Department of Natural and Environmental Resources
Commonwealth of Puerto Rico

Puerto Rico
Forest Action Plan





Puerto Rico Forest Action Plan

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Acknowledgements

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)

CCCPR (Consejo de Cambio Climático de Puerto Rico)

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)

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.

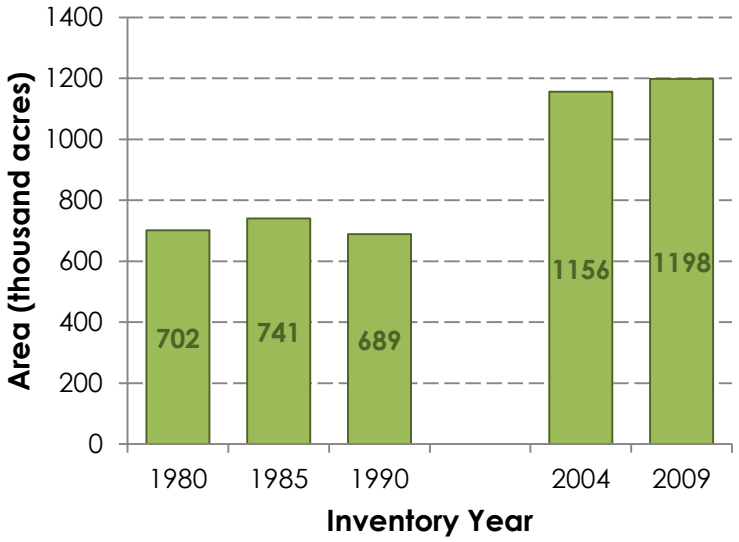

Figure 3. Forest area of mainland Puerto Rico as measured by forest inventories in 1980, 1985, 1990, 2004, and 2009 (Brandeis and Turner 2013)

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%.

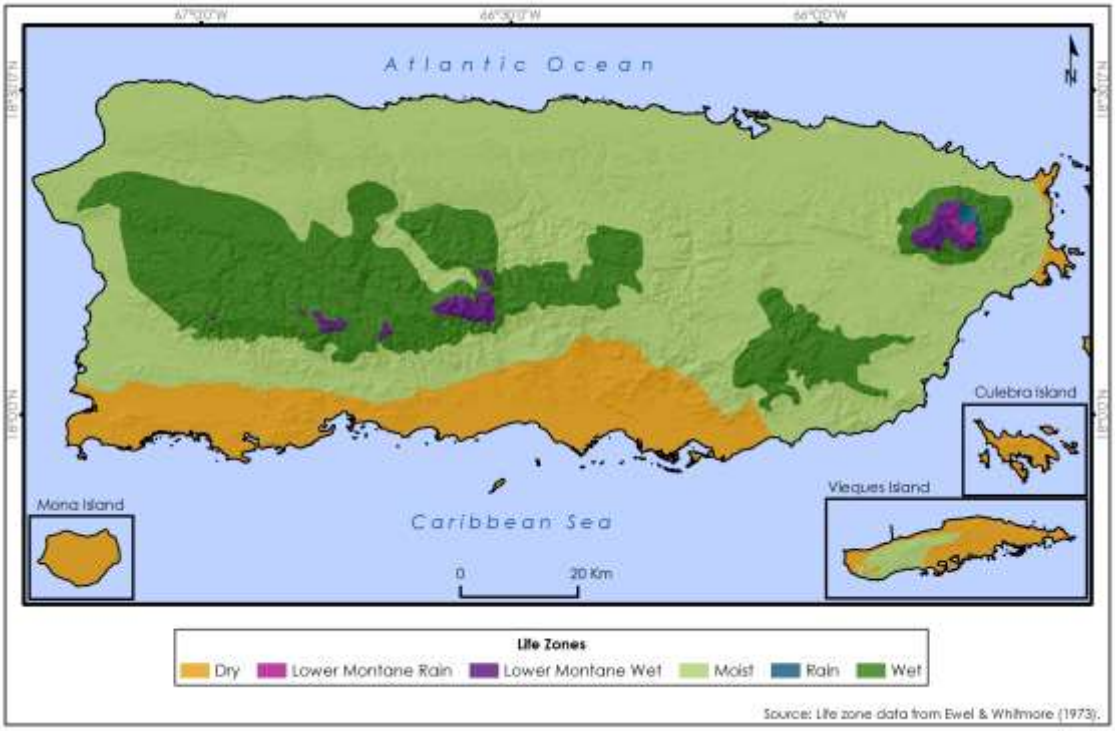

Figure 5. Land distribution among the Subtropical forest life zones of Puerto Rico, Vieques, Culebra, and Mona Islans (Brandeis et al. 2007)

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.

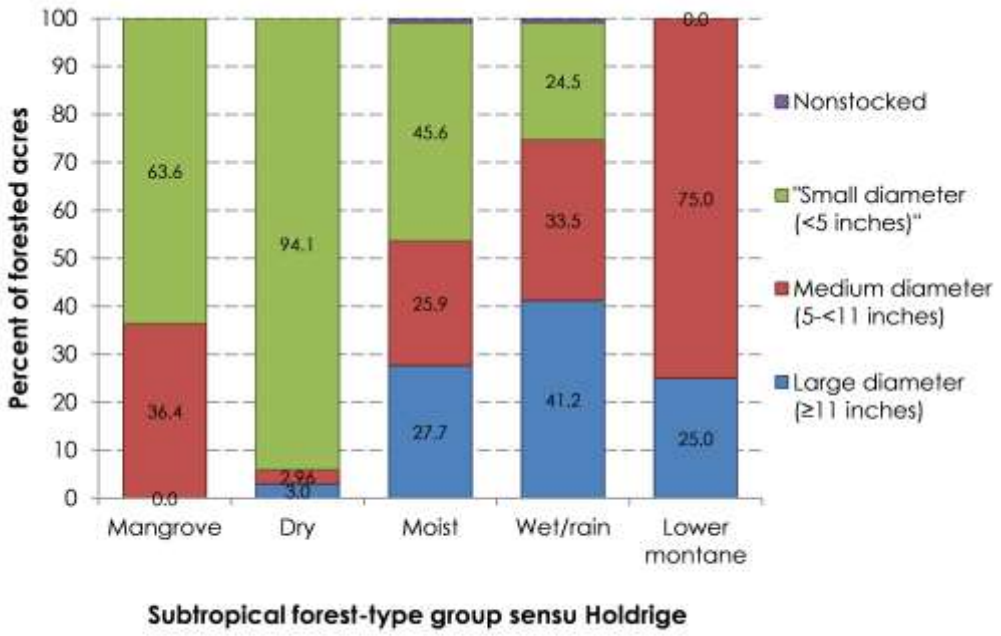

Figure 6. Percent of forested acres by stand-size class and forest-type group, Puerto Rico, 2009 (Brandeis and Turner 2013)

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.

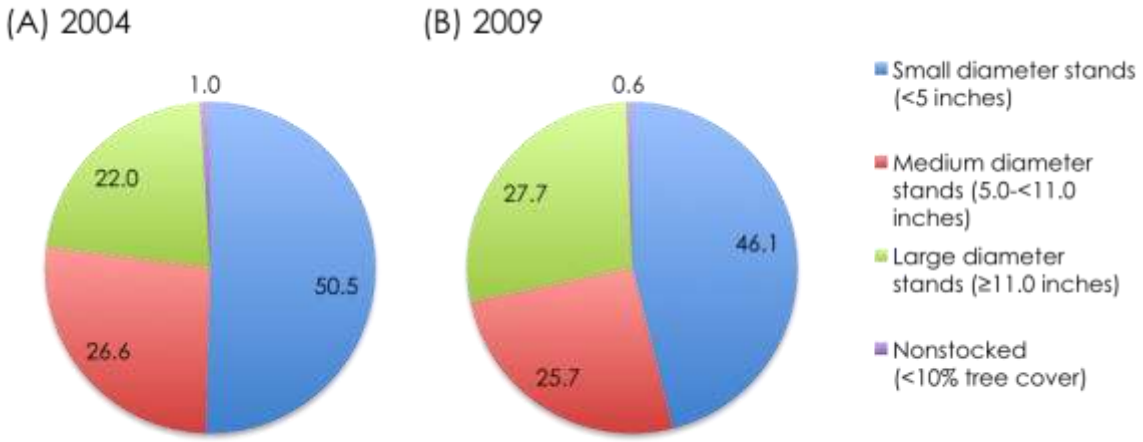

Figure 7. Percentage of stand-size class distribution, Puerto Rico, (A) 2004 and (B) 2009 (percentages may not sum to 100 due to rounding). (Brandeis and Turner 2013)

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	Submontane wet evergreen forest Active sun/shad coffee, submontane/lower montane wet evergreen forest/shrub, other agriculture Submontane/lower montane wet evergreen forest/shrub, active/abandoned shade coffee Lower montane wet evergreen forest[7]-tall cloud forest Lower montane wet evergreen forest[7]-palm and elfin cloud forest Lower montane wet evergreen forest-elfin cloud forest

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

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

delivering 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.

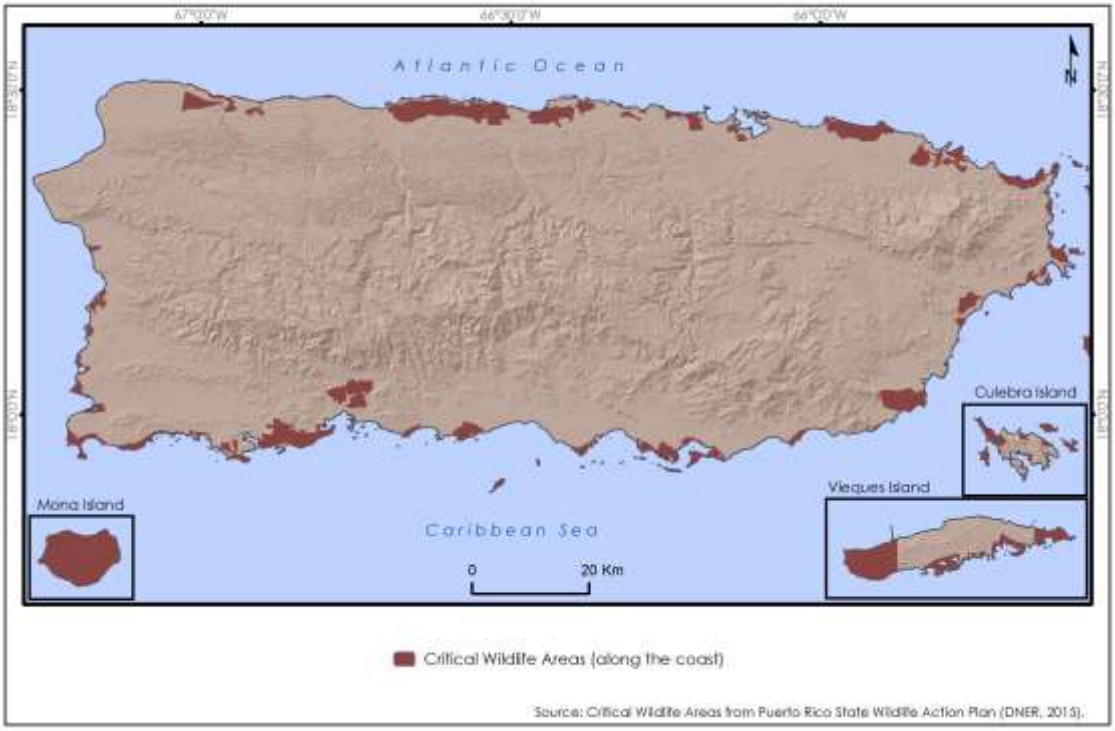

Figure 9. CWA's along the coast (DNER 2015)

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.

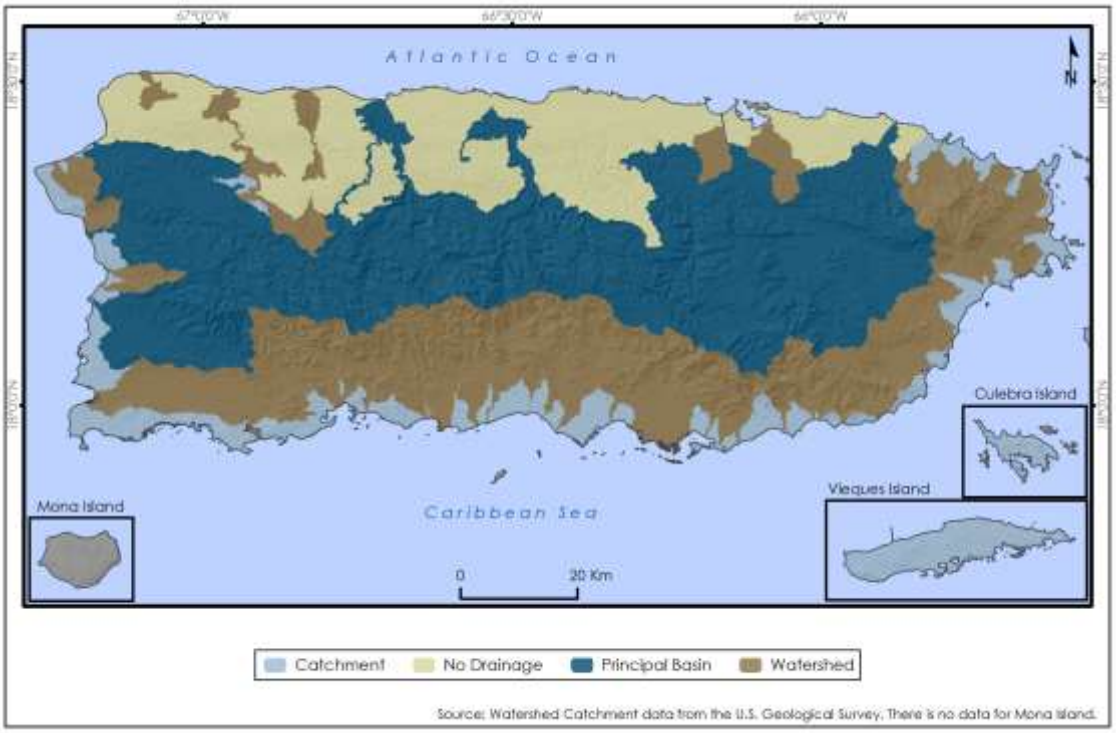

Figure 10. Surface catchment and drainage areas in Puerto Rico, Vieques, and Culebra.

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).

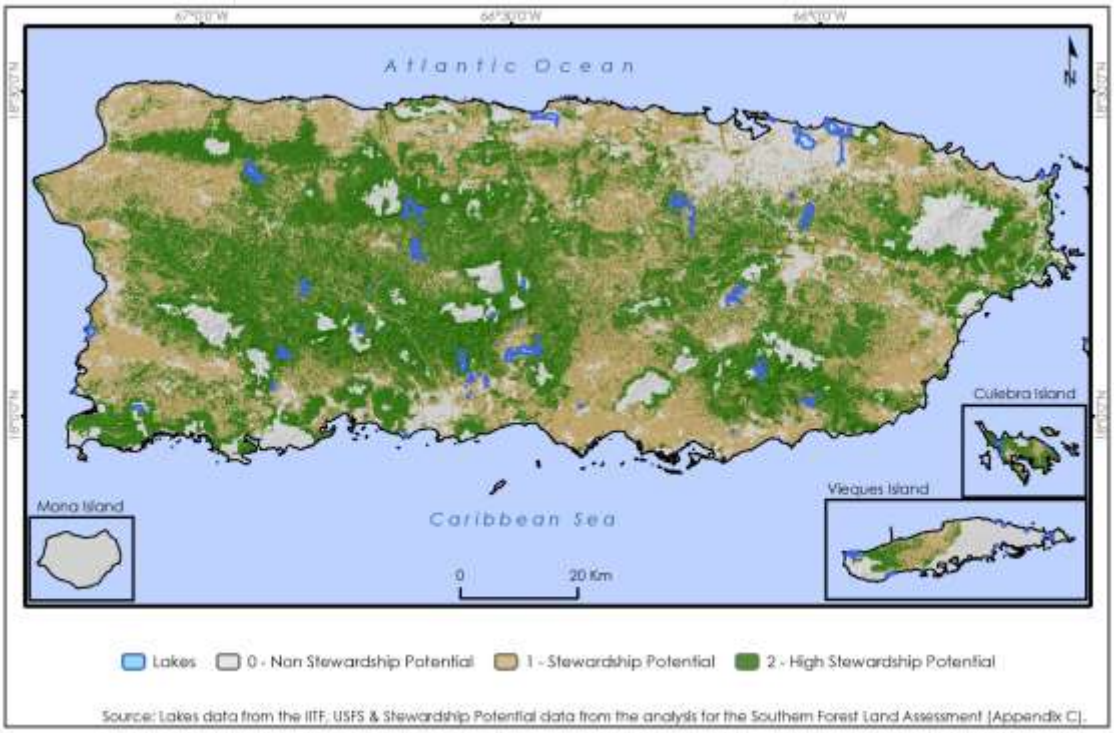

Figure 11. Water bodies in Puerto Rico, Vieques, and Culebra and their relationship to forest priority areas.

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.

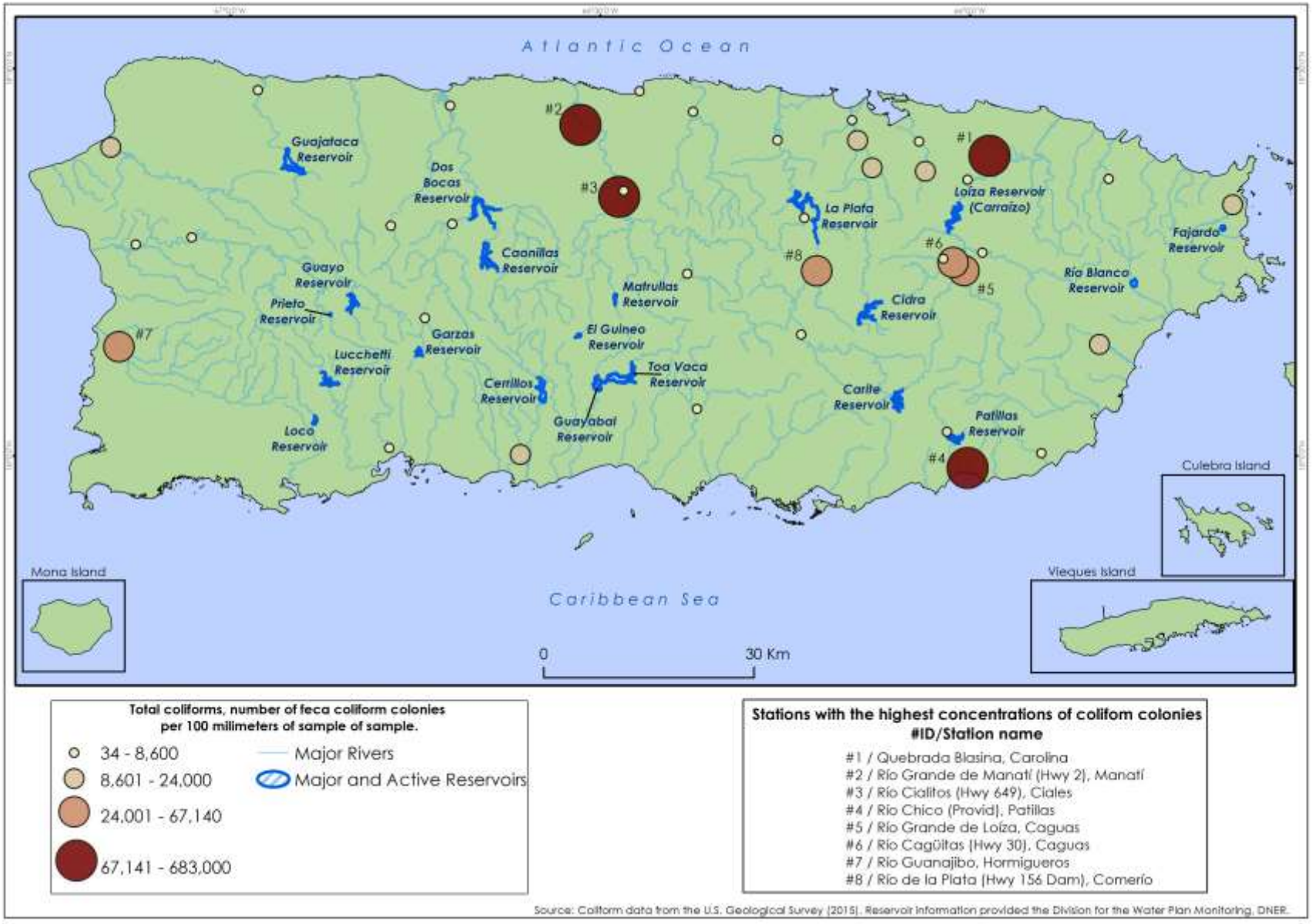

Figure 12. Concentration of fecal-origin bacteria in rivers, reservoirs, and lagoons in Puerto Rico (2015)

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 13.

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.

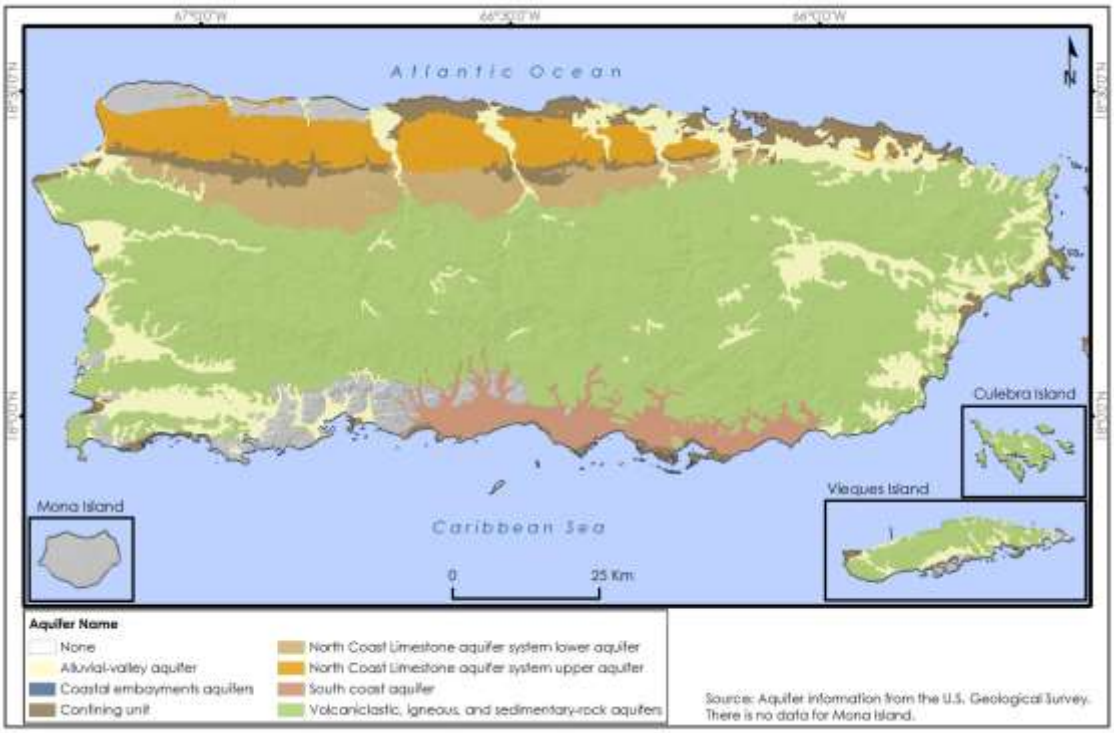

Figure 14. Classification and location of the aquifers in Puerto Rico, Vieques, and Culebra.

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.

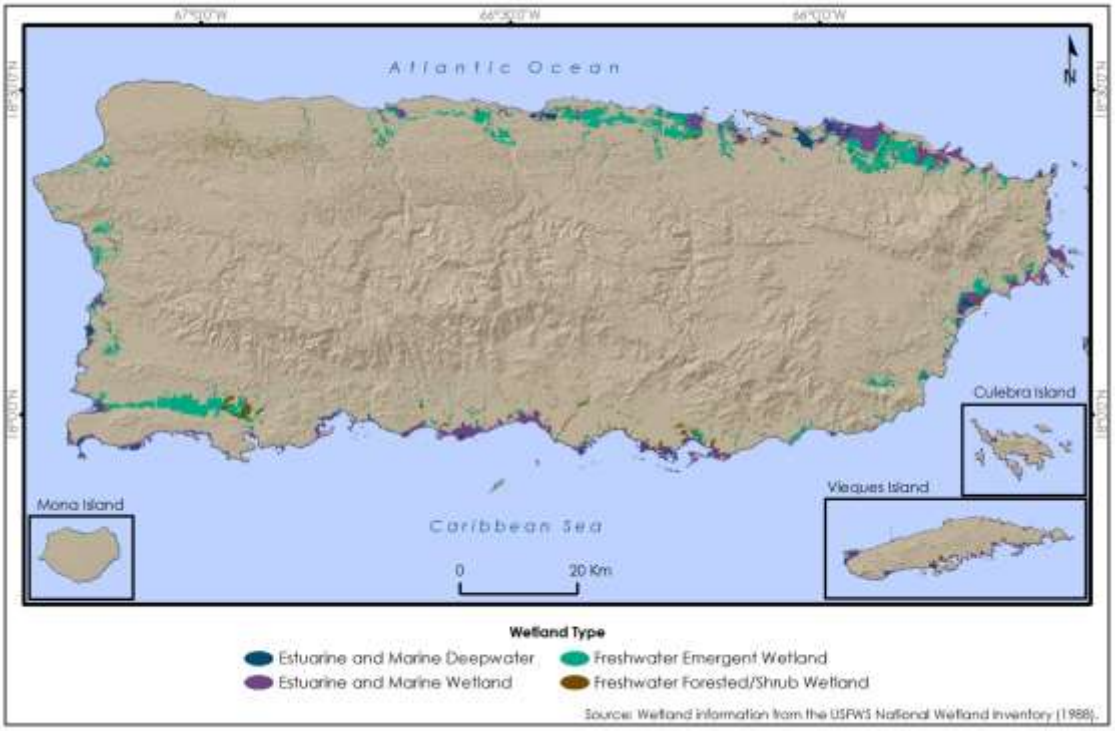

Figure 15. Overview of coastal wetlands in Puerto Rico (National Wetlands Inventory 1988)

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.

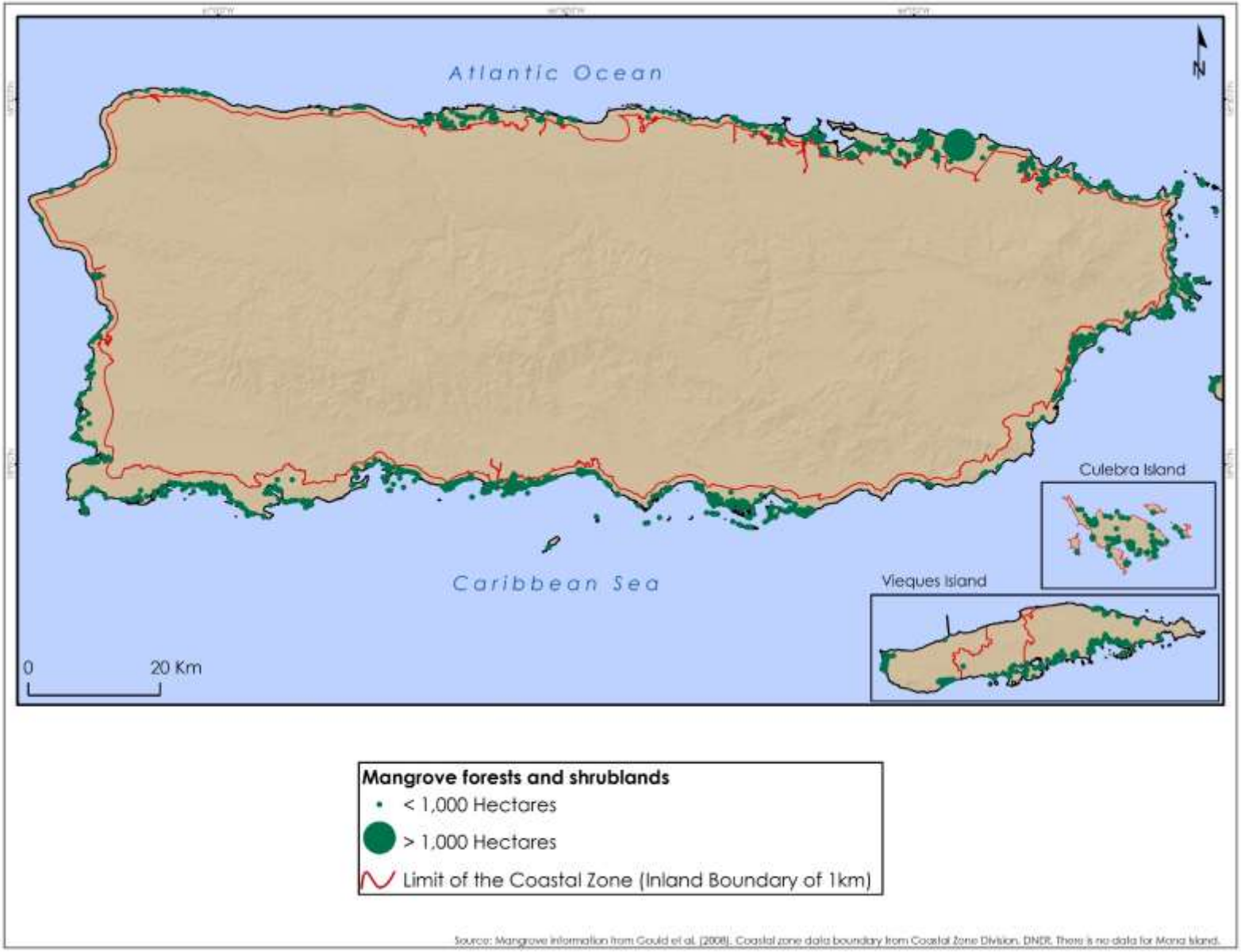

Figure 16. Location of mangrove forests in Puerto Rico, Vieques and Culebra.

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).

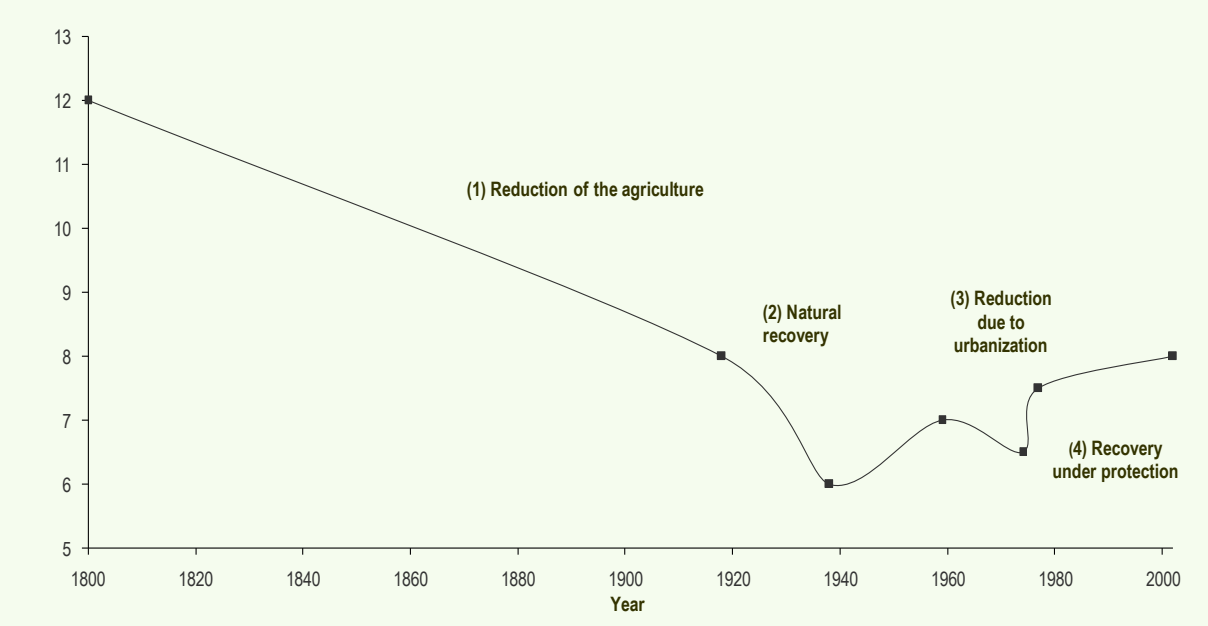

Figure 17. Changes in mangrove forest cover in Puerto Rico over the last 200 years. (Martinuzzi et al. 2009)

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).

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. 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 though 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 (CCCPR 2013). Sixteen percent (16%) of the Island is in urban use and supports 2.3 million people (CCCPR 2013); 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.

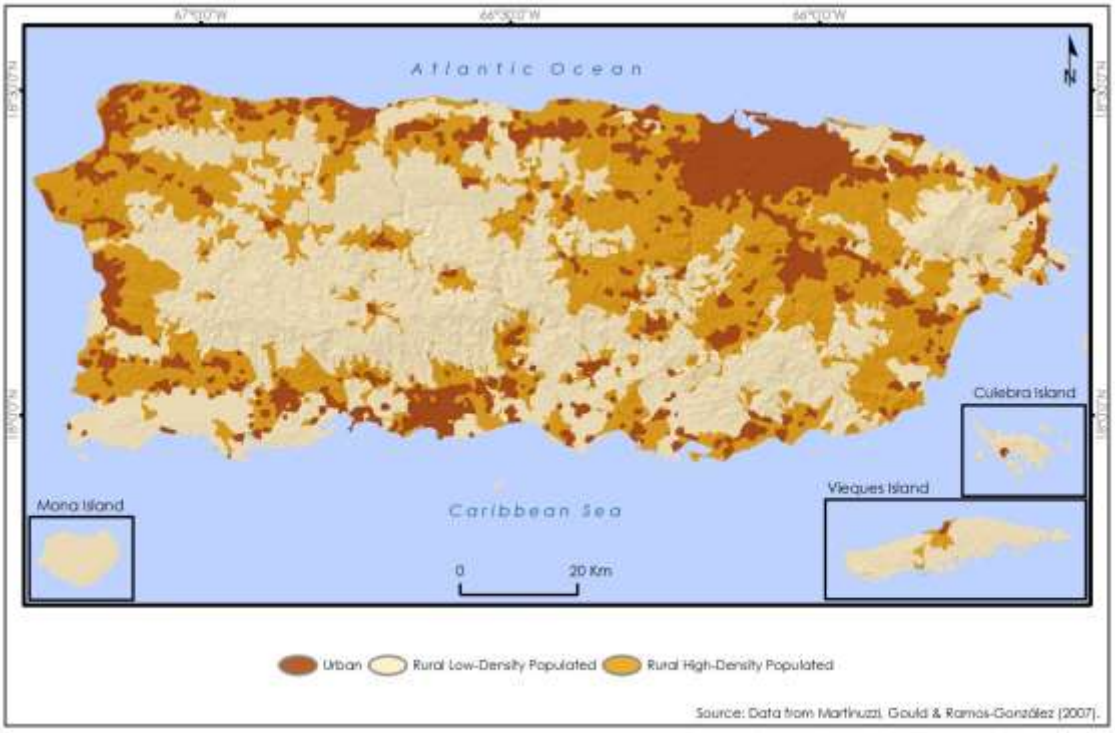

Figure 18. Distribution of population across Puerto Rico (Martinuzzi et al. 2007)

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).

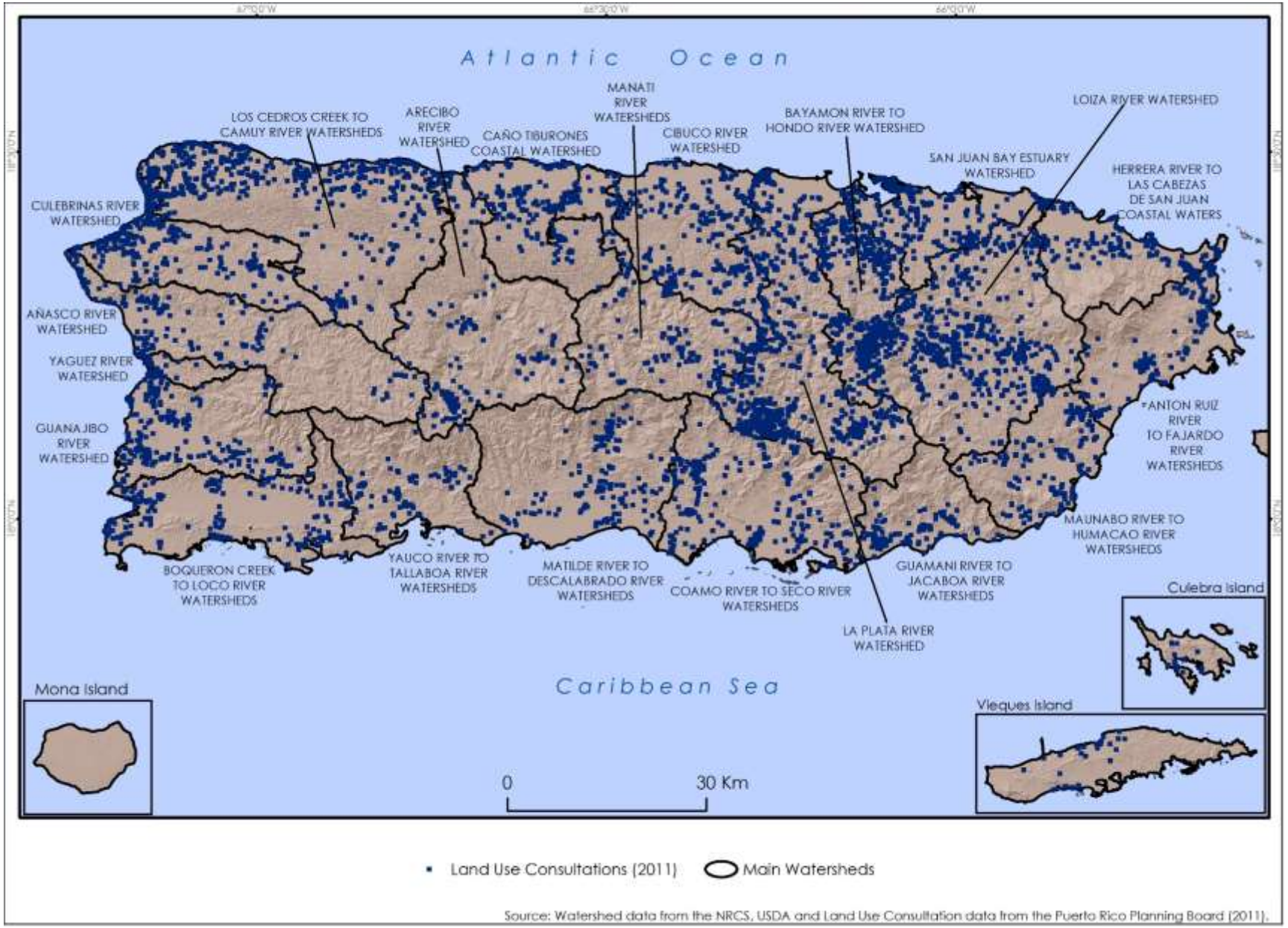

Figure 19. Locations of consultations related to commercial, industrial, residential, and other development in Puerto Rico.

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.

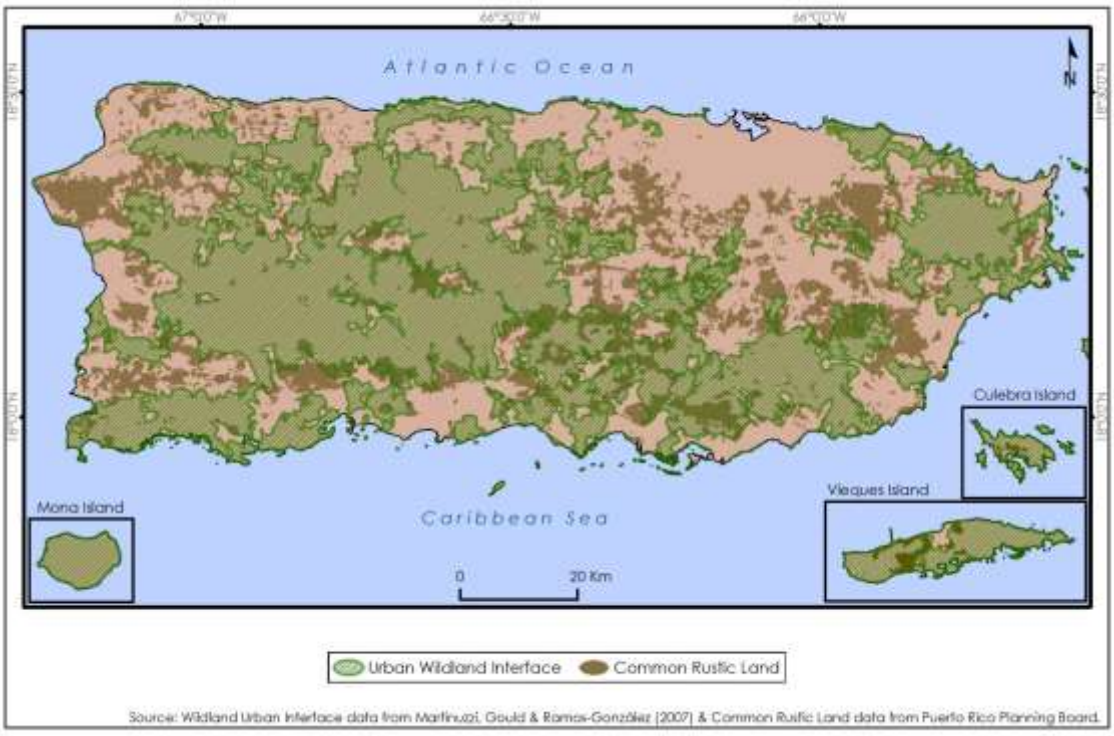

Figure 20. Intersection of wildland urban interface and "Common Rustic Lands" zoning acording to Puerto Rico

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.

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).

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 (CCCPR 2013). The CCCPR (2013) 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).

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. 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 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 21). Climate warming is mainly caused by increasing CO_2 emissions in the atmosphere. According to the Environmental Protection Agency (EPA), 26 large facilities reported a total of 16,342,726 metric tons of CO_2 emissions in 2014 (EPA 2015). Carbon sequestration by forests is one way to mitigate ambient greenhouse gasses, such as CO_2, 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.

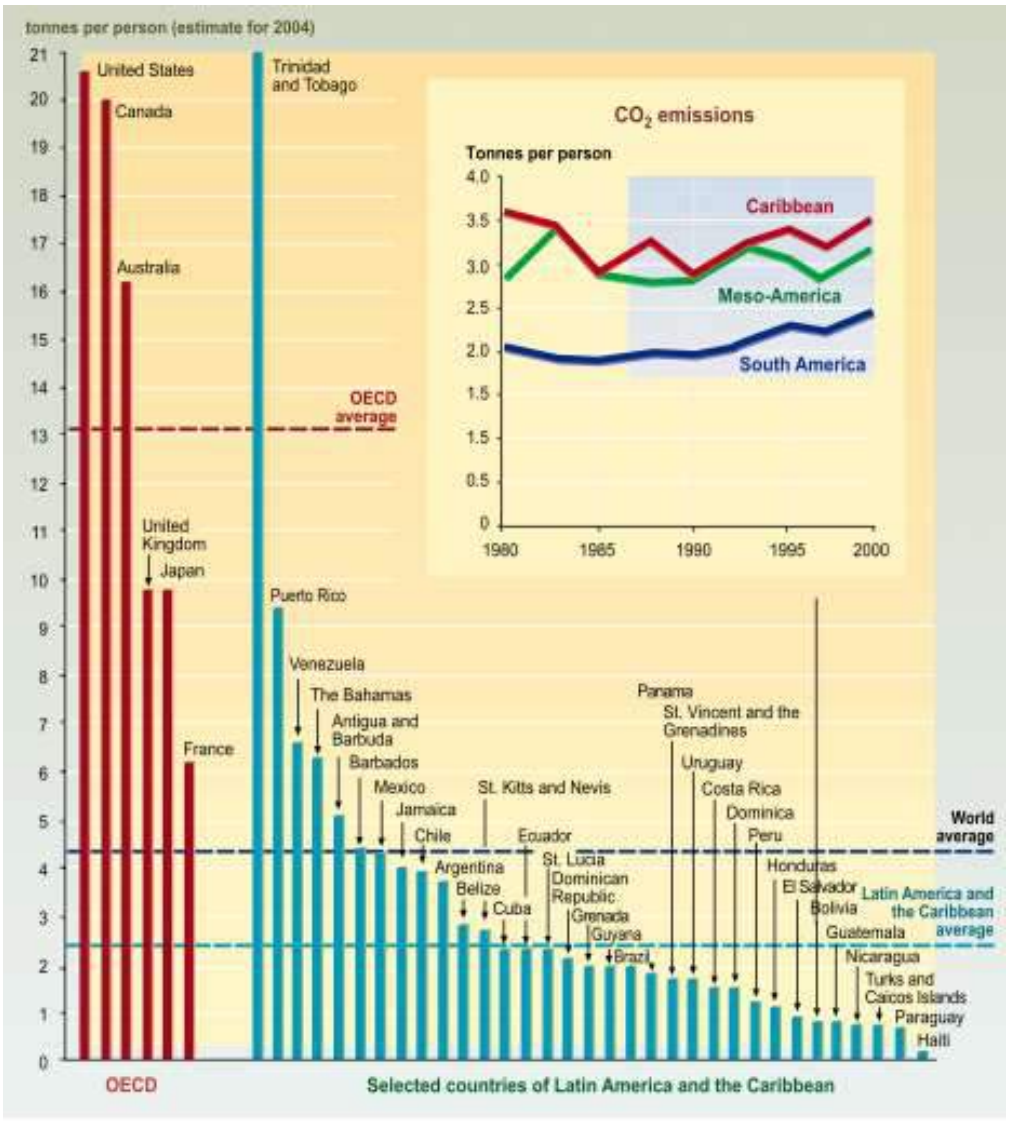

Figure 21. CO_2 emissions per person in Latin America and the Caribbean and average emissions of Organization for Economic Cooperation and Development (OECD). Obtained from World Bank's Development Indicators of year 2008 and US Energy Information Administration.

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 5.

Table 5. Puerto Rico Exotic Agricultural Pests Invasive Species

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

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 MacIsaac 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; Jenkings 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 6 shows a list of the concerned species considered pests in Puerto Rico forests and their host woody plants (Martorell 1982).

Table 6. 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
Apate monacha	the apate borer/ "escarabajo taladrador del tallo"	*Bixa orellana; Bucida buceras; Casuarina equisitefolia; Delonix regia; Inga vera; Eugenia jambos; Linociera domingensis; Melia azedarach; Persea americana; Picramnia pentandra; Salix chilensis*;
Aphis gossyppi	"áfido"	no information available
Aspidotus destructor	the coconut scale/ "la queresa del coco"	*Cocos nucifera; Annona glabra/ Barringtonia speciosa; Grevillea robusta; Mammea americana; Persea americana; Phoenix dactylifera; Psidium guajava; Terminalia catappa*
Chlorida festiva	the mango borer/ "el barrenador del mangó"	*Albizzia lebbeck; Casuarina equisetifolia; Mangifera indica; Stahlia monosperma*
Chrysomphalus aonidum	the Florida red scale	no information available
Diapprepes abbreviatus	sugarcane weevil/ "vaquita de la caña"	*Albizzia lebbeck; Andira jamaicensis; Byrsonima spicata; Cedrela mejicana; Cedrela odorata; Ceiba pentandra; Chrysophyllum cainito; Coccoloba uvifera; Cordia alliodora; Delonix regia; Ficus stahlii; Guaicaum officinale; Inga vera; Lagerstromia speciosa; Melicocca bijugata; Thespessia grandiflora; Persea americana; Psidium guajava; Swietenia macrophylla; Swietenia mahogani; Tamarindus indica;*

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

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

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

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

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 stewardship[9] 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 22).

[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 7). 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 7. USDA Forest Service Cooperative Programs available in Puerto Rico

Program	Purpose
Forest Stewardship Program, FSP	-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.
Urban and Community Forestry, U&CF	-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.
Forest Legacy Program, FLP	-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 purchase conservation easements Puerto Rico competes

Program	Purpose
	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	-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.
Forest Health Management	-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.
Forest Health Monitoring	-Monitors the forests of the United States to determine detrimental changes or improvements to forest health that occur over time.
State Fire Assistance	-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.
Volunteer Fire Assistance	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: • Available funding to renovate equipment obtained through the Federal Excess Personal Property Program • Improved fire protection capabilities and capacity in

Program	Purpose
	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
Good Neighbor Authority (FY 2014 Appropriations Act and the 2014 Farm Bill)	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)

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 7). The cost incentive programs are the one most commonly used to establish, restore and manage forestland (Table 8).

Table 8. USDA NRCS and USFWS incentive programs available to non-industrial private landowners in Puerto Rico

Program	Purpose
Environmental Quality Incentives Program, EQIP	-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 eligible producers install or implement conservation practices on eligible agricultural land.

Program	Purpose
Partners for Fish and Wildlife, PFW	-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.
Conservation Reserve Program, CRP **(Farm Service Agency)**	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.
Conservation Stewardship Program, CSP	A voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner by: • Undertaking additional conservation activities; and • Improving, maintaining, and managing existing conservation activities,
Regional Conservation Partnership Program, RCPP	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 restoring or sustaining natural resources such as: • Clean and abundant water

Program	Purpose
	• 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 23). The distribution of the private forests enrolled in DNER AFP and FSP by 2015 is presented in Figure 24. 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.

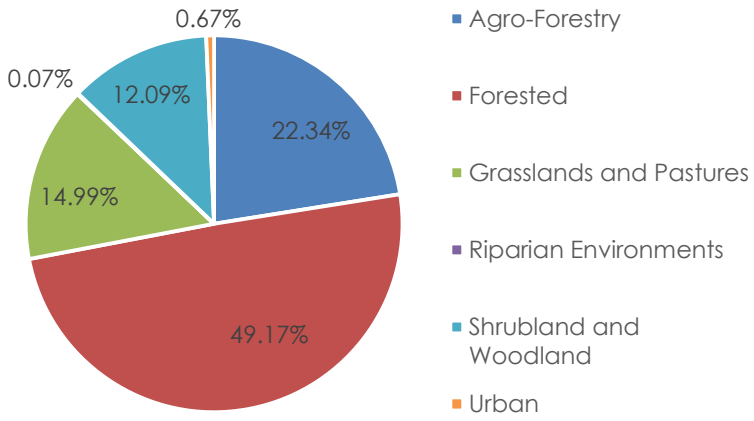

Figure 23. Land use classification on properties enrolled in the AFP by 2015.

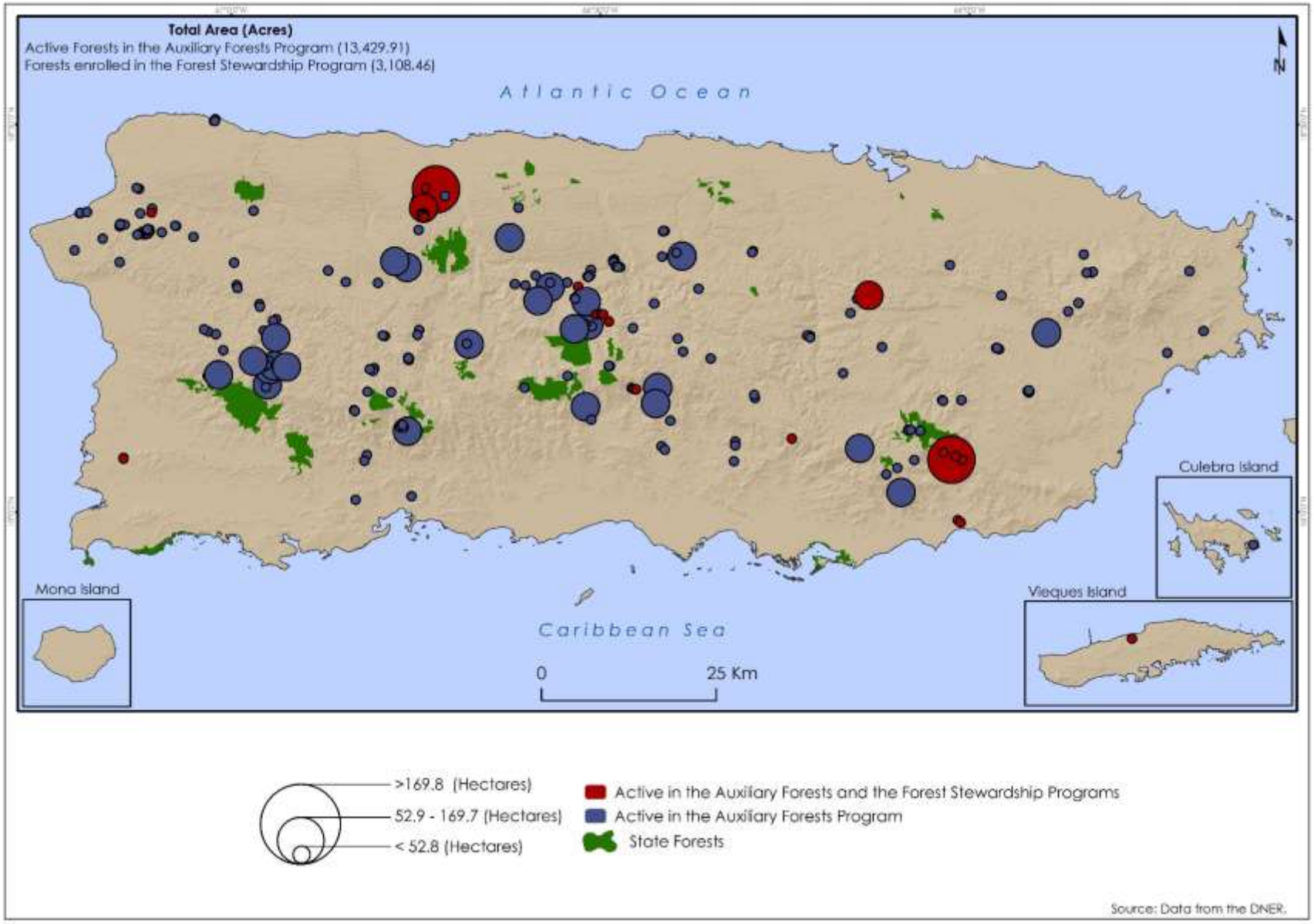

Figure 24. Location of private forests enrolled in state DNER state auxiliary forest programs.

There are numerous laws related to forest resources in Puerto Rico. The most significant are listed in Table 9.

Table 9. 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 Foresting 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 Resources Rangers	It creates DNER Rangers Corp who is supposed to enforce all the Commonwealth statutes available for the protection of all natural resources

Statutes	Name	Objective
	Corp Act	(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 iiassociated 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 25). 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.

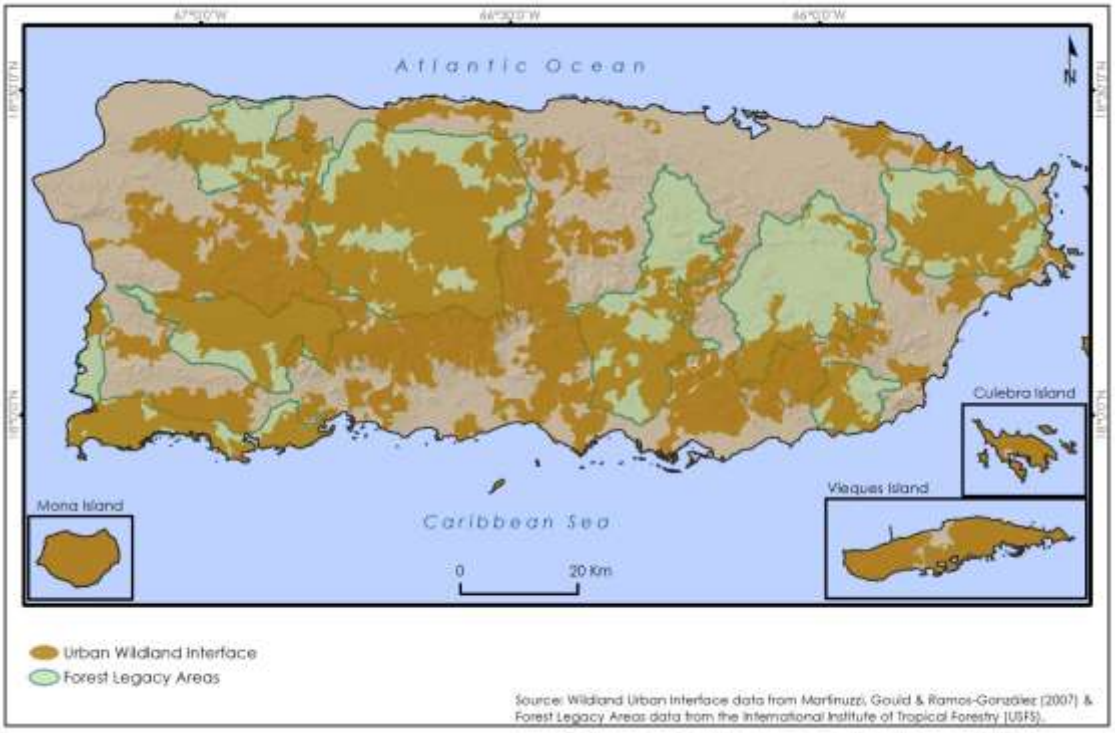

Figure 25. Overview of urban wildland interface zones (Martinuzzi et al. 2007) and Forest Legacy Areas in Puerto Rico.

2. Critical Wildlife Areas (CWA's)

Figure 26 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.

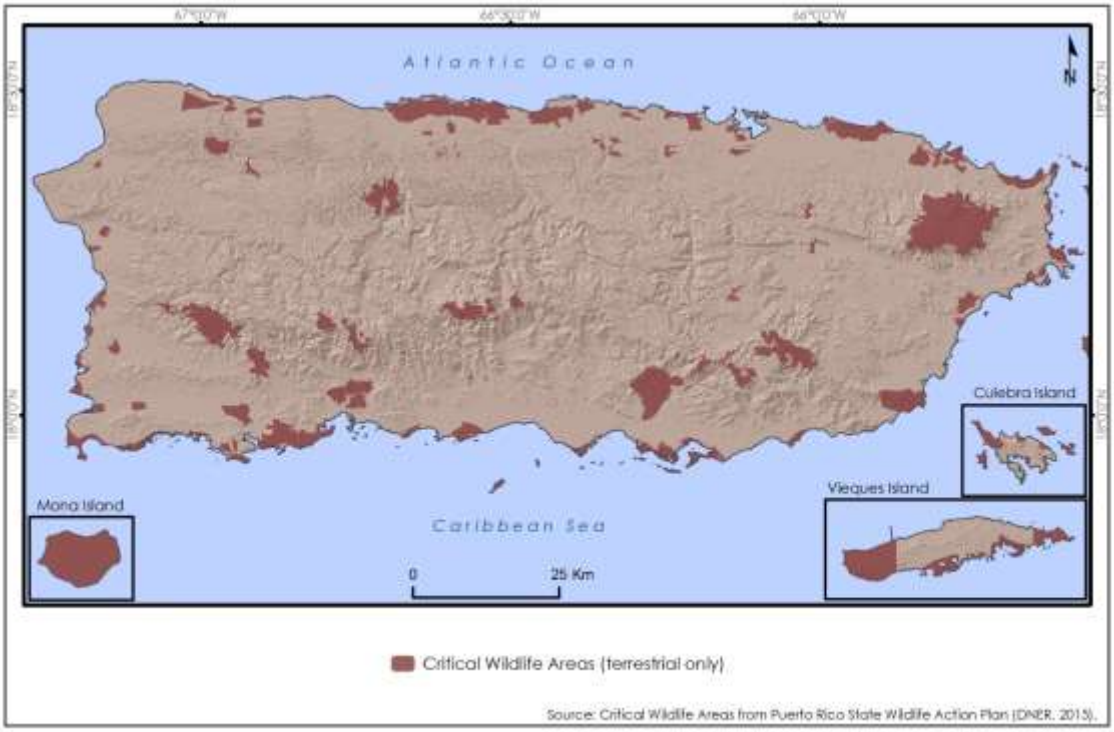

Figure 26. CWA's of Puerto Rico and their respective geographical locality obtained from PRSWAP (DNER 2015)

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 27) as well as Hydrological Reserves (Table 10). 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).

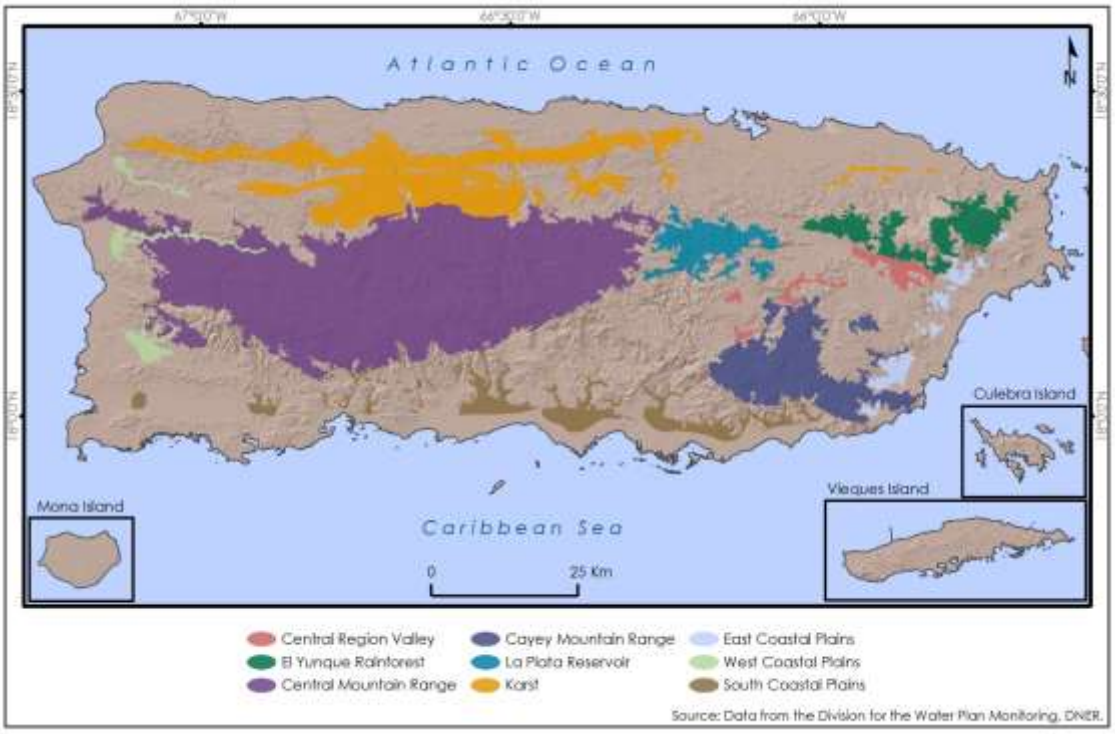

Figure 27. Hydrological regions in Puerto Rico recommended for water quality protection by DNER and Puerto Planning

Table 10. 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 28 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.

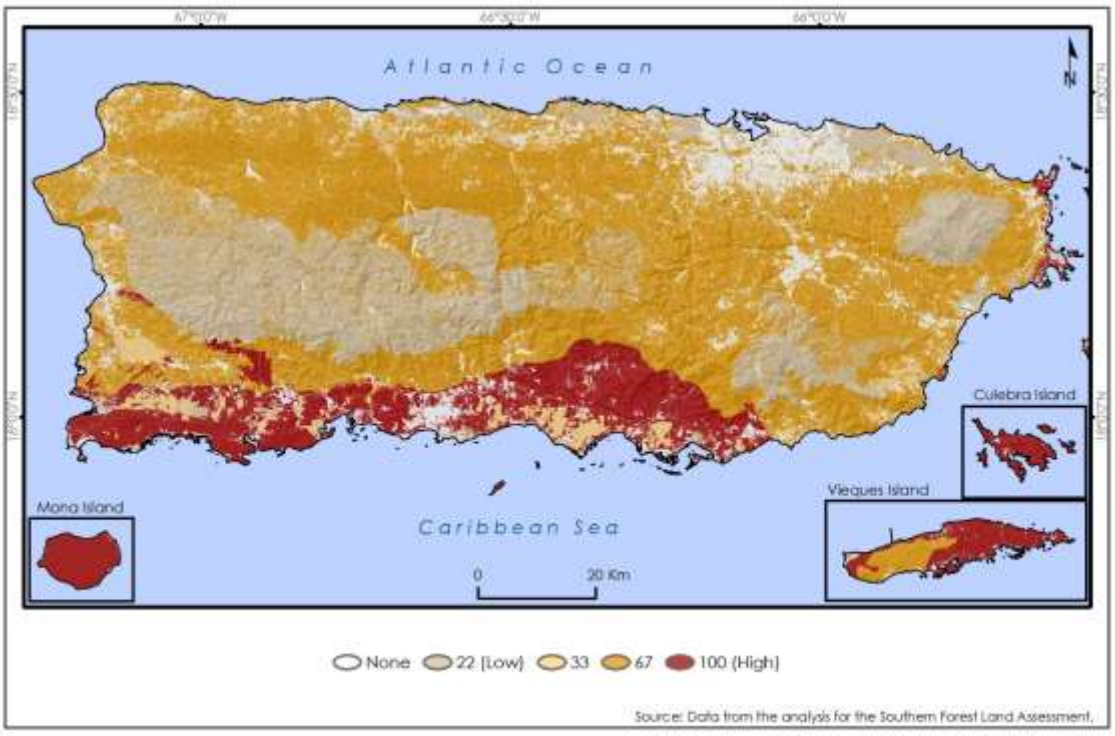

Figure 28. Overview of areas of Puerto Rico, Vieques, and Culebra under different levels of wildfire incidence according to SFLA

In 2014, a total of 3,743 fires burnt 16,327.7 acres of land (Table 11). 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 11. 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 29).

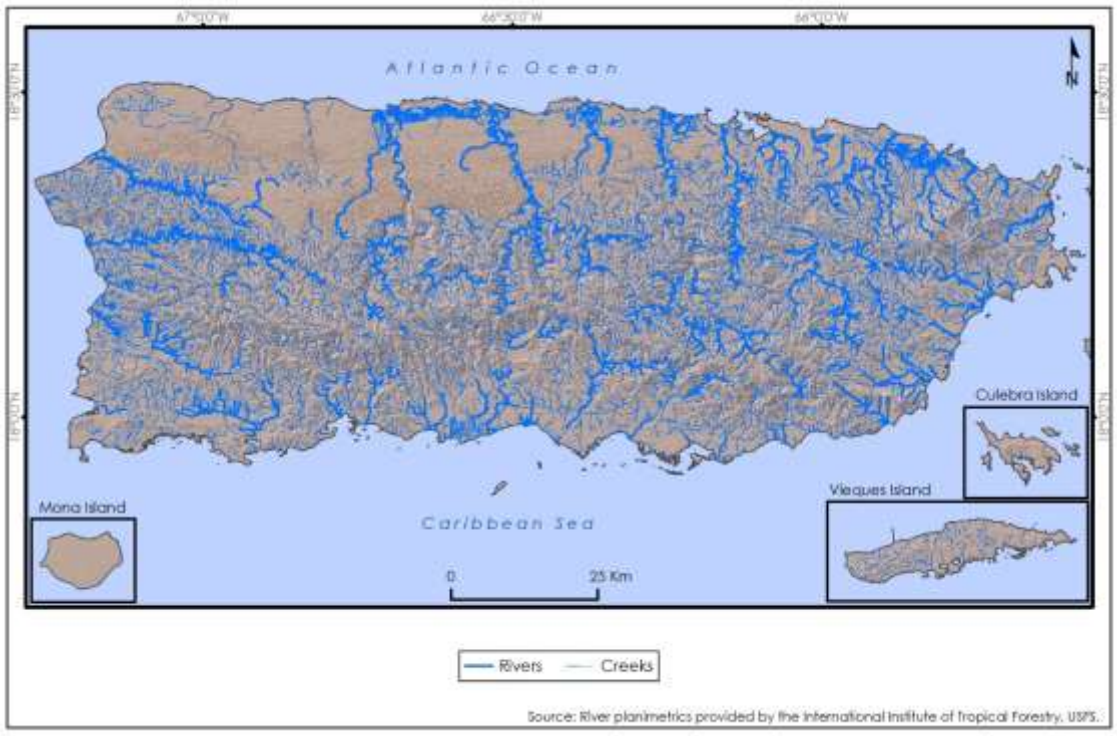

Figure 29. Overview of riparian areas in Puerto Rico, Vieques, and Culebra

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 30). 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.

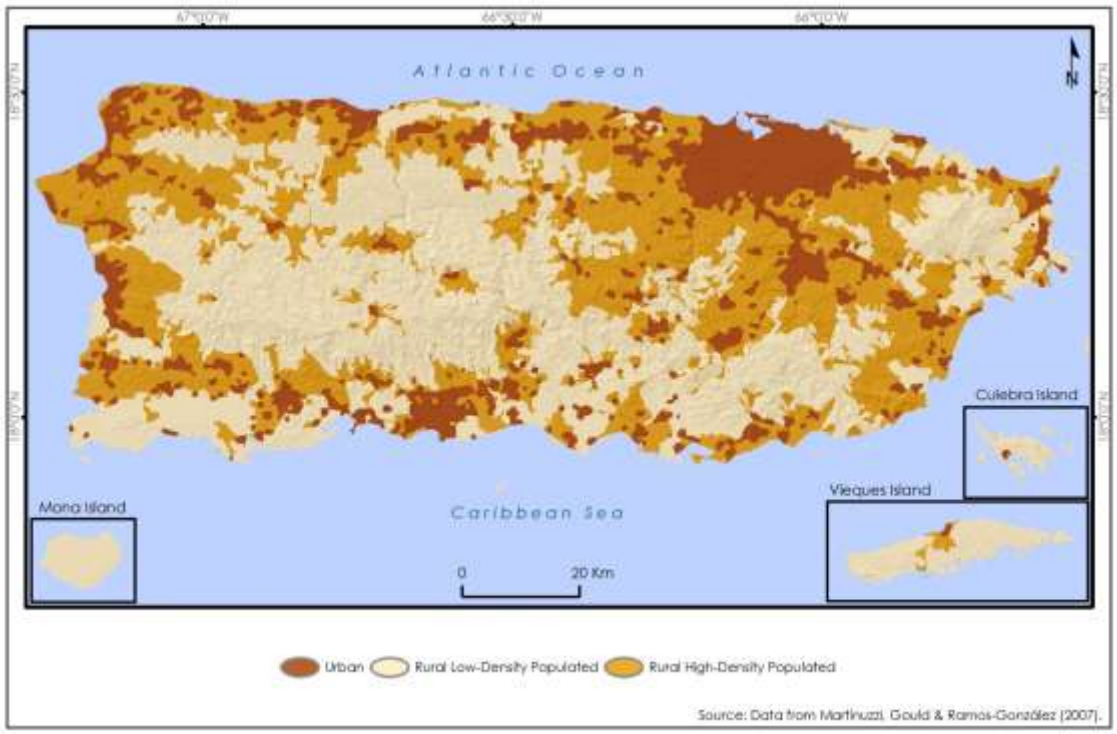

Figure 30. Overview of urban and rural (densely v. low populated) areas distribution in Puerto Rico.

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 31). 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 Puero Rico Fire Department (PRFD) and the State Forest are working on wildland fire strategies.

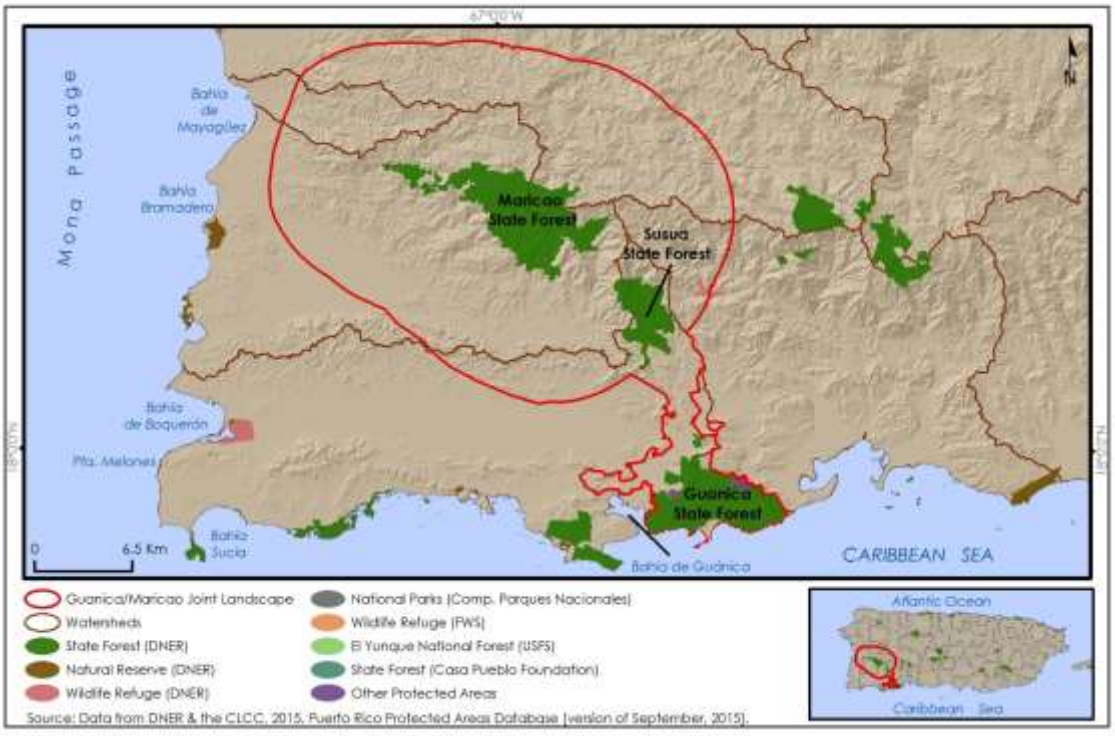

Figure 31. Overview of the Guánica/Maricao joint landscape

- 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 Natural Reserves of Humacao and Cabezas de San Juan, the Northeast Ecological Corridor, and the El Yunque National Forest (Figure 32). The Northeast Ecological Corridor was established in 2012 under Act No. 126, as amended (Figure 33), and is distinguished by containing most of the general types of coastal wetlands classified in Puerto Rico.

Figure 32. Overview of the Humacao joint priority landscape

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).

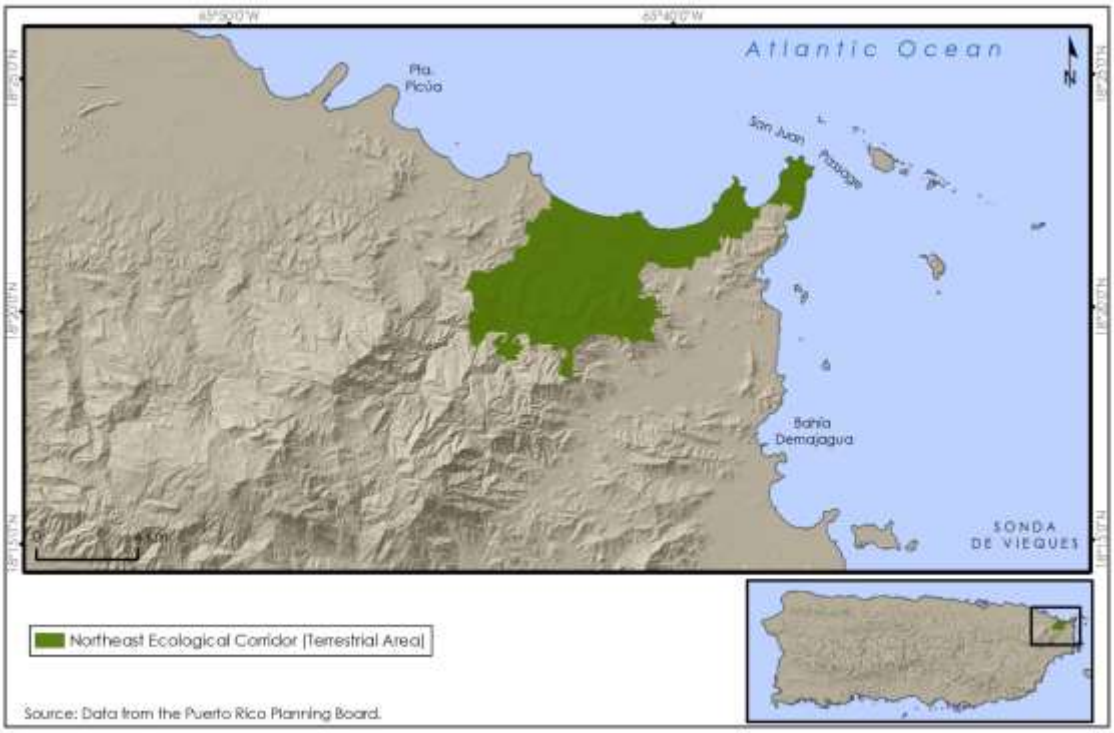

Figure 33. Overview of the Northeast Ecological Corridor

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 34). 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.

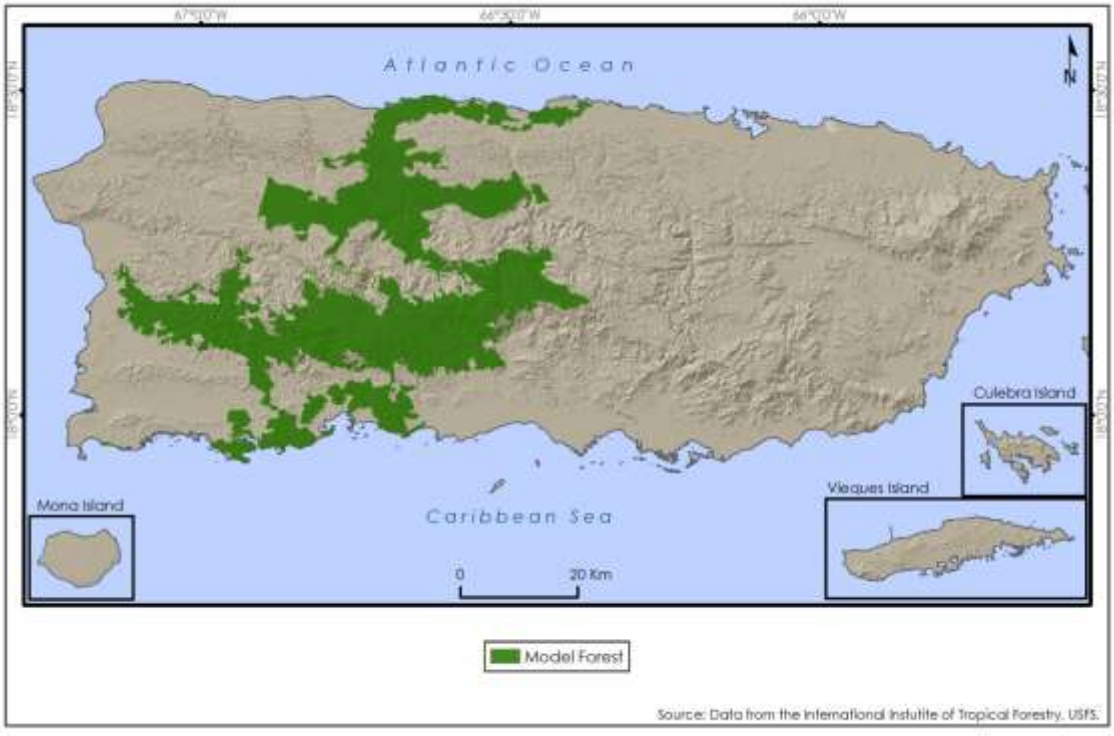

Figure 34. Overview of the Model Forest of Puerto Rico

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 12. Goal 1: Conserving Working Forest Landscapes

Outputs	Priority landscape	Strategies	Resources	Performance Measures
-Recreation **-Tourism**	-Public lands -Surrounding private lands	-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.	-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	-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.
Wood products	Area around Toro Negro State Forest due to high risk of development.	-Continue land acquisition of key forested land by available mechanisms (USFS FLP)	-USFS FLP -DNER PR Natural Heritage Program -DNER PR High Ecological Value Land Acquisition and	-High priority forest ecosystems and landscapes are protected from conversion (acres-annual and

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

Outputs	Priority landscape	Strategies	Resources	Performance Measures
-Shade **-Aesthetics** **-Climate control** **-Mental health** **-Wood products** **-Mulch** **-Wildlife** **-Green infrastructure** **-Recreation** **-Safety** **-Energy conservation** **-Air quality improvement**	Urban Areas and wildland urban interface.	-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).	-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	-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
		-Develop nursery quality standards. -Introduce agroforestry concepts. -Promote arboriculture in University curricula.	-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	-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 wildand fire suppression.
9. Develop an effective communication strategy between partners involved in the suppression of wildand 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 13. 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
Fire map showing fire occurrence information.	-Biodiversity -Wildlife habitat and populations -Water quality -Air quality esp. in Urban environment -Recreation experiences -Coastal resources.	-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 -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	-PRFD Fire Prevention Program -DNERFSB -USFWS -USFS -USFS Cooperative Fire Program -USFS Volunteer Fire Program	-Number of acres treated to restore fire-adapted ecosystems that are (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
		-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 wildand fire suppression. -Develop an effective communication tool between partners involved in the suppression of wildand fires		capacity as evidenced by: (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	-Loss and displacement of wildlife -Decreased reproduction -Stained wood	-Establish a forest health monitoring program at the DNERFSB -Encourage early detection and rapid response from forest managers -Provide professional training to forest managers	-USFS Forest Health Monitoring Program -UPR Extension Service Forest Health Clinic and	-Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects, diseases and

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
	-Poor tree form -Aesthetics -Hazard trees -Increase fire risk Fragmentation	-Promote public education about possible detrimental effects on forest floristic components -Maintain adequate urban tree inventories and management practices -Promote Integrated Pest Management	Diagnostics Lab -DNER Forest Health Program -UPR -USFS	plants. -Percent of population living in communities developing or managing programs to plant, protect and maintain their urban and community trees and forests.
-Development **-Urban Sprawl** **-Fragmentation** **(consultation map, urban sprawl map).**	Decreased and fragmented forest cover decreases the quantity and quality of all forest dependent values	-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 -Encourage planting trees to increase canopy cover and create green corridors -Promote proper land use planning and accurate	-USFS FLP -USFS FSP -Professionals who evaluate zoning, planning and permits -Municipalities -USFS CFP	-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 plant, protect

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
		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: (1) Increase outreach, (2) Increase Water Conservation, (3) Enhance Forest Diversity, (4) Enhance all restored riparian habitats.	-USFS U&CF Program -PR U&CF Council -International Society of Arboriculture -PR Association of Professional Arborists	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)	-Biodiversity -Wildlife -Urban forest -Forest products -Recreation experiences	-Urban forest inventory -Tree Management Plan development -Hazard tree mitigation -Tree selection	-USFS U&CF Program -PR U&CF Council -International Society of Arboriculture -PR Association of Professional Arborists -Tree City USA -ITree (adapted	-Number of communities and percent of population served under an active urban forest management plan. -Percent of population living

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
	-Coastal resources		to tropics) -FEMA Programs -PR Conservation Trust	in communities developing or managing programs to plant, protect and maintain their urban and community trees and forests.
Climate change (sea level rise map)	Coastal forests and wildlife, salinization of fresh water swamps, increase fire, more intense storms, salt water intrusion, biodiversity, forest products, decreased recreational experiences	-Corridors for tree migration -Increase carbon storage through increases in tree cover - Urban forest inventory -Tree Management plan development -Hazard tree mitigation -Tree selection	-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 -ITree (adapted	-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
			to tropics) -PR Conservation Trust -UPR Marine Science Department	
Flooding	-Water quality -Tree health human safety -Stream and bank erosion -Erosion and sedimentation	-Forested wetland protection -Riparian buffer installations -Maintain and increase forest cover in catchment and groundwater recharge areas -Urban tree inventory and hazard mitigation	- USFS U&CF Program -USFS FSP -International Society of Arboriculture -PR Association of Professional Arborists -PR Conservation Trust	-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	-Biodiversity -Wildlife -Displacement of indigenous species	-Professional and public education -Promote native and other suitable species -Early eradication -Law enforcement -Early detection	-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	-Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects, diseases and plants (annual).
Invasive animals	-Wildlife habitat -Egg predation -Rare pant seedling recruitment	-Law enforcement -Public education	-DNER -San Juan Bay Estuary Program -Puerto Rico Conservation Trust -Lion Fish Control Program	-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 14. Goal 3: Enhance public benefits associated with trees and forests.

Benefits	Priority area	Strategy	Resources	Performance measures
Water Quality Benefits	-Riparian areas around rivers and reservoirs. -Aquifer Recharge areas -Upland Catchments	-Continue encouraging reforestation -Maintain and manage existing forest	-DNER reforestation program -USFS FSP -NRCS HFRP -USFWS State Wildlife Grant -NRCS EQIP	-Acres and percent of priority watershed areas where S&PF activities are enhancing or protecting water quality and quantity.
Coastal Resources	-Through all PR Coastal Zone (1 km from the sea) -Existing forested wetlands (i.e.mangrove and *Pterocarpus* or *Annona* swamps, etc.) -Coastal upland remnants	-Continue encouraging reforestation -Maintain and manage existing forest	-COE Wetland Banking -USFS FSP -NRCS HFRP -USFWS State Wildlife Grant -NRCS HFRP	-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 -Mature forest habitats -Corridors that link mature forest areas (i.e. riparian areas along streams) -Corridors required under Commonwealth Law Number 14 of 1999 -Threatened and Endangered Species habitat.	-Private forested land acquisition by several means including FLP -Encourage Conservation Easements -Promote voluntary private land conservation management. -Provision of proper management on public forested lands -Continue land acquisition programs to conserve mature forest -Promote and Encourage agroforestry practices (sun coffee plantations to shade grown coffee)	-UFSF FLP -DNER PR Natural Heritage Program -DNER PR High Ecological Value Land Acquisition and Conservation Fund -USFS FSP -NRCS EQIP -USFWS PFW -Federal and State agencies management -NRCS HFRP	-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 -Detectable increased in frequency numbers of priority critical species for WHIP. Establishment of wild reproductive couples of Puertorrican Parrot in Maricao Commonwealth Forest. -Increase of riparian forests under conservation practices. -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

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 Rio 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 15. 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
5-Expand reserves in the limestone	(no specific forested habitat	Quebradillas;

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
hills	mentioned)	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)
9- Development of small and intermediate-sized parks and open	Urban forests created by tree planting or by protection of spontaneous	All eight Puerto Rico Forest Legacy

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
spaces within urban areas that serve as habitats as well as recreational and educational resources for communities.	forested patches in urban or urbanizing areas	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
10-The protection of unique habitats associated to particularly rare endemic, amphibious species such as: * mountain valleys that shelter *Eleutherodactylus cooki* (the guajón); *** the freshwater nonforested wetlands that shelter *Eleutherodactylus juanriveroi* (the coquí llanero)**	Only *Eleutherodactylus cooki* is associated to a forested habitat, particularly wet forests over intrusive volcanic geology ; *Eleutherodactylus juanriveroi* 's only habitat known, although it is present at a coastal plain, it is not a forested one but an open freshwater marsh	Maunabo (urban wildland interface zones are included)
11-The restoration of formerly extensive habitats such as : *** freshwater swamps or riparian forests of *Pterocarpus officinalis*;** *** moist lowland ausubo (*Manilkara bidentata*) forests**	Bloodwood swamps and Bullet-wood lowland forests	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)

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 35). 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.

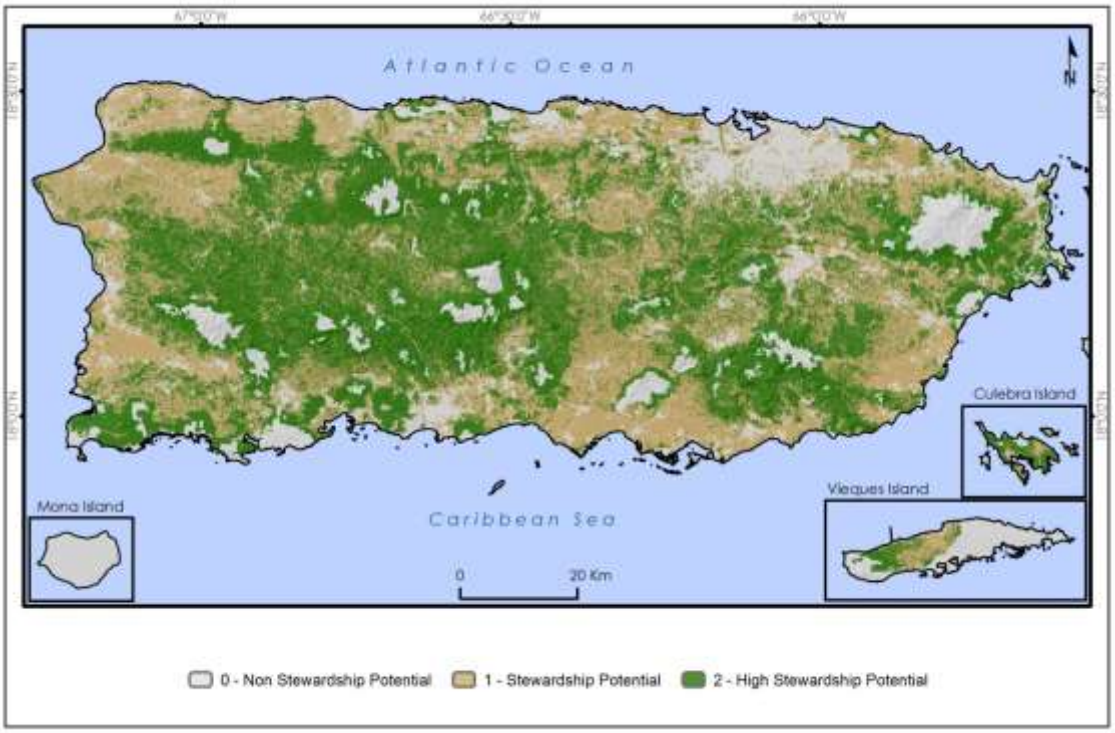

Figure 35. High priority landscape areas as indicated by the SFLA

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 16 for weight values utilized.

Table 16. 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 17). 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 17. Research into public perspectives of current forest conservation and management.

Report	Purpose
***Culture and Landscape: Towards a Political Ecology and Etnography of Communities and the Co-Management of Forests in Puerto Rico.* (Torres Abreu 2008);**	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.
***Community and Sustainability: Perception, Appraisal and Utility of Forests in Puerto Rico* (Torres Abreu 2009);**	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.
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 18). 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 18. 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 36. Humfredo Marcano (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 19.

Table 19. 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 20. 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

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