheds and forest areas.
<p>Urban and Community Forestry, U&CF</p>	<ul style="list-style-type: none"> -Provides technical and financial assistance to communities, public and private entities and municipalities on the management of urban forest resources to promote a sustainable ecosystem. -The program has an Advisory Council composed of representatives of various sectors of society, whose primary function is to advise the director of the DNERFSB in the process of implementing the program. Provide technical and financial assistance to communities, public and private entities and municipalities on the management of urban forest resources to promote a sustainable ecosystem.
<p>Forest Legacy Program, FLP</p>	<ul style="list-style-type: none"> -Promote the protection of forest areas through the purchase of private land forest value that are under threat to be converted to non-forest uses and have features that warrant preservation and enrich our natural areas. This goal can be achieved through the purchase of land or

Program	Purpose
	purchase conservation easements Puerto Rico competes with other states for funding of this program, which should provide a matching 25% of the state.
Community Forest and Open Space Conservation Program, CFP	<p>-The purpose of the CFP is to competitively award grants to enable local governments, Indian Tribes, and nonprofit organizations to establish community forests by acquiring and protecting private forest lands that will provide continuing and accessible community benefits. Community benefits provided by community forests established through this program include, but are not limited to: economic benefits through sustainable forest management; environmental benefits such as clean water and wildlife habitat; benefits from forest-based educational program, including vocational education program in forestry and serving as models to guide stewardship on private forest lands; and recreational benefits, including hunting and fishing. Public access to the community forests is required and intended to enhance public health and well-being.</p>
Forest Health Management	<p>-Works in partnerships to prevent, suppress and slow-the-spread of native and nonnative forest insects, pathogens, and invasive plants affecting urban, rural, and wildland forests.</p>
Forest Health Monitoring	<p>-Monitors the forests of the United States to determine detrimental changes or improvements to forest health that occur over time.</p>
State Fire Assistance	<p>-Provides financial and technical support directly to the states, to enhance firefighting capacity, support community-based hazard mitigation, and expand outreach and education to homeowners and communities concerning fire prevention. The program requires a 50-50 match by the state. The delivery system is through the State Forester.</p>
Volunteer Fire Assistance	<p>Provides financial, technical and other assistance to rural communities with a population of less than 10,000 matched on a 50-50 basis either by the state or community. The State Foresters and their staff deliver this program. Some benefits include:</p>

Program	Purpose
	<ul style="list-style-type: none"> • Available funding to renovate equipment obtained through the Federal Excess Personal Property Program • Improved fire protection capabilities and capacity in rural areas to protect lives and other rural investments • Improved effectiveness of fire protection in wildland urban interface areas • Complements state and federal firefighting forces to optimize fire protection across ownerships • Complements the Rural Fire Assistance Program provided by the Bureau of Land Management
<p>Good Neighbor Authority (FY 2014 Appropriations Act and the 2014 Farm Bill)</p>	<p>These authorities encourage the USFS to enter into Good Neighbor Agreements with the States, the Commonwealth of Puerto Rico, and State Forestry Agencies to carry out authorized forest, rangeland, and watershed restoration and protective services when similar and complementary projects are being performed on adjacent State or private lands, and on and off National Forest System lands. (CFR 2015)</p>

2. USDA Natural Resource Conservation Service (NRCS) and US Fish and Wildlife Service (USFWS) Incentive Programs

The US Department of Agriculture and the US Department of Interior have technical and financial assistance programs that are complementary to the Cooperative Programs described above (Table 8). The cost incentive programs are the one most commonly used to establish, restore and manage forestland (Table 9).

Table 9. USDA NRCS and USFWS incentive programs available to non-industrial private landowners in Puerto Rico

Program	Purpose
<p>Environmental Quality Incentives Program, EQIP</p>	<p>-Provides a voluntary conservation program for farmers, ranchers and owners of private, non-industrial forest land that promotes agricultural production, forest management and environmental quality as compatible national goals. EQIP offers financial and technical help to assist</p>

Program	Purpose
<p>Partners for Fish and Wildlife, PFW</p>	<p>eligible producers install or implement conservation practices on eligible agricultural land.</p> <p>-Partners with landowners, municipalities, schools, and other organizations to restore habitats on private lands. The program provides technical assistance and matching federal funds to more than 90 projects to restore stream banks, uplands, wetlands, and other habitats used by wildlife in Puerto Rico and the Virgin Islands. Projects are designed to benefit fish and wildlife while meeting the needs and desires of private landowners.</p>
<p>Conservation Reserve Program, CRP (Farm Service Agency)</p>	<p>The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners. Through CRP, you can receive annual rental payments and cost-share assistance to establish long-term, resource-conserving covers on eligible farmland.</p>
<p>Conservation Stewardship Program, CSP</p>	<p>A voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner by:</p> <ul style="list-style-type: none"> • Undertaking additional conservation activities; and • Improving, maintaining, and managing existing conservation activities,
<p>Regional Conservation Partnership Program, RCPP</p>	<p>Partners with agricultural producers, farmers, state or local governments, NGOs, and higher education institutions to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale by</p>

Program	Purpose
	restoring or sustaining natural resources such as: <ul style="list-style-type: none"> • Clean and abundant water • Healthy, productive soils • Enhanced, wildlife and pollinator habitat
Agricultural Conservation Easement Program, ACEP	Provides financial assistance to eligible partners for purchasing Agricultural Land Easements that protect the agricultural use and conservation values of eligible land. In the case of working farms, the program helps farmers and ranchers keep their land in agriculture. It also provides technical and financial assistance to restore, protect, and enhance wetlands through the purchase of a wetland reserve easement. Eligible partners include state and local governments and NGOs that have farmland or grassland protection programs.
Healthy Forests Reserve Program, HFRP	Assists landowners, on a voluntary basis, in restoring, enhancing and protecting forestland resources on private lands through easements, 30-year contracts and 10-year cost-share agreements.

3. DNER Auxiliary Forests Program

The DNER Auxiliary Forests Program (AFP) was created by the Puerto Rico Forests Law of 1975, as amended, to promote conservation of private forestlands by providing tax exempt status to eligible properties enrolled in the program. Eligibility requirements include minimum area (more than 5 cuerdas or 4.855 acres), a DNER inspection, and a signed contract between the landowner and DNER. Property data (owner information, property tax number, eligible area, etc.) is submitted to the local municipal tax agency (CRIM) once contract is signed. Enrollment in the program is voluntary and may be renewed yearly upon request by the landowners and confirmation of eligibility.

Private conservation and management are necessary to preserve the ecological benefits of forests since it has been documented that as much as 82 percent of forests in Puerto Rico are held in private ownership (DNER 2000). In 2007, 67 landowners and 7259 acres were active in the AFP, by 2015 these numbers increased considerably to 254 landowners representing a total of 13,430 acres. Of this acreage nearly 49 percent is forested, 12 percent contains grasslands and shrublands, 22 percent is classified as agroforestry, and 0.07 percent is in riparian environments (Figure 24). The distribution of the private forests enrolled in DNER AFP and FSP by 2015 is presented in Figure 25. The data was created using CRIM property tax maps and information compiled from available DNERFSB Auxiliary Forests files and reflect location of properties that are actively participating in the programs.

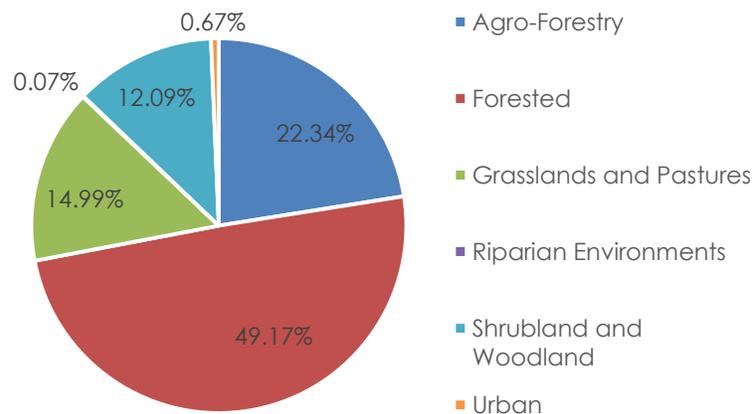


Figure 23. Land use classification on properties enrolled in the AFP by 2015.

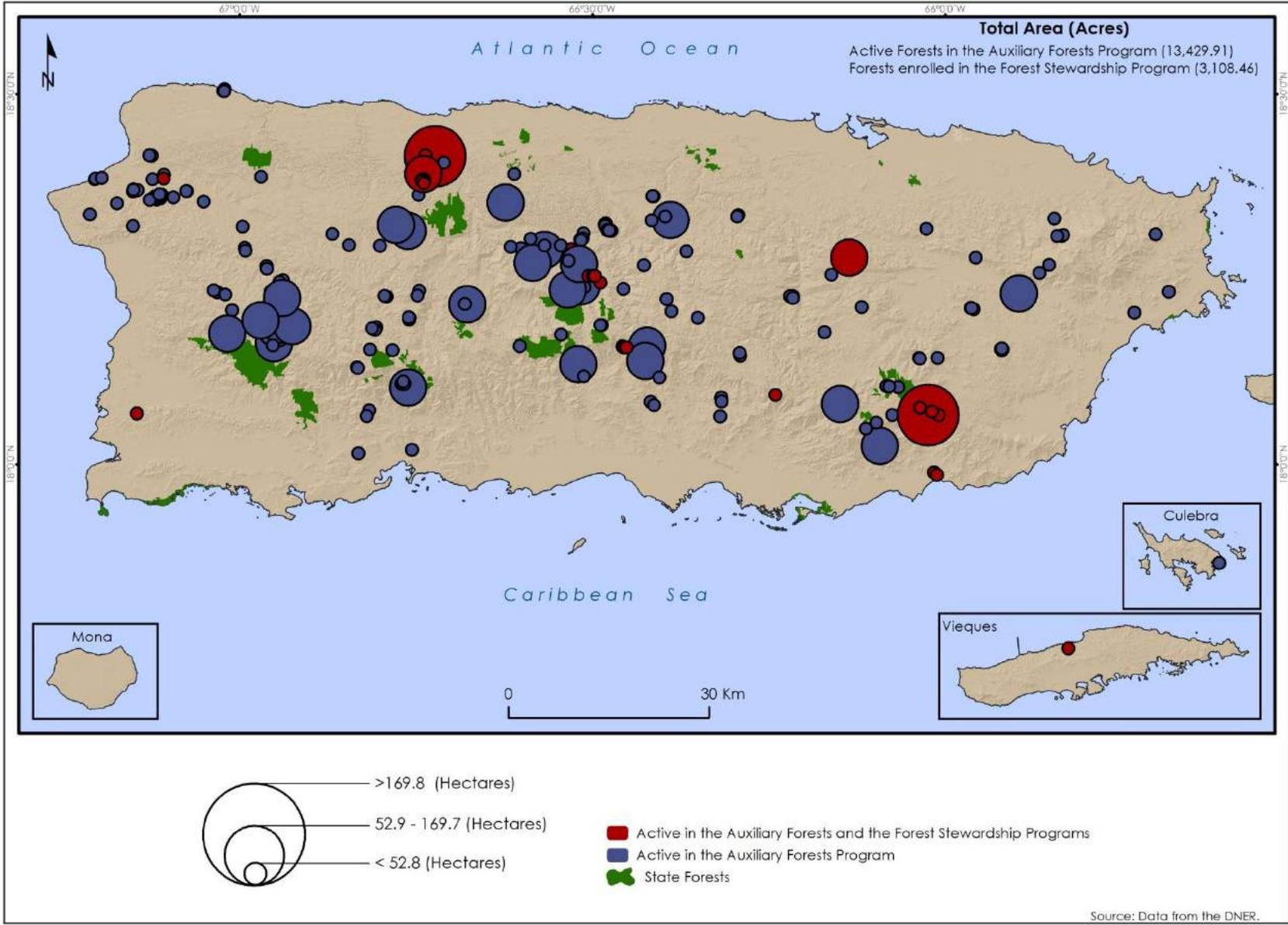


Figure 24. Location of private forests enrolled in state DNER state auxiliary forest programs.

There are numerous laws related to forest resources in Puerto Rico. The most significant are listed in Table 10.

Table 10. List of selected statutes related to forest resources protection in Puerto Rico.

Statutes	Name	Objective
Constitution of the Commonwealth of Puerto Rico adopted In 1952		It establishes as a public policy “the most efficient conservation of natural resources, as well as the best development and use of these for the benefit of the community”.
Commonwealth Law No. 23 of 1972, as amended	Organic Law of the Department of Natural and Environmental Resources	It creates DNER and assigns to it, among several things, the responsibility of establishing programs for the conservation of the PR natural resources, forests included.
Commonwealth Law No. 133 of 1975, as amended	Puerto Rico Forests Act	It establishes the public policy of the Commonwealth to protect, expand and conserve the forest resources of PR. It creates the Commonwealth Forest Service.
Planning Board Regulation No. 25	Planting, Cutting and Forestry Regulations for Puerto Rico,	It requires a DNER permit for cutting and grooming trees on public or private land in Puerto Rico.
Commonwealth Law No. 144 of 1976, as amended	Law for the extraction and excavation of Earth's crust components	It prohibits the issuance of Earth's crust components extractions and excavations in natural resources “reserves” (includes Commonwealth Forests).
Commonwealth Law No. 136 of 1976 (Also known as the “Water Act”)	Act for the Conservation, Development and Use of the Water Resources of Puerto Rico	It assigns to DNER the faculty of planning and ruling the usage, conservation and development of water resources in the Commonwealth, those superficial as much as subterranean.
Commonwealth Law No.29 of 1976	Department of Natural and Environmental	It creates DNER Rangers Corp who is supposed to enforce all the Commonwealth statutes available for

Statutes	Name	Objective
	Resources Rangers Corp Act	the protection of all natural resources (forests included)
Commonwealth Law No. 241 of 1999, as amended	New Wildlife Law of Puerto Rico	It authorizes the Secretary of DNER to rule all activities related to the wildlife well-being, included its habitats (forests included)
Commonwealth Law No.182 of November 3, 2014	Model Forest Act	To recognize the ecological value of the area, by establishing an umbrella effect on ecosystems and associated diversity of these areas, and the role of citizens in landscape conservation by declaring the Model Forest of Puerto Rico as a priority area for planning and a geographic sustainable development platform to promote criteria for management and conservation

III. PUERTO RICO STATE-WIDE STRATEGIES FOR FOREST RESOURCES
a. STRATEGIES OVERVIEW

In 2008 the Congress of the USA enacted the Food, Conservation, and Energy Act. This Act included an amendment to the Cooperative Forestry Assistance Act of 1978. The amendment required each State and Territory to provide a Statewide Assessment of Forest Resources and a Statewide Forest Resources Strategy to the Secretary of Agriculture, USDA. This document fulfills the requirement for the Puerto Rico Statewide Forest Resources Strategy. The Puerto Rico Statewide Assessment of Forest Resources identified three broad goals for the Puerto Rico DNERFSB:

1. Conserving working forest landscapes
2. Protect forests from harm
3. Enhance public benefits associated with trees and forests

Within each of these goals are a number of priority issues to be addressed. The issues were identified in the forest resources assessment section and are as follows:

i. Priority Issues

1. *Fragmentation of forest systems*

There is concern by the public about the urbanization and development of land previously in forest, cropland or pasture especially, the loss of public open space and fragmentation of large forest parcels.

2. Water resources and watershed conservation strategies

Water quality is an issue of concern to the public and natural resource professionals. For domestic water supply watersheds, management practices and forest cover are viewed as key to maintaining the quantity and quality of water resources.

3. Information needs related to ecosystem services and other benefits from public and private forest land

The people of Puerto Rico have begun to raise awareness about the conservation of its natural resources and to develop new initiatives among government agencies, Non-Governmental Organizations (NGO's) and citizen groups. Private landowners want information in order to manage their own land responsibly. The larger public needs information about the benefits of conservation programs, protected natural areas, and existing and new economic opportunities in order to integrate conservation into public policy decisions regarding land use throughout the island (e.g. initiatives to bring together regional planning efforts for the conservation of natural resources).

4. Disturbances affecting forests (hurricanes, floods, fires, pests, etc.)

The natural and anthropogenic disturbances were a concern or area of interest of the participants in the public consultation by DNERFSB. The types of disorders most commonly identified by participants were hurricanes, forest fires and climate change.

5. Concern over invasive species

People want to know which exotic invasive tree and wildlife species are problematic and why. They are most concerned about impacts in natural areas.

6. Economic opportunities and alternative market development

People want to expand existing and develop new viable economic markets associated with forests. This includes providing market opportunities for private landowners (agro-forestry, wood and non-wood forest products), non-extractive uses of public lands (e.g. eco-tourism, recreation), and ecosystem service markets (e.g. valuation and sale of forest services (i.e. carbon storage, water production, biodiversity conservation, coastal protection)).

ii. Priority Landscapes

One of the greatest challenges in natural resource conservation and management is to effectively integrate and use many types of information in decision-making. Landscapes are useful because they have geographic boundaries that help identify the scope of the ecological social and economic conditions that need to be considered. The landscape scale is well suited for collaboration and the tactical and operational planning needed to implement conservation practices and conduct forest management. The Areas presented as Priority Landscapes each highlight different high priority concerns and a primary implementation focus rooted in the State and Private Forestry (S&PF) Cooperative programs. They are not mutually exclusive. The strategies section that follows gives a more comprehensive picture of the range of programs and partnerships to be used.

Eight priority landscapes have been identified based on analysis of the public issues, resource status and trends, and partnership opportunities. They are:

- Interface Landscapes
- Critical Wildlife Areas
- Areas of Hydrologic Importance
- Fire Prone Landscapes
- Urban Forests
- Riparian Corridors
- Joint Priority Landscapes
- Model Forest of Puerto Rico

Addressing these priority issues to achieve the aforementioned goals requires creating a set of instrumental strategies for such objective. It also requires the provision of guidelines as to how the goal contributes to the management of the issues. For each goal a matrix of strategies has been provided that address the issues. These strategies are meant as guides to the process of managing Puerto Rico forest resources into the near future.

1. Interface Landscape

The DNERFSB will focus on acquiring land and easements in the portions of Forest Legacy Areas that fall within the wildland urban interface (Figure 26). The primary objective is to retain large blocks of high quality contiguous forest that provide for the critical elements in the attached Assessment of Need. (Appendix A)

The Forest Legacy Program (FLP) is a volunteer land acquisition and conservation easement program that is administered by USFS, and implemented cooperatively with the DNERFSB. At present, eight Forest Legacy Areas have been identified based on the following criteria: forest condition, water basins, biodiversity, scenery, cultural attributes, wildlife habitat, and recreational potential. They are Guánica, Caonillas–Dos Bocas, El Yunque, La Plata-Coamo, Maricao, Maunabo, Quebradillas, Río Grande de Loíza.

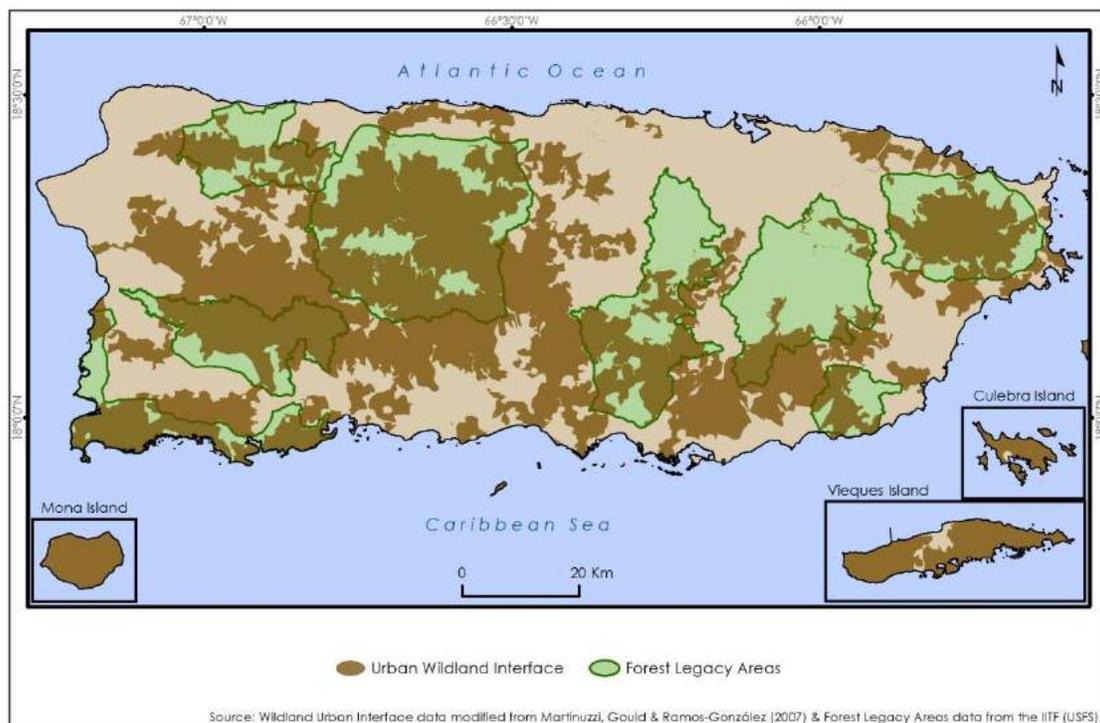


Figure 25. Overview of urban wildland interface zones (Martinuzzi et al. 2007) and Forest Legacy Areas in Puerto Rico.

2. Critical Wildlife Areas (CWA's)

Figure 27 displays the CWA's identified in the PRSWAP (DNER 2015). These areas were delineated by determining the location of land “necessary” to perpetuate the existence of species of special interest to the DNER. The species underlying selection of these areas are classified as threatened using the IUCN red list methodology. The purpose of this landscape is to ensure forest habitat is available to sustain the most threatened species on the island. A list of public land within each areas is found in the Appendix E. The DNERFSB will work closely within and without the Department to manage their own land to meet this need, to prepare private forest management plans that consider wildlife objectives, and to educate community.

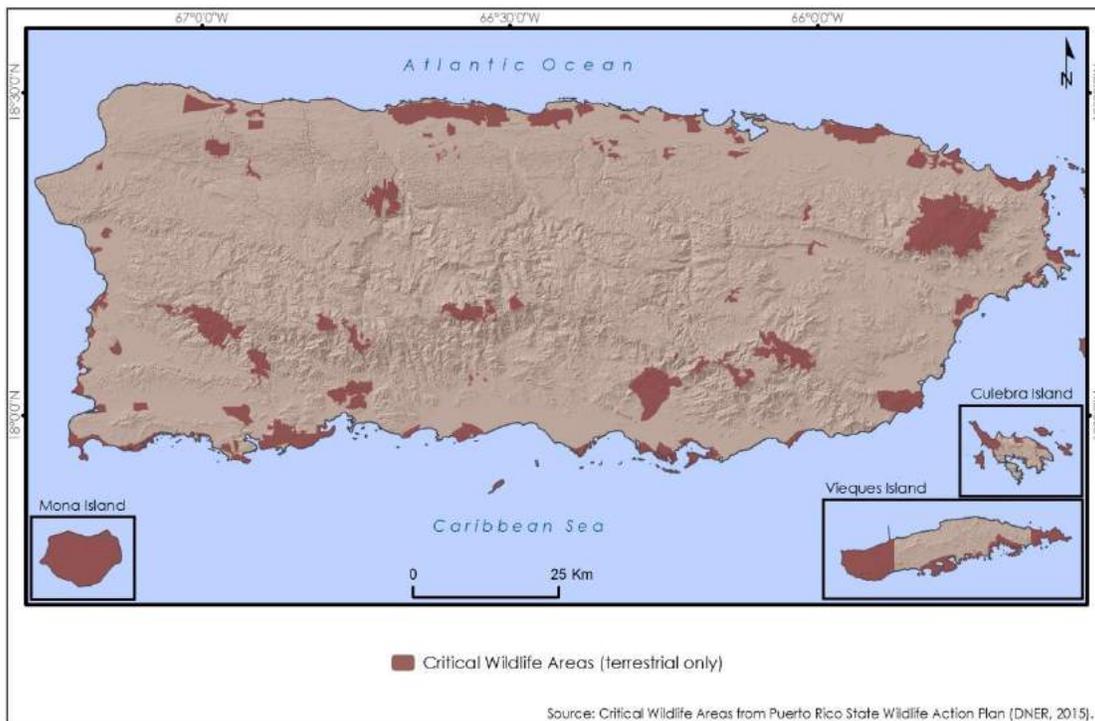


Figure 26. CWA's of Puerto Rico and their respective geographical locality obtained from PRSWAP (DNER 2015)

3. Areas of hydrologic importance

The primary objective in this landscape is to maintain and/or restore sufficient forest cover to extend the lifespan of existing water supply reservoirs. The target zones are areas upstream of existing reservoirs (Figure 28) as well as Hydrological Reserves (Table 11). Management activity will focus on lands where reforestation or other forest management will improve sediment and erosion control. The analysis was conducted by the DNER and the Office of the Land Use Plan of the Puerto Rico Planning Board. It considered precipitation intensity, slope, soil types, aquifer recharge zones, and land use in the preparation of the base map. Alternative and much more expensive responses to loss of reservoir capacity include new construction, hydraulic engineering, and continuation of existing dredging operations (DNER 2008-a).

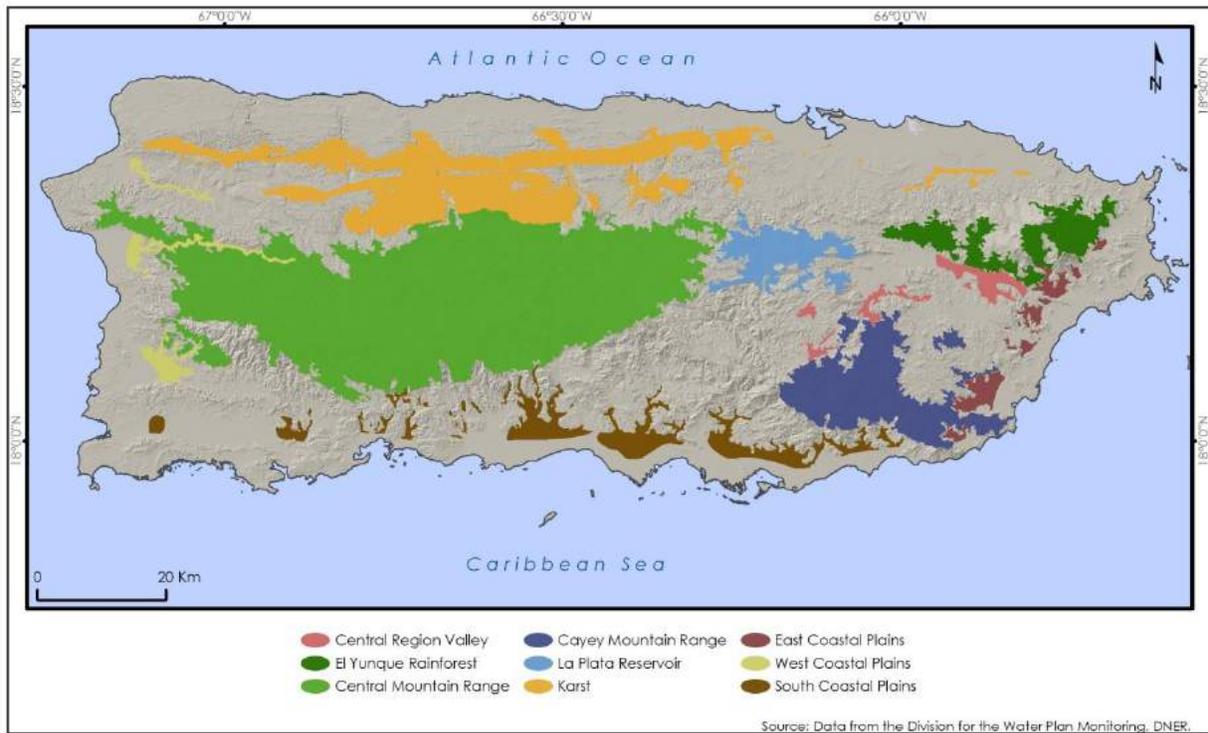


Figure 27. Hydrological regions in Puerto Rico recommended for water quality protection by DNER and Puerto Planning

Table 11. Hydrological Reserves

I-Surface Hydrological Protection Areas	II-Groundwater Hydrological Protection Areas	III-Combined Hydrological Protection Areas (surface and groundwater)
Cordillera Central Hydrologic Reserve	Southern Coastal Plains Hydrologic Reserve	Karst Hydrologic Reserve
Sierra de Luquillo Hydrologic Reserve	Eastern Coastal Plains Hydrologic Reserve	
Sierra de Cayey Hydrologic Reserve	Western Coastal Plains Hydrologic Reserve	
La Plata Hydrologic Reserve	Interior Plains Hydrologic Reserve	

4. Fire Prone Landscape

The area in red on Figure 29 constitutes the fire prone landscape. People, dry fuels, and climatic conditions are account for the large number of fires in the southern coastal plain. Reduction of fire risk, rapid fire suppression, and public education are the major objectives in this area. The Puerto Rico Fire Service is the lead agency for wildfire suppression and fire risk reduction. However, the DNER works as a close partner, especially in the Mayaguez and Ponce Administrative Regions.

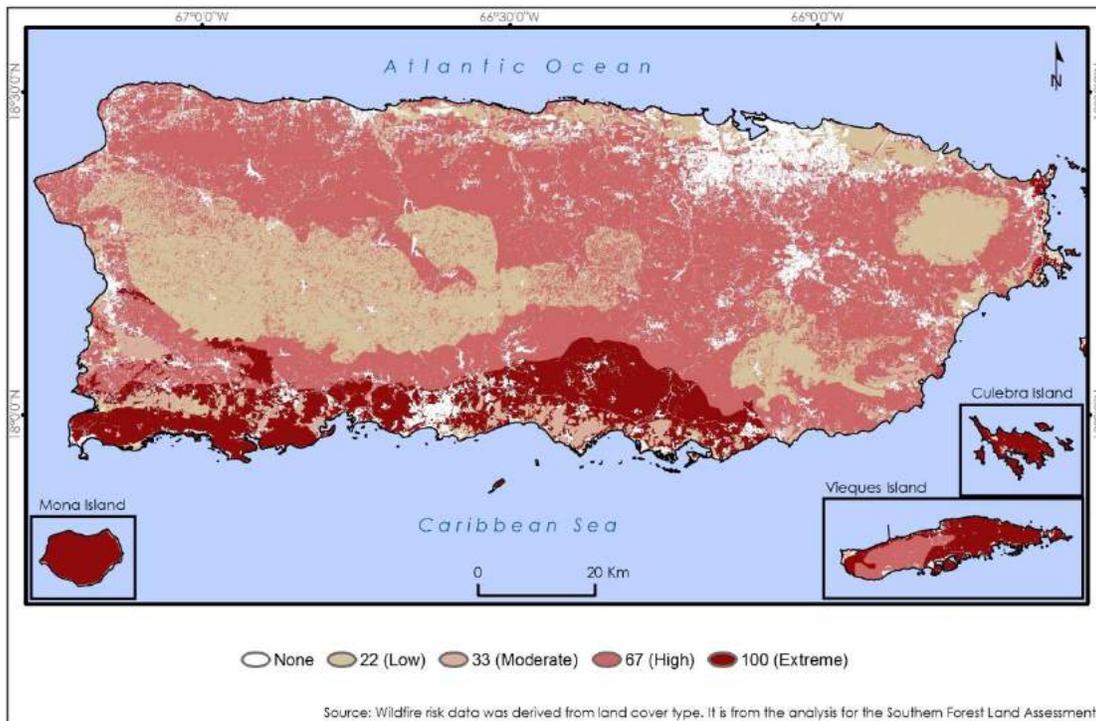


Figure 28. Overview of areas of Puerto Rico, Vieques, and Culebra under different levels of wildfire incidence according to SFLA

In 2014, a total of 3,743 fires burnt 16,327.7 acres of land (Table 12). By the end of September, 2015 4,074 fires had already affected 11,920 acres of land; 127 more fires occurred by the same date in 2014. When large numbers of fires occur in a short period of time, the response to any individual fire may be slower. This increases the risk of the fire going out of control. Most fires in Puerto Rico are set by people without regard to the wind, weather or air quality conditions at the time they are set. When large numbers of fires are set at once it is likely that some fires will burn larger areas than they would with a rapid response. Prescribed burning is a cost effective way to remove fuels that would be burned in an uncontrolled environment. It allows professionals to minimize the hazards to soil, air quality, and human safety. Cutting and clearing of brush is a more expensive means of removing fuels. Public education is needed about the effects and risks of fires in Puerto Rico

Table 12. Incidence of wildfires in Puerto Rico between January 2014 and September 2015

2014		
Month of occurrence	# of fires	Acres
January	403	1,531.25
February	588	3,675.75
March	996	3,380.20
April	504	2,383.50
May	197	523.75
June	381	2,475.00
July	441	2,147.75
August	87	146.50
September	19	10.00
October	46	17.00
November	15	8.00
December	66	29.00
2015		
Month of occurrence	# of fires	Acres
January	157	283.00
February	156	471.50
March	464	1,834.25
April	819	2,495.75
May	1,313	3,906.25
June	397	1,179.50
July	434	715.00
August	312	1,009.00
September	21	25.75

5. Riparian corridors

Riparian areas are the lands adjacent to a body of water, stream, river, marsh, or shoreline and a high priority for forest conservation and management. They have unique ecological attributes. Restoration and management of forest cover in riparian areas adjacent to reservoirs, agricultural fields and urban streams is a high priority in every DNER administrative region. Water quality, soil protection, and wildlife habitat are the most common objectives for riparian forest corridors and are influenced by their setting. Economic values, aesthetics, protection, safety, and the potential for outdoor recreation will also be considered. Bentrup (2008) provides useful design criteria. Technical assistance will be provided to ensure that appropriate species are used.

Riparian forests can help remove or ameliorate the effects of pollutants in runoff, and increase the biological diversity and productivity of aquatic communities by improving habitat and adding to the organic food base. Riparian forests can also play a large role in buffering urban and agricultural development. When conserved and managed as buffers, riparian forests can dramatically reduce the impacts of land use activities (Welsch 1991). In fact, studies show dramatic reductions from 30 to 98 percent in nutrients, sediments, pesticides, and other pollutants in surface and groundwater after passing through a riparian forest buffer (Lowrance et al. 1984). Agricultural runoff is one type of nonpoint pollution that can be reduced by using streamside forests as buffers. Streamside forests are important riparian areas (Figure 30).

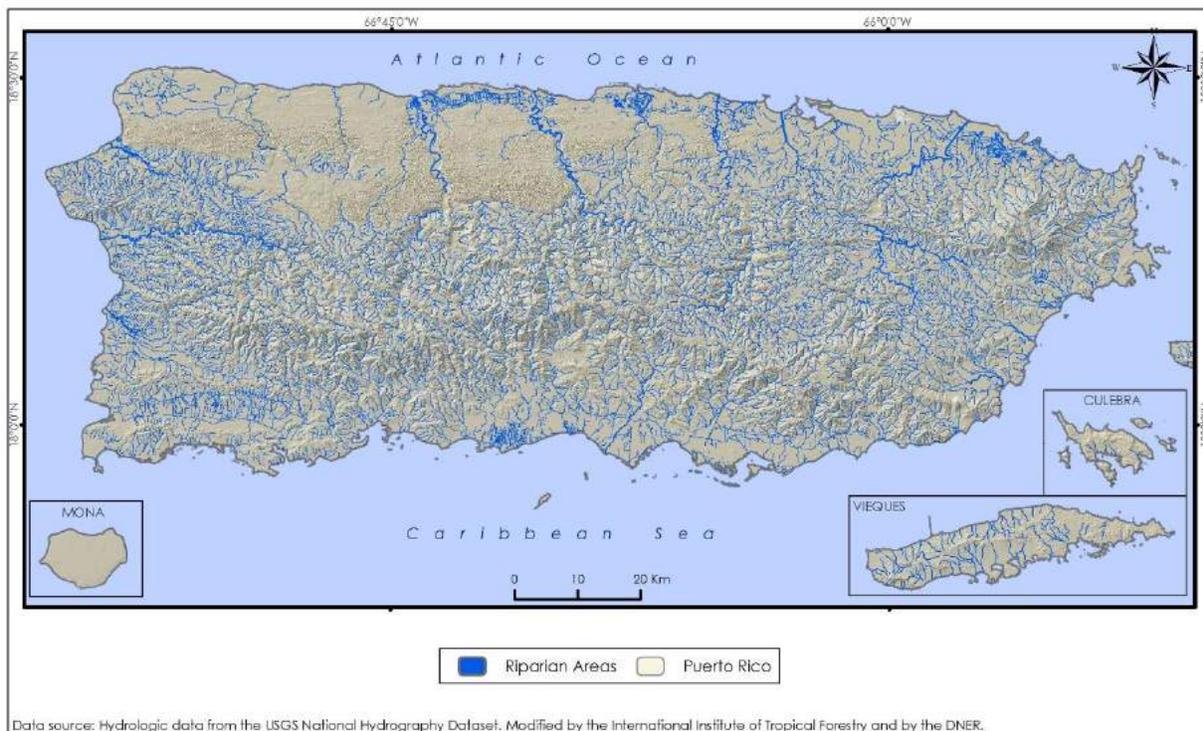


Figure 29. Overview of riparian areas in Puerto Rico, Vieques, and Culebra

6. Urban Forests

Urban forests are more than the forest cover of a city. The term includes natural forest stands, natural corridors along riparian zones, artificial corridors along streets and avenues, and green space constructed by people (Lugo 2004). Large and small urban areas are identified as priority landscapes (Figure 31). The intent is to increase the biodiversity and health of urban forests, establish and/or maintain, green infrastructure with all its associated benefits, and reduce tree hazards and flooding hazards that affect public safety.

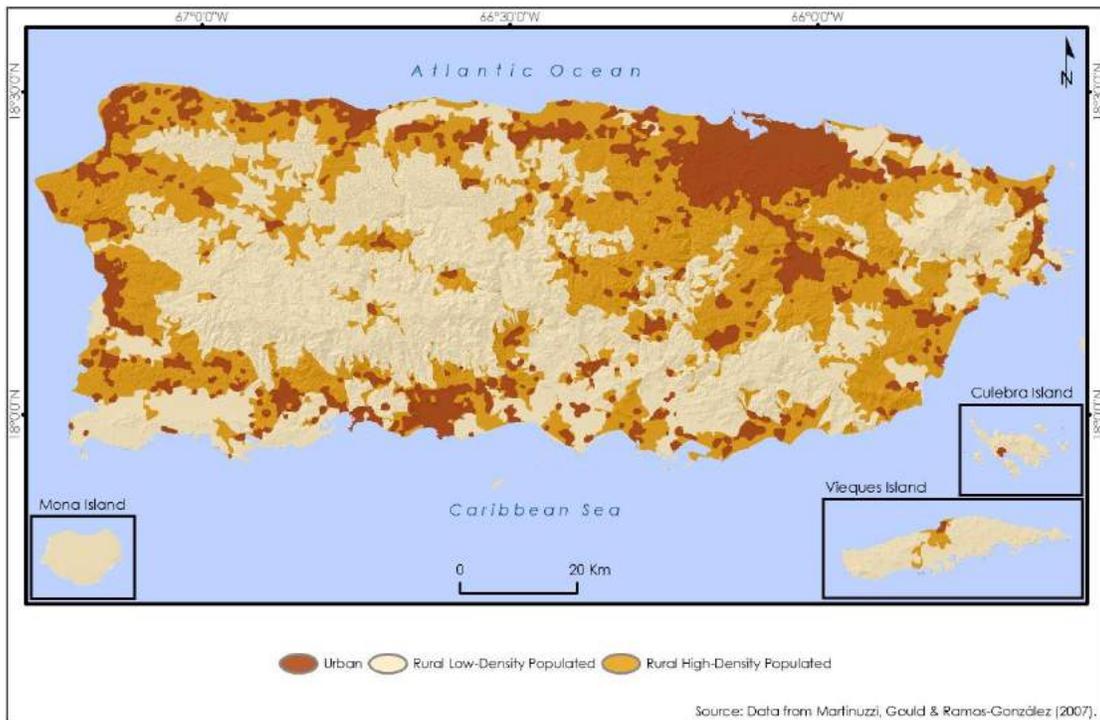


Figure 30. Overview of urban and rural (densely v. low populated) areas distribution in Puerto Rico.

7. Joint Priority Landscapes

People are both the cause and the consequence of ecosystem change. There are always times and places where Federal and State agencies and non-government partners independently establish complementary conservation priorities and it makes sense to leverage resources, one against the other. Joint priority landscapes have the potential to take many forms. Watershed approaches, ecological unit approaches, and issue-centered approaches are three possibilities. Finally these efforts explicitly seek public engagement, ideally in a unified manner that respects the time and talents of community members.

There are two joint priority landscapes to work during the plan implementation period:

- The Guanica/Maricao joint priority landscape

This joint priority landscape is located in the southwestern corner of mainland Puerto Rico. The total area includes a 5-mile buffer zone around the State Forest of Maricao and a biological corridor towards the south, both encompassing the areas of the Río Loco Watershed and the States Forests of Susúa and Guánica (Figure 32). The Guanica/Maricao joint landscape would leverage most of the federal agencies efforts and cooperative and independent state efforts as a start. The NOAA Coastal Zone Management Program is working to protect the coral reef system, the NRCS is working with local famers to improve water quality in the Río Lobo watershed and reduce soil erosion that affects streams and the reefs. Multiple wildlife and forestry agencies are working with coffee growers to convert their plantations from sun to shade coffee to benefit migratory birds. EPA is looking at a major estuary restoration effort; the USFS and the DNERFSB are promoting riparian buffers and agroforestry pilots in the DNER and USFWS Guanica, Cabo Rojo Wildlife Refuge, and the Maricao CWA. The Puerto Rico Fire Department (PRFD) and the State Forest are working on wildland fire strategies.

- The Humacao joint priority landscape

This area is located in the southeastern corner of mainland Puerto Rico in an area of urban sprawl. The area includes a 5-mile buffer zone, which encompasses the Northeast Ecological Corridor, Ceiba State Forest, El Yunque National Forest, the tranfered lands of Roosevelt Roads, and the Natural Reserves of Río Espíritu Santo and Humacao (Figure 33). The Northeast Ecological Corridor was established in 2012 under Act No. 126, as amended, and is distinguished by containing most of the general types of coastal wetlands classified in Puerto Rico.

All the federal and state partners in the NRCS State Technical committee endorsed collaborative efforts in this joint priority landscape. This joint priority landscape brings multiple local communities into the conservation effort. Federal financial and technical assistance and cost incentive programs are in operation here. The DNER and USFS concentrates efforts in this landscape through both the U&CF Program, the FSP, the FLP, and the new CFP. The federal and state fish and wildlife agencies are working on endangered and threatened species habitat protection. Also, the El Yunque National Forest is revising its Land and Resource management plan (USDA Forest Service 2015-b). The ecological sustainability of the forest was the emphasis of previous planning processes. This plan intends to address the human needs and uses of the forest within the present conditions of the forest by promoting sustainable socioeconomic development and integrating communities in the vicinity of this national forest (CCP 2015). A Public Participation Consulting Committee, with around twenty (20) members from different sectors, was created with the goal of establishing co-management measures and to provide feedback to the Land and Resource management plan (CCP 2015).



Figure 31. Overview of the Guánica/Maricao joint landscape

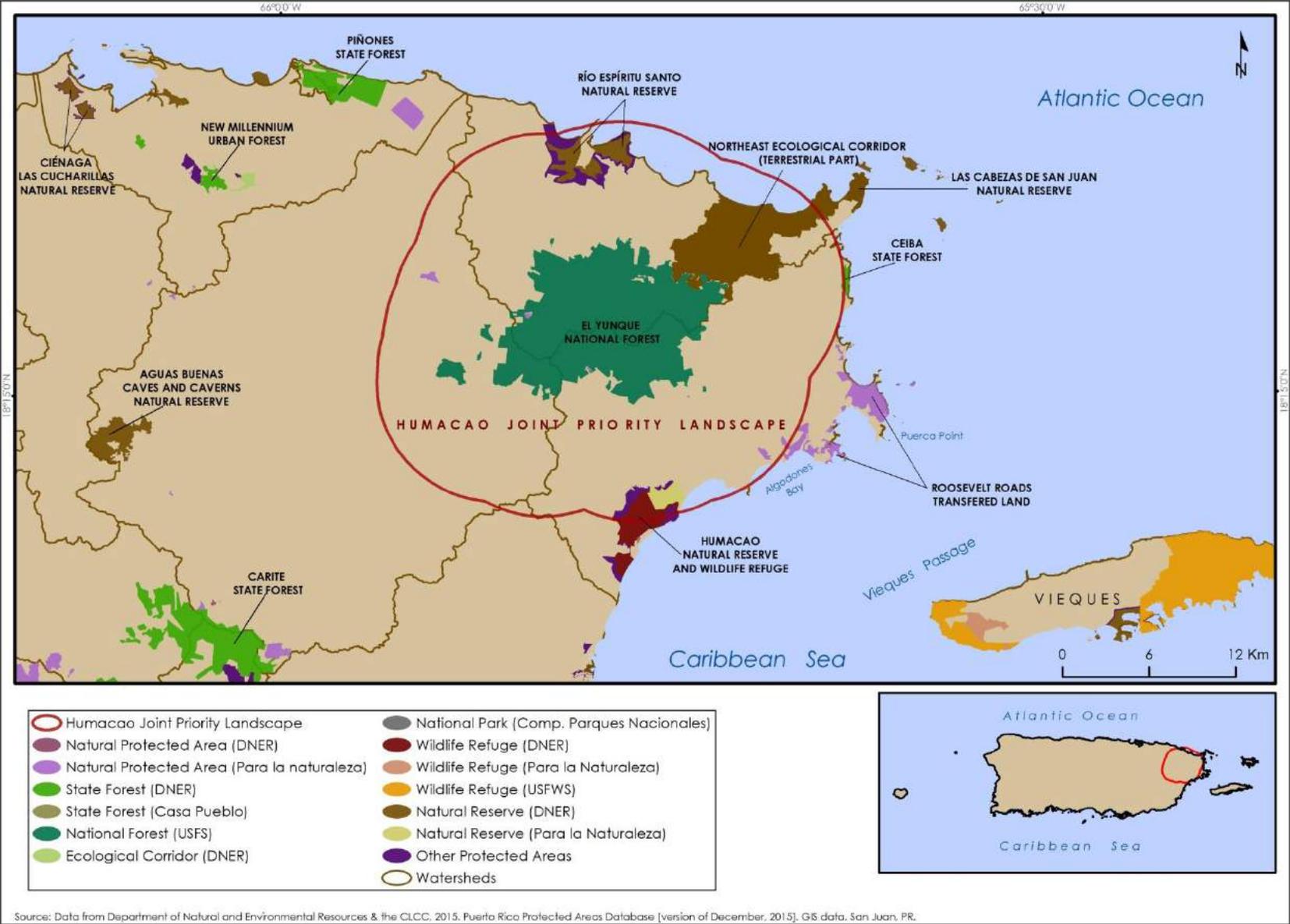


Figure 32. Overview of the Humacao joint priority landscape

8. The Model Forest of Puerto Rico

According to the International Model Forest Network model forests are based on an approach that combines the social, cultural and economic needs of local communities with the long-term sustainability of large landscapes in which forests are an important feature. People with differing interests and perspectives partner to manage their own natural resources in a way that makes the most sense to them given their history, economic and cultural identities and in a way that does not jeopardize future generations.

Community initiatives encouraged the Government of Puerto Rico to approve Act No. 14 Unifying Act of State Forests of Maricao, Susúa, Toro Negro, Guilarte and the Municipality of Adjuntas. This Act orders the DNER to identify the lands between these forests and draw two biological corridors linking them; delimit buffer zones; and determine acquirement and conservation strategies. By 2004, the Planning Board of Puerto Rico approved the *Conservation Plan of Sensitive Areas for Adjuntas and Adjacent Municipalities*, which includes the first ecological corridor of Puerto Rico linking the forest of *Bosque del Pueblo* in Adjuntas with the forests of Toro Negro, Tres Picachos, La Olimpia and Guilarte, covering 35,687 acres of land in ten (10) municipalities. This regional conservation initiative contributed to the Adjuntas Model Forest Lands and a proposal for sustainable development that takes place in a larger geographical framework aimed at connecting a forest landscape from north to south of the island that underlies the proposed Model Forest of Puerto Rico.

By 2014, the Commonwealth of Puerto Rico established the Puerto Rico Model Forest Act under Commonwealth Law Num. 182, being the first country to establish a Model Forest through legislation. This law recognizes the ecological value of the area, by establishing an umbrella effect on ecosystems and associated diversity of these areas, and the role of citizens in landscape conservation by declaring the Model Forest of Puerto Rico as a priority area for planning and a geographic sustainable development platform to promote criteria for management and conservation, sustainable tourism, education, and agriculture when implementing regional programs. The Model Forest of Puerto Rico interconnects nineteen (19) protected areas; including *Bosque del Pueblo*, Toro Negro, Tres Picachos, La Olimpia, among others; throughout 378,777 acres of land from the north coast to the southern dry zone between Guanica and Cabo Rojo (Figure 35). This is a novel approach in Puerto Rico, because it does not consider protected areas as a separate landscape, but protects existing forest cover in conformity with economic development, and incorporates communities and other stakeholders in the management of the forested landscape as part of the conservation objectives of the entire region.

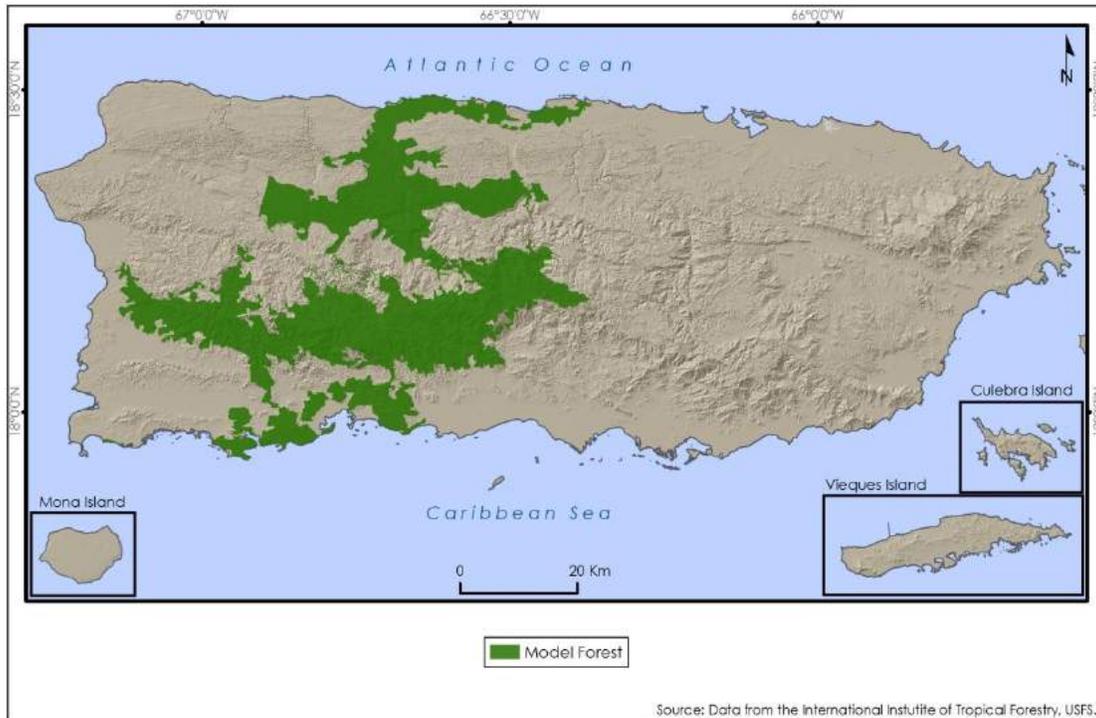


Figure 33. Overview of the Model Forest of Puerto Rico

b. Goals and Strategies

i. Goal 1: Conserving working forest landscape

This goal encompasses the need to perpetuate the multiple values, uses and services provided by the Puerto Rico forest cover. These benefits may be protected or increased by implementing better conservation practices. To main objectives under this goal are:

- identify and conserve high priority forest ecosystems and landscapes in Puerto Rico currently under private control;
- actively and sustainably manage private forested land.

The strategies recognized as of great value for this goal are the following (outputs are included):

- 1- Continue land acquisition programs of key private forested land by available mechanisms (e.g. FLP)
 - recreation and tourism; wood products
- 2- Promote conservation easements on private forested land
 - recreation and tourism; wood products
- 3- Provide adequate conservation management to private forests through FSP
 - recreation and tourism
 - water conservation
- 4- Develop forest and wildlife interpretation trainings
 - recreation and tourism

- 5- Develop management information on agroforestry practices suitable to the Río Loco Watershed at Guánica Bay Watershed.
 - agroforestry products; wood; fruits; medicinal products; craft products; coffee, energy conservation, air quality improvement
- 6- Increase capacity of community to manage trees (i.e. promote municipal tree boards)
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety, energy conservation, air quality improvement
- 7- Increase tree canopy cover and condition
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; energy conservation, air quality improvement
- 8- Acquire community open spaces to protect key forested areas
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; water conservation
- 9- Hazard tree mitigation
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; energy conservation, air quality improvement
- 10-Increase use of native plant material (native tree propagation and use)
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety, energy conservation, air quality improvement
- 11-Develop nursery quality standards (Work with nursery growers to provide quality nursery stock)
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; energy conservation, air quality improvement.
- 12-Develop educational programs and activities (i.e. demonstration of forests projects)
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety, energy conservation; air quality improvement
- 13-Introduce agroforestry concepts
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; economic opportunities
- 14-Promote arboriculture in universities curricula
 - shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; trained professionals

Table 13. Goal 1: Conserving Working Forest Landscapes

Outputs	Priority landscape	Strategies	Resources	Performance Measures
<p>-Recreation -Tourism</p>	<p>-Public lands -Surrounding private lands</p>	<p>-Continue land acquisition of key forested land by available mechanisms (USFS FLP). -Promote Conservation Easements on private forest land. -Provide adequate conservation management to private forests through FSP. -Develop forest and wildlife interpretation trainings.</p>	<p>-USFS FLP -DNER PR Natural Heritage Program -DNER PR High Ecological Value Land Acquisition and Conservation Fund -USFS FSP -NRCS HFRP -USFWS State Wildlife Grant -PR Conservation Trust Land Acquisition Initiative</p>	<p>-High priority forest ecosystems and landscapes are protected from conversion (acres-annual and cumulative). -Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship Management Plan -Number of interpretation trainings offered to private landowners and community members.</p>
<p>Wood products</p>	<p>Area around Toro Negro State Forest due to high risk of development.</p>	<p>-Continue land acquisition of key forested land by available mechanisms (USFS FLP)</p>	<p>-USFS FLP -DNER PR Natural Heritage Program -DNER PR High Ecological Value</p>	<p>-High priority forest ecosystems and landscapes are protected from conversion (acres-</p>

Outputs	Priority landscape	Strategies	Resources	Performance Measures
		<p>-Promote Conservation Easements on private forest land</p> <p>-Provide adequate conservation management to private forests through Forest Stewardship plans</p>	<p>Land Acquisition and Conservation Fund</p> <p>-USFS FSP</p> <p>-NRCS HFRP</p> <p>-USFWS State Wildlife Grant</p> <p>-PR Conservation Trust Land Acquisition Initiative</p> <p>-PRIDCO PR Arts and Crafts Development Program</p>	<p>annual and cumulative).</p> <p>-Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship Management Plan (cumulative1) – through a Nationally consistent monitoring program.</p>
<p>-Agroforestry products</p> <p>-Wood</p> <p>-Fruit</p> <p>-Medicinal products</p> <p>-Craft products</p> <p>-Shade grown coffee</p>	<p>-Rio Loco Watershed</p> <p>-Guánica Bay Watershed</p>	<p>-Develop management information on agroforestry practices suitable to the Río Loco Watershed at Guánica Bay Watershed</p> <p>-Develop nursery quality standards (Work with nursery growers to provide quality nursery stock)</p>	<p>-USFS FSP</p> <p>-NRCS HFRP</p> <p>-USFWS State Wildlife Grant</p>	<p>-Number of educational fact sheets, talks, and training sessions offered to landowners and community members.</p> <p>-Number of nursery growers participating.</p> <p>-Number of nurseries producing high quality nursery stock.</p>

Outputs	Priority landscape	Strategies	Resources	Performance Measures
<ul style="list-style-type: none"> -Shade -Aesthetics -Climate control -Mental health -Wood products -Mulch -Wildlife -Green infrastructure -Recreation -Safety -Energy conservation -Air quality improvement 	<p>Urban Areas and wildland urban interface.</p>	<ul style="list-style-type: none"> -Increase capacity of communities to manage trees (i.e. promote municipal tree boards). -Increase tree canopy cover and condition. -Acquire community open space to protect key forested areas. -Hazard tree mitigation. -Increase use of native plant material (native tree propagation and use). -Develop educational programs, activities (i.e. demonstration forests projects). 	<ul style="list-style-type: none"> -USFS U&CF Community Cost-share Grants -NGOs Education Programs -Tree City USA -PR Via Verde Program -DNER Reforestation Programs -USFS Community Forest and Open Space Conservation Program -International Society of Arboriculture -Municipalities 	<ul style="list-style-type: none"> -Number of cities protecting urban forests after working with U&CF to develop management plans and ordinances. -Number of cities and communities managing their urban forest. -Number of Municipal Tree Boards. -Number of cities participating of the Tree City USA Program. -Number of ISA Certified Arborists (private and public sector).

Outputs	Priority landscape	Strategies	Resources	Performance Measures
		<ul style="list-style-type: none"> -Develop nursery quality standards. -Introduce agroforestry concepts. -Promote arboriculture in University curricula. 	<ul style="list-style-type: none"> -Universities -DNER -PR U&CF council -University of Puerto Rico (UPR) Extension Service -PR Association of Professional Arborists -College of Architects and Landscape Architects. -PR Correctional and Rehabilitation Department 	<ul style="list-style-type: none"> -Number of communities participating of the Open Space Community Forest Program. -Number of nursery growers improving nursery protocols. -Number of nurseries producing high quality nursery stock. -Number of demonstration projects using high quality plant material and native species. -Number of arboriculture courses offered at the UPR in Mayaguez, College of Agriculture

ii. Goal 2. Protect forest from harm

This goal pursues the recognition of real threats or harm causes affecting forested lands, and to identify ways to control or reduce substantially their harmful effects. Two main objectives under this goal are:

- identify, manage and reduce threats to forested ecosystems health;
- reduce risks of wildfire impacts.

Main threats considered of strong capacity to affect present forest resources in the island have been identified by the Puerto Rico Statewide Assessment of Forest Resources and are hereby presented, followed by the strategies recognized as of great value under the objectives of this goal:

A- Fire

1. Create a database to collect information on fire occurrences recording:
 - (1) location,
 - (2) type of vegetation,
 - (3) number of acres affected,
 - (4) resources used, and
 - (5) resources needed
2. Develop and implement a Fire Danger Rating System for the areas with high wildland fires occurrences.
3. Offer Fire prevention education to the communities within the areas with high wildland fire occurrences. Increase efforts on the wildland urban interface.
4. Develop Community Wildfire Protection Plans and educational programs
5. Wildland Fire suppression.
6. Use Prescribed Burning as a resource to control fire occurrences in areas with high fire incidence.
7. Tree planting and resource restoration in areas affected by fires.
8. Acquire, maintain, and pre-position essential equipment and supplies for wildland fire suppression.
9. Develop an effective communication strategy between partners involved in the suppression of wildland fires.

B. Insect pests and disease

- 1- Establish a Forest Health Monitoring Program at the DNERFSB.
- 2- Encourage early detection and rapid response from DNER Forest Managers.
- 3- Provide professional training to DNER Forest Managers.
- 4- Promote public education about possible detrimental effects on forest floristic components.
- 5- Maintain adequate urban tree inventories and management practices.
- 6- Promote Integrated Pest Management.

C- Development; urban sprawl; fragmentation

- 1- Protect developed large contiguous forest areas and corridors to insure connectivity by:
 - Land acquisition (see Appendix A)
 - Conservation easements
 - Adequate land use zoning
 - Voluntary protection
- 2- Encourage planting trees to increase tree canopy cover and green corridors.
- 3- Promote proper land use planning and accurate zoning on forested areas.
- 4- Promote professional training about assessing the forest cover and its benefits on agencies involved in determining present and future land use.
- 5- Increase programs availabilities for the East side of the Islands by:
 - (1) Increase outreach,
 - (2) Increase Water Conservation
 - (3) Enhance Forest Diversity,
 - (4) Enhance all restored riparian habitats.

D-Climate Change

- 1- Create and conserve corridors for tree mitigation.
- 2- Increase carbon storage through increases in tree canopy cover.
- 3- Conduct urban forests inventories.
- 4- Encourage development of management plans.
- 5- Perform hazard tree mitigation.
- 6- Provide professional training.

E- Hurricane/storms

- 1- Conduct urban forests inventories.
- 2- Develop management plans.
- 3- Perform hazard trees mitigation.
- 4- Promote adequate tree selection.

F- Flooding

- 1- Promote forested wetland protection.
- 2- Promote riparian buffer installations.
- 3- Maintain and increase forest cover in catchment and groundwater recharge areas.
- 4- Conduct urban trees inventories and perform hazard mitigation.

G- Drought

(See fire and climate change)

H- Invasive plants and animals

- 1- Provide professional and public education.
- 2- Promote usage of native and other suitable species.
- 3- Apply eradication practices.
- 4- Adequate law enforcement against introduction of exotics.
- 5- Promote early detection of invasive species.

Table 14. Goal 2: Protect forests from harm - identify, manage and reduce threats to the forest, such as urban development, storms, floods, insects, diseases, invasive species, and fire.

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
<p>Fire map showing fire occurrence information.</p>	<ul style="list-style-type: none"> -Biodiversity -Wildlife habitat and populations -Water quality -Air quality esp. in Urban environment -Recreation experiences -Coastal resources. 	<ul style="list-style-type: none"> -Create a database to collect information on fire occurrences recording: <ul style="list-style-type: none"> (1) location, (2) type of vegetation, (3) number of acres affected, (4) resources used, and (5) resources needed -Develop and implement a Fire Danger Rating System for the areas with high wildland fires occurrences -Offer Fire prevention education to the communities within the areas with high wildland fire occurrences. Increase efforts on the wildland urban interface -Develop Community Wildfire Protection Plans and educational programs -Wildland Fire suppression 	<ul style="list-style-type: none"> -PRFD Fire Prevention Program -DNERFSB -USFWS -USFS -USFS Cooperative Fire Program -USFS Volunteer Fire Program 	<ul style="list-style-type: none"> -Number of acres treated to restore fire-adapted ecosystems that are <ul style="list-style-type: none"> (1) moved toward desired conditions and (2) maintained in desired conditions. -Total # of acres treated to reduce hazardous fuels on state and private lands through State Fire Assistance -Percentage of at risk communities who report increased local suppression

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
		<ul style="list-style-type: none"> -Use Prescribed Burning as a resource to control fire occurrences in areas with high fire incidence -Tree planting and resource restoration in areas affected by fires -Acquire, maintain, and pre-position essential equipment and supplies for wildland fire suppression. -Develop an effective communication tool between partners involved in the suppression of wildland fires 		<p>capacity as evidenced by:</p> <ul style="list-style-type: none"> (1) The increasing number of trained and/or certified fire fighters and crews, or (2) Upgraded or new fire suppression equipment obtained, or (3) Formation of a new fire department or expansion of an existing department involved in wildland fire fighting.
Insect pests and disease	<ul style="list-style-type: none"> -Loss and displacement of wildlife -Decreased reproduction -Stained wood 	<ul style="list-style-type: none"> -Establish a forest health monitoring program at the DNERFSB -Encourage early detection and rapid response from forest managers -Provide professional training to forest managers 	<ul style="list-style-type: none"> -USFS Forest Health Monitoring Program -UPR Extension Service Forest 	<ul style="list-style-type: none"> -Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects,

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
	<ul style="list-style-type: none"> -Poor tree form -Aesthetics -Hazard trees -Increase fire risk Fragmentation 	<ul style="list-style-type: none"> -Promote public education about possible detrimental effects on forest floristic components -Maintain adequate urban tree inventories and management practices -Promote Integrated Pest Management 	<ul style="list-style-type: none"> Health Clinic and Diagnostics Lab -DNER Forest Health Program -UPR -USFS 	<ul style="list-style-type: none"> diseases and plants. -Percent of population living in communities developing or managing programs to plant, protect and maintain their urban and community trees and forests.
<ul style="list-style-type: none"> -Development -Urban Sprawl -Fragmentation <p>(consultation map, urban sprawl map).</p>	<p>Decreased and fragmented forest cover decreases the quantity and quality of all forest dependent values</p>	<ul style="list-style-type: none"> -Protect developed large contiguous forest areas and corridors to insure connectivity by: <ul style="list-style-type: none"> -Land acquisition (see Appendix A) -Conservation easements -Adequate land use zoning -Voluntary protection -Encourage planting trees to increase canopy cover and create green corridors 	<ul style="list-style-type: none"> -USFS FLP -USFS FSP -Professionals who evaluate zoning, planning and permits -Municipalities 	<ul style="list-style-type: none"> -Number of communities and percent of population served under an active urban forest management plan. -Percent of population living in communities developing or managing programs to

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
		<ul style="list-style-type: none"> -Promote proper land use planning and accurate zoning on forested areas -Promote professional training about assessing the forest cover and its benefits on agencies involved in determining present and future land use -Increase programs availabilities for the East side of the Islands by: <ol style="list-style-type: none"> (1) Increase outreach, (2) Increase Water Conservation, (3) Enhance Forest Diversity, (4) Enhance all restored riparian habitats. 	<ul style="list-style-type: none"> -USFS CFP -USFS U&CF Program -PR U&CF Council -International Society of Arboriculture -PR Association of Professional Arborists 	<ul style="list-style-type: none"> plant, protect and maintain their urban and community trees and forests. -Number of acquisitions completed that are instrumental for corridor protection. -Number of communities participating of the CFP.
Hurricanes/storms (Island-wide)	<ul style="list-style-type: none"> -Biodiversity -Wildlife -Urban forest -Forest products 	<ul style="list-style-type: none"> -Urban forest inventory -Tree Management Plan development -Hazard tree mitigation -Tree selection 	<ul style="list-style-type: none"> -USFS U&CF Program -PR U&CF Council -International Society of Arboriculture -PR Association of Professional Arborists 	<ul style="list-style-type: none"> -Number of communities and percent of population served under an active urban forest management plan.

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
	<ul style="list-style-type: none"> -Recreation experiences -Coastal resources 		<ul style="list-style-type: none"> -Tree City USA -ITree (adapted to tropics) -FEMA Programs -PR Conservation Trust 	<ul style="list-style-type: none"> -Percent of population living in communities developing or managing programs to plant, protect and maintain their urban and community trees and forests.
<p>Climate change (sea level rise map)</p>	<p>Coastal forests and wildlife, salinization of fresh water swamps, increase fire, more intense storms, salt water intrusion, biodiversity, forest products, decreased recreational experiences</p>	<ul style="list-style-type: none"> -Corridors for tree migration -Increase carbon storage through increases in tree cover - Urban forest inventory -Tree Management plan development -Hazard tree mitigation -Tree selection 	<ul style="list-style-type: none"> -USFS U&CF Program -USFS FSP -USFS FLP -USFS Community Forest and Open Space Conservation Program -International Society of Arboriculture -PR Association of Professional Arborists -Tree City USA 	<ul style="list-style-type: none"> -Population of communities benefiting from S&PF activities designed to contribute to an improvement in air quality. -Population of communities benefiting from S&PF activities that result in energy conservation.

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
			<ul style="list-style-type: none"> -ITree (adapted to tropics) -PR Conservation Trust -UPR Marine Science Department 	
Flooding	<ul style="list-style-type: none"> -Water quality -Tree health human safety -Stream and bank erosion -Erosion and sedimentation 	<ul style="list-style-type: none"> -Forested wetland protection -Riparian buffer installations -Maintain and increase forest cover in catchment and groundwater recharge areas -Urban tree inventory and hazard mitigation 	<ul style="list-style-type: none"> - USFS U&CF Program -USFS FSP -International Society of Arboriculture -PR Association of Professional Arborists -PR Conservation Trust 	<ul style="list-style-type: none"> -Percent of population living in communities developing or managing programs to plant, protect and maintain their urban and community trees and forests to mitigate the effects of flooding events.
Drought (See fire, see climate change)				

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
Invasive plants	<ul style="list-style-type: none"> -Biodiversity -Wildlife -Displacement of indigenous species 	<ul style="list-style-type: none"> -Professional and public education -Promote native and other suitable species -Early eradication -Law enforcement -Early detection 	<ul style="list-style-type: none"> -Nursery growers and buyers, -DNER -Puerto Rico Forest Health Advisory Committee -USFS Forest Health Program -San Juan Bay Estuary Program -Puerto Rico Conservation Trust -PR Department of Agriculture 	<ul style="list-style-type: none"> -Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects, diseases and plants (annual).
Invasive animals	<ul style="list-style-type: none"> -Wildlife habitat -Egg predation -Rare pant seedling recruitment 	<ul style="list-style-type: none"> -Law enforcement -Public education 	<ul style="list-style-type: none"> -DNER -San Juan Bay Estuary Program -Puerto Rico Conservation Trust -Lion Fish Control Program 	<ul style="list-style-type: none"> -Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects, diseases and plants (annual).

iii. Goal 3: Enhance public benefits associated with trees and forests

Several objectives are implied under this goal, which in general focuses on maximizing the profitable social, environmental and economical services trees and forests provide to the community. Among the objectives it is worth mentioning:

- protect and enhance water quality and quantity;
- improve air quality and conserve energy;
- assists communities in planning for and reducing forest health risks;
- maintain and enhance economics benefits and values of trees;
- protect, conserve and enhance wildlife and fish habitat;
- connect people to trees and forests, and engage them in environmental stewardship activities
- manage trees and forests to mitigate and adapt to global climate change.

The strategies recognized as of great value for this goal are the following (benefits are included):

- 1- Continue encouraging reforestation
 - Water quality benefits; coastal resources well being
- 2- Maintain and manage existing forests
 - Water quality; coastal resources well being
- 3- Private forested land acquisition by several means including FLP
 - Wildlife habitat; protecting plant biodiversity
- 4- Encourage conservation easements
 - Wildlife habitat; protecting plant diversity
- 5- Promote voluntary private land conservation management
 - Wildlife habitat; protecting plant biodiversity
- 6- Continue land acquisition programs to conserve private mature forests
 - Wildlife habitat; protecting plant diversity
- 7- Promote and encourage agroforestry practices (sun coffee plantations to shade grown coffee)
 - Wildlife habitat
- 8- Establish Maricao Commonwealth Forest and a 5 mile buffer (it includes Susúa Commonwealth Forest) wildlife habitat
- 9- Provision of proper management on public forested lands
- 10- Plant biodiversity
- 11- Retain forest cover
- 12- Carbon sequestration
- 13- Manage for forest health and growth
- 14- Carbon sequestration
- 15- Forest products benefits to incentivize protecting and enhancing forest cover
- 16- Carbon sequestration

Table 15. Goal 3: Enhance public benefits associated with trees and forests.

Benefits	Priority area	Strategy	Resources	Performance measures
Water Quality Benefits	<ul style="list-style-type: none"> -Riparian areas around rivers and reservoirs. -Aquifer Recharge areas -Upland Catchments 	<ul style="list-style-type: none"> -Continue encouraging reforestation -Maintain and manage existing forest 	<ul style="list-style-type: none"> -DNER reforestation program -USFS FSP -NRCS HFRP -USFWS State Wildlife Grant -NRCS EQIP 	<ul style="list-style-type: none"> -Acres and percent of priority watershed areas where S&PF activities are enhancing or protecting water quality and quantity.
Coastal Resources	<ul style="list-style-type: none"> -Through all PR Coastal Zone (1 km from the sea) -Existing forested wetlands (i.e.mangrove and <i>Pterocarpus</i> or <i>Annona</i> swamps, etc.) -Coastal upland remnants 	<ul style="list-style-type: none"> -Continue encouraging reforestation -Maintain and manage existing forest 	<ul style="list-style-type: none"> -COE Wetland Banking -USFS FSP -NRCS HFRP -USFWS State Wildlife Grant -NRCS HFRP 	<ul style="list-style-type: none"> -High priority forest ecosystems and landscapes are protected from conversion (acres-annual and cumulative). -Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship Management Plan

Wildlife Habitat	-Coastal upland forest remnants	-Private forested land acquisition by several means including FLP	-UFSF FLP	-High priority forest ecosystems and landscapes are protected from conversion (acres-annual and cumulative).
	-Mature forest habitats	-Encourage Conservation Easements	-DNER PR Natural Heritage Program	-Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship Management Plan
	-Corridors that link mature forest areas (i.e. riparian areas along streams)	-Promote voluntary private land conservation management.	-DNER PR High Ecological Value Land Acquisition and Conservation Fund	-Detectable increased in frequency numbers of priority critical species for WHIP.
	-Corridors required under Commonwealth Law Number 14 of 1999	-Provision of proper management on public forested lands	-USFS FSP	Establishment of wild reproductive couples of Puertorrican Parrot in Maricao Commonwealth Forest.
	-Threatened and Endangered Species habitat.	-Continue land acquisition programs to conserve mature forest	-NRCS EQIP	-Increase of riparian forests under conservation practices.
		-Promote and Encourage agroforestry practices (sun coffee plantations to shade grown coffee)	-USFWS PFW -Federal and State agencies management	-Reduction of predator numbers on Maricao

		-Establish Maricao Commonwealth Forest and a 5 mile buffer (it includes Susúa Commonwealth Forest)		Commonwealth Forests and it 5 mile buffer zone. -Increase the number of ecological corridor created between public and private forested land.
Plant biodiversity	Public forested lands	Private forested land acquisition by several means including FLP -Promote voluntary private land conservation management.	-USFS FLP -USFS CFP -Conservation Easement Commonwealth Law -DNER Puerto Rico Natural Heritage Program -DNER High Ecological Value Land Acquisition and Conservation Fund -NRCS HFRP -USFS FSP -USFWS State Wildlife Grant	-High priority forest ecosystems and landscapes are protected from conversion (acres-annual and cumulative). -Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship Management Plan

Carbon Sequestration

Private forested land

-Retain forest cover

-Manage for forest health and growth

-Forest products benefits to incentivize protecting and enhancing cover

-USFS FSP

-USFS FLP

-USFS CFP

-Conservation Easement Commonwealth Law

-NRCS HFRP

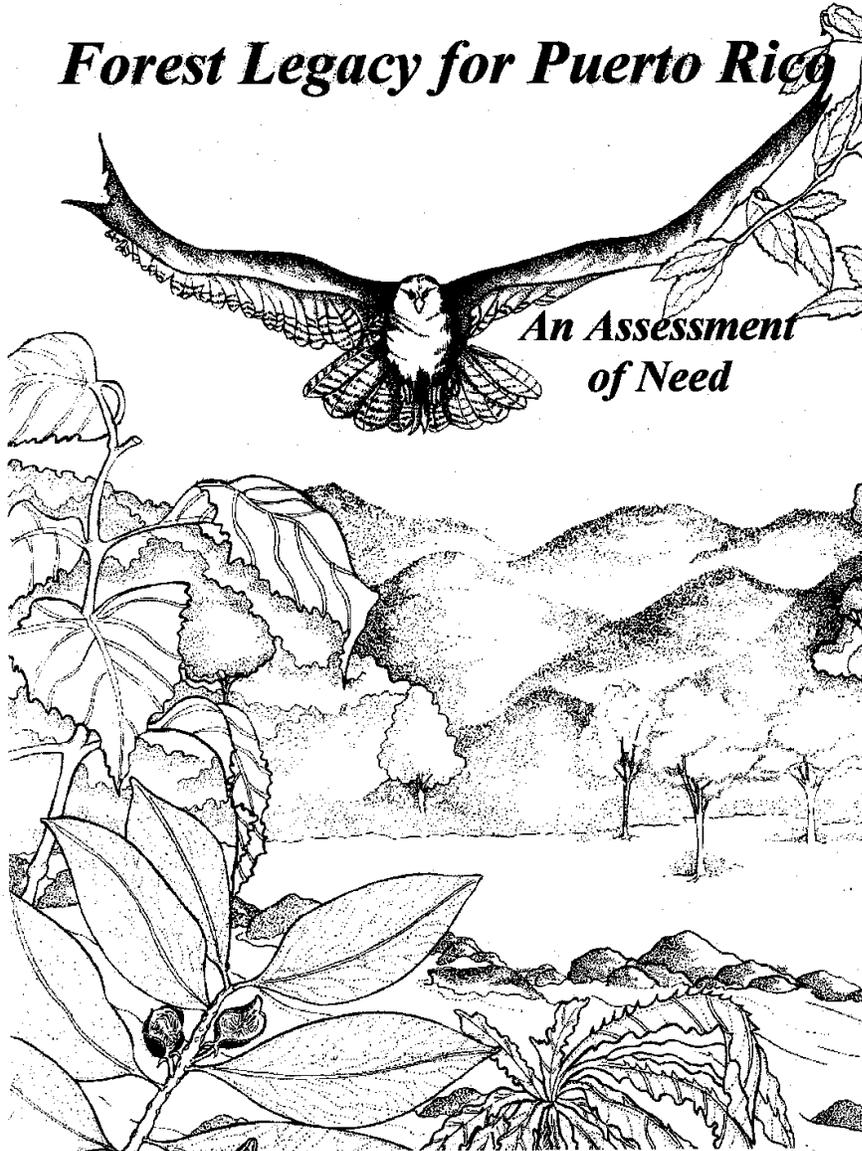
-Population of communities benefiting from S&PF activities designed to contribute to an improvement in air quality.

-Population of communities benefiting from S&PF activities that result in energy conservation.

Appendix A. Puerto Rico Forest Legacy Assessment of Need

Forest Legacy for Puerto Rico

An Assessment of Need



Department of Natural and Environmental Resources
Forest Service Bureau



U.S. Department of Agriculture
Forest Service



International Institute of Tropical Forestry

July 2000

Abstract

In the 1940's Puerto Rico was one of the most severely deforested and eroded regions in the world with only six percent (6%) of its land area under forest cover. Today, still recovering from this devastation, only thirty-two percent (32%) of its territory is currently in forest use, down from approximately thirty-four percent (34%) in 1985. It is estimated that eighty-two percent (82%) of all current forested land is in private ownership.

The forests of Puerto Rico are currently threatened by conversion to non-forest uses because of increasing pressures stemming from population growth and demand for land development. Puerto Rico is one of the most densely populated areas in the world. Population encroachment on forested areas have begun to affect the capacity of the natural ecosystems to provide renewable resources that have been taken for granted, such as a clean water supply. Valuable forest reserves, including two which have been named Biosphere Reserves by the United Nations in recognition of their uniqueness, are receiving increasing pressures to develop non-forest uses on their buffer zones. With the disappearance and/or fragmentation of forested areas many unique plant and animal species are increasingly coming to be endangered with extinction.

Puerto Rico's participation in the Forest Legacy Program is an important step to address the urgent need to protect private forest lands threatened by conversion to non-forest uses. Eight Forest Legacy Areas have been identified.

As appropriate, periodic review and revision to this Assessment of Need will be made to meet the future needs of the citizens of the Commonwealth of Puerto Rico.



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Commonwealth of Puerto Rico
San Juan, Puerto Rico

Date: 9/30/97

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FOREST LEGACY PROGRAM

AN ASSESSMENT OF NEED FOR PUERTO RICO

INTRODUCTION

Located between 18°31' and 17°55' N latitude and 63°37' and 67°17' W longitude lies the island of Puerto Rico, the easternmost and smallest of the Greater Antilles. Puerto Rico consists of a large main island, and several smaller islands, the largest of which are Vieques, and Culebra to the East and Isla de Mona to the West. Puerto Rico is roughly rectangular in shape measuring approximately 100 miles east to West and 35 miles North to South. It is a small mountainous island with a remarkable diversity in its physical environment (Picó, 1974). Within its 3,500 square miles there are over 2,600 species of flowering plants, more than 400 species of ferns, 21 species of mammals, 68 species of reptiles and amphibians, 106 species of resident birds and an even more diverse fauna of invertebrates (Natural Heritage Division, 1985).

The island inhabited by 3.7 million people, averaging over 1,000 persons per square mile, making Puerto Rico one of the most densely populated places in the world. The projected population change from 1990 to 1996 was 7.4%. Increasing commercial, industrial and residential land use needs are generating pressure and conflicting demands over limited resources. These demands are creating stress in the delicate natural balance of the island's ecosystem which have already resulted in costly water shortages, flooding, endangerment of habitats and indigenous species and loss of biodiversity and other irreplaceable natural resources.

Forests are the most important plant formations in Puerto Rico. They provide an ample array of benefits, including clean water, control of erosion and floods, recreational opportunities, thriving wildlife populations and an astounding variety of species. In fact, the Caribbean National Rain Forest (locally known as El Yunque), administered by the USDA Forest Service and the Guánica State Forest, administered by the Commonwealth of Puerto Rico, have been distinguished by the United Nations as Biosphere Reserves of planetary importance.

Concerned by increasing pressures for commercial, industrial and residential land development on valuable privately owned forest lands in Puerto Rico, including the buffer zones of protected reserves, the Commonwealth's Department of Natural and Environmental Resources is applying for participation in the USDA Forest Legacy Program. This program was created by Congress as part of the 1990 Farm Bill to identify and protect environmentally important private forests and lands threatened with conversion to non-forest uses. The Forest Legacy Program will be an important instrument in retaining and expanding the role of forests in this natural ecosystem balance, protecting them also for the benefits of future generations.

To be eligible to participate in the Forest Legacy Program, Puerto Rico must prepare an island wide assessment of need that documents the necessity of the Program, identifies eligibility requirements for designation and recommends areas meeting these requirements for inclusion in the Forest Legacy Program. This document was prepared to fulfill this requirement.

I. THE FORESTS OF PUERTO RICO

A. THE SETTING

The island of Puerto Rico was created by the combined effects of volcanic and tectonic stresses along a submarine fault line, beginning with the extension of the fault (the Antillean Geosyncline) into the Caribbean Region about 120 million years ago. The accumulation of volcanic deposits and uplifting land mass which, in the course of succeeding millions of years was reduced by subsidence and rising sea levels, formed Puerto Rico, the neighboring Virgin Islands and Hispaniola (Dominican Republic and Haiti). Although the character of Puerto Rico's geology and topography largely reflects its volcanic origin, a temporary re-submergence of the island's margins between 40 and 50 million years ago led to the formation of the extensive limestone deposits so widely found today.

The most prominent physical and geological feature of the island is the central mountain range, the Cordillera Central. The highland region extends almost the whole length of the island, the crest averaging more than 3,500 feet in elevation along its length, with the highest peak rising 4,389 feet. The range is largely composed of volcanic lavas with masses of intrusive rock, mainly granodiorite and diorite. Second in its prominence to the central range, in geological and physiographic terms, are the extensive karst regions formed by the deep deposition of limestone during submergence of the land over several millions of years. In the course of Puerto Rico's geological history these areas, which were originally flatland, have been deeply dissected by dissolution and erosion. Though the peaks found in these areas are of almost uniform height, the region is characterized by river valley formations and very broken solution topography. Distinctive karst formations abound much of the surface karst is underlined by extensive caves and underground waterways.

Most important to human activity are the coastal plains formed by soils crated from the volcanic limestone formations in the interior of the island. The coastal plain is most hospitable to economic and agricultural activity and is where the great majority of the population lives and works.

A high proportion of the Puerto Rico landscape is very steeply sloped. Over 80percent of the land is either hill or mountain land and 38 percent has a slope of 45° or more. Much of its area is physically unsuited for extensive agriculture, industry or even domestic settlement on a wide scale.

The soils of Puerto Rico are exceptionally diverse in proportion to the size of the island and closely reflect the rock formations from which they are derived, upland soils are mainly residual in nature and contain the same minerals as the dioritic and volcanic supporting bedrock.

The island has a typical ocean-island tropical climate. Warm temperatures with little variation, steady breezes and abundant rainfall result from the constantly high levels of solar radiation, the presence of the marine Trade winds and the mountainous nature of the island itself.

The north slope of Puerto Rico, from the crest of the Cordillera Central Mountain Range to the sea, receives most of the island's rainfall. The heaviest rainfall area in the island is the Rain Forest on the ridges of the El Yunque mountain area, which receives a yearly

average of 3,810mm. Lying in the “rain shadow” of the Cordillera Central, the southern slopes receive substantially less rainfall, with some areas such as the Guánica State Forest, receiving less than 762 mm a year.

Puerto Rico also experiences occasional hurricanes, most of which pass through the Caribbean between August and September. In 1898, 1928, 1932, 1956, 1989, and 1995 storms have passed over the island. Hurricane Hugo in 1989 caused wide destruction of trees and changes in the forest composition and growth rates particularly affecting forest lands in the east coast, including Caribbean National Forest.

Most of the rivers are short in length and none are very large in terms of size and flow. The largest river is the Río Grande de Loíza, draining an area of 296 square miles. There are only seven rivers on the island with drainage areas greater than 100 square miles, although more than 100 streams discharge into the ocean. The large number of drainage basins in the island results in a surface hydrology characterized by a multitude of small basins and catchments.



Figure 34. Location of Puerto Rico

B. FORESTS IN PUERTO RICO: PAST AND PRESENT

1. The importance of Forest Areas in Puerto Rico

The Department of Natural and Environmental Resources has identified sixty types of plant communities within its fourteen public forest. In terms of trees, Little, Wadsworth and Woodbury (1974) have identified 547 species, 109 of which can only be found in Puerto Rico. Additionally, there are 203 species naturalized (Little et al., 1974). Such striking richness of tree flora within a small area is an important consideration in an assessment of Puerto Rico's forest. The island has four distinct types of forest corresponding to different environmental conditions.

a. Mangrove Forests

They are found in the coastal zone and contain plant communities which have adapted themselves to the conditions of salinity typical of tropical coasts. The structure and functions of these forests in Puerto Rico vary according to their specific location. Those of the North coast are larger and grow behind the sand dunes. The species *Avicennia minans* or black mangrove and *Laguncularia racemosa* or white mangrove predominate in this coast. In the South coast the mangrove forests have less extension being most frequently strips of *Rhizophora mangle* or red mangrove along the coastline. The differences in climate, tides and geomorphology of the coasts are responsible for the different types of mangrove that predominate in the area.

An assorted variety of animal life is dependent on the mangrove forest. The protected substrate provides a habitat for a large variety of organisms, which in turn serve as a food base for marine fauna. It is estimated that two thirds of all salt water fish depend directly or indirectly on these wetlands. Some fish of commercial importance are found among the mangrove roots, while others spend part of their life cycle there breeding and spawning. Other marine animals, insects and birds find habitat in these forests at least for portions of their lives.

Mangrove forests are important in the protection and formation of coastal terrain. Their roots reduce the speed of the marine currents permitting the settling of suspended materials and this gradually raising land level and producing organic soils. These forests, as any other land formation, also play an important role in the absorption and utilization of carbon dioxide and in the removal of dust from the atmosphere. This function is particularly important in mangrove forests that are near or surrounded by urban or industrial areas. Mangroves offer an undeveloped recreational potential and are of continuing scientific value.

In Puerto Rico, 75% of mangrove covered areas have been destroyed as the result of the dredging and filling drainage changes affecting the salt-water wetlands, destruction of protective sand dunes, pollution from industrial sources (thermal pollution from thermoelectric plants, oil spills, petrochemical effluents, etc.) and pollution from sewage and from sanitary landfill leachate. Many of these forests have been converted to urban and agricultural uses, with the exception of very limited shoreline areas surrounding both natural and artificial fresh and salt water wetlands.

b. Dry Forests

Located in the coastal areas not influenced by rivers or tidal flooding, and that fall behind the "rain shadow" or low annual precipitation due to the interception of rain clouds by the Cordillera Central Mountain Range, we find the dry forests, plant formations which survive adapting themselves to conditions of scarcity of water, salinity and strong winds.

The variations in the size and diversity of the flora of these ecosystems relate to these three factors: the intensity of the winds, degree of salinity, and the accessibility to fresh water. Strong winds limit the size and shape of the plants, salinity limits the diversity of species, as not all plants can resist high concentrations of salt, and the lack of water controls the density of the population as plants grow separated one from the other developing extensive root system where water is scarce. The combined effects of these three factors cause changes in the characteristics of the vegetation typical of the dry forest. The leaves are thick and very strong; forest ceilings are low and closely woven, tree trunks grow twisted, and plants form an impenetrable thicket. These adaptations isolate the community from the hardships of the coastal climate and moderate the micro climate where wildlife can then survive. Plant growth is slow making this type of forest very susceptible to abuses by man.

In spite of its arid appearance, the dry forest is of incalculable value for wildlife. The Guánica State Forest, for example, serves as habitat for half of all the species of land birds in Puerto Rico. Very endangered species of birds have been found in this forest, such as *Caprimulgus vociferus noctitherus* (the Puerto Rican Nightjar), once thought to be extinct.

c. Karst Forests

The landforms on the North coast limestone of Puerto Rico constitute one of the finest examples of tropical karst in the world. The terrain appears as clusters of haystack hills that vary between 50 and 300 feet of height, separated from one another by rounded depressions. These hills are remnants of thousands of years of erosion of what were limestone formations deposited during the time this area of the island was submerged. The area is abundant in sinkholes, funnel-shaped cavities which are locally known as "sumideros" and through which rainfall quickly disappears. Caves and caverns are abundant and rivers appear, disappear and reappear throughout the area.

The natural vegetation of this karst region has long disappeared except in the most inhospitable areas as man has used the fertile valleys formed by eroded soils between the hills for agricultural purposes. Plant life is scarce. Trees and other plants must extract water and minerals exploring with their roots the sinkholes in the limestone to penetrate them. This condition makes plant growth slow and poor. Existing vegetation, however, is still impressive and sustains a significant variety of wildlife and of plant species that are in the verge of extinction.

The karst region is particularly valuable as a recharge area for the bountiful aquifers of the north coast which provide water for industrial as well as residential water uses. Four State Forests are located in this karst region: Cambalache, Vega, Guajataca, and Río Abajo. All of them contain unique natural areas, relatively undisturbed lands which contain distinct vegetation, wildlife and/or environmental features not readily available separately or as a composite. The karst forests are currently experiencing considerable

pressures related to the construction of highways and its accompanying accessibility for future development. In fact, part of the Río Abajo State Forest has been lost to the construction of highways PR-10. Intense future development in this area is predicted for the near future due to the access that will be provided by these highways.

d. Forests of the Mountains

The forests of the mountains of Puerto Rico belong to the wet and rain forest life zones (Ewel and Whitmore, 1973). Consequently, these ecosystems are not limited by the availability of water and due to the tropical location, they develop under temperatures optimal growth. These forests are characterized by their great diversity of species by unit of area. It is difficult to describe the typical vegetation because it changes as one ascends the mountain and also varies in relation to the orientation and soil types of the slopes. Those facing east receive more rain than those facing west but have more diverse species composition because of a larger variety of soil types or as a product of less evaporation due to protection from the wind. Slopes facing north have more abundant vegetal growth than those facing south.

The Subtropical Wet Forest occupies much of the higher parts of the mountains of Puerto Rico. This is a high rainfall life zone, encompassing areas with mean annual precipitation within the approximate range of 2,000 to 4,000 mm per year. Abundant moisture in this life zone is evident in the characteristics of the vegetation. Epiphytic ferns, bromeliads and orchids are common, the forests are relatively rich in species and the growth rates of successional trees are rapid. Mature forest remnants in this life zone exist in the Carite and Toro Negro State Forests and the Caribbean National Forest. This type of forest is more commonly known in the island as the tabonuco type, named for dominant tree *Dacryodes excelsa* (Tabonuco). Two other prominent species are *Sloanea berteriana* (Cacao, Motillo) and *Manilkara bidentata* (Ausubo). This is an impressive forest containing more than 150 species of trees and forming a dark, complete canopy at about 20m.

The Subtropical Rain Forest, the wettest of the sea level belt of subtropical life zones occupies very little area in Puerto Rico, occurring only in a single crescent shaped band on the windward side of the Luquillo Mountains. It lies wholly within the Caribbean National Forest. This life zone is characterized by a superabundance of precipitation. The annual total of 3,400 mm of runoff is more than twice as much as most areas of the world receive as annual rainfall input.

The species found here are the same, for the most part, as those found in the surrounding Subtropical Wet Forest. Its main features are the high frequency of the Palma de Sierra, *Prestoea montana* and a superabundance of epiphytes. Because of the small area it occupies, the Subtropical Rain Forest in Puerto Rico is primarily of academic interest and recreational value. Nearly a million people visit annually the recreation area at La Mina. The Baño de Oro natural area, much of which lies in this life zone may be the only place in the world where an example of the mature vegetation of Subtropical Rain Forest is likely to receive long-term protection, while still being readily accessible.

There are two Lower Montane life zones in Puerto Rico of which the Subtropical Lower Montane Wet Forest is by far the most extensive, occurring in both the eastern and central parts of the island up to the summits of the most of the mountains above 1,000 meters

and occasionally extending down to almost 700 meters. The Colorado Forest type, named for the common *Cyrilla racemiflora* corresponds to the mature vegetation of this zonal association. The *Cyrilla* is the same species which grows as a shrub or small tree in the titi swamps in the southeastern U.S. but the mountains of Puerto Rico it is a large, reddish-barked canopy tree. The hollow trunks of the older individuals are the main nesting sites for the nearly extinct Puerto Rican parrot. This forest is characterized by open-crowned trees and is poorer in species than the adjacent Subtropical Wet Forest.

Because of the high rainfall, the Lower Montane Wet Forest Zone is too fragile for any commercial forestry or agriculture, although in some areas dairy cattle are pastured mostly on molasses grass. Here again, as in other life zones with exceedingly high rainfall, the primary value lies in watershed yield.

The Subtropical Lower Montane Rain Forest zone occupies less area than any other in Puerto Rico and is found only in a narrow band in the windward slopes of the Luquillo Mountains, immediately above the Subtropical Rain Forest. The vegetation of this life zone is similar to that of Lower Montane Wet Forest but has a greater abundance of epiphytes, epiphyllae, palms and tree ferns. Most of this life zone in Puerto Rico is located in the dwarf cloud forest association where much of the vegetation on the exposed ridges has a windswept appearance. This forest is primarily a biological curiosity but an invaluable one since it represents an environmental extreme and as such is an excellent tool for investigating the response of natural ecosystems to environmental stress.

This dwarf forest is a habitat for a very distinctive flora and fauna. Moss, orchids, bromeliads, and other epiphytic plants cover available surfaces in the trees. These trees are small with twisted trunks and thick small leaves with roots that grow over the surface of the ground.

2. Long term forest area trends

The dominant vegetation upon Columbus' arrival at the end of the 15th century was forest throughout the island. Out of an 890,000 hectares total, 850,000 ha (95%) were estimated to be forested in 1500¹⁰. However, timber use increased with the arrival of the Europeans as well as forest destruction for agricultural uses.

Most of the early farm clearing was for subsistence farming. In 1828 there were 587,000 ha in forest use and by 1899 it was down to 182,000 ha or about 20% of the island (Wadsworth, 1950). The production of field crops prior to 1900 did not involve as much lands as did pasturing but required the clearing of steeper slopes. The introduction of coffee (*Coffea arabica*) in 1736 began a culture which was destined to push back into the then heavily forested mountainous interior of the island. Production of coffee increased rapidly after 1755 and soon became an important product to be exported. By 1899 more than three quarters of the land surface of Puerto Rico had been deforested and forest cover reduced to 182,000 ha. Pasture accounted for about 490,000 ha and coffee production occupied 77,000 ha (Wadsworth, 1950).

¹⁰ Discussion taken from the article "Notes in the Climax Forest of Puerto Rico and their Destruction and Conservation Prior to 1900." By Frank Wadsworth in the Caribbean Forester of January, 1950

Early in the 20th century, forests covered only about 20% of the island, but only one third of this forest land could yield wood products other than charcoal or fuelwood (Murphy, 1916). The rate of forest destruction declined during the first part of the 20th century. Only the most remote and marginally productive land remained uncultivated. During the ensuing decades, pressure on land resources came from many directions: increasing population, expanding production of export crops, and fluctuating economic conditions. During periods of high unemployment people were forced to subsistence agriculture, encroaching on the remaining lands in the interior.¹¹

During the late 1940's the natural forest area of Puerto Rico declined to a minimum of 6% of the land area. Cropland¹² and pasture each accounted for about 42%, with the remaining 10% in buildings, roads and wasteland (Koenig, 1953) Puerto Rico became one of the most severely deforested and eroded regions in the world.²

Operation Bootstrap, or the efforts to industrialize Puerto Rico, resulted in an exodus of population from the mountainous interior of the island. Many migrated in search of employment and better living conditions to the US mainland or to the cities in the coast, such as San Juan. Since then, forests gradually recovered because cropland and pastured were abandoned on eroded hillsides in the Island's mountainous region. By 1980, forest occupied about 250,000 ha and coffee shade about 30,000 ha (Birdsey and Weaver, 1982).

Forest area trends as reported by Birdsey and Weaver in their 1985 inventory update include an increase of total forest area from 279,000 in 1980 to 300,000 ha in 1985. From an all-time low of 6% in 1940m forest area increased to 34% in a little over forty years. Preliminary and unpublished data from the 1990 inventory update by the USDA Forest Service shows, however, a probable declining trend will tend to occur in the future. The most probable cause for this expected declining trend is the demand for space and natural resources from a rapidly growing population.

¹¹ Discussion taken from: Birdsey and Weaver, The Forest Resources of Puerto Rico, USDA Forest Service Publications, Resource Bulletin SO-85 of October, 1982.

¹² The category "cropland" included tree-covered coffee, some 8% of Puerto Rico then. (Wadsworth)

Table 16. Historical estimates of forest area for Puerto Rico¹³

YEAR OF ESTIMATE	FORESTED AREA¹⁴ in hectares	COFFEE SHADE¹⁵ in hectares	SOURCE OF INFORMATION
1500	850,000	0	Murphy, 1916 Wadsworth, 1950
1828	587,000	7,000	Wadsworth, 1950
1899	182,000	77,000	Wadsworth, 1950
1912	169,000	77,000	Murphy, 1916
1916	178,000	68,000	Murphy, 1916
1931	81,000	Gall, 1931
1940	68,000	Koenig, 1953
1948	57,000	57,000	Koenig, 1953
1960	82,000	Englerth, 1960
1972	284,000	73,000	DNER, 1972
1980	279,000		USDA Forest Service, 1982
1985	300,000		USDA Forest Service, 1987
1990	287,700		USDA Forest Service, 1995 (Preliminary unpublished data)

¹³ Birdsey and Weaver, *The Forest Resources of Puerto Rico*, USDA Forest Service Publication, Resource Bulletin SO-85 of October, 1982.

¹⁴ Does not include non-stocked forest land.

¹⁵ "Secondary forestland resulting from the abandonment of coffee production under shade trees. Coffee shade is a multistory, multicrop system used principally for the production of coffee. An upper story of shade trees is characteristic." USDA Forest Service, Research Notes, SO-331, February 1987, page 4.

3. Forest ownership

In 1990 it was estimated that 82% of all forested land in Puerto Rico was in the property of private owners. The largest forested areas in public ownership are the State Forest System, the Caribbean National Forest, Mona Island¹⁶ and Roosevelt Roads Navy Base. The DNER also holds several areas of smaller extent that are managed by the Conservation Trust of Puerto Rico, a private non-profit corporation. Other important landholders are the Land Authority, the Land Administration, and the Industrial Foment Administration, all public corporations. Their lands may or may not be forested.

The State Forest System includes 16 States Forests scattered throughout the island. The Caribbean National Forest covers much of the Luquillo Mountains in the northeastern part of the island. Together the public forests protect valuable soil and water resources, wildlife habitats and many rare tree species. They also provide recreation and research opportunities in all the major natural ecosystems found on the island. These areas include nearly all of the remaining virgin forests.

Table 17. Forest ownership classified areas for Puerto Rico

Ownership Class	Area (hectares)	Source of Information
Public:		
Commonwealth forests	22,700	DNER, 1976
Commonwealth islands (Mona and Monito)	5,500	Environmental Quality Board, 1973
DNER¹⁷	2,000	Rusanowsky, 1978
Caribbean National Forest	11,300	
U.S. Military	1,900	U.S. Fish and Wildlife Service, 1978
Total Public	43,400	
Total Private	235,300	
ALL OWNERSHIP	278,700	

Source: Birdsey, Richard A. and Peter Weaver, Forest Resources of Puerto Rico, USDA Forest Service, Resource Bulletin SO-85, October, 1982

¹⁶ Although a separate island, Mona falls under the Commonwealth Forest System.

¹⁷ Lands previously purchased by the Conservation Trust were turned over the DNER in 1981.

4. Demands on Forested Areas¹⁸

Numerous benefits and uses are derived from forested lands in Puerto Rico, among them control of water quantity and quality, control of erosion, wildlife protection, habitat of rare and endangered species, recreation, tourism, research opportunities, scenic and cultural resources and timber.

a. Soil and Water

Of the fresh water lakes in Puerto Rico only two, Laguna Tortuguero and Laguna Cartagena, are natural. All rivers of the island rise in the forested mountainous central area of Puerto Rico. The headwaters of these rivers supply most of the island's 25 major reservoir sites which yield water to meet domestic, industrial and agricultural demands.

Forest cover is responsible for the high quality of water of the rivers and artificial lakes in these areas. Where forest cover has been eliminated, serious sedimentation and population problems have developed in the rivers and the artificial lakes. Those that are surrounded partially or totally by forests of the central highlands have the highest quality of water, scenery and fishing, as characterized by Guajataca, Carite, and El Guineo Lakes. These contrast with other lakes such as Cidra, Loíza, Coamo and La Plata which lack forest protection and suffer severe problems of sedimentation, pollution, bilharzia (*Schistosoma mansoni*), and intrusion of aquatic plants. For example, the annual rate of siltation of the Loíza reservoir, which serves most of the San Juan Metropolitan Area, is reported at 1.6AF/sq. mile. If no measures are taken, this reservoir is expected to be completely silted by the year 2020. (At present the Loíza Lake is being dredged.) Severe water shortages have been plaguing the San Juan Metropolitan Area during 1994, 1995, and 1997 provoking extended water rationing periods, at a considerable economic costs for business.

Of all sources of water quality degradation, sediments brought by surface runoff is by far the most widespread and noticeable cause of this problem in Puerto Rico. The damaging effects of sedimentation include the siltation of reservoirs, destruction of spawning beds for fish and shellfish, increased nutrient inputs leading to eutrophic conditions in reservoirs and disrupting "desirable" aquatic food chains, and greatly increased turbidity in nearshore areas resulting in coral reef mortality.

Steep topography, heavy rainfall and erodible soils contribute to a high erosion potential, and rapid clearing and development of land for agriculture and other uses cause major erosion and sedimentation problems. The erosion of the topsoil seriously curtails the soil's productivity.

b. Wildlife, Rare and Endangered Species

Wildlife populations are entirely dependent on their habitat, so the link between wildlife and forests is a crucial one. Forests constitute one of the most important habitat for wildlife in Puerto Rico. For example, half of all the species of land birds in Puerto Rico

¹⁸ Much of this discussion is taken from: Birdsey and Weaver, The Forest Resources of Puerto Rico, USDA Forest Service Publication, Resource Bulletin SO-85 of October, 1982.

can be found in the Guánica State Forest, twice the density of birds found anywhere else.

The island's native wildlife species are limited. It consists of a variety of insects and other lower groups of animals, particularly marine species, although it is scarce in mammals. Resident native mammals include 15 species of bats, manatees and dolphins. Of an estimated 200 bird species (Bond 1971, Leopold, 1963), 14 are endemic, 107 local breeders, 71 migrants and 21 strays. About 70 species of reptiles and amphibians, and 33 species of fresh water fish are native to Puerto Rico (Rivero 1978), (Erdman, 1972).

The destruction or disturbance of wildlife habitats is the most important threat to animal communities in Puerto Rico. Hunting, predators introduced to the island (such as rats and mongoose), pesticides and other chemicals are also important factors affecting wildlife survival.

The diversity of habitats has led to the establishment or evolution of many plant species on the island. However, the limited size of the land mass combines with rampant destruction of large areas for agriculture and other uses has decreased some species to dangerous rarity. Over 500 species of endemic and non-endemic plants have been classified as rare, endangered or poorly distributed (DNER, 1975). There are 13 rare endemic tree species classified as endangered and 22 endemic trees species that are threatened with extinction mainly because of habitat destruction and disturbance (Little and Woodbury, 1980). Again, the Guánica State Forest has 346 genera of plants and trees with 641 species represented. At least 48 of these species, if they were lost at Guánica, would virtually disappear from Puerto Rico. Sixteen species are endemic, found at no other location in the world.

c. Recreation and Tourism

Puerto Rico's numerous beaches, coral reefs, waterfalls, canyons, scenic mountain roads; limestone caves and cliffs, combined with year-round moderate weather provide the basis for outdoor recreation, particularly in the small but well distributed acreage of federal and Commonwealth forests.

The Caribbean National Forest is one of the main eco touristic attractions of the island. The forest has 11,300 ha of uninhabited woods administered by the USDA Forest Service and offers facilities for passive recreation as well as for scientific research. Puerto Rico has five other forests owned and administered by the Commonwealth government in the mountainous central region and has a total of 16 State Forests around the island. The Piñones State Forest, within the San Juan Metropolitan Area, is one of the favorite recreational and outdoor sports areas. Major activities include swimming, snorkeling, picnicking, boating, fishing, camping, hiking, water skiing, kayaking, or just driving through the forested area. Any spot on the island is within an hour's drive of a major recreational area. Given the island's limited area and high population density, the existing forested areas are a critical resource for both residents and tourists.

Puerto Rico's karst region in the north central region of the island is one of the few places in the world with such rock formation. The Camuy Cave System, through which the Camuy River flows, is part of this unique karst topography and represents an area of natural beauty that has been developed for recreational purposes. The DNER has listed 189 caves in its inventory, many of which have been explored.

In contact with coastal forested areas lie rare bioluminescent bays, such as Bahía Fosforescente and Monsio José of Lajas in the southern coast, and Caño Hondo on the offshore island of Vieques. The prominent luminescence of these bays and their rarity and importance to marine biology make them internationally significant natural areas.

d. Scenic and Cultural Resources

Puerto Rico is a tropical island of varied topography with many valuable areas of natural beauty. Being an island, beaches and other marine related areas of beauty are abundant. The interior of the island, with its rugged mountainous terrain has canyons, waterfalls, caves, forests and views of breathtaking beauty. Many of these areas have been developed into resorts with facilities to house visitors, others have been developed into sophisticated tourist resorts with whereas, and the many others remain as virgin areas, particularly where difficult accesses are the limitations.

Important archaeological sites have been found within forested areas near the coast and in the mountainous interior area of the island, mostly dating back prior to 1200 AD. Important historical sites, particularly those related to early coffee and Tabaco industries can also be found in the forested areas of the central mountain highlands. One of these areas, Hacienda Esperanza in Ponce, has been converted by the Conservation Trust of Puerto Rico into a living museum.

e. Research Opportunities

Puerto Rico's tropical forests have been a regional focus for forestry and ecological research throughout this century. Lands in the Forest Legacy Program could add significantly to the pool of available sites for research particularly on animals, soils, and vegetation types that are not well represented in established research sites, such as the Caribbean National Forest. Examples include the karst region, deep sandy soils, and a range of forest types from moist to dry that are representative of tropical America. These lands have a degree of diversity in both plant and animal species. The diversity of ecological zones and stages of succession with associated bird and reptile species are unusually high. Puerto Rico also presents an unusual degree of diversity related to population and land uses. Together these factors provide numerous important research opportunities.

f. Timber

Non-timber forest resource uses are currently more important than timber production in Puerto Rico. More than 16% of the land area is covered with forests whose primary use is for watershed protection, recreation and wildlife habitat. Timber harvest occurs on a very limited basis, although a timber industry has been and will continue to be promoted by the DNER and the USDA Forest Service.

Puerto Rico originally included more than 500 species of trees in 70 botanical families. These occurred in extensive and luxuriant forests of which only scattered relics may be found today. Data from the least disturbed of remaining stands suggest that the island contained about 195 million cubic meters of wood (Wadsworth. 1950). Today most of the original forest has been replaced by agricultural and other land uses, or secondary forest where agricultural activities have been abandoned.

The USDA Forest Service survey divides forest areas on the island into commercial and non-commercial forest land. Commercial or timberland is defined as forest land that is producing or capable of producing crops of industrial wood. Forest lands with higher priority uses are excluded. Coffee cultivated under tree shade is included in this category¹⁹. According to the 1985 USDA Forest Service Survey of forest areas, the commercial area under forest cover increased from 130,500 ha in 1980 to 160,200 ha in 1985. Preliminary 1990 figures, yet unpublished, reveal a downward tendency of estimated commercial forest land to 148,100 ha, a loss of 12,000 ha in 5 years.

The non-commercial forest land is area capable of yielding crops of industrial wood because of adverse site conditions, withdrawn through statute or administrative regulation, or with higher priority use (except coffee shade). The non-commercial forest land declined from 148,000 ha in 1980 to 139,000 ha in 1985.

II. THE FOREST LEGACY PROGRAM: ADDRESSING THE PROBLEM

The Cooperative Forest Assistance Act of 1978, as amended by the 1990 Farm Bill establishes the Forest Legacy Program *“for the purposes of ascertaining and protecting environmentally important forest areas that are threatened by conversion to non-forest uses and through the use of conservation easements and other mechanisms, for promoting forest land protection and other conservation opportunities. Such purposes shall also include the protection of important scenic, cultural, fish, wildlife, and recreational resources, riparian areas, and other ecological values”*²⁰.

The Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico is the custodian of the island's forest resources, has recognized in the Forest Legacy Program a potentially important institutional instrument to tend to one of the most serious problems affecting forestlands in the island, the threat to conversion to non-forest uses on 82% of the island's forestlands currently in private property. Still recovering from the elimination of forest cover from all but 6% of its territory, situation that made the island one of the most severely deforested and eroded regions in the world in the 1940's, Puerto Rico again faces a similar threat from powerful economic and social forces whose land use demand has again encroached on forested areas. Preliminarily unpublished data compiled by the USDA Forest Service seems to indicate a declining tendency in the amount of forest covered areas in comparison with 1985.

¹⁹ “Secondary forest land resulting from the abandonment of coffee production under shade trees. Coffee shade is a multistory, multicrop system used principally for the production of coffee. An upper story of shade trees is characteristic.” US Forest Service, Research Notes, SO-331, February 1987, page 4.

²⁰ The Cooperative Forestry Assistance Act of 1978, amended in the 1990 Farm Bill, Section 7(a).

A. GOALS AND PRIORITIES OF THE PUERTO RICO FOREST LEGACY PROGRAM

The goal for the Puerto Rico Legacy Program is to protect environmentally important forest areas belonging to private owners that are threatened by conversion to non-forest uses and that respond to established program eligibility criteria.

Priority for program implementation has respond to the conservation objectives championed by land trust institutions and other conservation organization in PR. These include:

- a. The protection and restoration of forested areas in watersheds developed as sources of public water supply
- b. Buffer zones of existing forest reserves
- c. Conservation of forested areas in primary or close to primary conditions
- d. Conservation of biodiversity and unique features

Fragile coastal forests, currently severely subjected to development pressures, karst, and Cordillera Central forested areas, rich in environmental resources and particularly valuable for water yield, were the primary targeted areas. Selected Legacy Areas represent a rich and varied assortment of these forest lands and have been delimited to contain identified tracts in private property given very high conservation priority originally by DNER (the Natural Heritage Division and the Forest Service Bureau), and by the USDA Forest Service and enriched and modified by comments from the public information focus groups and meetings carried out. Area boundaries were defined using existing roads. These Legacy Areas also contain within their limits areas that are not forested and that have no protection interest for the Puerto Rico Forest Legacy Program. However, all tracts to be protected by the Puerto Rico Forest Legacy Program are included within the specified Forest Legacy Areas.

B. ELIGIBILITY CRITERIA

The determination of Legacy Areas was taken with regards to set the goals and priorities for the Forest Legacy Program and the following eligibility criteria:

1. Present a vegetal cover typical of forests, according to the definition of Puerto Rico Forest Act, in at least 20% of its extension;
2. Be threatened by present or future conversion to non-forest uses;
3. Contain one or more of the following important public values:
 - a. Watershed values, including the protection of public water supply
 - b. Conservation of biodiversity and unique features
 - c. Aesthetic and scenic values
 - d. Existing or potential public recreation opportunities
 - e. Known cultural/historic areas
 - f. Fish and wildlife habitat
 - g. Known threatened and endangered species
 - h. In primary or close no primary forest conditions
 - i. Other ecological values, and/or
4. Promote the development of commercial timberland, and/or
5. Promote the preservation of the forest land base

C. CRITERIA EVALUATION FACTORS

1. Present a vegetal cover typical of forests:

This eligibility factor has to be certified by the Forest Service Bureau. Areas not in vegetal cover typical of forests or with a lower percentage of forest cover can qualify if they belong to geographical areas not adequately represented (diversity) within existing conservation land stock, contain resources deemed unique by the FLP and/or constitute areas targeted for reforestation for water basin protection.
2. Threat by conversion to non-forest uses:

These are lands which have characteristics that make them attractive to changes in use such that forest values are reasonably expected to be at risk. These threats can include, but are not limited to, currently development trends in the area, proximity to roads, short travel time to population centers, proposed housing, industrial, commercial, public or recreational development, encroaching housing development, improvement of roads, sewer line, and power line extensions, fragmentation of land ownership in smaller, less manageable parcels.
3. Contain one or more important public values:
 - a. Watershed values, including the protection of public water supply:
 - i) Area contributes to public or private water supply, including underground sources of water
 - ii) Area is important to erosion and sediment control in watersheds developed for public or private water supply
 - iii) Area contains major river/stream, water body, or contains and/or is the recharge area for major underground water resources
 - iv) Areas that maintain flood control by naturally collecting water runoff
 - v) Areas that would be most adversely impacted by nonpoint source pollution, such as lands where riparian buffers have been removed
 - b. Conservation of biodiversity and unique features:
 - i) Areas representative of any one of the 18 geoclimatic regions currently underrepresented in the land conservation stock in Puerto Rico
 - ii) Areas with a unique or exceptional mix of ecological communities
 - iii) Area contains ecological communities that are dwindling
 - iv) Area has unique or exceptional geological/physiographic resources
 - c. Aesthetic and scenic values:
 - i) Area listed in DNER's inventory of aesthetic and scenic resources
 - ii) Area includes locally important panoramic views
 - iii) Area is situated along designated scenic road
 - d. Existing or potential public recreation opportunities:
 - i) Existing or potential recreational uses such as water based recreation, trails, day use recreation such as hiking, picnics, horseback riding

- ii) Existing or potential natural resource based recreation such as camping and nature tours
 - iii) Areas critical for access to places of outstanding recreational opportunities or tourism resources
 - iv) Areas with existing or potential eco-touristic resources
 - e. Known cultural/historic areas:
 - Areas that contain evidence of the earlier human occupation in Puerto Rico which comprises a unique and irreplaceable resource as do historic features, such as old coffee and tobacco plantation artifacts and structures, and vernacular landscapes.
 - f. Fish and wildlife habitat:
 - Preventing the fragmentation of forest tracts into smaller units is crucial objective to maintaining viable populations of particular wildlife species. Factors to be considered:
 - i) Area contains outstanding habitat for one or more species
 - ii) Area exhibits connective habitats, corridors, habitat linkages and areas that reduce biological isolation
 - iii) Area contains plant and animal species on federal or DNER list as endangered, rare or of special concern
 - iv) Area has unique, rare and/or important variety of vegetative cover types and size classes
 - v) Areas of nesting, resting and feeding of migratory species
 - vi) Areas with significant wildlife population
 - g. Known threatened and endangered species:
 - i) Presence of endangered species habitat for federal, or DNER listed plant and/or animal species, or suitable habitat for such species that are documented on adjacent properties
 - ii) Rare natural habitats, communities or ecosystems and their buffers
 - iii) Unusually diverse or otherwise special biological community
 - iv) Forest lands necessary for the recovery or reintroduction of natural occurring species
 - h. Forest in primary or close to primary conditions:
 - Areas that have over 10% of the forested parcel in primary or close to primary forest conditions
 - i. Other ecological values, such as:
 - i) Any area that exhibits additional or exceptional conditions that are important and add value to the quality of the Forest Legacy Areas
4. Promote the development of commercial timberland:
 According to USDA Forest Service report on forest area trends, Puerto Rico's forest resource "is approaching a stage of recovery that could support

sustained removals of useful timber products from selected areas”.²¹ Selection criteria include the following:

- a. Areas under a management plan for timberland development or recommended by a management plan for such uses, including those areas already participating of other local or state, public or private programs
 - b. Potential areas for commercial timberland development and use
 - c. Productive soils with significance to forestry
 - d. Maintaining timbering activities
5. Promote the preservation of the forest land base in order to:
- a. Protect and promote the creation of large blocks of protected forest land to yield greater ecological and watershed benefits
 - b. Buffer or simplifying management of, existing forested areas considered of high value
 - c. Provide contiguous land to protect wildlife habitat corridors, recreation areas, threatened watersheds and other important public values

D. ACQUISITION METHODS AND TOOLS

The commonwealth of Puerto Rico elects the State Grant Option for the implementation of the program. The following activities are eligible uses under the PR-FLP:

1. Purchase of lands or interests (conservation easements) in lands from willing sellers for inclusion in the FLP;
2. Facilitation of donations of lands or interests in lands to a qualified and will done for FLP purposes
3. Lands or easements purchased by Commonwealth, Municipal or land trusts are considered part of the Forest Legacy Program by contributing to the minimum 25% non-Federal share of program costs
4. Zoning, term easements and other incentives or methods may further Forest Legacy goals, but are not part of the Federal Forest Legacy Program. Commonwealth, Municipal Governments and land trusts may pursue these methods outside of the Federal Forest Legacy Program

E. QUALIFICATIONS PROPOSED ACQUISITIONS MUST MEET

The acquisition of a track, including pre-acquisition work, must meet the following:

1. Federal appraisal standards;
2. The landowner must be informed of the fair market value and the sale of the property is strictly voluntary;
3. The landowner must be notified in writing that the property will NOT be purchase if negotiation do not result in amicable agreement;

²¹ Birdsey, Richard A. and Peter L. Weaver, “Forest Trends in Puerto Rico”, Research Note, SO331, February 1987, USDA Forest Service, Southern Forest Experiment Station.

4. Payment to the landowner for lands or interest in lands is not more than fair market value determined under item 1;
5. Assure title is free and unencumbered property;
6. If relocation is involved the requirements in PL-91-646 must be followed;
7. The track must be located within and approved Forest Legacy Area
8. The track must include a forested land threatened by present or future conversion to a non-forest use (areas not in vegetal cover typical of forests can qualify if they belong to geographical areas not adequately represented (diversity), contain resources deemed unique by the PR-FLP and/or constitute areas targeted for reforestation for water basin protection);
9. Be nominated by the landowner in writing or with the written permission of the landowner;
10. Be approved by the DNER-Forest Service Bureau;
11. Have a forest stewardship plan or other similar multiple use management plan in place at the time of the closing if a landowner is retaining the right to harvest timber or the right to conduct other land or resource management activities. A management plan will not be required if the aforementioned rights are not retained, or if a fee interest is being acquired. Preparation of the plan is the responsibility of the landowner with the help of the Forest Service Bureau's Rural Landowner Assistance Section.

F. PROGRAM IMPLEMENTATION CONSIDERATIONS

1. Contribution of Puerto Rico Forest Legacy Program to the Institutional Framework of the Commonwealth of Puerto Rico

Puerto Rico's institutional framework addressing forest protection and conservation combines federal, Commonwealth of Puerto Rico and municipal government agencies. Federal government agencies provide technical and financial assistance to local government agencies through established forest-related programs and some agencies directly manage forested areas, such as the USDA Forest Service that manages the Caribbean National Forest and the US Fish and Wildlife Service that manages the Boquerón Wildlife Refuge. In addition, the US Army and the US Navy hold extensive forested areas, specifically those in Ceiba, Cataño, and Salinas.

Within the Commonwealth of Puerto Rico, the Department of Natural and Environmental Resources is the agency that has been given by law the responsibility over all natural and environmental resources on the island, including the conservation and management of forested areas. Matters pertaining to forests fall under the Forest Service Bureau of the Living Resources Area of the Administration of Natural Resources. (See Charts 1 and 2 in Appendix A)

The Forest Service Bureau is in charge of implementing programs, such as, the Forest Stewardship, Forest Resource Management, Seeding, Tree and Nursery Improvement, Urban and Community Forestry Assistance, and Rural Development, which provide technical and financial assistance to rural and urban landowners. These programs have been established with the support and sponsorship of the USDA Forest Service. In addition,

the Forest Service Bureau of the Living Resources Area of the Administration of Natural Resources (See Charts 1 and 2 in Appendix A).

The Forest Service Bureau is in charge of implementing programs, such as, the Forest Stewardship, Forest Resource Management, Seeding, Tree and Nursery Improvement, Urban and Community Forestry Assistance. And Rural Development, that provide technical and financial assistance to rural and urban landowners. These programs have been established with the support and sponsorship of the USDA Forest Service. In addition, the Forest Service Bureau administers the Auxiliary Forest Program, that promote the conservation and restoration of forested areas and some can exercise control of uses during specified periods of time, as agreed with the owner(s). This program provides property tax exemption to participating private landowner.

The Natural Heritage Division of DNER has the authority by law “to acquire, restore and manage areas of natural interest”. The Natural Heritage Act of August 4, 1988 grants the DNER a mechanism that allows for the acquisition of areas of great natural value to protect and conserve them for the use and enjoyment of present and future generations of Puerto Rico.

The Commonwealth of Puerto Rico protects and promotes appropriate land uses in areas deemed of importance for the protection and conservation of environmental values through several instruments. In addition to the powers of purchasing, the traditional way to acquire control over a property, the Commonwealth of Puerto Rico has a Planning Board with the authority of establishing zoning districts, special planning areas and power to limit uses within specifically delimited areas. Currently, for example, the buffer zone of the Caribbean National Forest has a special planning area with zoning restrictions designed to protect the forest reserve.

The Municipal Reform Law (Act 81 of August 30, 1991) passed in 1991 give local municipalities the responsibility to regulate land use within their territory with power to restrict uses within specifically zoned areas. This enables them to contribute to the protection and conservation of forested areas without resorting to acquisition procedures. They must develop Municipal Land Use Plans with the approval of the Planning Board in order to acquire this delegated authority.

Outside the governmental arena, there are several private institutions that carry out environmental protection programs. The Conservation Trust of Puerto Rico is a non-profit corporation that purchases and/or administers state owned properties of environmental and cultural values for conservation programs. It develops them for educational and recreational uses.

Within this existing institutional framework, the Puerto Rico Forest Legacy Program would have several important contributions to make to the Commonwealth of Puerto Rico:

- a. Conservation easements constitute a legally binding commitment in perpetuity with property owners. At present, the Planning Board's zoning faculties are established and implemented in a precarious balance with what can constitute illegal taking of property owner rights. What can be done within the zoning restrictions is subject to reinterpretations by the Board and/or appellate instances and to all sorts of pressures exerted by owners and other interest groups. A recent example of the precarious situation for protected

- areas are projects in the buffer zone deemed threatening to the Caribbean National Forest by the USDA Forest Service that have received preliminary approval. Other forests lack adequate zoning protection precisely because of the Planning Board's legal difficulties with establishing and enforcing these zoning restrictions.
- b. The conservation easement, which is locally very limited for protection purposes, potentially reduces the cost of acquiring land control. Funding shortage for acquisitions are one of the basic limitations of existing conservation programs. The Forest Legacy Program addresses forest value conservation through the acquisition of property control using conservation easements. The easement reduces the cost of acquiring control because only the transfer of specific right is negotiated.
 - c. The Forest Legacy Program extends protection to a much larger area of forest resources, including forested areas with development potential. The Natural Heritage Division, for example, is specifically for resource conservation. Timber, recreational and tourist development, for example, is excluded. In the Forest Legacy Program, the landowner retains the property and the right to use it in any way consistent with the terms of the easement. The Forest Legacy Program is not solely a protection program. In general, Forest Legacy Areas will be encouraged to be 'working forests', where forest land is managed for the production of forest products and traditional forest uses maintained. This last objective is not covered by other existing protection programs in the island which are more concerned with conservation and preservation of forests. Although currently timber harvesting is a very limited activity in Puerto Rico but could be considered a potential industry.
 - d. Holding conservation easements can propitiate the direct involvement of landowners and/or easement overseers in forest conservation efforts, supplementing the limited surveillance capability of government agencies.

2. Possible Issues Related to Puerto Rico Forest Legacy Program Implementation

Public involvement activities brought forth several issues to be considered during the implementation phase of the project. Recommendations include the creation of a local legacy program under the DNER that actively involves and integrates efforts of community organizations active in forest protection and reforestation programs at different levels. Presentation of legislation for these purposes was suggested. *(Please refer to page 50 of this document.)*

Possible issues pertaining to the implementation of the Puerto Rico Forest Legacy Program that need to be looked into and maybe form part of the proposed legislation are the following:

- a. The need to legally define and provide incentives for the conservation easement to assure its effectiveness. These incentives should be competitive with those provided for alternative agricultural uses. The implementation of the Forest Legacy Program as designed by the USDA relies on the use of the conservation easement as the basic mode of acquisition of rights. The

- conservation easement represents an important and needed alternative to outright ownership for conservation purposes, which more often than not, is not feasible. The use of conservation easements, where appropriate, can be a highly efficient means of stretching the limited funds currently available for land conservation. Environmental law is a relatively new addition to the Puerto Rican legal system. This type of legislation has been adopted from the US Code. The conservation easement is not defined in Puerto Rico's Legal Code except as briefly mentioned in the law that establishes the Natural Heritage Division in the DNER (Act 150 of August 4th, 1998). The lack of legal definition of the conservation easement has several consequences. Qualifying characteristics and conditions for the recipient of the easement are not established. Rights, restrictions, permitted uses and reservations are not specifically established. Most important of all, no incentives to stimulate landowners are provided by law, such as, property and/or income tax incentives (which are given for alternative uses such as agricultural activities). (U.S. IRS Laws, except social security, are not applicable for business not receiving income outside of Puerto Rico.) In a highly incentive-laden economy as ours, in addition to the lack of land conservation tradition, conservation easements could be difficult to acquire.
- b. Easement ownership by the federal government could entail potential jurisdictional conflicts, loss of control by the Commonwealth of Puerto Rico over participating Forest Legacy Program properties and possibly a loss in efficiency of the Forest Legacy Program was brought forth as an issue in all of the public participation activities carried out. It was recommended by the DNER staff and in the public involvement activities that federal government ownership of easements possible be considered only for areas bordering federal owned forest property, such as the Caribbean National Forest, the Boquerón Wildlife Refuge and military property.
 - c. The Puerto Rico Forest Legacy Program has to establish a working coordination with the Planning Board and with those municipalities that have already acquired their territorial planning powers. The combination of mechanisms in the establishment of the Forest Legacy Areas will considerably strengthen the Forest Legacy Program.
 - d. A financial assistance program with lowers interest rates for landowners that require financing for forest maintenance and management should also be considered.

III. THE PUERTO RICO FOREST LEGACY AREAS
A. THE GUANICA LEGACY AREA

1. General Location

The Guánica Legacy Area is located on the southwestern corner of Puerto Rico, basically including the coastal area of the municipalities of Guánica, Lajas, Cabo Rojo, and a small portion of Yauco and Mayagüez. It extends from Punta Verraco on its southeastern portion, to the Cabo Rojo coast on its western portion, and to Laguna Joyuda in Mayagüez on the north (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 25,767 ha.

2. Summary of Important Environmental Values

The Guánica Legacy Area contains the following significant resource areas:

- a. the Guánica State Forest and Biosphere Reserve and its buffer zone,
- b. the Boquerón State Forest and its buffer zone,
- c. the Sierra Bermeja (Cerro Mariquita) area,
- d. the Laguna Joyuda Natural Reserve Area,
- e. Laguna Guaniquilla Reserve,
- f. the National Wildlife Refuge of Boquerón,
- g. the Mogotes de Boca Prieta and those to the east of Boca Prieta,
- h. Guánica Lagoon,
- i. Ciénaga Anegado of Lajas,
- j. a portion of the Susúa's State Forest,
- k. DNERs Bird Refuge, and
- l. the caves of Pedernales in Cabo Rojo.

(See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements for tracts should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Mineral rights

4. List of Objectives

- a. Establishment of a buffer zone for the Guánica State Forest
- b. Protection of endangered species habitat
- c. Protection of scenic quality
- d. Public access for recreation
- e. Conservation of wildlife habitat
- f. Continuation of traditional forest uses

5. Public Benefits to be Derived

- a. Enhance and maintain biodiversity

- b. Reduce potential impacts on Guánica State Forest
- c. Enhance and maintain natural elements for ecotourism activities
- d. Provide traditional forest products
- e. Enhancement of general quality of life

6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

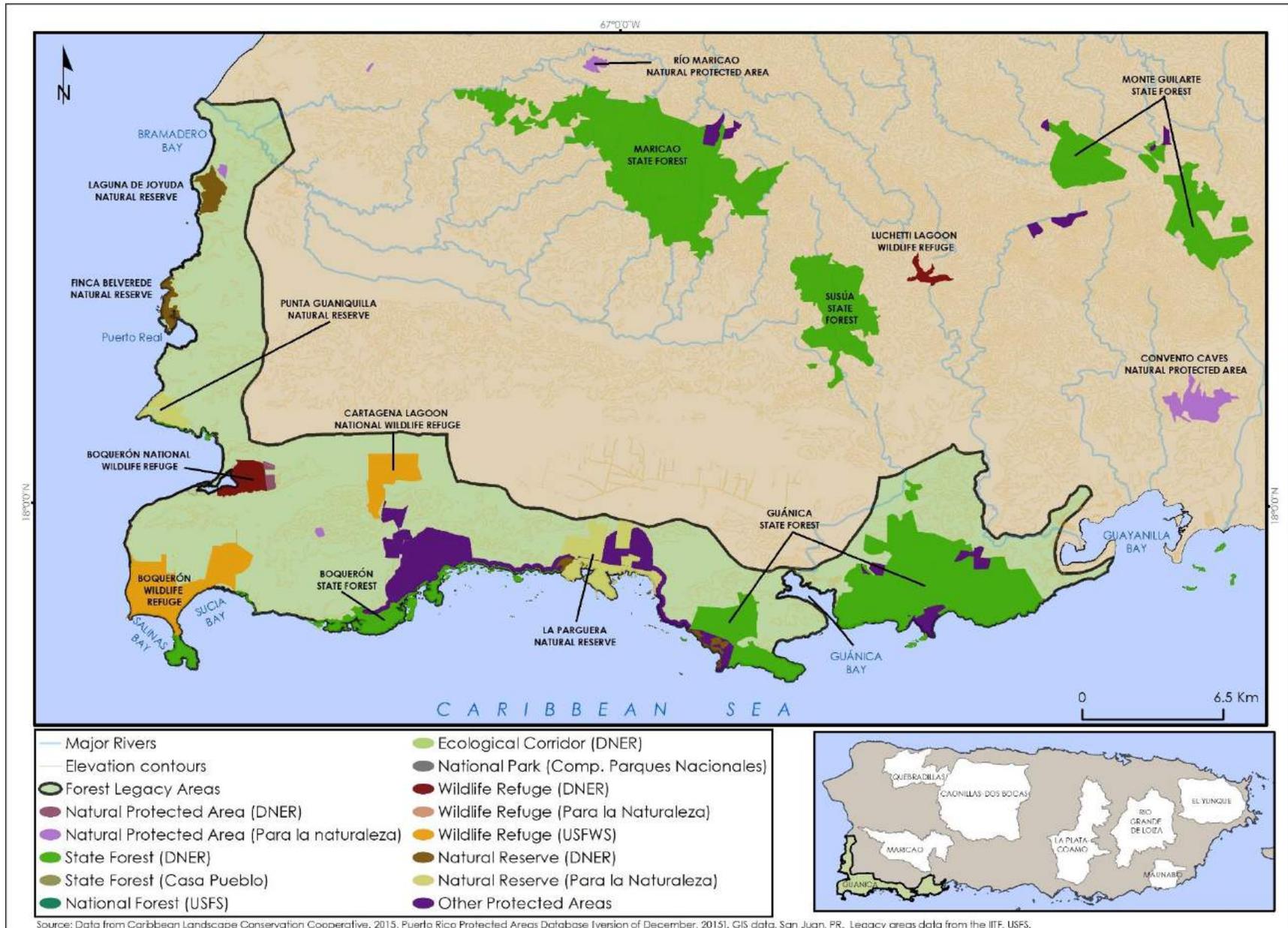


Figure 36. Location of the Guánica Legacy Area

B. THE MARICAO LEGACY AREA

a. General Location

The Maricao Legacy Area is located on the southwestern portion of the Cordillera Central, extending to the west to the municipality of Mayagüez, to the east to a portion of the municipality of Yauco, including also portions of the municipalities of San Germán and Sabana Grande (see Appendix B for the map and detailed information on boundaries). The size of the Area is approximately 29,013.33 ha.

b. Summary of Important Environmental Values

The Maricao Legacy Area contains the following significant resource areas:

- a. the Maricao and Susúa State Forest and their buffer zones,
- b. transitional tabonuco forest between these forest reserves;
- c. the Rodadero Peak area,
- d. the Indiera sections of Maricao, and
- e. the Cerro Las Mesas area of Mayagüez.

(See Appendix B for more details)

c. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Protection of public water supply
- f. Mineral rights

d. List of Objectives

- a. Establishment of a buffer zone for the Maricao and Susúa State Forests
- b. Protection of endangered species habitat corridor
- c. Protection of scenic quality
- d. Public access for recreation
- e. Conservation of wildlife habitat
- f. Continuation of traditional forest uses

e. Public Benefits Derived

- a. Decrease potential negative impacts on the Maricao and Susúa Forests
- b. Enhancements and maintenance of biodiversity
- c. Allow for development of ecotourism activities
- d. Provide traditional forest products

f. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

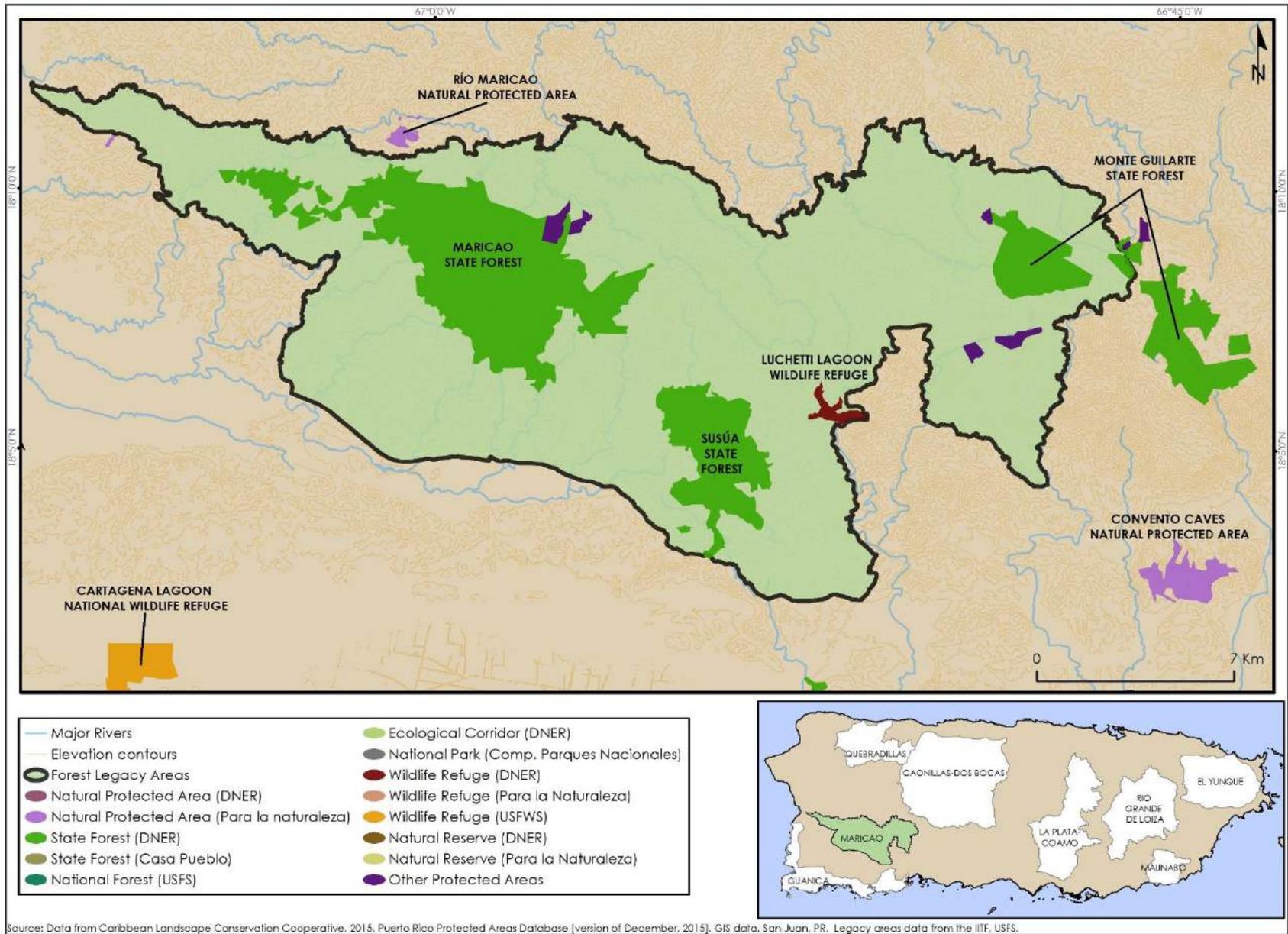


Figure 37. Location of the Maricao Legacy Area

C. THE QUEBRADILLAS LEGACY AREA

1. General Location

The Quebradillas Legacy Area is located on the northwestern portion of the karst region, extending towards the west to the municipality of Isabela, to the east to a portion of the municipality of Arecibo, including also portions of the municipalities of Quebradillas, Camuy, Hatillo and San Sebastián (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 22,683.33 ha.

2. Summary of Important Environmental Values

The Quebradillas Legacy Area contains the following significant resource areas:

- a. the karst forest region,
- b. the Guajataca State Forest and its buffer zone
- c. the Quebrada Bellaca area,
- d. the Guajataca Gorge and the intermediate basin of the Guajataca Lake, and
- e. the caves of Terranova and Guajataca in Camuy.

(See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Protection of public water supply
- f. Mineral rights

4. List of Objectives

- I. Establishment of a buffer zone for the Guajataca State Forest
- II. Protection of endangered species habitat
- III. Protection of scenic quality
- IV. Public access for recreation
- V. Conservation of wildlife habitat
- VI. Continuation of traditional forest uses
- VII. Protection of water resources, including undergrounds sources

5. Public Benefits to be Derived

- a. Decrease potential negative impacts on the Guajataca Forest Service
- b. Enhancement and maintenance of biodiversity
- c. Allow for development of ecotourism activities
- d. Provide traditional forest products
- e. Provide reliable sources of good water quality and quantity

6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

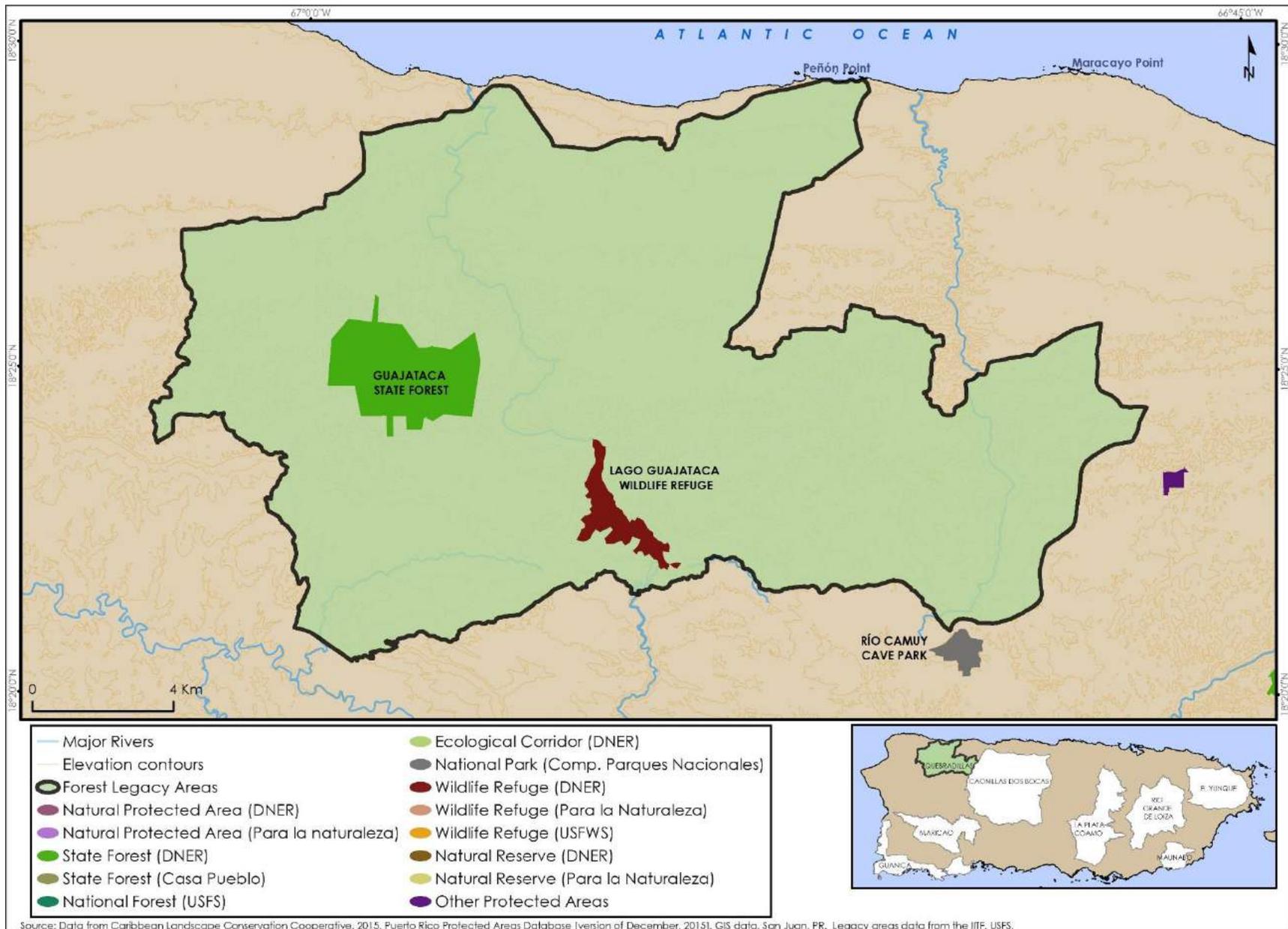


Figure 38. Location of the Quebradillas Legacy Area

D. THE CAONILLAS-DOS BOCAS LEGACY AREA

1. General Location

The Caonillas-Dos Bocas Legacy Area is located on the northcentral region of the island. It includes portions of the karst limestone region and the Cordillera Central, extending to the west to the municipalities of Manatí, Ciales and Orocovi, including also portions of the municipalities of Adjuntas, Jayuya, Utuado, Florida and Barceloneta (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 51,013 ha.

2. Summary of Important Environmental Values

The Caonillas-Dos Bocas Legacy Area contains the following significant resource areas:

- the basin of the Caonillas and Dos Bocas Lakes,
- the karst limestone region,
- the Lago Guineo area,
- the copper mines area,
- the Biáfara de Arecibo, Arrozal area,
- the Hato Viejo area,
- the Toro Negro State Forest and its buffer zone,
- the Rio Abajo State Forest and its buffer zone,
- the Bosque del Pueblo de Adjuntas State Forest and its buffer zone.

(See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements for tracts should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Protection of public water supply
- f. Mineral rights

4. List of Objectives

- a. Establishment of a buffer zone for the Toro Negro Forest
- b. Establishment of a buffer zone for the Rio Abajo State Forest
- c. Establishment of a buffer zone for the Bosque del Pueblo de Adjuntas State Forest
- d. Protection of endangered species habitat
- e. Protection of scenic quality
- f. Public access for recreation
- g. Conservation of wildlife habitat
- h. Continuation of traditional forest uses

5. Public Benefits to be Derived

- a. Decrease potential negative impacts on the Toro Negro State Forest
- b. Decrease potential negative impacts on the Rio Grande State Forest
- c. Decrease potential negative impacts on the Bosque del Pueblo de Adjuntas State Forest
- d. Enhancement and maintenance of biodiversity
- e. Allow for development of ecotourism activities
- f. Provide traditional forest products
- g. Provide reliable sources of good water quality and quantity

6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

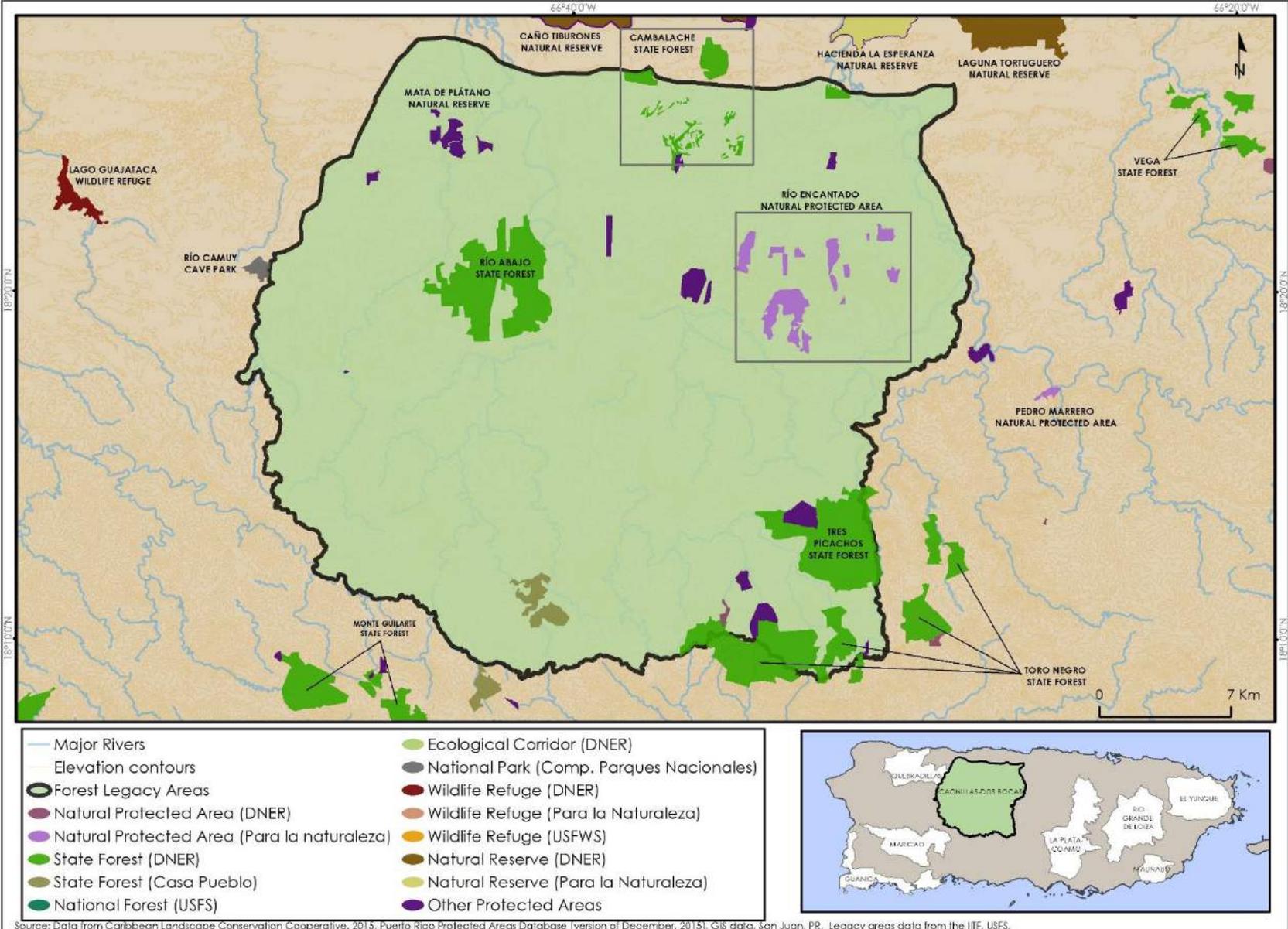


Figure 39. Location of the Caonillas-Dos Bocas Legacy Area

E. THE LA PLATA-COAMO LEGACY AREA

1. General Location

The La Plata-Coamo Legacy Area is located on the central and southern portion of the Cordillera Central, including a considerable section of the basin of the Plata River and a southern portion extending to the municipalities of Coamo and Salinas (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 45,417 ha.

2. Summary of Important Environmental Values

The la Plata-Coamo Legacy Area contains the following significant resource areas:

- a. the watershed of Lake La Plata, (one of the main providers of water supply to the San Juan Metropolitan Area),
- b. the Pasto and Piedras Chiquitas areas,
- c. primary Ucar forested areas in Salinas, and
- d. the Tetas de Cayey Area.

(See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements for tracts should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Protection of public water supply
- f. Mineral rights

4. List of Objectives

- a. Protection of endangered species habitat
- b. Protection of scenic quality
- c. Public access for recreation
- d. Conservation of wildlife habitat
- e. Continuation of traditional forest uses
- f. Protection of water supply systems

5. Public Benefits to be Derived

- a. Enhancement and maintenance of biodiversity
- b. Allow for development of ecotourism activities
- c. Provide traditional forest products
- d. Provide reliable sources of good water quality and quantity

6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

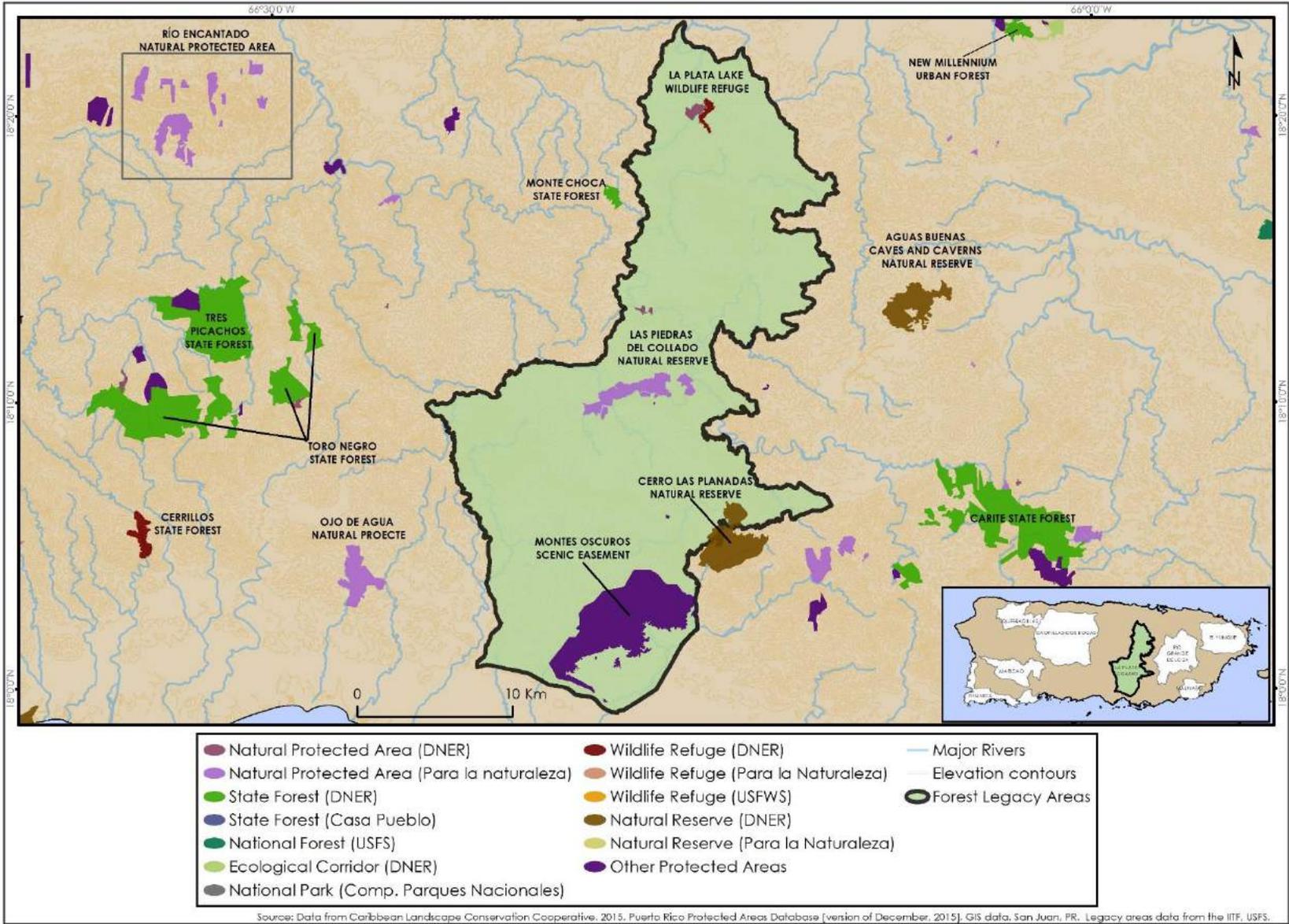


Figure 40. Location of the La Plata-Coamo Legacy Area

F. THE RIO GRANDE DE LOÍZA LEGACY AREA

1. General Location

The Rio Grande de Loíza Legacy Area is located on the central eastern portion of the Cordillera Central, extending to the west to the municipalities of Aguas Buenas and Cidra, to the east to a portion of the municipalities of Gurabo and San Lorenzo, including also portions of the municipalities of Cayey, Juncos, and Trujillo Alto (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 23,410 ha.

2. Summary of Important Environmental Values

The Rio Grande de Loíza Legacy Area contains the following significant resource areas:

- a. the upper basin of the Carraízo Lake (Lake Loíza, the main water supply source of the San Juan Metropolitan Area),
- b. the immediate basin of Cidra Lake (another principal water supply source for the San Juan Metropolitan Area),
- c. the Carite Lake (a water supply source for the southern portion of the island), and
- d. the Carite State Forest and its buffer zone

(See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements for tracts should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Protection of public water supply
- f. Mineral rights

4. List of Objectives

- a. Establishment of a buffer zone for the Carite State Forest
- b. Protection of endangered species habitat
- c. Protection of scenic quality
- d. Public access for recreation
- e. Conservation of wildlife habitat
- f. Continuation of traditional forest uses
- g. Protection of public water supply

5. Public Benefits to be Derived

- a. Decrease potential negative impacts on the Carite State Forest
- b. Enhancement and maintenance of biodiversity
- c. Allow for development of ecotourism activities
- d. Provide traditional forest products
- e. Provide reliable sources of good water quality and quantity

- 6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities**
 - a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
 - b. Local municipal governments
 - c. The Conservation Trust of Puerto Rico

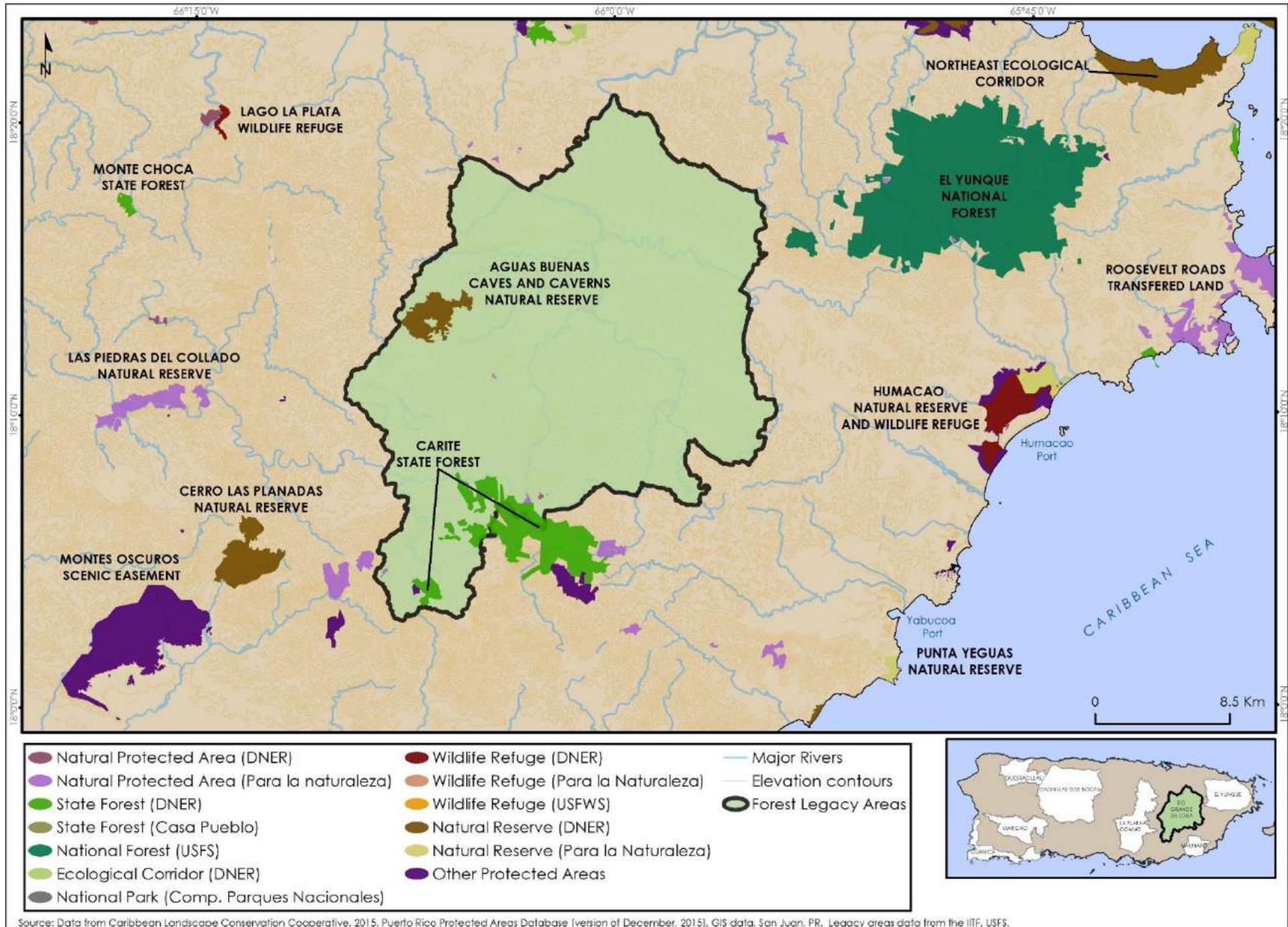


Figure 41. Location of the Rio Grande de Loiza Legacy Area

G. THE MAUNABO LEGACY AREA

1. General Location

The Maunabo Legacy Area is located on the southeastern coast of the island, including portions of the municipalities of Maunabo and Yabucoa (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 10,233 ha.

2. Summary of Important Environmental Values

The Maunabo Legacy Area contains the following significant resource areas:

- a. the Cuchilla Panduras Region

(See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements for tracts should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species

4. List of Objectives

- a. Protection of endangered species habitat
- b. Protection of scenic quality
- c. Public access for recreation
- d. Conservation of wildlife habitat
- e. Continuation of traditional forest uses

5. Public Benefits to be Derived

- a. Enhancement and maintenance of biodiversity
- b. Allow for development of ecotourism activities
- c. Provide traditional forest products
- d. Provide reliable sources of good water supply and quantity

6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

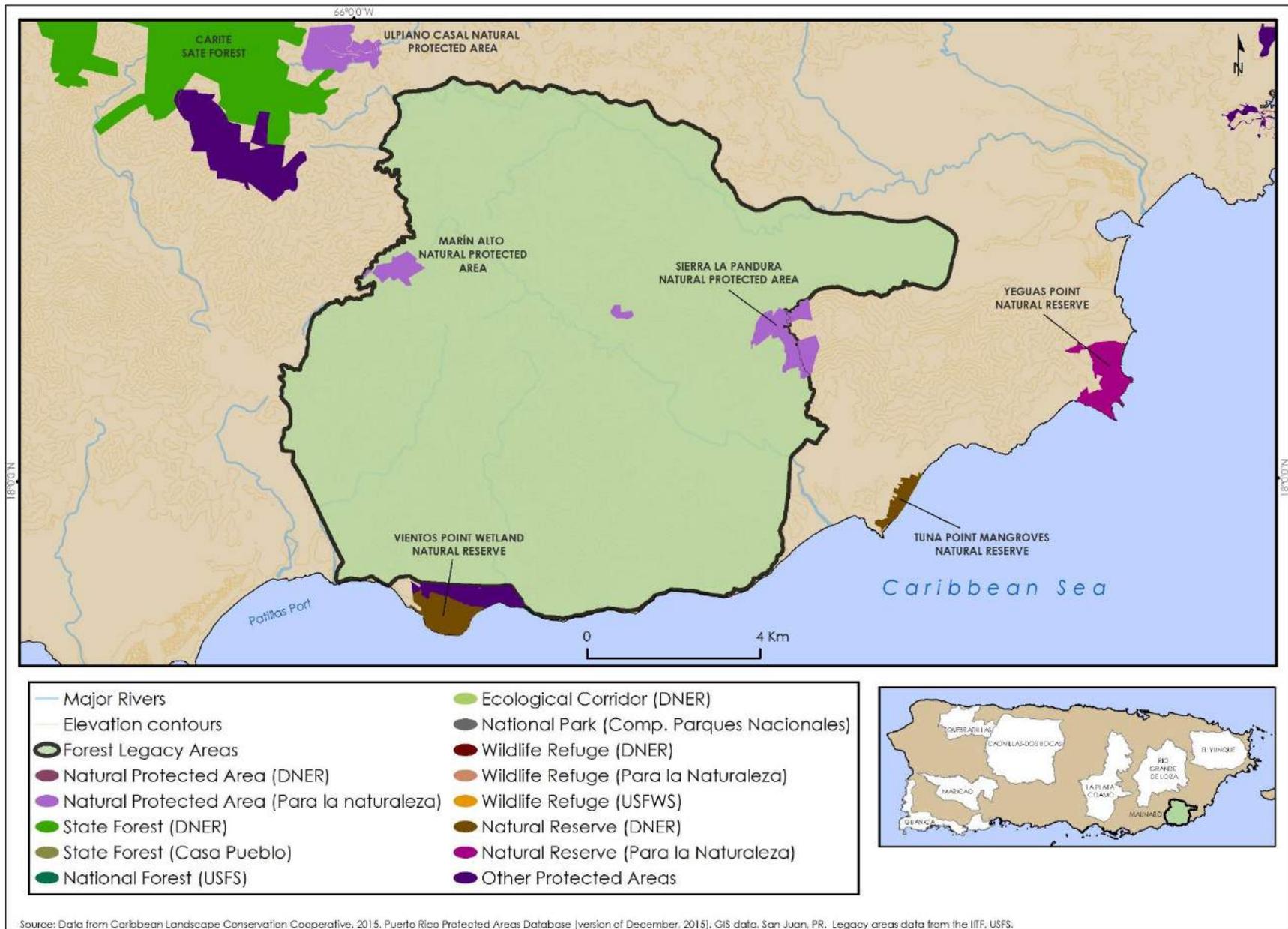


Figure 42. Location of the Maunabo Legacy Area

H. THE EL YUNQUE LEGACY AREA

1. General Location

The El Yunque Legacy Area is located on the eastern portion of the island on the Sierra de Luquillo Mountains, including the buffer zone of the Caribbean National Forest and Biosphere Reserve (see Appendix B for map and detailed information on boundaries). The size of the Area is approximately 20,890 ha.

2. Summary of Important Environmental Values

The El Yunque Legacy Area contains the following significant resource areas:

- a. the Caribbean National Forest and Biosphere Reserve and its buffer zone. (See Appendix B for more details)

3. Conservation and Protection Methods

Fee simple acquisition and/or conservation easements.

Conservation easements for tracts should address:

- a. Development rights
- b. Management of land for traditional forest uses, recreational purposes and wildlife habitat and scenic resources
- c. Public access
- d. Protection of rare and endangered species
- e. Protection of public water supply
- f. Mineral rights

4. List of Objectives

- a. Establishment of a buffer zone for the Caribbean National Forest
- b. Protection of endangered species habitat
- c. Protection of scenic quality
- d. Public access for recreation
- e. Conservation of wildlife habitat
- f. Continuation of traditional forest uses
- g. Protection of public water supply

5. Public Benefits to be Derived

- a. Decrease potential negative impacts on the Caribbean National Forest
- b. Enhancement and maintenance of biodiversity
- c. Allow for development of ecotourism activities
- d. Provide traditional forest products
- e. Provide reliable sources of good water supply and quantity

6. Entities that may be Assigned Administrative, Monitoring, and/or Management Responsibilities

- a. Commonwealth of Puerto Rico, Department of Natural and Environmental Resources, Forest Service Bureau
- b. Local municipal governments
- c. The Conservation Trust of Puerto Rico

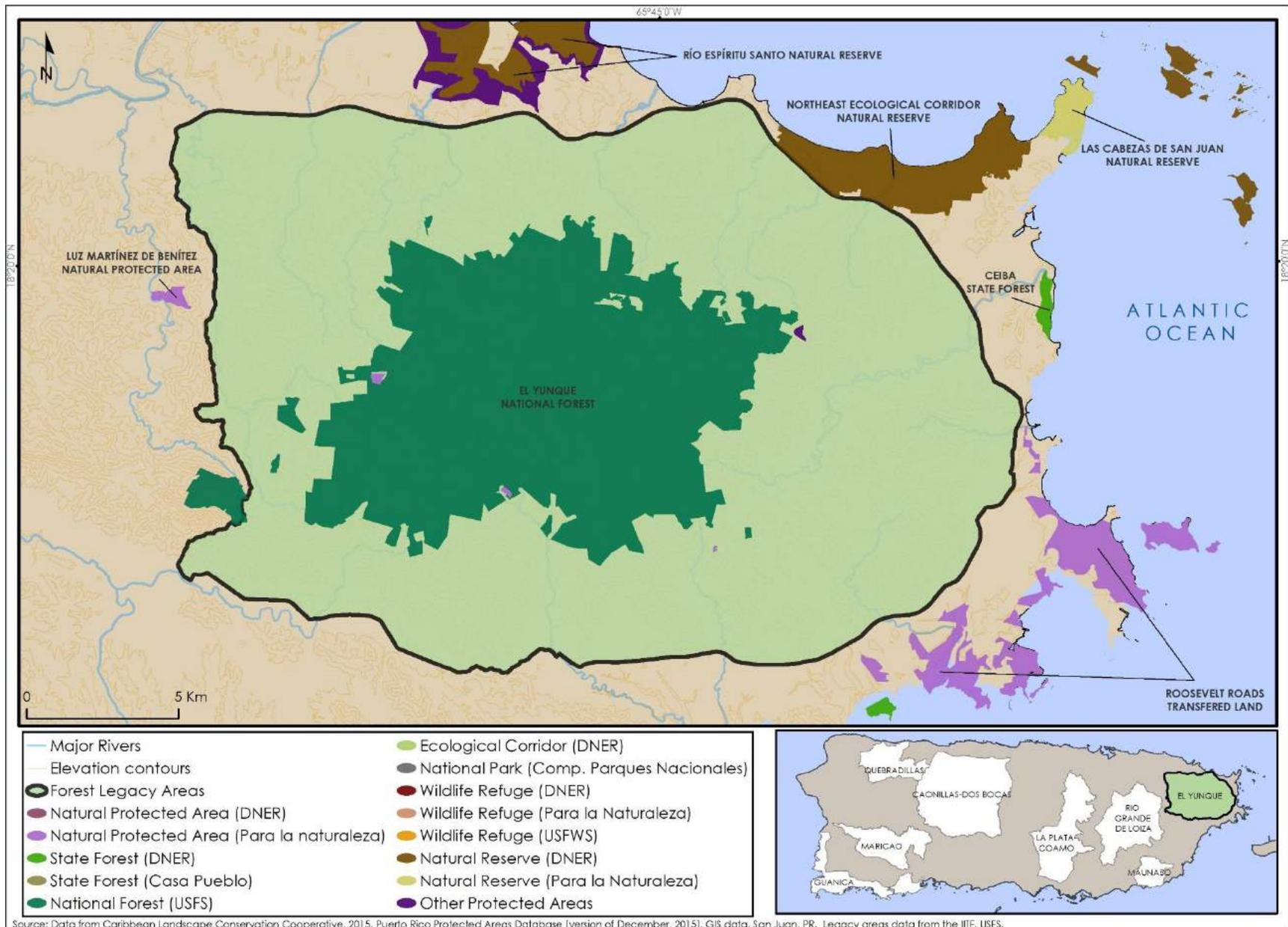


Figure 43. Location of El Yunque Legacy Area

IV. PUBLIC INVOLVEMENT IN THE ASSESSMENT PHASE

The public involvement process for the preparation of the Assessment of Need for the Puerto Rico Forest Legacy Program began internally with the in-depth discussion of the program with the staff of the Forest Service Bureau, the Natural Heritage Division and other relevant areas within the Department of Natural and Environmental Resources (DNER). Issues concerning program need, interrelationships of the FLP with other federal and Commonwealth programs currently active in the DNER were discussed and goals and objectives of the program clearly defined. An important distinction in regards to the Natural Heritage Division goals and objectives was established concerning the focus of the program on working forests, differing from the Natural Heritage Division whose goal is strictly conservation.

The second level was the presentation of the Forest Legacy Program to the Forest Advisory/Conceptual Team (FACT), a public involvement committee organized by the Forest Service Bureau which encompasses the Forest Stewardship Committee. FACT broadly represents the spectrum of organizations involved in all aspects related to forestry and environmental issues in Puerto Rico. The FACT members agreed on the desirability of implementing Forest Legacy Program in Puerto Rico with the recommendation that its adaptation to the local realities be reviewed. The recommendations were taken into consideration in the assessment analysis.

The Forest Legacy Areas were initially nominated by the Forest Service Bureau, the Natural Heritage Division and USDA Forest Service personnel. The FACT reviewed and expressed agreement with the nominated Forest Legacy Areas.

In an effort to establish an Association of Private Forest Landowners, three focus meetings were organized with private forest landowners, these were highly successful. The desirability of the implementation of the Forest Legacy Program in Puerto Rico was highly approved by all participating landowners. The following recommendations were made:

1. That the program be also created locally as a program of the DNER. They deemed the program as so very important to Puerto Rico that it should be implemented even if the program does not continue at the federal level. The presentation of legislation for this purposes was recommended.
2. That an act be drafted and presented for the approval by the PR Legislature creating conservation easements in Puerto Rico.
3. The private forest landowner is penalized as s/he receives no incentives for maintaining the land forested and must pay taxes when these are exempted when the property is agricultural uses. Agricultural uses provide many incentives, including programs that promote the elimination of forest cover such as those promoting sun grown coffee. Additional incentives to the Forest Legacy Program are recommended because it will compete with other land uses promoted by such programs.
4. Landowners need financial assistance in reforestation processes, as this is a very expensive activity. They also need technical assistance on

forest management and trained workers to perform adequately the required activities.

5. For those landowners who do not have large extension of land, it is very hard to consider a perpetuity agreement and other ways through which these landowners can participate should be explored. Alternatives included a shorter period of time with less benefits.
6. It was recommended that alternatives be explored to raise funds for watershed reforestation and conservation from the higher income cities which are consumers of the water supplies generated by the lower income mountainous area.
7. The landowners recommended that no legacy areas be pre-defined as the program should have the flexibility to acquire important tracts anywhere on the island.

Another phase of the public involvement process included meeting and sharing of documents with pertinent government agencies such as the Puerto Rico Planning Board, and with environmental organizations such as the Conservation Trust of Puerto Rico and the Puerto Rico Conservation Foundation (Fundación Puertorriqueña de Conservación). They all recognized the desirability of implementing the Forest Legacy Program in Puerto Rico.

Appendix A

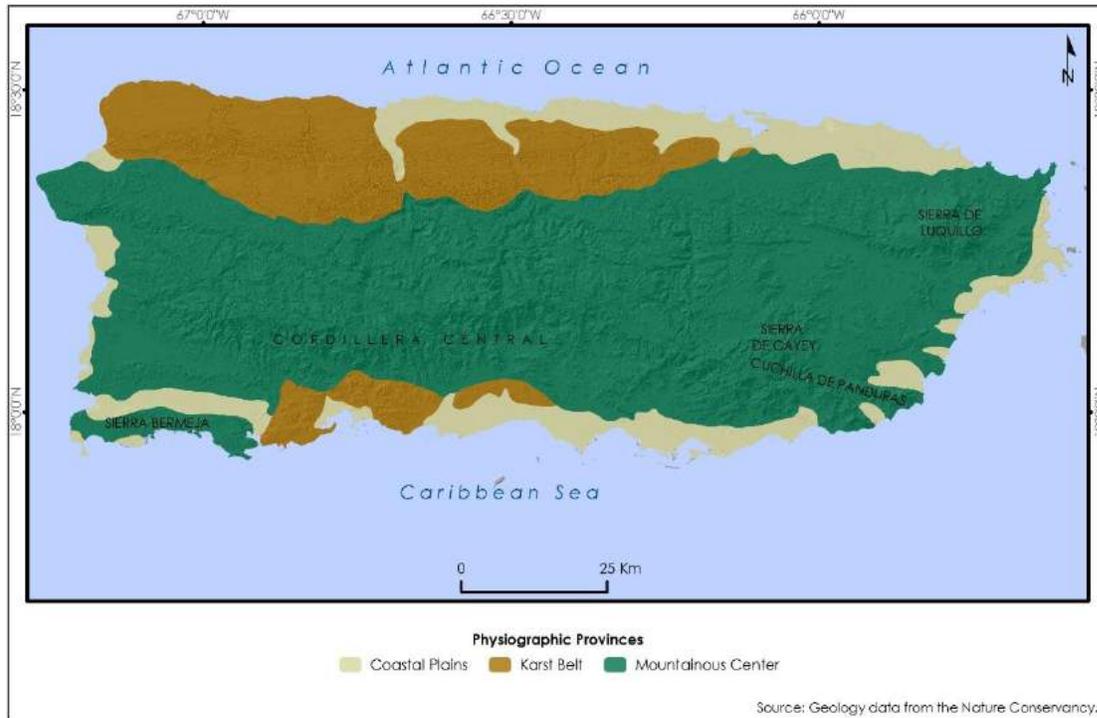


Figure 44. Physiographic Provinces of Puerto Rico



Figure 45. Elevations of Puerto Rico

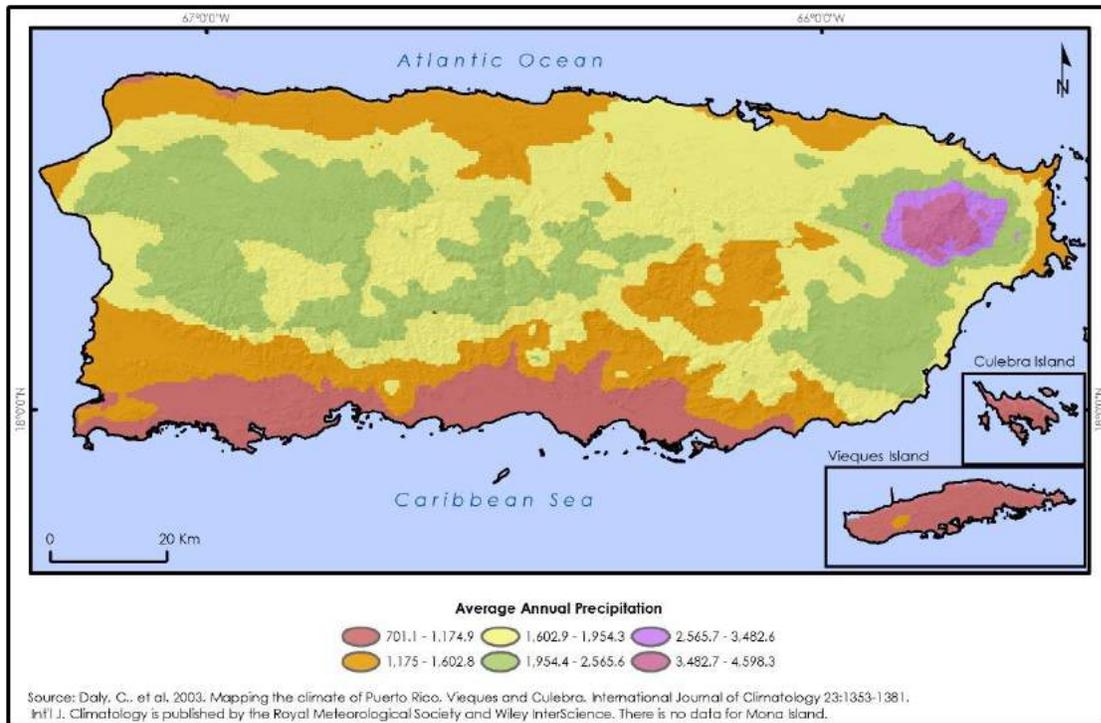


Figure 46. Average Annual Precipitation of Puerto Rico



Figure 47. Average slope percent distribution of Puerto Rico



Figure 48. Overview of the reservoirs of Puerto Rico

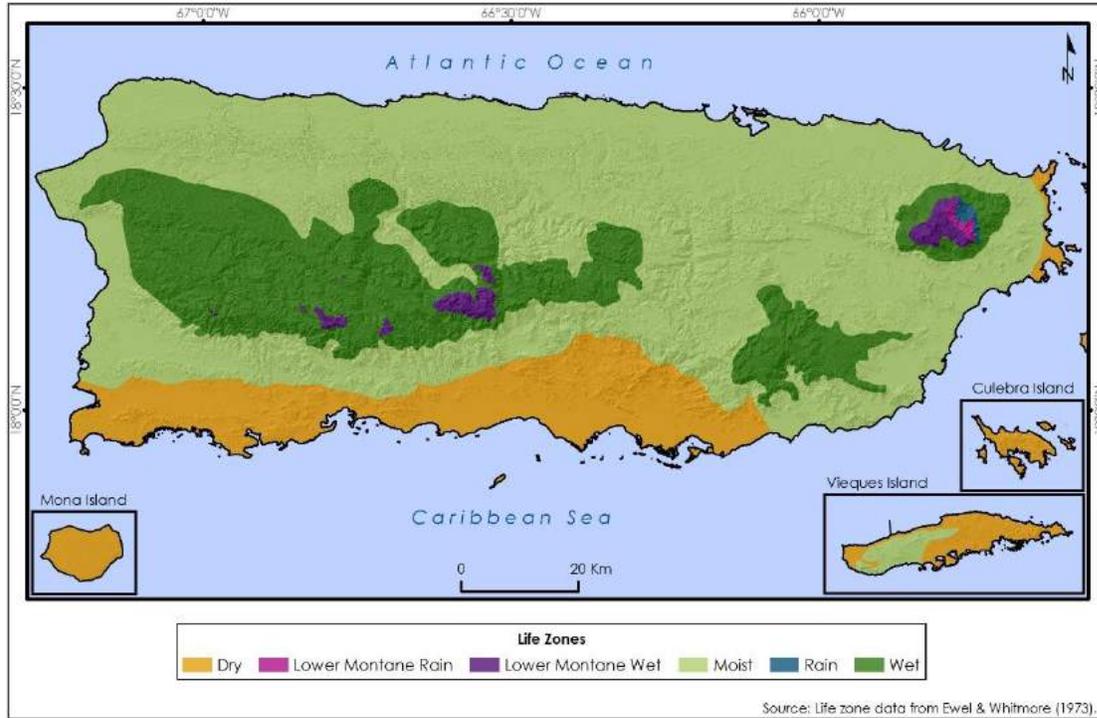
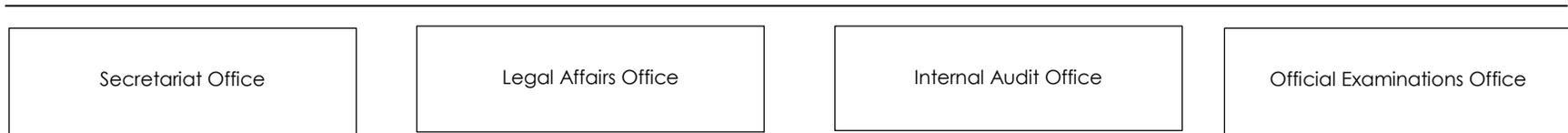
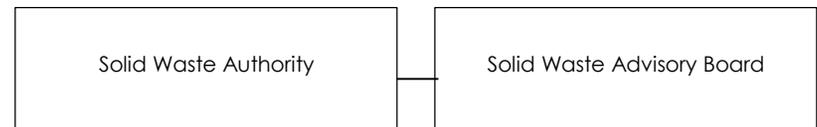


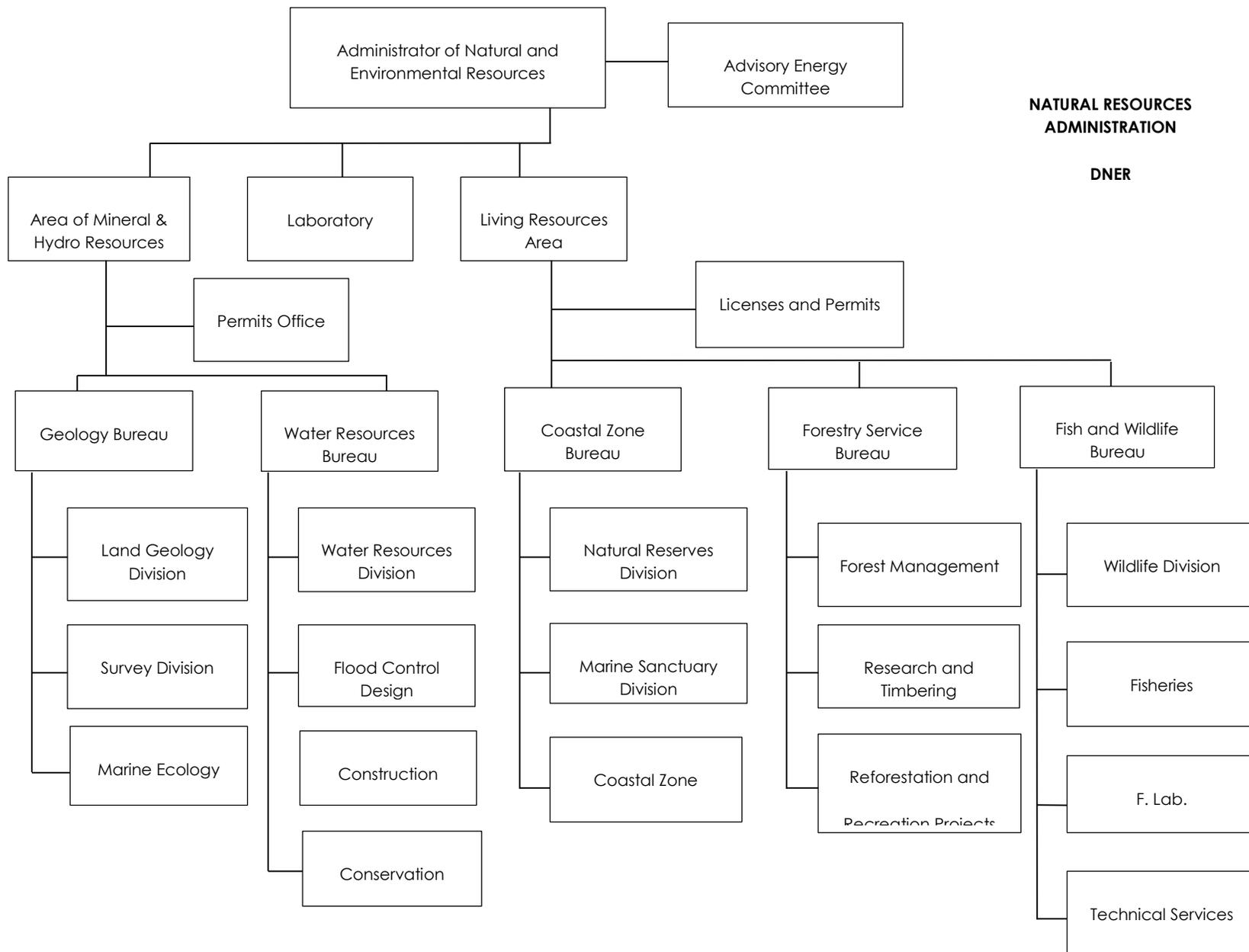
Figure 49. Land distribution among the Subtropical forest life zones of Puerto Rico, Vieques, Culebra, and Mona Islands (Brandeis et al. 2007)



Department of Natural and Environmental Resources

ORGANIZATIONAL CHART





**NATURAL RESOURCES
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Appendix B

DETAILED INFORMATION ON THE PUERTO RICO FOREST LEGACY AREAS

Legacy areas are defined as large general delimitation within which, and only within which, tracts can be selected for the purpose of acquiring conservation easements. To simplify the delimitation, the Legacy Area boundaries are defined by existing roads, as presented in the official State Road Map for Puerto Rico prepared by the Department of Transportation and Public Works and dated December 31, 1993. Therefore, not all the territory within each Legacy Area is of interest to the Puerto Rico Legacy Program. However, all areas of interests are included within a Legacy Area.

THE GUANICA LEGACY AREA

I. Boundary Delimitation

The Guánica Legacy Area lies between its northern boundary and the coastline. The northern boundary is defined as follows, beginning to the east on Punta Verraco, Municipality of Guayanilla. (Please refer to Map for this Legacy Area):

1. West on PR 135 to \perp^{22} with PR 335
2. West on PR 335 to \perp with PR 2
3. West on PR 2 to \perp with PR 117
4. West on PR 117 to \perp with PR 322
5. South on PR 322 to \perp with PR 116
6. West on PR 116 to \perp with PR 305
7. West on PR 305 to \perp with PR 303
8. North on PR 303 to \perp with PR 101
9. West on PR 101 to \perp with PR 100
10. North on PR 100 to \perp with PR 2
11. North on PR 2 to \perp with PR 340
12. West on PR 340 to coastline

II. Important Environmental Values of this Legacy Area

A. The Guánica State Forest and Biosphere Reserve

This Forest Legacy Area establishes a buffer zone for the Guánica State Forest and Biosphere Reserve. This State Forest belongs to the Commonwealth of Puerto Rico and has been rightfully called “the best example of subtropical dry forest vegetation in the world”. Only one percent of the dry forest vegetation originally covering the planet now remains. The relatively undisturbed Guánica forest with its mosaic of habitats, is a vital refuge for dry forest organisms that are vulnerable to hunting and degradation of their habitat. Many species of plants and animals living in this forest are found nowhere else in the world. The reserve is so valuable it has merited a designation of Biosphere Reserve of planetary importance by the United Nations.

These 3,600 ha of forest reserve contain a great richness in plant and bird life. Over 700 species of plants have been reported for the Guánica Forest. Of these species, 246 are trees, 48 are considered rare or endangered, and 16 are only found within the forest's

²² \perp Intersection

boundaries. According to Kepler and Kepler (1970), the diversity of bird in the Guánica Forest is greater than in the Caribbean National Forest. Half of all the species of land birds found in Puerto Rico are represented in the Guánica Forest. In addition, it has twice the density of birds found anywhere else. It is by far the richest forest in Puerto Rico in avian fauna. In 1951, a bird previously considered extinct from the world, the Puerto Rican Nightjar was rediscovered in the Guánica Forest. Today it is still found nowhere else. Nine of Puerto Rico's fourteen endemic bird species occur in this forest. These are: *Sauroptera vieilloti* (the Puerto Rican Lizard Cuckoo), *Chlorostilbon maugaeus* (the Puerto Rican Emerald Hummingbird), *Melanerpes portoricensis* (the Puerto Rican Woodpecker), the Puerto Rican Flycatcher, *Agelaius xanthomus* (the Yellow-shouldered Blackbird), *Vireo latimeri* (the Puerto Rican Vireo), *Loxigilla portoricensis* (the Puerto Rican Bullfinch, and *Caprimulgus vociferus noctitherus* (the Puerto Rican Nightjar). Two of these, the Yellow-shouldered Blackbird and the Puerto Rican Nightjar are endangered species.

The forest also supports an important herpetofauna that includes such rare and endemic forms as *Ameiva wetmorei* and *Anolis cooki*. Recently a large breeding population of *Peltophyrne lemur* was discovered within the forest boundaries. *Goecarcinus ruricola*, the purple land crab is abundant. This species of edible crab is very rare and is being considered for inclusion in the DNER endangered species list.

The Forest Legacy Area proposed includes land that conforms the natural buffer zone of this important biosphere reserve. Specific tracts have already been identified as many landowners in the immediate vicinity of the forest and whose properties could constitute the much needed buffer zone have expressed their willingness to sell their properties. The area has experienced pressures for hotel construction and industrial development.

B. The Boquerón State Forest

The Boquerón Forest is also a Commonwealth forest and consists of mangrove swamps on the coast, many of them cut from the mainland by channels. The forest is a wildlife refuge containing at least 58 species of fish and over 50 species of birds, many of them considered rare and endangered. The lagoons serve as feeding grounds for the aquatic birds and fishes.

This Legacy Area includes tracts of land that can conform a much needed buffer zone for this important forest reserve.

C. Sierra Bermeja (Cerro Mariquita)

Sierra Bermeja is a mountainous formation located between the municipalities of Cabo Rojo and San Germán. Cerro Mariquita is its highest peak, reaching approximately 300 meters of elevation. Sierra Bermeja is probably the oldest rock formation on the island. It contains 169 species of plants, some which are of singular importance, several are endemic to Puerto Rico and not known to be found elsewhere, others are of restricted or scarce distribution. The following are species found in the area that are in the endangered list or candidates for such list: *Aristida chaseae*, *Aristida portoricensis*, *Leptocereus quadricostatus*, *Luonia truncata var proctorii*, and *Vernonia proctorii*.

D. Laguna Joyuda Natural Reserve

The Joyuda Lagoon is located on the west coast of Puerto Rico, approximately five miles from the city of Mayagüez. It belongs to the Commonwealth of Puerto Rico and is of public use.

The lagoon has brackish water and is linked to the sea by a small channel. It is bordered by a forest of red mangroves (*Rhizophora*) forming an extensive swamp covering approximately 120 ha. with a depth of approximately 8 feet which is an extraordinary habitat for birds, insects and fish.

Currently the lagoon is used as a fishing area, a site for scientific studies by the Energy Studies Center and by the Department of Natural and Environmental Resources.

This natural reserve encompasses strictly the water limits of the lagoon and the surrounding mangrove forest is not protected. The proposed legacy area includes a buffer zone for its natural reserve.

E. Other Important Areas

The Proposed Legacy area includes other environmentally important areas (that are not necessarily forests) such as: The National Wildlife Refuge, a dry forested area similar to the Guánica Biosphere Reserve administered by the US Fish and Wildlife Service; Cabo Rojo Salines; Guaniquilla Lagoon; the Boca Prieta knolls, including those to the east of Boca Prieta, Guánica Lagoon, Ciénaga Anegado of Lajas, a portion of the Susúa State Forest, DNER's bird refuge and the Caves of Pedernales in Cabo Rojo.

THE MARICAO LEGACY AREA

I. Boundary Delimitation

The Maricao Legacy Area extends eastward from the city of Mayagüez as follows: (Please refer to Map for this Legacy Area):

- Out of Mayagüez to the southeast on PR 349 [⊥]²³ with PR 119
- South on PR 119 to ⊥ with PR 2
- Southeast on PR 2 to the town of Sabana Grande
- Out of Sabana Grande to the east on PR 368 to the town of Yauco
- Out of Yauco to the north on PR 128 to ⊥ with PR 373
- Northeast on PR 373 to ⊥ with PR 372
- East then south on PR 372 to ⊥ with PR 375
- Southeast on PR 375 to ⊥ with PR 378
- North on PR 378 to ⊥ with PR 131
- North on PR 131 to ⊥ with PR 525
- West on PR 135 to ⊥ with PR 128
- Southwest on PR 128 to ⊥ with PR 105
- West on PR 105 into the city of Mayagüez

²³⊥ Intersection

II. Important Environmental Values of this Legacy Area

A. The Maricao State Forest

The Maricao State Forest lies at the western end of the Cordillera Central and is divided into two separate segments comprising 4,100.8 ha. This forest represents vegetation types of serpentine soils and probably has the most diversified flora of any area of the same size in Puerto Rico, 7 are endemic subspecies, 16 are breeding residents and 10 are migrants from North America. This is the habitat of the endemic Broad Winged Hawk and Sharp-Shinned Hawk and the rare Elfin Woods Warbler. There is circumstantial evidence that the supposedly extinct rodent *Isolobodon portoricensis* (jutía) may be surviving in the Maricao Forest. The headwaters of the Maricao River is the habitat of a tree frog found in only one other locality in western Puerto Rico.

The Maricao State Forest probably has the most diversified flora. The vegetation of the Maricao forest is outstanding because of the relative rarity elsewhere of many of the plant species present. The forest's total vascular flora of 845 species (278 reaching tree size) includes 123 species endemic to Puerto Rico and 20 endemics to Maricao. The rich diversity of trees resulting in unique forest types occurring only in Puerto Rico may be due to the closed nutrient cycling, adequate rainfall received on well aerated serpentine soils in addition to the unusual combination of physiographic features (serpentine and volcanic soils).

Five vegetation associations have been delineated in three bioclimatic life zones. A dwarfed vegetation of evergreen, small-leafed species occupies the narrow ridges, peaks and summits exposed to strong winds and is probably unique to Puerto Rico. Along the ridges and towards the windward lopes, large cushions of the rare rainier moss form a unique element of the forest floor.

The plant life of the Maricao State Forest is unique because of three circumstances:

1. The climate of the area is restricted to less than 10% of Puerto Rico;
2. The physiologically dry soils create a seasonal or monsoon growth environment not found elsewhere in Puerto Rico; and
3. In contrast to virtually all similar adjacent areas, the natural vegetation has never been removed from larger areas within the forest.

The Maricao State Forest provides habitat for at least 44 species of birds including two species of endangered hawks. Scenic vistas and unique rock formations are found in Rio Cruces and Quebrada Agustina. The forest has also watershed importance for the western portion of the island²⁴.

The proposed Maricao Legacy Area provides a much needed buffer zone to the Maricao Forest, including connecting the wildlife corridor that exists between this forest and the Susúa Forest further south and rounding out the forest holdings.

²⁴ Text and map of land acquisitions taken from "The Master Plan for the Commonwealth Forest" prepared by the Department of Natural and Environmental Resources.

B. The Susúa State Forest

The Susúa State Forest is property of the Commonwealth of Puerto Rico and covers 1,114 ha. The forest is important as it represents not only the influence of a climatic transition zone (dry to moist) but also a combination of volcanic and serpentine soils. The serpentine derived soils support a unique vegetation which contains a number of endemic but does not support any significant agriculture or forestry. Common species found in the Susúa forest include: *Bursera simaraba*, *Exostema caribeum*, *Linociera axillaris*, *Coccoloba microstachia*, and *Terebraria resinosa*.

C. Other Important Areas

The Legacy Area includes other important forested areas, such as the Rodadero Peak, the Indiera Sections, and the Cerro Las Mesas area. These are all forested areas that conform a buffer zone to the Maricao and Susúa Forests and constitute important habitat areas and wildlife corridors.

THE QUEBRADILLAS LEGACY AREA

I. Boundary Delimitation

The Quebradillas Legacy Area is located on the northwestern coast of Puerto Rico. The boundary delimitation begins at the town of Isabela:

- East along the coastline to the town of Camuy
- Out of Camuy to the south on PR 119 to ⊥ with PR 483
- South then east on PR 483 to ⊥ with PR 496
- East on PR 496 to ⊥ with PR 488
- Northeast to south on PR 488 to ⊥ with PR 130
- South on PR 130 to ⊥ with PR 129
- South then west on PR 129 to ⊥ with PR 454
- South on PR 454 to ⊥ with PR 111
- Northwest on PR 111 to ⊥ with PR 450
- Northwest on PR 450 to ⊥ with PR 445
- North on PR 445 to ⊥ with PR 112
- North on PR 112 to the coastline (town of Isabela)

II. Important Environmental Values of this Legacy Area

The landforms developed on the north coast limestone of Puerto Rico constitute one of the finest examples of tropical karst in the world. The terrane appears as clusters of haystack hills separated from one another by rounded depressions. The karst forest region is a unique natural area because of its tropical karst topography, many forested areas of this region are in primary or close to primary conditions.

The Guajataca State Forest belongs to the Commonwealth of Puerto Rico and has an area of 784.66 ha. with an elevation ranging from 150 to 300 meters. Approximately 45 bird species occur commonly in this forest, 8 are endemic to Puerto Rico, 34 are breeding residents, and 11 are migratory. Most of these forest forms that require well wooded habitat for their survival. The proposed Legacy Area provides a buffer zone for this State Forest.

The Guajataca River gorge at the Quebrada Bellaca section is a densely forested area and one of two sectors on the island that provides a habitat to the species *Peltophyrne lemur* (sapo concho nativo), an amphibian in danger of extinction because of destruction to its habitat. The section also contains endemic trees in danger of extinction and/or rare such as: *Goetzea elegans* (matabuey), *Daphnopsis helleriana*, *Zanthosylum thomasianum* (prickly ash), *Aurodendron pauciflorum*, *Bumellia bellonis*, *Schoepfia arenaria*, *Manilkara pleena* (Zapote de costa), *Antirhea portoricensis* (quina), *Eupatorium oteroir*, *Ottoshultzia rhodoxylon* (palo de rosa), *Rollinia mucosa* (anón cimarrón), *Coccoloba pallida* (uvillo), *Coccoloba tenuifolia* (uvillo), *Drypetes ilicifolia* (encinilla), *Licaria trianda* (Palo de Misanteco), *Chionanthus ligustrinus*, and *Chinanthus axilliflorus*.

The Quebradilla Forest Legacy Area also protects the Camuy River, portions of which are underground. This river has created one of the most complex cave systems in the world, part of which is developed for recreational purposes. The area contains several endemic species, some in danger of extinction. Species include the manaca palm, the plant *Philodendron fragrantissimum*, the reptile *Diploglossus pleei*, and the bat *Eptesicus fuscus wetmorei*.

The Quebradillas Forest Legacy Area also includes the buffer zone to the Guajataca Lake for watershed protection. The karst limestone region is also a recharge area for extensive aquifers that provide water for municipal and industrial uses.

THE CAONILLAS-DOS BOCAS LEGACY AREA

I. Boundary Delimitation

The Caonillas-Dos Bocas Legacy Area lies on the north coast. The boundary delimitation begins at the city of Arecibo.

- Out of Arecibo to the east on PR 22 to \perp with PR 2
- East on PR 2 to the town of Manatí
- Out of Manatí to the south on PR 6685 to \perp with PR 149
- South on PR 149 to \perp with PR 143
- West on PR 143 to the town of Adjuntas
- Out of Adjuntas to the northwest on PR 143 to \perp with PR 135
- Northwest on PR 135 to \perp with PR 129
- North on PR 129 to \perp with PR 600
- North on PR 600 to \perp with PR 134
- North on PR 134 to \perp with PR 129
- North then east on PR 129 to \perp with PR 165
- East then north on PR 635 to the city of Arecibo

II. Important Environmental Values of this Legacy Area

A. Caonillas and Dos Bocas Lakes

The Caonillas and Dos Bocas lakes are water reservoirs which the Puerto Rico Aqueduct and Sewer Authority (PRASA) is in the process of connecting by a pipeline to the San Juan Metropolitan Area aqueduct system in order to provide for the increasing water supply demand in the area. The legacy area proposes the protection and reforestation of the basins of these lakes.

B. The Río Abajo and the Toro Negro State Forests

The Río Abajo State Forest belongs to the Commonwealth of Puerto Rico and is a moist limestone forest with very irregular topography, subterranean drainage, caves, natural depressions or sinkholes and haystack hills, all characteristic of karst geological development. Unique natural features of the forest include its classical tropical karst topography, caves, unique areas of natural forest including endemic flora and wildlife and panoramic and scenic views. It has been recently the object of highway development pressures. Part of the reserve has been destroyed for the construction of highway PR 10. The Legacy Area provides a much needed buffer zone for this forest.

The Toro Negro State Forest also belong to the Commonwealth of Puerto Rico and is especially critical for soil and water conservation. Its high peaks and mountain ridges contain distinct flora and fauna and panoramic views. It has spectacular waterfalls that not only illustrate geologic history but also support interesting and unique plant and animal life.

The proposed Legacy Area includes an important buffer zone for this forest. Within this buffer zone is the El Guineo Lake and Cerro Rosa sector, densely forested terrain which contain several species candidates to the list of endangered species such as the *Accipiter straitus venator*, *Lepanthes dodiana*, and *Campylocentrum pygmaeum*. It also includes Roncador Peak, a densely forested area in which 295 plant species have been identified.

C. Arrozal Biáfara Sector

This is a karst zone that contains a rich treasure of trees, including the following that are in the list of endangered species or are candidates to the list, and/or are endemic and rare or are species of very limited distribution in Puerto Rico and the Antilles, such as: *Maytenus ponceana* (cuero de sapo), *Polygala cowelli* (árbol de violeta), *Myrcia paganii* (ausu), *Dyosyros sintenisii* (guayabota níspero), *Cynometra portoricensis* (oreganillo), *Drypetes ilicifolia* (encinillo), *Guatteria caribaea* (hoya blanca), and *Drupetes lateriflora* (cueriduro).

THE LA PLATA-COAMO LEGACY AREA

I. Boundary Delimitation

The boundary delimitation for this Legacy Area begins on the south coast, at the town of Peñuelas:

- Out the town of Peñuelas to the north on PR 153 to ⊥ with PR 14
- North on PR 153 to ⊥ with PR 155
- North then east on PR 155 to ⊥ with PR 143
- East on PR 143 to ⊥ with PR 720
- Northeast on PR 720 to ⊥ with PR 156
- East then north on PR 156 to ⊥ with PR 152
- North on PR 152 to ⊥ with PR 811
- North then south on PR 165 to ⊥ with PR 861
- East on PR 861 to ⊥ with PR 829
- South on PR 829 to ⊥ with PR 812

- East then south on PR 812 to ⊥ with PR 879
- West then south on PR 879 to ⊥ with PR 791
- West on PR 791 to ⊥ with PR 7774
- South on PR 7774 to ⊥ with PR 775
- South on PR 775 to ⊥ with PR 730
- East then south then west on PR 730 to ⊥ with PR 1
- South then west on PR 1 to the town of Peñuelas

II. Important Environmental Values of this Legacy Area

A. La Plata Reservoir

La Plata Lake is one of the principal water suppliers to the San Juan Metropolitan Area. Its basin is severely deforested and the lake consequently is manifesting rapid sedimentation rates. Recent reductions in rainfall averages have resulted in costly interruption of water supply services due to low reserves in the lake. This Legacy Area provides for crucial tracts to be reforested in the basin of this lake.

B. Other Important Resources

The conservation of the area known as Las Tetas de Cayey protects the only location known for the shrub *Solanum drymophyllum* and two other critical and endemic species of trees are found in the area. The Pasto sector of Coamo contains at least one species in the list of endangered species, another one which is classified as candidate to the list, the only known location in the work for a subspecies of an endemic species and three other rare and endemic species which are unprotected. The Legacy Area also protects tracts that are in primary forested conditions.

THE RIO GRANDE DE LOIZA LEGACY AREA

I. Boundary Delimitation

The boundary delimitation begins to the north east of the city of Cayey at the intersection of PR 738 with the Luis A. Ferré Expressway (PR 52).

- On PR 738 (at its intersection with PR 52) to the north to ⊥ with PR 1
- On PR 1, take PR 135 west then north to ⊥ with PR 734
- North on PR 734 to ⊥ with PR 173
- North on PR 173 to ⊥ with PR 156
- North on PR 156 to ⊥ with PR 173
- North on PR 173 to ⊥ with PR 1
- East then north on PR 1 to ⊥ with PR 175
- North then west on PR 175 to ⊥ with PR 895
- Southeast on PR 895 to ⊥ with PR 852
- Southeast on PR 852 to ⊥ with PR 853
- South on PR 853 to ⊥ with PR 185
- South on PR 185 to ⊥ with PR 919
- South on PR 919 to ⊥ with PR 813
- South on PR 919 to ⊥ with PR 917
- South then west on PR 917 to ⊥ with PR 916

- Northwest then south on PR 916 to ⊥ with PR 912
- South on PR 912 to ⊥ with PR 902
- West on PR 902 to ⊥ with PR 745
- Southwest then northwest on PR 745 to ⊥ with PR 7740 then to ⊥ with PR 184
- South on PR 184 to ⊥ with PR 7740 then to ⊥ with PR 179
- South then west on PR 179 to ⊥ with PR 741 then to ⊥ with PR 738

II. Important Environmental Values of this Legacy Area

This Legacy Area contains three principal water supply sources, the Carraízo Lake (or Lake Loíza) which is one of the primary sources of water for the San Juan Metropolitan Area, Lake Cidra which also provides water for the SJMA and the Carite Lake which provides water to the south coast. Recent reduction in rainfall averages have resulted in costly interruption of water supply services due to low reserves in these lakes (except Carite). This Legacy Area provides for crucial tracts to be reforested in the basin of these group of water reservoirs.

THE MAUNABO LEGACY AREA

I. Boundary Delimitation

The boundary delimitation begins at the town of Patillas, located at the southeastern coast of Puerto Rico.

- Out of Patillas to the south on PR 3 to ⊥ with PR 53
- East on PR 53 to ⊥ with PR 3
- North on PR 3, past the town of Maunabo to the town of Yabucoa
- Out of Yabucoa to the west on PR 182 to ⊥ with PR 181
- South on PR 181 to the town of Patillas

II. Important Environmental Values of this Legacy Area

The Maunabo Legacy Area contains basically the Cuchilla Panduras Region. This is a unique forest area of volcanic and plutonic formations that include caves, grottos and cavities. It is the exclusive habitat of the *Eleutherodactylus cooki* (coquí guajón), an endangered species.

THE EL YUNQUE LEGACY AREA

I. Boundary Delimitation

The boundary delimitation begins at the town of Fajardo on the northeastern extreme of the island of Puerto Rico.

- Out of Fajardo to the south on PR 3 to the town of Ceiba
- Out of Ceiba to the west on PR 53 to ⊥ with PR 31
- West on PR 31 to ⊥ with PR 946
- North on PR 946 to ⊥ with PR 186 to ⊥ with PR 185 into the town of Canóvanas

- Out of Canóvanas to the east on PR 3 to the town of Río Grande
- Out of Río Grande to the east on PR 3 to the town of Fajardo

II. Important Environmental Values of this Legacy Area

This Legacy Area will provide a buffer zone to the El Yunque Caribbean National Forest, declared Biosphere Reserve by the United Nations and administered by the USDA Forest Service.

Appendix B. Forest Legacy Evaluations

One requirement of the 2008 Farm Bill was to integrate the state assessment and strategy development with the requirement to update the Forest Legacy Analysis of Need. The DNERFSB evaluated the utility of the current Forest Legacy Assessment of Need (Appendix A) and concluded that the current Legacy Areas should be retained to focus land acquisition in the future.

Since 1999 Puerto Rico has acquired 12 tracts covering 1340 acres through federal funding and 7 tracts totaling 1517 acres with matching state funds. The land acquired to date has been located in the Karst and volcanic areas of the Caonillas–Dos Bocas Area; and the dry limestone area of Guánica. Some ongoing Legacy projects as well as others submitted since 2007 compliment efforts by the agency to establish forest corridors among State Forests and other DNER administered areas (State Forests, Natural Reserves as Guánica –Susúa—Maricao; Guilarte-Bosque del Pueblo-Toro Negro-Tres Picachos).

Puerto Rico participated in a USFS SFLA (Appendix C), which identified priority areas based on the richness of the forest resource and perceived threats. There was good correspondence between the existing Legacy Areas and the SFLA output.

The continued relevance of the selected Forest Legacy Areas for biodiversity was affirmed by evaluating the conservation recommendations from the PR-GAP (Gould et al. 2008) against the existing legacy areas (Table 15). Another major issue in Puerto Rico is the loss and fragmentation of forest in the urban wildland interface (WUI).

Table 18. Matrix showing interactions between findings in PR-GAP (Gould et al. 2008) and current eight Forest Legacy Areas in Puerto Rico

Biodiversity components or particular habitats of special relevance highlighted by PR-GAP (Gould et al. 2008)	Priority forested zones considered instrumental for the protection of Puerto Rico biodiversity components sensu PR-GAP (Gould et al. 2008)	Forest Legacy Areas containing forested habitats identified by Gould et al. (2008) at PR-GAP
1-Bird highest diversity	Open forests next to open upland or wetland habitats or streams at coastal plains and hills	Guánica; Maunabo; La Plata-Coamo; Río Grande de Loíza; El Yunque; Caonillas-Dos Bocas (urban wildland interface zones in all of above are included)
2-Mammal and reptile diversity	Northern karst region; dryland habitats	Quebradillas; Caonillas Dos Bocas; Guánica (urban wildland interface zones in all of above are included)
3-Amphibians diversity	Moist forested mountains peaks	El Yunque; Maricao
4-Endangered and endemic species in general	Mature forest habitats	All eight Puerto Rico Forest Legacy Areas

Biodiversity components or particular habitats of special relevance highlighted by PR-GAP (Gould et al. 2008)	Priority forested zones considered instrumental for the protection of Puerto Rico biodiversity components sensu PR-GAP (Gould et al. 2008)	Forest Legacy Areas containing forested habitats identified by Gould et al. (2008) at PR-GAP
5-Expand reserves in the limestone hills	(no specific forested habitat mentioned)	Quebradillas; Caonillas-Dos Bocas; Guánica (urban wildland interface zones in all of above are included)
6-Expand reserves in the coastal plains	Matrix of uplands and wetlands as in Roosevelt Roads and Sabana Seca former naval bases, Northeast Ecological Corridor, Piñones, etc. (this description would imply mosaics combining areas of coastal upland forests and coastal swamps (estuarines and/or palustrines))	Guánica; Maunabo (urban wildland interface zones in all of above are included)
7-Better protection of the periphery of existing reserves to maintain the integrity of wetlands and to maintain viable corridors and buffer zones in the upland reserves	(no specific forested habitats mentioned)	All eight Puerto Rico Forest Legacy Areas (urban wildland interface zones in all of above are included)
8-Development of ecological corridors, including riparian corridors to connect existing reserves with green spaces	Riparian forests geographically associated to existing reserves or green spaces; forested patches acting as corridors between existing reserves	All eight Puerto Rico Forest Legacy Areas (urban wildland interface zones in all of above are included)

<p>Biodiversity components or particular habitats of special relevance highlighted by PR-GAP (Gould et al. 2008)</p>	<p>Priority forested zones considered instrumental for the protection of Puerto Rico biodiversity components sensu PR-GAP (Gould et al. 2008)</p>	<p>Forest Legacy Areas containing forested habitats identified by Gould et al. (2008) at PR-GAP</p>
<p>9- Development of small and intermediate-sized parks and open spaces within urban areas that serve as habitats as well as recreational and educational resources for communities.</p>	<p>Urban forests created by tree planting or by protection of spontaneous forested patches in urban or urbanizing areas</p>	<p>All eight Puerto Rico Forest Legacy Areas* (urban wildland interface zones in some of the above are included) *this evaluation was done by photointerpretation of 2006 satellite images provided by the Geoinformatic Division of DNER</p>
<p>10-The protection of unique habitats associated to particularly rare endemic, amphibious species such as: * mountain valleys that shelter <i>Eleutherodactylus cooki</i> (the guajón); * the freshwater nonforested wetlands that shelter <i>Eleutherodactylus juanriveroi</i> (the coquí llanero)</p>	<p>Only <i>Eleutherodactylus cooki</i> is associated to a forested habitat, particularly wet forests over intrusive volcanic geology ; <i>Eleutherodactylus juanriveroi</i> 's only habitat known, although it is present at a coastal plain, it is not a forested one but an open freshwater marsh</p>	<p>Maunabo (urban wildland interface zones are included)</p>
<p>11-The restoration of formerly extensive habitats such as : * freshwater swamps or riparian forests of <i>Pterocarpus officinalis</i>; * moist lowland ausubo (<i>Manilkara bidentata</i>) forests</p>	<p>Bloodwood swamps and Bullet-wood lowland forests</p>	<p>El Yunque; Maunabo (a known Bullet-wood lowland forest remnant in Puerto Rico (at Canóvanas) is not presently included in any of the eight Puerto Rico Forest Legacy Areas)</p>

Appendix C. The Southern Forest Lands Assessment

The model “Southern Forest Land Assessment” was created by the Southern Group of State Foresters (SGSF) (National Association of State Foresters) and is based on the Spatial Analysis Project module of the Forest Stewardship Program. It combines a set of layers to generate a priority index for the Forest Stewardship Program (FSP). We applied this module to Puerto Rico, in order to demarcate those areas that will be considered a priority for conservation for the Forest Stewardship Program (Figure 36). We included the following layers:

- Forestland
- Forest Patches
- Riparian Areas
- Forested Wetlands
- Priority Watersheds
- Proximity to Public Lands
- Public Drinking Water
- Threatened and Endangered Species
- Slope
- Developmental Level
- Wildfire Risk
- Model Forest
- Joint Priority Landscape of Humacao
- Joint Priority Landscape of Maricao
- Karst Area of Special Protection

Then, the state decides the relative importance of each layer by applying a weight. The model assesses the forest resource richness versus the forest resource threats and provides an index of priorities for the Forest Stewardship Program. The final map presents potential areas of concern, while it offers a benchmark to assess program effectiveness in protecting such forest resources. The weights assigned to each layer were originally developed by the leaders of the Southern Region of the National Association of State Foresters.

All data information layer used had been previously published. These maps reflect forest resource priorities according to this model and give base for the spatial analysis and for the identification of potential areas of concern, while at the same time offering a benchmark, to assess program effectiveness in protecting such forest resources. The results are organized by different S&PF programs, and DNER administrative region

Each of these layers was assigned a level of importance (weight), originally developed by the leaders of the Southern Region of the NASF. Please refer to Table 17 for weight values utilized.

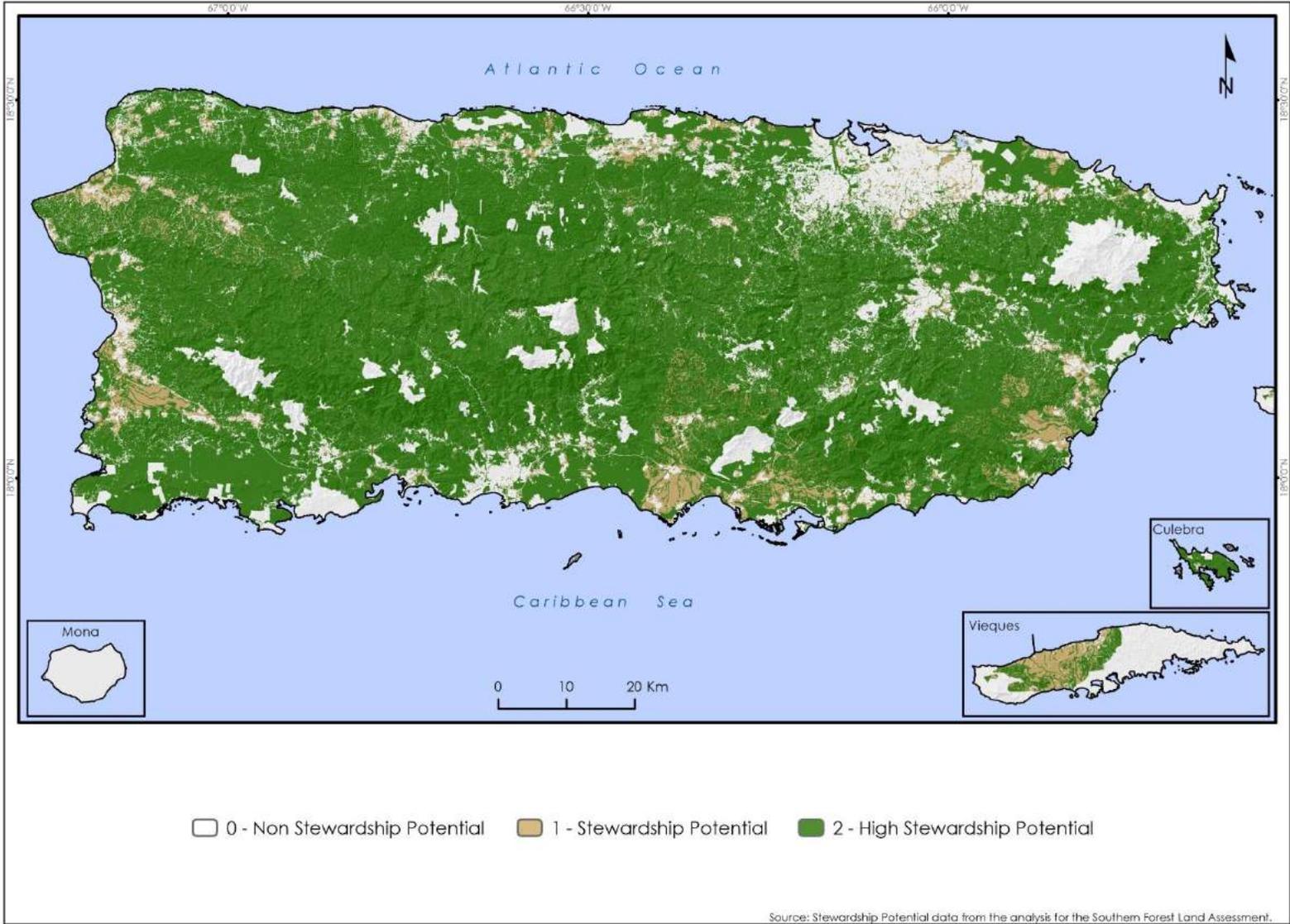


Figure 50. High priority landscape areas as indicated by the SFLA

Table 19. Geographic layers weighted according to importance in analysis

Layer	Weights
Forestland	11.1
Development Level	11.1
Riparian Areas	11.1
Wildfire Risk	2.5
Public Drinking Water	11.1
Priority Watersheds	11.1
Forest Patches	7.4
Forested Wetlands	0.8
T&E Species	7.4
Proximity to Public Lands	11
Slope	7.4
Bosque Modelo	2
Joint Priority Landscapes: Humacao	2
Joint Priority Landscapes: Maricao	2
Karst Area of Special Protection	2
Total	100

Appendix D. Identification of Public Issues and Concerns

The DNERFSB used a variety of means to identify public issues and concerns related to forest conservation and management. They held internal discussions and discussions with other resource professional. Research was evaluated include two recent studies involving the perspectives of local forest based communities (Table 18). They also conducted an extensive public scoping process before beginning the assessment called the Forest Landscape Analysis project (FLAP). Collectively these efforts resulted in outreach to an extensive list of stakeholders.

Table 20. Research into public perspectives of current forest conservation and management.

Report	Purpose
<p><i>Culture and Landscape: Towards a Political Ecology and Ethnography of Communities and the Co-Management of Forests in Puerto Rico. (Torres Abreu 2008);</i></p>	<p>To identify the existing perceptions held by members of social communities located close to state forests. Information collected include perspective related to forest management practices, ways to diversify ongoing conservation approaches, and the willingness of these communities to actively participate as co-managers and to what extent.</p>
<p><i>Community and Sustainability: Perception, Appraisal and Utility of Forests in Puerto Rico (Torres Abreu 2009);</i></p>	<p>To identify the perception that social communities geographically related to some of the state forests have about functions, values and utilities forests of Puerto Rico possess and how they could become more accessible to them to have a better quality of life.</p>

Findings

Findings from the communities on both above mentioned works included: perception of a lack of personnel to cover educational duties in the forest and also to adequately maintain recreational areas; services to forest visitors have worsened particularly the state of some of the trail systems and the information to be offered to the public by means of the sign system or by means of guides; a lack of a management plan for the forest ; perception of a lack of availability of quality of information about the forest; lack of integration between the social communities and the administrative system of the forest; perception of a lack of integration and of knowledge by the community with relation to the forest; perception of a lack of funding to develop projects the

community visualize could be done in the forest. Findings also highlighted alternatives that could strengthen and increase the interactions with the forest-community, among others: start fruit and vegetable orchards in certain forest areas with the involvement of the adjacent social community; to establish a group of forest friends to be in charge of regularly giving talks concerning global warming and produce educational material about the ecological balance of the forest.

Findings from the forest administrators and managers included: perception of a lack of more personnel to work on recreational areas and of needed infrastructure; perception that forests have reached their maximum capacities of sustaining more recreational areas; lack of educational processes for the benefit of people concerning what the forest is and lack of integration of the communities in the protection of the forest due to their lack of knowledge; perception of a lack of scientific research useful to help making wise decisions on management issues about the forest; perception of a wrong policy by DNER of allowing increasing numbers of forest visitors and users not considering forest carrying capacity.

Appendix E. Forest Land Analysis Project (FLAP)

Traditionally, the public has not been effectively consulted regarding their concerns and recommendations regarding the forest landscape. The FLAP of Puerto Rico was conducted in order to determine the public's perception of public forests and green spaces in Puerto Rico. The goal was to determine how stakeholders utilize these public resources and what their unique priorities and concerns are. Determining the unique conditions and desires of the public in each region was intended to allow the DNER to tailor future programs to specific regions of Puerto Rico rather than treat the entire island as a single homogeneous area.

The first stage of the process gathered together members of the Puerto Rico Forest Stewardship Council and a group of local, natural resources experts to prepare a data set to share with the stakeholders and also organized a series of questionnaires aimed at determining the public need in targeted areas. The data that FLAP provided was primarily derived from the recent FIA conducted by the USFS. The FIA data provided a snapshot the current status of forests resources in Puerto Rico and also described trends in recent forest cover change. The FLAP solicited questions, recommendations and ideas from the public that could be considered in new projects or as part of an evaluation of the forestry situation in Puerto Rico.

The second stage of the process solicited input through a structured consultation process participants were questioned about the use of forests and public areas, the definition and areas of concern for forests and the economic component related to the possible use of forest systems and green areas of Puerto Rico. In this second phase included input from the community and the public, taking into account information presented to them and their experience as a resident, farmer, researcher or citizen. This was accomplished through an open dialogue with stakeholders in all seven DNER regions over a two month period (Table 19). During the meetings each participant was rotated through three small group discussion sessions (Table 18). Lists of meeting participants are available in the DNERFSB office.

Table 21. FLAP public meeting schedule

REGION	DATE	LOCATION	TIME
HUMACAO	September 9, 2008	UPR, Humacao Campus	7:00 pm
GUAYAMA	September 10, 2008	UPR, Cayey Campus	7:00 pm
PONCE	September 23, 2008	Interamerican University, Ponce	7:00 pm
ARECIBO	September 24, 2008	Ernesto Ramos Antonini Theater, Barceloneta	7:00 pm

REGION	DATE	LOCATION	TIME
AGUADILLA	October 22, 2008	UPR- Aguadilla Campus	7:00 pm
MAYAGUEZ	October 23, 2008	Rebekah Colberg Sports Complex, Cabo Rojo	7:00 pm
SAN JUAN	October 28, 2008	Environmental Building, Río Piedras	7:00 pm

FLAP Group A Questions

- 1) When was the last time you visited a forest managed by the DNER? What do you remember of the experience?
- 2) What activities do you enjoy out in the woods?
- 3) How do you understand that forests can benefit your benefit or quality of life and your community?

FLAP Group B Questions

- 1) In your experience, what are the characteristics of a forest? What is a forest for you?
- 2) The characteristics that make up a forest, what, if any, have changed (positively or negatively) in green or woodland area near your neighborhood?

FLAP Group C Questions

- 1) What recreational activities would include among the services and opportunities for visitors of our forests?
- 2) What ideas, programs or understand incentives could benefit land owners so that they keep them like a forest?
- 3) What benefits if you can identify any of the forests that you visit or know?

Mail and electronic mail participation in FLAP

As part of the process, copies of the documents, presentations, the methodology, data and draft and final reports were kept and copies were available on the DNER website (www.drna.gobierno.pr). Likewise, it was announced that persons who could not participate at public meetings could participate and submit comments by electronic mail (paisajeforestal@drna.gobierno.pr). Also, the questionnaires could be printed and the answers submitted by regular mail or electronically. The methodology was patterned on processes in other efforts like *The Southern Forest Futures Project using Public Input to Define the Issues* (Wear, DN, Greis, JG, and Walters, N. 2009).

Priority issues analysis



Figure 51. Humfredo Marciano (USFS) reporting FIA data at the Guayama public meeting.

All presentations and public meetings were documented with the permission of the participants with photos and recordings to include a transcription of the process of public input. In all the meetings, attendees were provided with a copy of "The State of Forests in Puerto Rico, 2003." The information obtained from all the meetings was reviewed and like comments were grouped together into fifteen (15) issues. The DNERFSB also analyzed results to establish connections between them and possible clustering in terms of specific tasks within the Bureau.

The public information analysis resulted in the identification of ten (10) draft issues as follows:

1. Fragmentation (loss of large patches of forest)
2. Water and watershed conservation
3. Climate change (what is being done; are there impacts expected)
4. Environmental Services (use of forest resources for recreation, therapy, etc.).
5. Loss of forests and urban interface within rural areas (remnant, parks, housing subdivisions)
6. Disturbances that are affecting forests (hurricanes, floods, fires, plagues, etc.)
7. Education on forests and forest functions (desire to know or understand more and better)
8. The adverse effects of exotic species on our native ecosystems, their flora and wildlife well-being
9. Markets derived from wise uses of forests, including ecotourism (I want to buy souvenirs, photos, brochures, posters, etc.)
10. The integration of agricultural land ecosystem into sustainability strategies.

Threats

Main threats to forest cover of Puerto Rico were pointed out by public that attended the FLAP meetings. Types of disturbances mentioned more commonly, including concerned ones of natural origin as well as those induced by mankind, were identified and grouped by categories and classes. The results of this exercise are reported in Table 20.

Table 22. Categories and Class of Threats associated with Forest Resources in Puerto Rico as determined by public involvement in the Puerto Rico FLAP process.

Threat Category	Threat Class
Forest Habitat Conversion: Intentional conversion of natural habitat that is detrimental to wildlife use and survival.	Housing and urban development Agriculture
Forest Habitat Degradation: Degradation of wildlife habitat and available forage.	Intentional fires Illegal dumping Wetland filling Recreation Inadequate forest and woodland management Grazing Poor forest harvest practices
Consumptive Use of Biological Resources: Harvest or use of plant and animal populations in a manner that negatively impacts wildlife.	Excessive collection or harvest Illegal hunting and fishing practices
Pollution: Introduction and spread of unwanted matter and energy into ecosystems from point and non-point sources that causes increased mortality of wildlife and degradation of their habitats and available forage.	Solid waste Waste or residual materials Chemicals and toxins Eutrophicants substances Noise pollution
Invasive Species: Introduction and/or spread of exotic and native organisms that result in reduce food, fitness, or loss of wildlife habitat.	Invasive plants Invasive animals Pathogens

This information was presented and discussed with the Forest Stewardship Coordinating Committee for their information, discussion and recommendations. In this process it was recommended to consider grouping some of the ten (10) issues as sub-themes to facilitate the management and implementation of strategies to address these issues. Another argument considered in the clustering is the administrative organization of the DNERFSB, which is the unit within the DNER responsible for establishing strategies to address these issues with the assistance of the Programs of S&PF, and the help of non-profit community based organizations.

Appendix F. Table 23. Puerto Rico CWA's (2015) and their respective locality (Municipalities)

AREA	LOCALITY
1- Cucharilla's Marsh	Cataño
2- Buchanan Haystack Hills and Fort Buchanan Pond	Bayamón
3- Torrecillas Swamp System-Piñones-Vacía Talega	Carolina-Loíza-Canóvanas
4- Barrio Borinquen, Trujillo Alto Lake, Bairoa Lake La 25, and Gurabo River Mouth	Trujillo Alto-Caguas-Gurabo
5- Baja Swamp and Herrera River Mouth	Río Grande
6- Ensenada Comezón	Río Grande
7- Río Mar, North of Road # 968	Río Grande
8- Luquillo Mountains	Luquillo
9- San Miguel, La Paulina and El Convento Natural Area	Luquillo-Fajardo
10- Laguna Grande, Laguna Aguas Prietas and adjacent areas	Fajardo
11- Fajardo Coast Line	Fajardo
12- La Cordillera Natural Reserve	Fajardo
13- Flamenco Peninsula	Culebra
14- Flamenco Lagoon	Culebra
15- Cornelius Lagoon	Culebra
16- Resaca Mountain	Culebra
17- Resaca Beach	Culebra
18- Brava Beach	Culebra
19- Larga Beach and Zoní Lagoon	Culebra
20- Maillux Lagoon	Culebra

AREA	LOCALITY
21- Puerto del Manglar	Culebra
22- Los Caños	Culebra
23- Cementerio Bay	Culebra
24- Culebra's Surrounding Islets	Culebra
25- Vieques west coast	Vieques
26- Ensenada Honda Mangrove	Vieques
27- Yanuel Lagoon	Vieques
28- Chiva Swamp	Vieques
29- Tapón Bay	Vieques
30- Ferro Bay, Mosquito Bay, and Sombe Bay	Vieques
31- East tip of Vieques and Conejo Cay	Vieques
32- Roosevelt Roads Naval Base	Ceiba
33- Ceiba State Forest	Fajardo, Ceiba and Naguabo
34- Humacao Natural Reserve	Humacao
35- Pandura Mountain Range	Yabucoa-Maunabo
36- Palmas Pond	Arroyo
37- Carite State Forest	Cayey
38- Cerro El Gato and Associated Areas	Cayey
39- Cidra Lake	Cidra
40- Aguirre State Forest, Punta Pozuelo, Cayos Caribe and Mar Negro	Guayama-Salinas-Santa Isabel
41- Punta Arenas	Salinas
42- Salinas Training Area	Salinas
43- Punta Petrona Mangroves and Caracoles	Santa Isabel

AREA	LOCALITY
44- Cabuyón Mangrove and Fríos Cays	Ponce
45- Caja de Muertos Complex	Ponce-Juana Díaz-Santa Isabel
46- Serrallés Lakes	Juana Díaz-Ponce
47- Toro Negro State Forest	Ciales-Jayuya-Orocovis
48- Las Salinas Lagoon, El Tuque	Ponce
49- Monte Guilarte State Forest	Adjuntas-Guayanilla-Peñuelas-Yauco
50- Punta Verraco, Cerro Toro and Punta Ventana	Guayanilla
51- Guayanilla Hills	Guayanilla
52- Guánica Lagoon	Guánica
53- Guánica State Forest	Guánica
54- San Jacinto Salt Flats and Tamarind Lagoon	Guánica
55- Susúa State Forest and Adjacent Lands	Yauco-Sabana Grande
56- La Parguera Natural Reserve	Lajas
57- Cartagena Lagoon	Lajas
58- Boquerón State Forest	Cabo Rojo
59- Boquerón Wildlife Refuge	Cabo Rojo
60- Cabo Rojo Salt Flats and Adjacent Areas	Cabo Rojo
61- Punta Guaniquilla Natural Reserve	Cabo Rojo
62- Joyuda Lagoon Natural Reserve	Cabo Rojo
63- Cuevas Lagoon	Cabo Rojo
64- Sabanetas Swamp-Boquilla Channel	Mayagüez
65- Maricao State Forest	Maricao

AREA	LOCALITY
66- Mona Island	Mona
67- Monito Island	Monito
68- Pozo Hondo Swamp	Añasco
69- Cayures Swamp	Aguada
70- Desecheo Island	Desecheo
71- Barrio Coto	Isabela
72- Guajataca Cliffs	Isabela-Quebradillas-Camuy
73- Guajataca State Forest	Isabela
74- Guajataca Lake	Quebradillas
75- Barrio Cocos and Bellaca Creek	Quebradillas
76- Carrizales Mangroves	Hatillo
77- Tiburones Swamp and La Tembladera Pond	Arecibo
78- Cambalache State Forest	Arecibo
79- Río Abajo State Forest	Arecibo and Utuado
80- Hacienda La Esperanza Natural Reserve	Manatí
81- Tortuguero Lagoon, Cabo Caribe Swamp and Rica Lake	Vega Baja
82- Cibuco Swamp	Vega Baja
83- Vega State Forest	Vega Alta
84- Lakes and Forests of Dorado	Dorado
85- Mogotes Río Lajas y Nevárez	Dorado-Toa Baja
86- El Mameyal	Dorado
87- San Pedro Swamp	Toa Baja

References

- Acevedo, R. and J. Morelock. 1988. Effects of terrigenous sediments influx on coral reef zonation in southwestern Puerto Rico: Proceedings of the Sixth International Coral Reefs Symposium, Townsville, Australia; 8th to 12th of August 1988, v.2, contributed papers, p. 189-194
- Acevedo, R., J. Morelock, and R. A. Olivieri. 1989. Modification of Coral reef zonation by terrigenous sediment stress. *Palaios* **4**:92-100.
- Adams, B. D. and J.M. Hefner. 1999. *Humedales* (Traducido al español por Teresa Dopazo): U.S. Geological Survey Water-Supply Paper 2425, 6 pp.
- Almodovar, W. I. 2008. Forest Health Management. http://seam.uprm.edu/forest/pagina_insectos
- Almodovar, W. I. 2009. Manejo de plagas forestales: viveros y áreas urbanas y plagas de reciente introducción. Manual. Servicio de Extensión Agrícola. Universidad de Puerto Rico. Recinto de Mayagüez. 44 pp.
- Baskin, Y. 2002. A Plague of Rats and Rubbervines: The Growing Threat of Species Invasions. Washington, Island Press.
- Basnet, K., G. E. Likens, et al. 1992. Hurricane Hugo: Damage to a Tropical Rain Forest in Puerto Rico. *Journal of Tropical Ecology* **8**(1):47-55.
- Beller, W., M. A. Casellas, M. J. Cerame Vivas, L. Duffy, J. Elkoury, M. A. Ferrer, P. A. Gelabert, J. A. González Liboy, M. Hernández Ávila, N. Maldonado, C. A. Matos, A. Mignucci, E. Pantojas García, J. A. Rigau, M. Tacher Roffe, and F. Zalacaín. 1999. *Puerto Rico y el Mar-1999: Programa de acción para asuntos marinos*. Informe al Gobernador. San Juan, Puerto Rico.
- Bentrup, G. 2008. Conservation buffer: design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC. Department of Agriculture, USFS, Southern Region. 110 pp.
- BirdLife International. 2008. *State of the world's birds: indicators for our changing world*. Cambridge, UK: BirdLife International
- Birdsey, R. and L. P. Weaver. 1982. The forest resources of Puerto Rico. Research Bulletin. F. S. Department of Agriculture. New Orleans, Southern Forest Experiment Station. SO-85: 59.
- Birdsey, R. A. and L. P. Weaver. 1987. Forest area trends in Puerto Rico. Research Note. U.S. Forest Service. Ashville, North Carolina, Southern Forest Experiment Station: 1-5.
- Borman, F. H. and G. E. Likens. 1979a. Pattern and process in a forested ecosystem. Springer-Verlag, New York. 253 pp.
- Borman, F. H. and G. E. Likens. 1979b. Catastrophic disturbance and the steady state in northern hardwood forests. *American Scientist* **67**:660-669.

- Brandeis, T. J. 2006. Assessing tree species assemblages in highly disturbed Puerto Rican karst landscapes using forest inventory data. *Plant Ecology* **186**:189-202.
- Brandeis, T. J. and J. A. Turner. 2013. Puerto Rico's Forests, 2009. Resour. Bull. SRS-191. Asheville, NC. USDA Forest Service, Southern Research Station. 85 pp.
- Brandeis, J. T., E. Helmer, H. Marciano Vega, and A. E. Lugo. 2009. Climate shapes the novel plant communities that form after deforestation in Puerto Rico and the U.S. Virgin Islands. *Forest Ecology and Management* **258**:1704-1718.
- Brandeis, J. T., E. Helmer, et al. 2007. The Status of Puerto Rico's Forests, 2003. Resource Bulletin SRS-119. Knoxville, TN, United States Department of Agriculture, Forest Service. 75 pp.
- Brown, K., F. N. Scatena, et al. 2006. Effects of an invasive tree on community structure and diversity in a tropical forest in Puerto Rico. *Forest Ecology and Management* **226**:145-152.
- Callaway, R. and E. T. Aschehoug. 2000. Invasive plants versus their new and old neighbors: A mechanism for exotic invasion. *Science* **290**:521-523.
- Carlo Joglar, T. and C. G. García Quijano. 2008. Assessing ecosystem and cultural impacts of the green iguana (*Iguana iguana*) invasion in the San Juan Bay Estuary (SJBE) in Puerto Rico. Final Report 42 pp.
- Carlson A. E., A. N. LeGrande, D. W. Oppo, R. E. Came, G. A. Schmidt, F. S. Anslow, J. M. Licciardi, and E. A. Obbink. 2008. Rapid Early Holocene deglaciation of the Laurentide ice sheet. *Nature Geoscience* **1**:620-624
- Centro para la Conservación del Paisaje (CCP). "Proceso de revisión del Plan de Manejo de El Yunque, Puerto Rico" Online video clip. YouTube. YouTube, 5 Jun. 2015. Web. 11 Nov. 2015.
- Cerame Vivas, M. 2000. *Ecología, Puerto Rico y Pensamiento Crítico...para el Nuevo Milenio*. Río Piedras: Editorial Centenario.
- Clark, J. J. and P. R. Wilcock. 2000. Effects of land use change on channel morphology in northeastern Puerto Rico. *Geological Society of America Bulletin* **112**:1763-1777
- CFR. 2015. Good Neighbor Agreements with State Cooperators. 80 Federal Register 44 (6 March 2015), pp. 12145
- Colautti, R. I. and H. J. MacIsaac. 2004. A neutral terminology to define 'invasive' species. *Diversity and Distributions* **10**:135-141.
- Puerto Rico Climate Change Council (PRCCC). 2013a. Estado del Clima de Puerto Rico 2010-2013 Resumen Ejecutivo: Evaluación de vulnerabilidades socio-ecológicas en un clima cambiante, VERSIÓN ELECTRÓNICA. Programa de Manejo de la Zona Costanera, Departamento de Recursos Naturales y Ambientales, Oficina de Océanos y Recursos Costeros (NOAA-OCRM). San Juan, PR: 27 pp.
- Puerto Rico Climate Change Council (PRCCC). 2013b. Puerto Rico's State of the climate 2010-2013: Assessing Puerto Rico's Social-Ecological Vulnerabilities in a

- Changing Climate. Puerto Rico Coastal Zone Management Program, Department of Natural and Environmental Resources, NOAA Office of Ocean and Coastal resource Management. San Juan, PR.
- Cowardin, L. M., V. Carter, F. C. Golet, E. T. La Roe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C. 103 pp.
- Center for Sponsored Coastal Ocean Research. 2005. *Caribbean Coral Reef Institute Factsheet*. Retrieved from: <http://www.cop.noaa.gov/ecosystems/coralreefs/current/ccri-factsheet-cr.html>.
- Departamento de Recursos Naturales y Ambientales (DNER). 2000. *Nuevo reglamento para regir la extracción, excavación, remoción y dragado de los componentes de la corteza terrestre en Puerto Rico*.
- Departamento de Recursos Naturales y Ambientales (DNER). 2000. Programa de Legado Forestal para Puerto Rico. Reporte. 71 pp.
- Departamento de Recursos Naturales y Ambientales (DNER). 2003. *Plan de Manejo para el Área de Planificación Especial de los manglares de Puerto Rico*. Documento Final. DRNA. Programa de Manejo de la Zona Costanera.
- Department of Natural and Environmental Resources (DNER). 2005. Puerto Rico Comprehensive Wildlife Conservation Strategy. Report. 164 pp.
- Department of Natural and Environmental Resources (DNER). 2007. Coastal Zone Division Data Analysis on US Census 2000, using *Calculate Demographics*, written for ESRI® by Jeannette Kobbeman Muzslay.
- Department of Natural and Environmental Resources (DNER). 2008-a. Comprehensive Plan of Water Resources of Puerto Rico. eight chapters.
- Department of Natural and Environmental Resources (DNER). 2008-b. Forest Health Assessment and Management Applications. Proposal presented by the Puerto Rico Forest Bureau to the US Forest Service. Partnering Agencies : UPR Crop Ext. Service, El Yunque Nat. Forest, IITF, FIA, PR Dep. of Agriculture. 4 pp.
- Department of Natural and Environmental Resources (DNER). 2010. Puerto Rico Coastal and Estuarine Land Conservation Plan. Coastal Zone Management Program. 30 pp.
- Department of Natural and Environmental Resources (DNER). 2015. Puerto Rico State Wildlife Action Plan: Ten Year Review. 187 pp.
- Díaz, E. and A. Dragoni. 1999. *Cálculos no oficiales basados en datos del Borrador del Inventario Nacional de Humedales y cómputos propios de áreas naturales protegidas*. (PMZCPR, T 1.2)
- Dominguez-Cristobal, C. M. 1987. El inventario de los montes públicos de Puerto Rico (1870). *Acta Scientifica* **11**:93-95.

- Dwyer, J. F., D. J. Nowak, M. H. Noble, and S. M. Sisinni. 2000. Connecting people with ecosystems in the 21st century: an assessment of our Nation's urban forests. Gen. Tech. Rep. PNW-490. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 483 pp.
- Environmental Protection Agency (EPA). 2015. EPA Facility Level Greenhouse Gas Emissions Data from Large Facilities. Retrieved on 11 November 2015. <http://ghgdata.epa.gov/ghgp/main.do>
- Eusse, A. M. and T. M. Aide. 1999. Patterns of litter production across a salinity gradient in a *Pterocarpus officinalis* tropical wetland. *Plant Ecology* **145**:307-315.
- Ewel, J. J. and J. L. Whitmore. 1973. *The Ecological Life Zones of Puerto Rico and the U.S. Virgin Islands*. Research Paper ITF-18. U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry, San Juan, P.R.
- Figueroa-Colón, J. C. 1996. Geoclimatic regions of Puerto Rico (map). San Juan, Puerto Rico. U.S. Department of the Interior, Geological Survey Water Resources Division.
- Flynn, D. F. B., M. Uriarte, T. Crk, J. B. Pascarella, J. K. Zimmerman, T. M. Aide, and M. Caraballo. 2010. Hurricane disturbance alters secondary forest recovery in Puerto Rico. *Biotropica* **42**(1):149-157.
- Forero-Montaña, J. 2015. Potential of subtropical secondary forests for sustainable forestry in Puerto Rico. PhD. Dissertation. University of Puerto Rico, Río Piedras Campus.
- Foster, D., F. Swanson, et al. 2003. The importance of land-use legacies to ecology and conservation. *BioScience* **53**(1):77-88.
- Franco, P. A., P. L. Weaver, and S. Eggen-McIntosh. 1997. *Forest Resources of Puerto Rico 1990*. Ashville NC : USDA Forest Service, Southern Research Station, Resource Bulletin SRS-22
- Francis, J. K. 1995. Forest plantations in Puerto Rico. Pages 211-223 in A. E. Lugo and C. Lowe, editors. *Tropical Forests: Management and Ecology*. Springer-Verlag, New York, NY.
- Goenaga, C, and G. Cintron. 1979. Inventory of the Puerto Rican coral reefs. *Department of Natural Resources, Office of Coastal Zone Management*.
- Gould, W., C. Alarcón, B. Fevold, M. E. Jiménez, S. Martinuzzi, G. Potts, M. Solórzano, and E. Ventosa. 2007. *Puerto Rico Gap Analysis Project*. USGS Moscow, ID y el USDA Forest Service Internaciotional Institute of Tropical Forestry. Río Piedras, PR. 159 pp. abd 8 appendices.
- Gould, W. A. 2008. Editorial. *Ambio A Journal of the Human Environment* XXXVII (7-8): 521
- Gould, W. A., et al. 2008. The Puerto Rico Gap Analysis Project. Volume 1: Land cover, Vertebrate Species Distributions, and land Stewardship. USDA Forest Service. International Institute of tropical Forestry. General Technical Report IITF-GTR-39. 165 pp.

- Gordon, D. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: Lessons from Florida. *Ecological Concepts in Conservation Ecology* **8**(4):975-989.
- Grau, H. R., M. Aide, et al. 2003. The ecological consequences of socioeconomic and land-use changes in postagriculture Puerto Rico. *BioScience* **53**(12):1159-1168.
- Hartshorn, G. S. 1978. Tree fall and forest dynamics. Pp. 617-638 in Tomlinson, P and M. Zimmerman (eds.) *Tropical trees as living systems*. Cambridge University Press, Cambridge.
- Helmer, E. H. 2004. Forest Conservation and Land Development in Puerto Rico. *Landscape Ecology* **19**(1):29-40
- Helmer, E. H. and B. Ruefenacht. 2005. Cloud Free Satellite Image Mosaics with Regression Trees and Histograms Matching. *Photogrammetric Engineering and Remote Sensing* **71**(9):1079-1089
- Hernández, E., R. Laureano, and R. Montalvo. 2007. *Los jardines submarinos de Vega Baja: tesoros escondidos*.
- Holdridge, L. R. 1967. *Life Zone Ecology*. Revised edition. San José, Costa Rica: Tropical Science Center. 206 pp.
- Houghton, J. T. 2001. "Appendix I – Glossary". *Climate change 2001: the scientific basis: contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press. ISBN 0-521-80767-0. <http://www.ipcc.ch/ipccreports/tar/wg1/518.htm>.
- Hunter, M. L., Jr. 1996. *Fundamentals of conservation biology*. Cambridge, MA: Blackwell Science. 482 pp.
- International Union for the Conservation of Nature (UCN) Red List. 1994.
- Jenkins, C. N. and S. L. Pimm. 2003. How Big Is the Global Weed Patch? *Annals of the Missouri Botanical Garden* **90**(2):172-178.
- Junta de Planificación de Puerto Rico. 1995. *Objetivos y Políticas Públicas del Plan de Usos de Terrenos de Puerto Rico*.
- Kennaway, T. and E. H. Helmer. 2007. The Forest Types and Ages Cleared for Land Development in Puerto Rico. *GIScience & Remote Sensing* **44**(4):356-382
- Kueffer, C., C. C. Daheler, C. W. Torres-Santana, C. Lavergne, J. Y. Meyer, R. Otto, and L. Silva. 2009. A global comparisons of plant invasions on oceanic islands. *Perspectives in Plant Ecology, Evolution and Systematics* doi:10.1016/j.ppees.2009.06.002
- Kuo, F. E. and W. C. Sullivan. 2001. Environment and Crime in the inner city. Does vegetation reduce crime? *Environment and Behaviour* **33**:23
- Larsen, M. C. 2000. Analysis of twentieth century rainfall and stream flow to characterize drought and water resources in Puerto Rico. *Physical Geography* **21**(6):494-521

- Larsen, M. C. and A. Santiago-Román. 2001. Mass wasting and sediment storage in a small montane watershed: an extreme case of antropogenic disturbance in the humid tropics, in Dorava, J. M. , F. Fitzpatrick, B. B. Palcsak, and D. R. Montgomery, eds, *Geomorphic processes and riverine habitat: American Geophysical Union Monograph*, p. 142-170
- López, M. 2007. *Áreas Marinas Protegidas en Puerto Rico*. Programa de Manejo de la Zona Costanera: Los primeros 25 años.
- Lomascolo, T. and T. M. Aide. 2001. Seed and seedling bank dynamics in secondary forests following hurricane Georges in Puerto Rico. *Caribbean Journal of Science* **37**(3-4):259-270.
- Lowrance, R. R., R. L. Todd, and L. E. Asmussen. 1984. Nutrient cycling in an agricultural watershed. I. Phreatic movement. *Journal of Environmental Quality* **13**:22-27.
- Lugo, A. and E. Helmer. 2004. Emerging forests on abandoned land: Puerto Rico's new forests. *Forest Ecology and Management* **190**:145-161.
- Lugo, A. E. 1990. Removal of exotic organisms. *Conservation Biology* **4**(4):345.
- Lugo, A. E. 1992. More on exotic species. *Conservation Biology* **6**(1):6.
- Lugo, A. E. 2000. Effects and outcomes of caribbean hurricanes in a climate change scenario. *Science of the Total Environment* **262**(3):243-251.
- Lugo, A. E. 2004. The outcome of alien tree invasions in Puerto Rico. *Frontiers in Ecology and the Environment* **5**(2):265-273.
- Mann, C. 2006. 1491. New York, Vintage Books.
- Martinuzzi, S., W. Gould, and O. M. Ramos. 2007. Land development, land use and urban sprawl in Puerto Rico integrating remote sensing and population census data. *Landscape and Urban Planning* **79**: 288-297.
- Martinuzzi, S., W. Gould, A. Lugo, and E. Medina. 2009. Conversion and recovery of Puerto Rico mangroves: 200 years of change. *Forest Ecology and Management* **257**:75-84.
- Martorell, L. F. 1945. A survey of the forest insects of Puerto Rico. Part II. *The Journal of Agriculture of the University of Puerto Rico*. Agricultural Experiment Station, Río Piedras, P.R. p. 355-608
- Martorell, L. F. 1982. *Flora of Puerto Rico and adjacent island: a systematic synopsis*. Río Piedras, PR: Editorial de la Universidad de Puerto Rico. 342 pp.
- Mather, A. S. 1992. The Forest Transition. *Area* **24**(4):367-379.
- Mather, A. S. and C. L. Needle. 1998. The Forest Transition: a theoretical basis. *Area* **30**(2):117-124.
- Mendoza, M. 2010. Situación económica de la empresa de ornamentales. *Viveros de Puerto Rico* **1**(1):1. Servicio de Extensión Agrícola; Universidad de Puerto Rico.

- Morelock J., K. A Grove, and J. V. A. Trumbell. 1980. Sediments and recent geological history of the Guayanilla submarine canyon system, Puerto Rico: Novena Conferencia Geológica del Caribe, Santo Domingo, Dominican Republic
- Morelock J., K. A Grove, and M. L. Schwartz. 1983. Oceanography and patterns of shelf sediments Mayaguez, Puerto Rico. *Journal of Sedimentary Petrology* **53**(2):371-381.
- Morelock, J. K. A., M. Hernández Ávila, M. L. Schwartz, and D. M. Hatfield. 1985. Net shore-drift on the north coast of Puerto Rico. *Shore and Beach* **53**:16-21.
- Morelock J. and M. Barreto. 2002. An Update of Coastal Erosion in Puerto Rico. *Shore and Beach* **71**:7-12.
- Morelock, J., W. Ramírez, and M. Barreto. 2002. *The World's Coasts Online-Puerto Rico*. Retrieved from: http://geology.uprm.edu/Morelock/GELOCN_/wcprcoast.htm
- Myers, N., R. A. Mittermeier, et al. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**:6.
- Naiman, R. J., H. Decamps, M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* **3**(2):209-212.
- National Urban and Community Forestry Advisory Council. 2008. A Comprehensive Look at Tropical Urban Forestry. Executive summary to the Secretary of Agriculture. Report
- National Wetland Inventory. 1988. Puerto Rico Coastal Zone Wetland Maps. US Dep. of Interior Fish and Wildlife Service. maps. Odum, Eugene P. 1979. Ecological importance of the riparian zone. In: *Strategies for protection and management of floodplain wetlands and other riparian ecosystems: proceedings of the symposium*. Gen. Tech. Rep. WO-12. Washington, DC: U.S. Department of Agriculture, Forest Service: 2-4.
- Odum, E. P. 1979. Ecological importance of the riparian zone. In: *Strategies for protection and management of floodplain wetlands and other riparian ecosystems: proceedings of the symposium*. Gen. Tech. Rep. WO-12. Washington, DC: U.S. Department of Agriculture, Forest Service: 2-4.
- Pan, Y., R. A. Birdsey, J. Fang, R. Houghton, P. E. Kauppi, W. A. Kurz, O. L. Phillips, A. Shvidenko, S. L. Lewis, J. G. Canadell, P. Ciais, R. B. Jackson, S. W. Pacala, A. D. McGuire, S. Piao, A. Rautiainen, S. Sitch, and D. Hayes. 2011. A large and Persistent Carbon Sink in the World's Forests. *Science* **333**:988-993.
- Pérez, J. J. 2003. *Mitigación de humedales en Puerto Rico bajo el Joint Permit Application, la Sección 404 del Clean Water Act y la meta de cero pérdida neta*. Tesis sometida para obtener el grado de Maestría a la Escuela de Asuntos Ambientales, Universidad Metropolitana
- Pfeffer, W. and J. O'Neel. 2008. Kinematic constraints on glacier contributions to 21st-century sea-level rise. *Science* **321**:1340-1343.

- Pickett, S. T. A. and P. S. White. 1985. The ecology of natural disturbance and patch dynamics. Academic Press Inc. Orlando, Florida. 472 pp.
- Picó, R. 1988. Síntesis Geográfica de Puerto Rico. Monografía disponible en: Biblioteca Departamento de Recursos Naturales y Ambientales del Estado Libre Asociado de Puerto Rico.
- Pratt, P. D., V. Quevedo, L. Bernier, J. Sustache, and T. D. Center. 2005. Invasions of Puerto Rican Wetlands by the Australian Tree *Melaleuca quinquenervia*. Caribbean J. Sci. **41**(1):1-13.
- Pratt, P. D., M. B. Rayamajhi, L. Bernier, and T. D. Center. 2006. Geographic range expansion of *Boreioglycaspis melaleucae* (Hemiptera: Psyllidae) to Puerto Rico. Florida Entomol. **89**(4):529-531.
- Programa del Estuario de la Bahía de San Juan. 2000. Plan Integral de Manejo y Conservación para el Estuario de la Bahía de San Juan. 431 pp.
- Reilly, A. E. 1991. The Effects of Hurricane Hugo in Three Tropical Forests in the U.S. Virgin Islands. Biotropica **23**(5)
- Rivera-Ocasio, E., T. M. Aide, and N. Ríos López. 2007. The effects of salinity on the dynamics of a *Pterocarpus officinalis* forest stand in Puerto Rico. Journal of Tropical Ecology **23**:559-568.
- Robbins, A. M., C. Eckelmann, and M. Quiñones. 2009. Forest Fires in the Insular Caribbean. Ambio: A Journal of the Human Environment **37**:528-534.
- Rodriguez, L. F. 2006. Can invasive species facilitate native species? Evidence of how, when, and why these impacts can occur. Biological Invasions **8**:927-939.
- Rogers, C. S. 1990. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series **62**:185-202.
- Rudel, T. K., T. O. Coomes, et al. 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change **15**:23-31.
- Rudel, T. K., M. Perez-Lugo, et al. 2001. When fields revert to forest: Development and spontaneous reforestation in post-war Puerto Rico. Professional Geographer **52**:386-397.
- Sakai, A. K., F. W. Allendorf, et al. 2001. The population biology of invasive species. Annual Review of Ecological Systems **32**:305-332.
- Saunders, D., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conserv. Biol. **5**:18-32.
- Soler-López, L. R. 2007. Sedimentation history of Lago Dos Bocas, Puerto Rico, 1942-2005: U.S. Geological Survey Scientific Investigations Report 2007-5053, 36 p., 1 pl.
- Sutherland, W. J., M. Clout, et al. 2010. A horizon scan of global conservation issues for 2010. Trends in Ecology & Evolution **25**(1):1-6.
- Sweeney, B. W. 1993. Streamside forests and the physical, chemical, and trophic characteristics of Piedmont streams in eastern North America. Water Science and Technology **26**(12):2653-2673.

- Tanner, J. V. E., V. Kapos, and J. R. Healy. 1991. Hurricane effects on forest ecosystem in the Caribbean. *Biotropica* **23**(4a):513-521.
- Torres-Abreu, A. 2008. *Cultura y Paisajes: Hacia una Ecología Política y Etnografía de Comunidades y el Co-manejo de Bosques en Puerto Rico* Instituto de Investigaciones Interdisciplinarias. Universidad de Puerto Rico en Cayey
- Torres-Abreu, A. 2009. *Comunidad y Sustentabilidad: Percepción, Valoración y Utilidad de los Bosques en Puerto Rico-Bosque Seco de Guánica, Bosque Estatal de Río Abajo y Bosque Estatal de Carite.* Instituto de Investigaciones Interdisciplinarias. Universidad de Puerto Rico en Cayey
- Torres J. L. and J. Morelock 2002. Effects of terrigenous sediment influx on coral cover and linear extension rates of three Caribbean massive coral species: *Caribbean Journal of Science* **38**(3-4):222-229
- UNEP. 2008. *Climate Change in the Caribbean and the challenge of Adaptation.* in UNEP ed. UNEP Regional Office for Latin America and the Caribbean, Panama City, Panama
- U.S. Census Bureau, Population Division. 2015. *Annual estimated of the Resident Population for Selected Age Groups by Sex for the United States, States, Counties, and Puerto Rico Commonwealth and Municipios: April 1, 2010 to July 1, 2014.*
- USDA Forest Service. 2008. *International Institute of Tropical Forestry Strategic Plan for Fiscal Years 2008-2012* FS-914 pp 83
- USDA Forest Service. 2015-a. *Baseline Estimated of Carbon Stocks in Forests and Harvested Wood Products for National Forest System Units; Southern Region.* 60 pp. <http://www.fs.fed.us/climatechange/documents/SouthernRegionCarbonAssessmentTwoBaselines.pdf>
- USDA Forest Service. 2015-b. *El Yunque National Forest, Forest Plan Revision.* Retrieved from <http://www.fs.usda.gov/main/elyunque/landmanagement/planning>
- U.S. Office of Management and Budget. *Standards for defining Metropolitan and Micropolitan Statistical Areas, Federal register Notice 65 FR82228-822238.*
- Vilella, F. J., and E. R. García. 1995. Post-hurricane management of the Puerto Rican parrot. Pages 618-621. *In* J.A. Bissonette and P.R. Krausman, editors. *Integrating people and wildlife for a sustainable future. Proceedings of the first international wildlife management congress.* The Wildlife Society, Bethesda, Md.
- Vitousek, P. M., H. A. Mooney, et al. 1997. Human domination of Earth's ecosystems. *Science* **277**(5325):494-499.
- Wadsworth, F. H. 1950. Notes on the climas forests of Puerto Rico and their destruction and conservation prior to 1900. *Caribbean Forester* **11**(1):38-47.
- Warne, A. G., R. M. T. Webb, and M. C. Larsen. 2005. *Water, Sediment, and Nutrient Discharge Characteristics of Rivers in Puerto Rico, and their Potential*

- Influence on Coral Reefs: U.S. Geological Survey Scientific Investigations Report 2005-5206, 58 pp.
- Wear, D. N., J. G. Greis, and N. Walters. 2009. *The Southern Forest Futures Project using Public Input to Define the Issues* (Gen. Tech Rep. SRS-115. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 17 pp.
- Weaver, L. P. 1998. The effects of environmental gradients on hurricane impact in Cinnamon Bay Watershed, St John, US Virgin Islands. *Man and the Biosphere Series* 21.
- Weil, E. 2004. Coral Reef Disease in the wider Caribbean: *in* Rosemberg, E. and Y. Loya, eds. *Coral Health and Disease*, Springer-Verlag., p. 35-68.
- Welsch, D. J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. NA-PR-07-91. Radnor [Newtown Square], PA: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Northeastern Area. 20 pp.
- Wiley, J. W. and F. J. Vilella. 1998. Caribbean Islands. Pages 315-349 *in* Mac, M.J., P.A. Opler, C.E. Pucket Haecker, and P., D. Doran, eds. *Status and trends of the nation's biological resources*, Vol. 2. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.
- Wiley, J. W. and J. M. Wunderle, Jr. 1993. The effects of hurricanes on birds, with special reference to Caribbean islands. *Bird Conservation International* **3**:319-349.