

# Puerto Rico FOREST ACTION PLAN, 2021

Department of Natural and Environmental Resources

Draft

September 23, 2021

# Puerto Rico Forest Action Plan, 2021

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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, Inc. to complete this new section, which constitutes Addendum 1 and is placed at end of this new edition.

Under the 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. This revision includes a comprehensive revision of the Forest Legacy Assessment of Need, included in Appendix B.

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 (in alphabetical order):

Wanda Almodóvar (UPR-RUM)

Thomas Brandeis (USFS)

Cristina Cabrera (DNER)

Carlos Cao (DNER)

Carlos J. Cruz Quiñones (Consultant)

Francisco Catalá (DNER)

Magaly Figueroa (IITF)

William Gould (IITF)

Carmen Guerrero (DNER)

Humfredo Marcano (IITF)

Coralys Ortiz (DNER)

Carlos Paniagua (DNER)

Vicente Quevedo (DNER)

Maya Quiñones (IITF)

Mariana Quiñones Rosado (consultant)

Aixa Ramírez (PRDA)

Ramón L. Rivera Lebrón (DNER)

María Luisa Rivera Vázquez (DNER)

José Salguero (DNER)

Enrique Santiago (DNER)

Marilyn Santiago (USGS)

Sandra Soto Bayó (consultant)

José A. Sustache Sustache (DNER)

Juan G. Colón Rivera (DNER)

Marianela Torres (DNER)

Digna Vázquez (PRFD)

Yohaira Ayala (DNER )

Rosanna Vidal (DNER)

Document revised by: Estudios Técnicos, Inc.

Wanda I. Crespo Acevedo, Planner

Yoana López de Jesús, Planner

Alisa Ortiz Colón, Planner

Roberto Moyano Flores, GIS Analyst

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## Acronyms

ACJV	Atlantic Coast Joint Venture
ACS	American Community Survey
AFP	AFP (Auxiliary Forests Program)
AON	Assessment of Need
ASCEPR	American Society of Civil Engineers Puerto Rico Bureau for the Management of Natural Protected Areas and Forestry Services
BMNPAFS	
°C	Degrees Celsius
CCAP	Coastal Change Analysis Program
CCP	Centro para la Conservación del Paisaje
CFAA	Cooperative Forestry Assistance Act Community Forest and Open Space Conservation Program
CFP	Central Office for Recovery, Reconstruction and Resiliency
COR3	
CPA	Conservation Priority Areas
CRP	Conservation Reserve Program
CRPCP	Coral Reef Management and Conservation Program
CSCOR	Center for Sponsored Coastal Ocean Research
CSP	Conservation Stewardship Program
CWA	Critical Wildlife Areas
CWA	Critical Wildlife Area
DBH	Diameter Breast Height
DNER	Department of Natural and Environmental Resources
DRD	Sport and Recreation Department
DTOP	Department of Transportation and Public Works
EE.UU.	United States of America
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FEMA	Federal Emergency Management Agency
FIA	Forest Inventory Assessment
FLA	Forest Legacy Area
FLAP	Forest Landscape Analysis Project
FLP	Forest Legacy Program
FSP	Forest Stewardship Program
HFRP	Healthy Forests Reserve Program
IBA	Important Bird Areas
IITF	International Institute of Tropical Forestry
in/yr	inches per year
LWCF	Land and Water Conservation Fund
NASF	National Association of State Foresters
NGO	Non-Government Organization
NHP	Natural Heritage Program

NOAA	National Oceanic and Atmospheric Administration
NR	Natural Reserve
NRCS	Natural Resources Conservation Service
PFW	Partners for Fish and Wildlife
PLN	Para La Naturaleza
PNA	Protected Natural Area
PR	Puerto Rico
PRCCC	Puerto Rico Climate Change Council
PRDNER	Puerto Rico Department of Natural and Environmental Resources
PRFB	Puerto Rico Firefighters Bureau
PRFD	Puerto Rico Fire Department
PRGAP	Puerto Rico GAP Analysis
PRIDCO	Puerto Rico Industrial Development Company
PRLUP	Puerto Rico Land Use Plan
PRPB	Puerto Rico Planning Board
PRSWAP	Puerto Rico State Wildlife Action Plan
PRSWAP	Puerto Rico Sate Wildlife Action Plan
PRWFA	Puerto Rico's Waterfowl Focus Areas
RCPP	Regional Conservation Partnership Program
RTCA	Programa <i>Rivers, Trails and Conservation Assistance</i>
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SFAP	State Forest Action plan
SFLA	Southern Forest Land Assessment
SGCN	species of greatest conservation need
S&PF	State and Private Forestry
SLR	Sea Level Rise
SPA	Special Planning Areas
U&CF	Urban and Community Forestry
UPR	University of Puerto Rico
USACE	U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	US Forest Service
USFWS	US Fish and Wildlife Service
USGS	Unites States Geological Survey
4th NCA	4 <sup>th</sup> National Climate Assessment

# 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 B).

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	<ul style="list-style-type: none"><li>Conserve and manage the functional areas of the forest for multiple uses and values.</li></ul>
2: Protect forests from harm	<ul style="list-style-type: none"><li>Identify, manage, and reduce threats to the forest, such as storms, floods, insects, diseases, invasive species and fire.</li></ul>
3: Enhance benefits from trees and forests	<ul style="list-style-type: none"><li>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.</li></ul>

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.

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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 FOREST RESOURCES ASSESSMENT

## A. GENERAL CONTEXT OF PUERTO RICO

### I. GEOGRAPHY

Puerto Rico (PR) is an unincorporated territory of the EE.UU. since 1898. Population is estimated in 3,285,874 people (U.S. Census Bureau 2020). Puerto Rico is part of the Antillean archipelago located between the Caribbean Sea and the Atlantic Ocean (Figure 1). It includes the main island of Puerto Rico, the two populated islands of Vieques and Culebra to the east, Mona and Monito to the west, and Caja de Muertos to the south, as well as and other small islands and cays (Figure 2).

Puerto Rico is roughly rectangular in shape measuring approximately 100 miles or 161 kilometers east to west and 35 miles or 56 kilometers north to south. Puerto Rico's land surface is approximately 8,934 square kilometers (km<sup>2</sup>) or 3,449 square miles (mi<sup>2</sup>) (3,449mi<sup>2</sup>).

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 and reservoirs. Puerto Rico is divided into 78 municipalities.

Figure 1. Location of Puerto Rico



Figure 2. Puerto Rico and main islands



## II. CLIMATE OF PUERTO RICO<sup>1</sup>

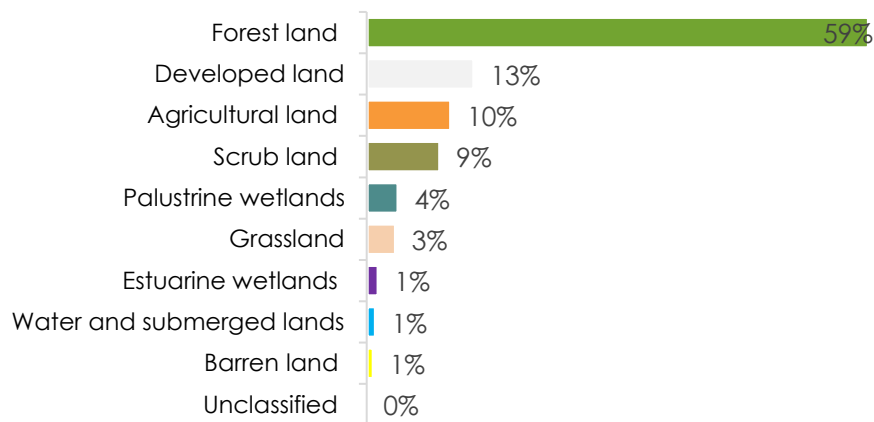
The island of Puerto Rico is divided into two climatologically distinct regions. The northern two-thirds of the island has a relatively humid climate, and the southern one-third of the island is semi-arid. Mean monthly air temperatures vary little throughout the year, ranging from a mean maximum and minimum of 27 and 24 degrees Celsius (°C), respectively in coastal areas; and a mean maximum and minimum of 25 °C and 22 °C in the interior mountainous areas (USGS, nd).

The spatial distribution of rainfall is variable, being greatest in the Sierra de Luquillo rainforest and lowest in southwestern Puerto Rico. In Sierra de Luquillo, the mean annual total rainfall is 169.0 inches per year (in/yr), while in the vicinity of Guánica at Ensenada, the mean annual total rainfall is 30.0 in/yr.

## III. LAND USE AND LAND COVER

Land cover in Puerto Rico consists of 59% forest land, 13% developed land, 10% agricultural land, 9% scrub land, 4% palustrine wetland, 3% grassland, and 1% estuarine wetlands, water and submerged lands and barren lands, respectively, according to the NOAA's Coastal Change Analysis Program (CCAP, 2017). (Figure 3).

Figure 3. Land cover in Puerto Rico



Source: Office for Coastal Management, 2021: C-CAP Land Cover, Puerto Rico, 2010, <https://www.fisheries.noaa.gov/inport/item/48301>. Estimates by Estudios Técnicos, Inc.

<sup>1</sup> Information was obtained from: USGS. Caribbean-Florida Water Science Center. Climate of Puerto Rico. Retrieved from: [https://www.usgs.gov/centers/car-fl-water/science/climate-puerto-rico?qt-science\\_center\\_objects=0#qt-science\\_center\\_objects](https://www.usgs.gov/centers/car-fl-water/science/climate-puerto-rico?qt-science_center_objects=0#qt-science_center_objects)

*Forest land*, which is the main cover (59%), is composed of mixed forest in areas dominated by trees generally 5 meters (16 feet) tall, and greater than 20% of total vegetation cover. In this class, neither deciduous nor evergreen species are greater than 75% of total tree cover. Scrub lands (9%) contains areas dominated by shrubs less than 5 meters (16 feet) tall with shrub canopy typically greater than 20% of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

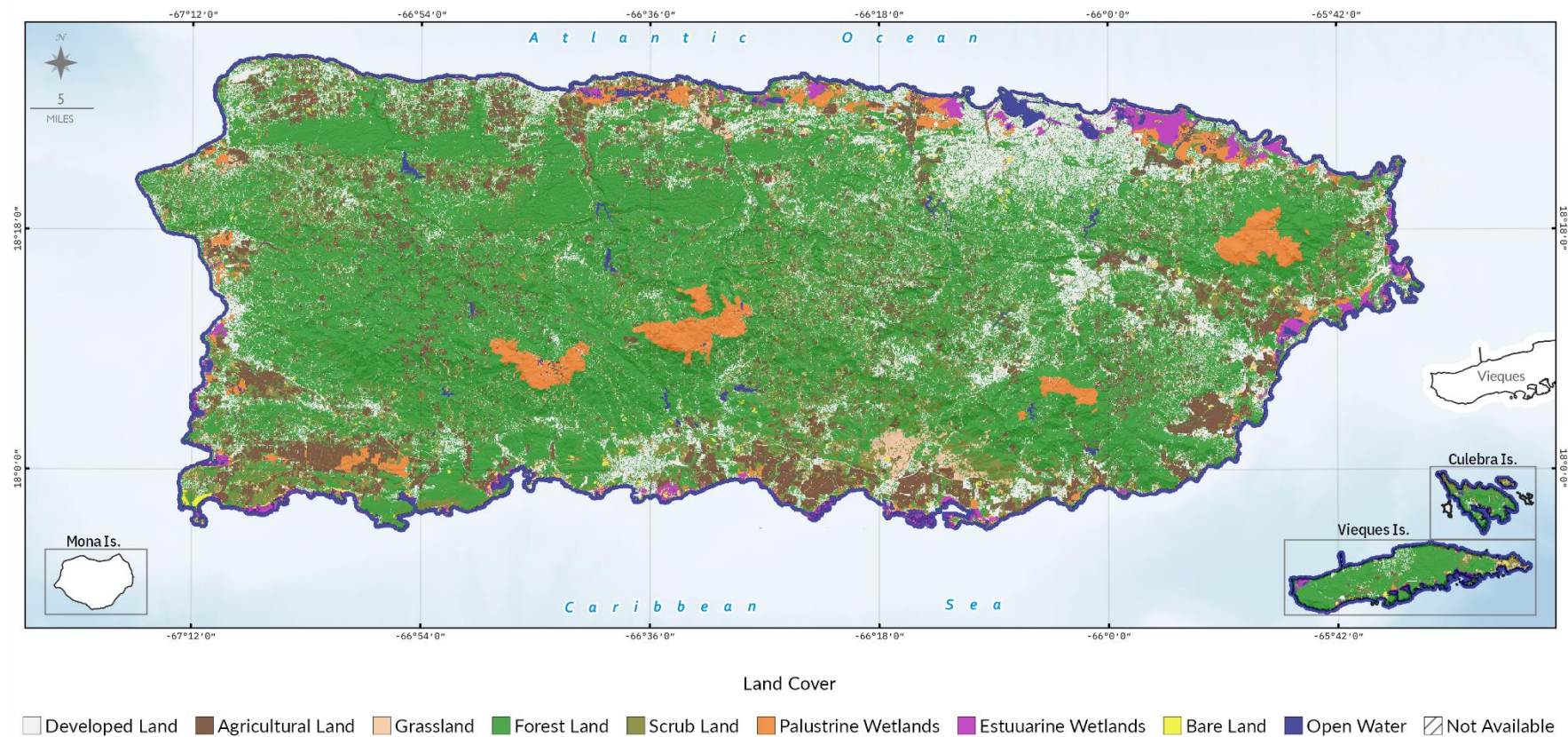
Developed land or impervious surface is the second highest land cover class, encompassing 12.6% of Puerto Rico's land cover. This land cover is higher in coastal communities, where 13.8% of the land is classified as developed and 16.2% of the coastal zone's inland limit (DNER, 2020). The third most abundant land cover in Puerto Rico is the agricultural land (10%). These are lands intensively managed to produce crops or is covered by grass or hay. Refer to Appendix 1 for more information on Puerto Rico's land cover.

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*Forest land, scrub land, palustrine wetlands, and estuarine wetlands account for 73% of Puerto Rico's land cover.*

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Figure 4. Land Cover in Puerto Rico (CCAP, 2017)



Source: C-CAP Land Cover, Puerto Rico, 2010-Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office for Coastal Management

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## B. CURRENT CONDITIONS AND BENEFITS OF FORESTS

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### I. FOREST COVER: PAST AND PRESENT

In Puerto Rico, forest cover has varied greatly over the past centuries. 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).

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.

The land use pattern during these several centuries of agricultural development was similar to that of other tropical countries. At the end of the 15th century, forests were the dominant vegetation on the island. Of the total 2,199,236 acres, about 2,100,394 acres (95%) were forest (Wadsworth, 1950). In subsequent centuries, the forest cover was gradually reduced by the increase in the use of wood by European settlers and by agricultural practices, which were mostly subsistence. In 1828 there were 1,450,507 acres in forest use and by 1899 it had been reduced to 449,731 acres (20% of the island) (Wadsworth, 1950).

The introduction of sun-grown coffee (*Coffea arabica*) cultivation in 1736, and other monocultures required the clearing of steeper slopes into the then heavily forested mountains. Production of coffee increased rapidly after 1755 and soon became an important product to be exported. By 1899 more than three quarters of Puerto Rico had been deforested, and forest cover reduced to 449,731 acres. Pasture accounted for about 490,000 ha and coffee production occupied 190,271 acres (Wadsworth, 1950).

Coastal forests have also been impacted by agriculture, especially sugar cane monoculture. This not only led to land clearing but also to hydromodifications that altered the vegetation cover and species composition. A significant decline in mangrove forests has been documented due to conventional

agricultural activities (1800–1940) and later between the 1960s and 1970s due to urban expansion (Martinuzzi, Gould, Lugo & Medina, E. 2009).

During the past decades, mangrove forests experienced an increase in area while palustrine forests, such as bloodwood swamps or *Pterocarpus* forests, have been reduced and fragmented, leaving only a few remnants across the island (Martinuzzi, Gould, Lugo & Medina, E. 2009; Feagin, Toledo-Rodríguez, Colón-Rivera, Smeins, & Lopez, 2013).

Early in the 20<sup>th</sup> century, forests covered only about 20% of the island, but only one-third of forest land could yield wood products other than charcoal or fuelwood (Murphy, 1916 as cited in DNER, 2000). In that period, what was considered the most remote and marginally productive lands remained uncultivated. Additional pressure on land resources resulted from other reasons such as increasing population and expanding production of export crops. Fluctuating economic conditions was another factor, since people were forced to subsistence agriculture during periods of high unemployment, encroaching on the remaining lands in the interior (Birdsey and Weaver, 1982).

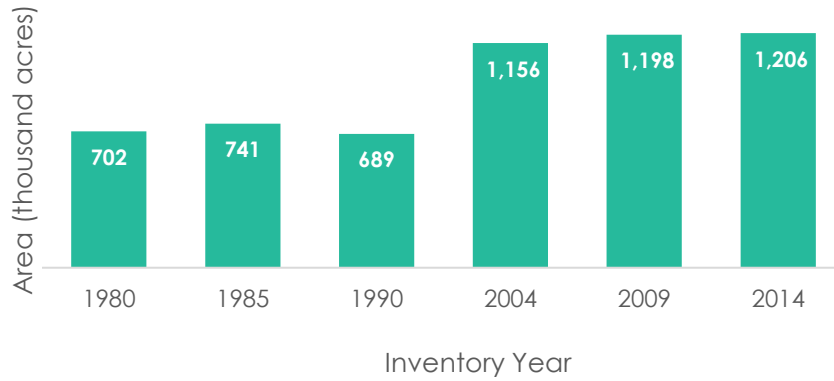
During the late 1940's the forest area declined to only 6% of the total land area of Puerto Rico. Cropland<sup>1</sup> and pasture each accounted for about 42%, with the remaining 10% in buildings, roads and wasteland (Koenig, 1953, as cited in Birdsey and Weaver, 1982). In that period, Puerto Rico became one of the most severely deforested and eroded regions in the world (Birdsey and Weaver, 1982).

After World War II wide-spread industrialization began under a program called Operation Bootstrap. The island's industrialization efforts resulted in an exodus of population from the central mountains to the coastal plains. 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 5. Forest cover remained relatively constant between the 1980 and 1990 inventories and then increased dramatically between the 1990 and 2004 inventories. In 1980, forest cover was 31.3%, and in 2004 was 52.8% (Marcano-Vega, 2017). The 2014 Forest Inventory Assessment (FIA) documented a phase of forest cover

steadiness in Puerto Rico since 2004.<sup>2</sup> This inventory reported a forest area of 1,172,439 acres in 2014 (54.8%). Total forest cover on Vieques was estimated at 77.1% (26,759 acres) and Culebra 91.1% (7,119 acres)(Marcano-Vega, 2017).

**Figure 5. Forest area of mainland Puerto Rico as measured by forest inventories in 1980, 1985, 1990, 2004, 2009 and 2014**

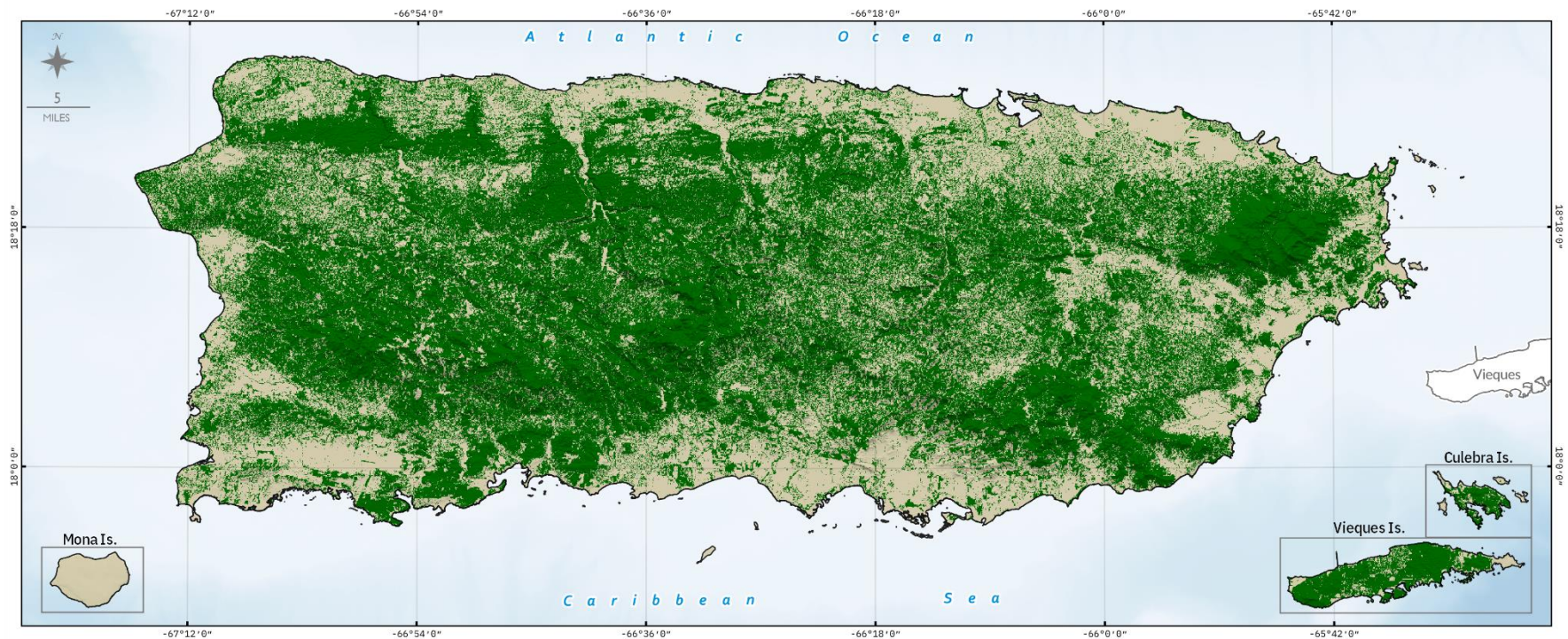


Source: Forest area of mainland Puerto Rico as measured by forest inventories in 1980, 1985, 1990, 2004, and 2009 (Brandeis, T. J. and J. A. Turner. 2013; Marcano Vega, 2017).

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<sup>2</sup> According to Marcano-Vega (2017), forest cover on mainland Puerto Rico has remained stable because such small changes are encompassed within sampling errors.

Figure 6. Forest cover in Puerto Rico, Vieques and Culebra (CCAP, 2017)



■ Forested Land Cover (includes Mixed Forest and Palustrine Forested Wetland)

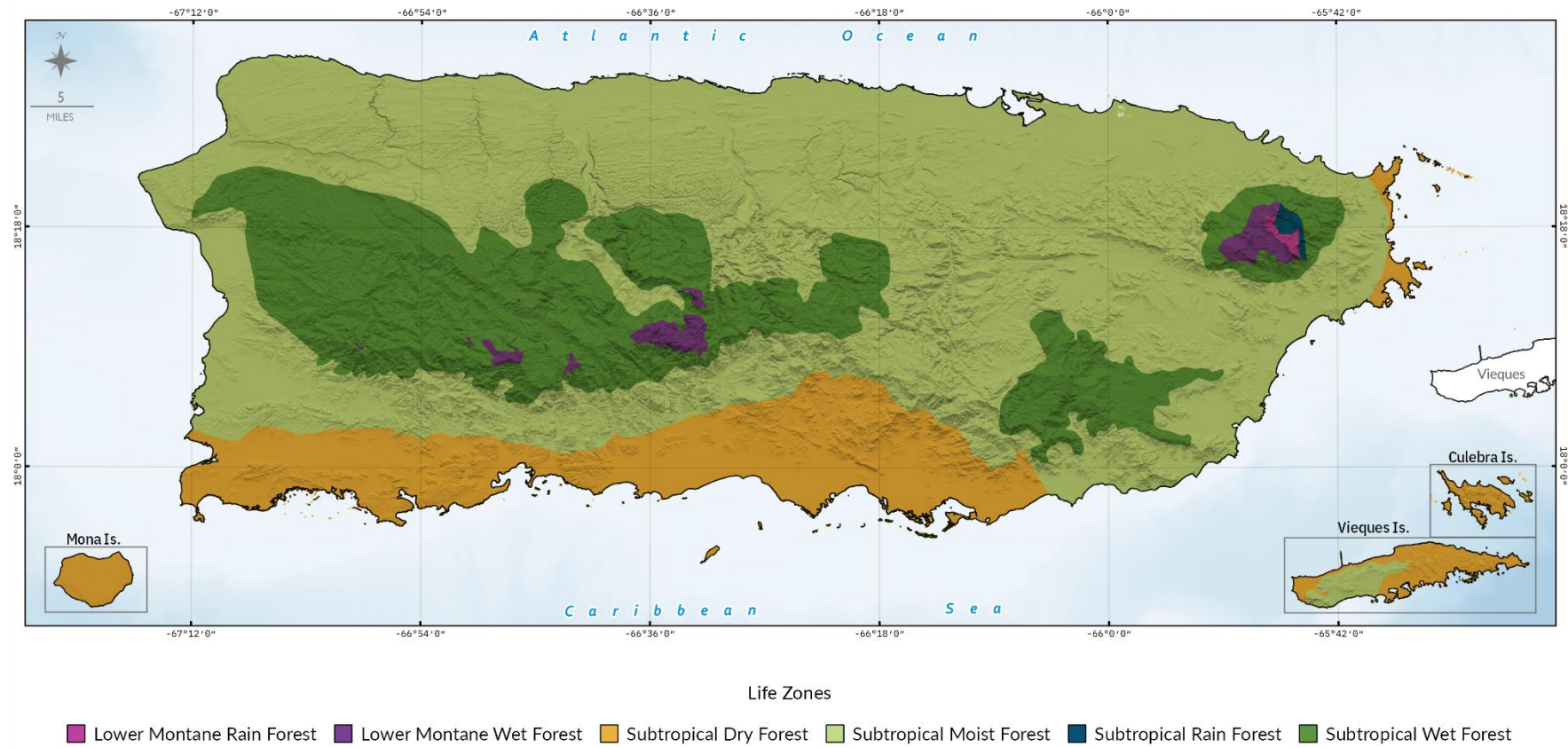
Source: C-CAP Land Cover, Puerto Rico, 2010-Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office for Coastal Management

## II. FOREST COMPOSITION AND STRUCTURE

Puerto Rico forests are extremely diverse for a landmass the size of the island (Miller & Lugo, 2008). Puerto Rico forests are commonly described using the Holdridge life zone classification system. Six life zones have been described for Puerto Rico, which include: subtropical dry, lowland moist, subtropical wet, lower montane wet, subtropical rain, and lower montane rain forest zones (Gould et al, 2008), Figure 7.

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 7. Land distribution among the Subtropical Forest life zones of Puerto Rico, Vieques, Culebra, and Mona Islands



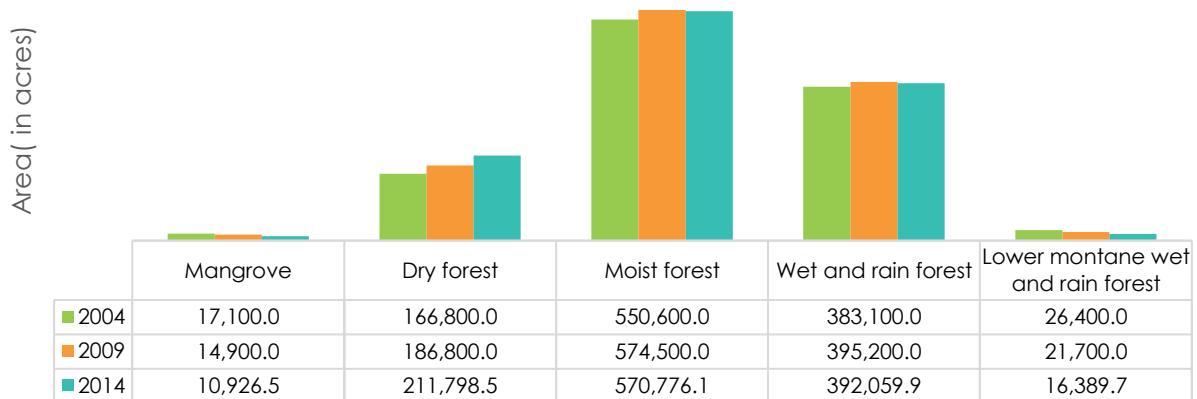
Source: Ewel & Whitmore, 1973

### 1. Forest area by forest type group

The moist forest is the dominant life zone in Puerto Rico as shown in Figure 8. Even when forest cover steadiness is observed, there have been land use changes that included deforestation in some areas, while natural forest regeneration occurred in others (Marcano-Vega, 2017).

The 2014 FIA showed changes in the acreage of forest types that are representative of coastal forests. There is a minor increase in the subtropical dry forest life zone, being 211.8 thousand acres, but a reduction in the mangrove coverage, in relation to the past assessments.

**Figure 8. Area of forest land/timberland per forest-type group/forest-types, Puerto Rico (2004, 2009 and 2014)**



Source: Table 998.1—Area of forest land/timberland per forest-type group/forest-types, Puerto Rico (Mainland, Vieques, Culebra). Inventory years: 2003, 2009 and 2014.

### 2. Forest composition and structure

Small-diameter stands are the largest area of forests in Puerto Rico, covering 41.7%. However, during the 2004-2014 period, forest area characterized by stands dominated by small diameter trees showed a decreasing trend, being 50.5% in 2004 (Marcano-Vega, 2017).

The 2014 FIA also reported slight maturity processes in forest regeneration. There is an increase in the area covered by stands with canopies dominated by medium and large diameter trees. In addition, there is a decrease in forest cover of small-diameter

stands (4 percent), along with an increase in medium-diameter stands and in large-diameter stands (of about 3 percent and 1 percent, respectively). The 2014 FIA indicated that these trends would allow to lay a foundation for the temporal state of Puerto Rican forest stand structure prior to the events of the 2014-2016 droughts and 2017 hurricanes.

The 2014 FIA found an increase in total net volume and total aboveground biomass in trees within dominant forest types, which is indicative of more mature stages of development within secondary forests (Marcano-Vega, 2017). However, this was collected prior to the occurrence of hurricanes Irma and María.<sup>3</sup>

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). There are 349 both native and introduced species that cohabit in the forests of Puerto Rico. The introduced African tulip tree (*Spathodea campanulata*), and natives guaraguao (*Guarea Guideria*) and yagrumo (*Cecropia schreberiana*) account for the highest biomass storage (Marcano-Vega, 2017).

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. 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.

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<sup>3</sup> Refer to section C-iv for more information on the impacts of hurricanes Irma and María on Puerto Rico's forests.

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

Satellite image mapping zone <sup>4, 5</sup>	Woody vegetation formations <sup>2</sup>
Dry forest-Alluvial	Lowland dry semi-deciduous forest or woodland/shrubland Tidally and semi-permanently flooded evergreen sclerophyllous forest
Dry forest <sup>6</sup> -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 <sup>7</sup>
Moist forest with rainfall<1500 mm yr <sup>-1</sup> Northern Limestone <sup>8</sup>	Lowland moist semi-deciduous forest or forest/shrub
Moist forest with rainfall>1500 mm yr <sup>-1</sup> - Northern Limestone <sup>5</sup>	Lowland moist and wet, seasonal evergreen and semi-deciduous forest and forest/shrub
Wet and lower montane wet forest-Serpentine	Submontane and lower montane wet evergreen sclerophyllous forest or forest/shrub <sup>9</sup>

<sup>4</sup> 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.

<sup>5</sup> 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.

<sup>6</sup> The Dry Volcanic/Sedimentary/Limestone Zone included southern limestone areas in the drier part of the moist forest zone.

<sup>7</sup> Coastal areas in southeastern Puerto Rico

<sup>8</sup> Northern Limestone refers to limestone areas north of the Central Cordillera with well-developed karst topography and areas at the Cordillera's southern edge.

<sup>9</sup> Includes forest in the rain forest zone sensu Holdridge (1967).

Satellite image mapping zone <sup>4, 5</sup>	Woody vegetation formations <sup>2</sup>
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 <sup>10</sup> -tall cloud forest Lower montane wet evergreen forest <sup>7</sup> -palm and elfin cloud forest Lower montane wet evergreen forest-elfin cloud forest

a. Wetlands

Wetlands are natural areas defined by their hydrology, soil and vegetation (Cowardin et al. 1979). According to the CCAP, palustrine and estuarine wetlands cover 111,692 acres in Puerto Rico, as shown in

Figure 10.

Palustrine wetlands include palustrine forested wetlands and palustrine scrub/shrub wetland.<sup>11</sup> Both account for 4% of the island’s forest cover. The palustrine forested wetlands include tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters (16 feet) in height. The palustrine scrub/shrub wetland includes tidal and non-tidal wetlands dominated by woody vegetation less than 5 meters (16 feet) in height. Species present could be shrubs, young trees and shrubs or trees that are small or stunted due to environmental conditions.

A palustrine coastal wetland of particular interest in Puerto Rico is the blood wood forest (*Pterocarpus officinalis*). The largest of the remaining bloodwood forests in Puerto Rico is in the coast of Humacao, protected as a Nature Reserve. Other remnants are in Humacao, Dorado, Mayagüez, and much smaller stands in other areas of Puerto Rico. Other palustrine forested wetland

<sup>10</sup> Includes forest in the lower montane rain forest zone sensu Holdridge (1967).

<sup>11</sup> The Palustrine Emergent Wetland was not considered as part of the forest cover discussed in this section, but values are included in the following table.

types include the cloud forest, colorado forest, and palm forest on the high mountain slopes (USGS, 1996). Palustrine forested wetlands are found in El Yunque National Forest and in other high and humid areas in Puerto Rico.

Estuarine wetlands represent 1% of the island's land cover. These are constituted by estuarine forested wetlands and estuarine scrub/schrub wetlands, each with total vegetation coverage greater than 20%. The estuarine forested wetlands include tidal wetlands dominated by woody vegetation greater than or equal to 5 meters (16 feet) in height, occurring in tidal areas with salinity equal to or greater than 0.5%. The estuarine scrub/schrub wetlands include tidal wetlands dominated by woody vegetation less than 5 meters (16 feet) in height, and wetlands in tidal areas with salinity equal to or greater than 0.5%.

The most extensive estuarine wetlands in Puerto Rico are the mangrove forests (forested or scrub-shrub wetlands). 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*).

Mangrove forests are particularly important coastal forests due to the variety of functions and benefits they provide (DNER 2010). These forests 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. Plant species in this type of forest have aerial roots, floating seeds, and specialized structures called lenticels and pneumatophores that allow the entrance of oxygen and the exit of carbon dioxide.

The largest mangrove stand in Puerto Rico is in the municipality of Loíza, most protected under the Piñones State Forest-Nature Reserve. There are other important mangrove areas in the east, west and south coast. Mangrove forests along the southern coast are subject to drier climatic conditions, generally in association with salt flats (USGS, 1996).

In the first inventory of mangroves, mandated by the 1870 "Land Act", some 29,134 acres were counted. An inventory done in 1972 found that the mangrove population had been reduced

to 17,480 acres. 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 16,556 acres of mangroves (Gould 2007).<sup>12</sup>

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 9).

**Figure 9. Changes in mangrove forest cover in Puerto Rico over the last 200 years (Martinuzzi et al. 2009) Reprinted with permission.**

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<sup>12</sup> 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.

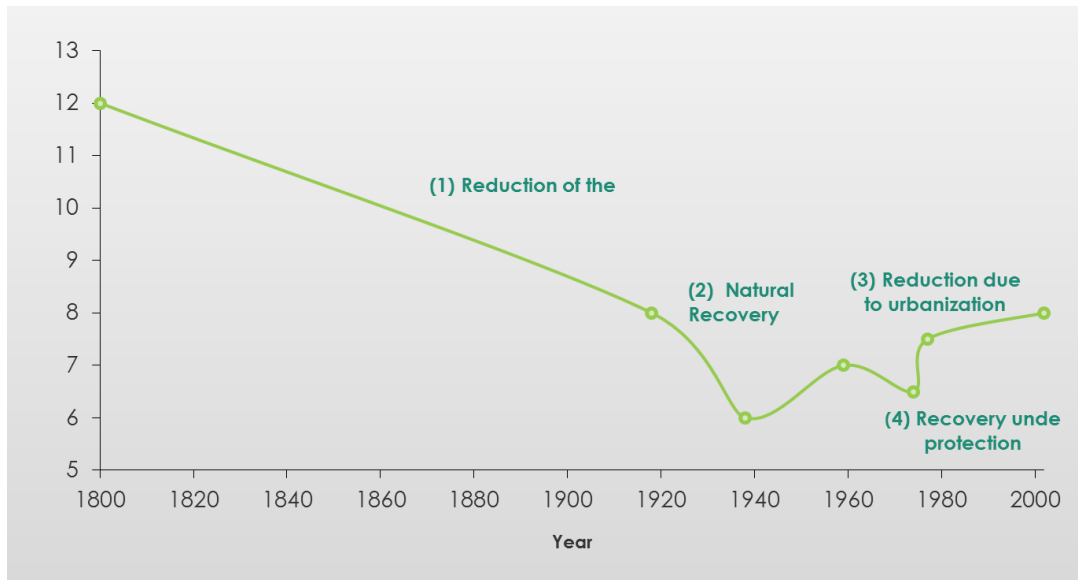
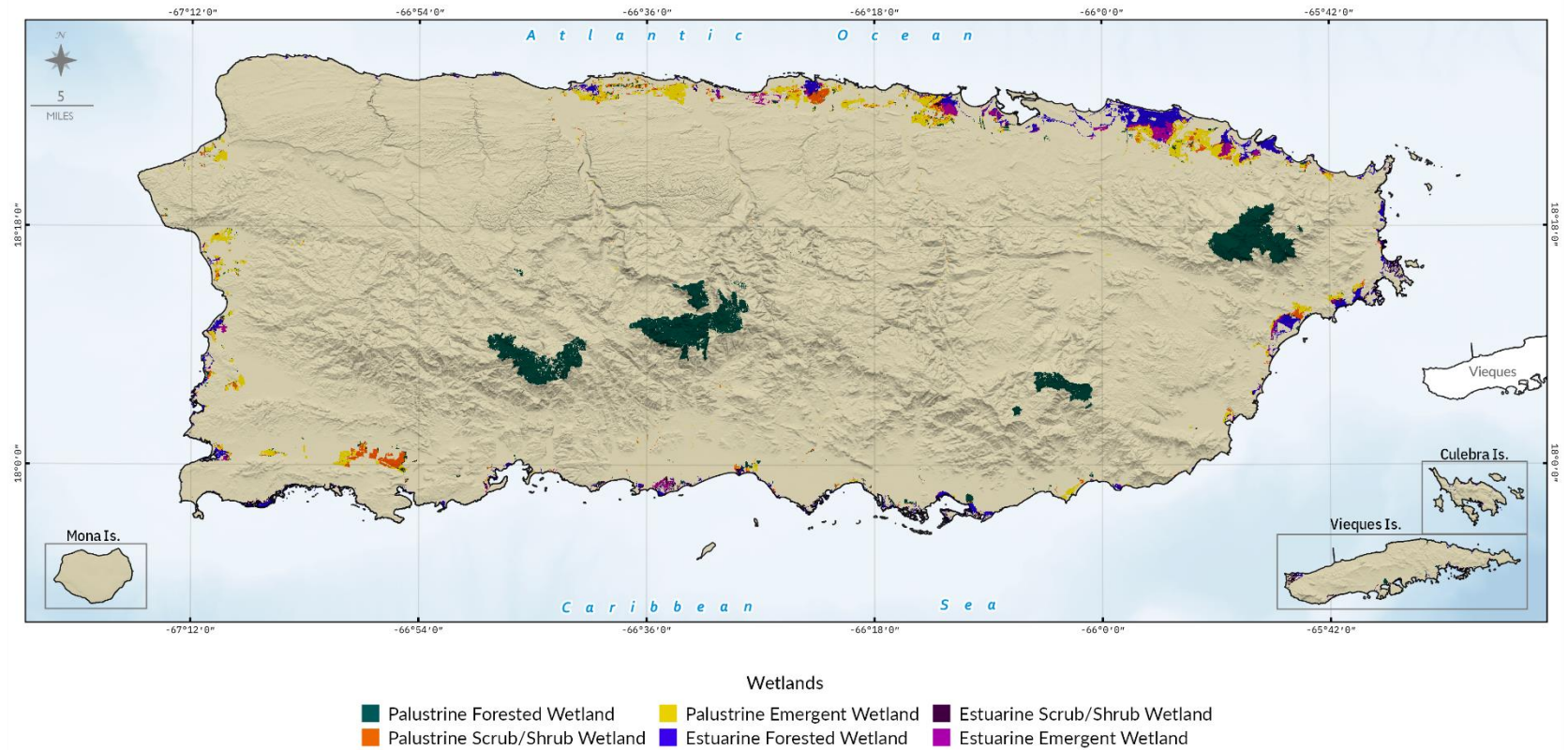
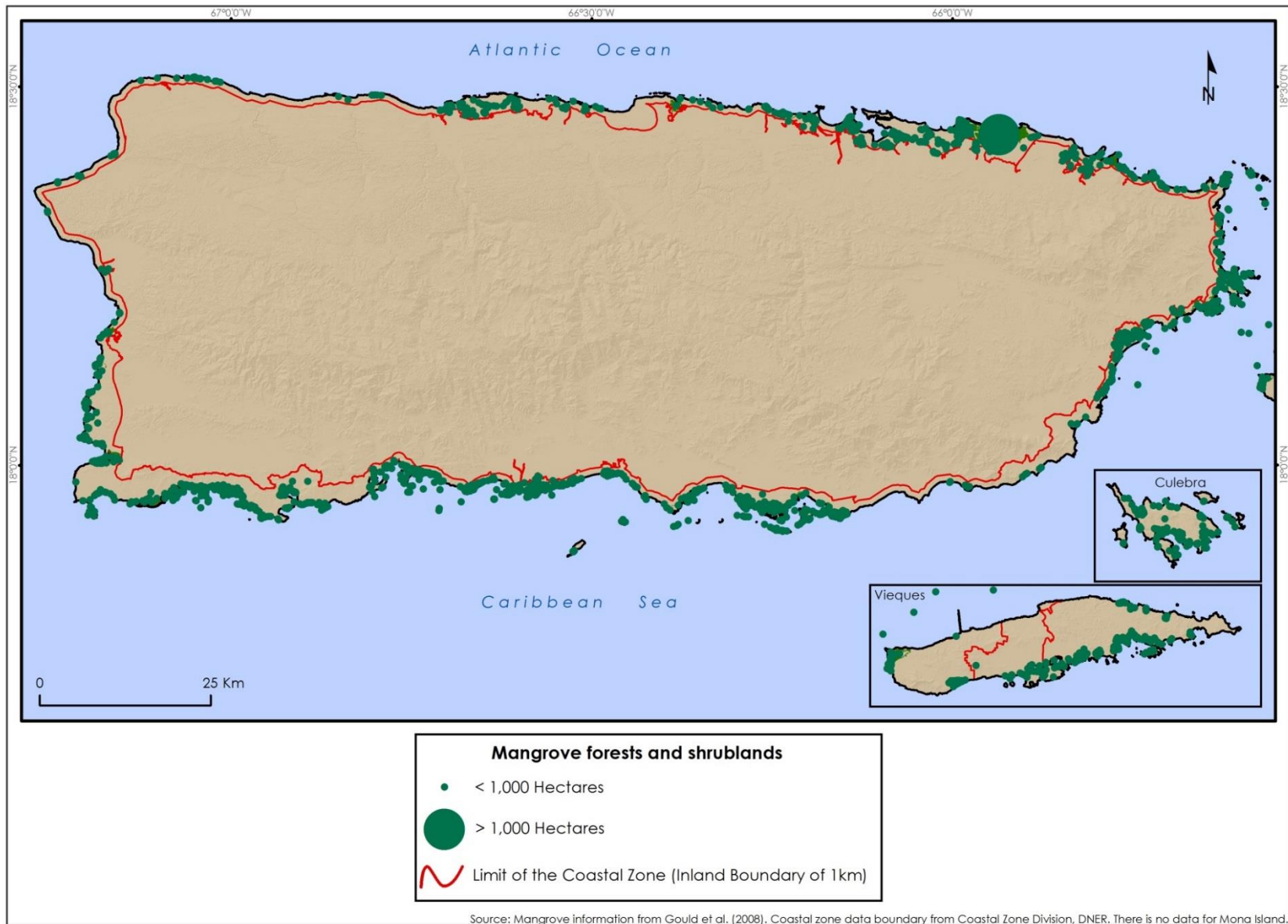


Figure 10. Palustrine and Estuarine wetlands in Puerto Rico (CCAP, 2017).



Source: C-CAP Land Cover, Puerto Rico, 2010-Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office for Coastal Management

Figure 11. Location of mangrove forests in Puerto Rico, Vieques, and Culebra.



*b. 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.

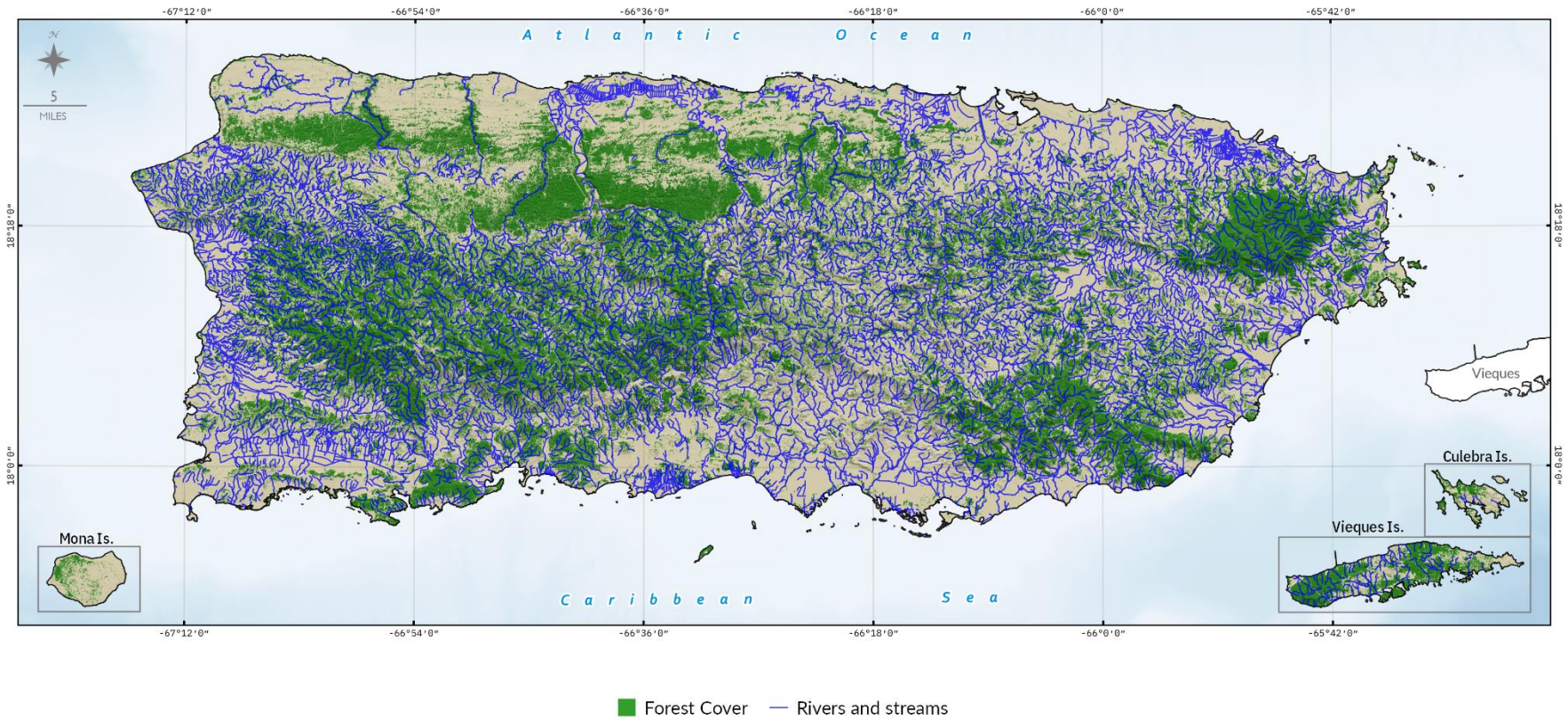
Streamside forests are important riparian areas. Under natural conditions these forests would protect most of the rivers and streams, but deforestation associated with agricultural and urban expansion has drastically reduced their extent. In agricultural areas, many floodplain forests have been reduced to isolated fragments no longer capable of supplying the river with essential woody debris or an adequate organic food supply for healthy fisheries. The linkage between streamside forests and the health of fish stocks may stretch to ocean fisheries where the natural process of delivering 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 (Welsch 1991). 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). 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 12). Agricultural runoff is one type of nonpoint pollution that can be reduced by using streamside forests as buffers.

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 (Sweeney 1993). Restoring streamside forests may be a 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).

Figure 12. Overview of riparian areas in Puerto Rico, Vieques and Culebra



Source: Forest Cover modified from Gould et al. (2008); Rivers and Streams from National Hydrography Dataset, USGS, (2019).

c. 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.

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 (NUCFAC 2008).

**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 <sup>2</sup> (390 people/ km <sup>2</sup> ) plus surrounding census blocks with at least 500 people/mi <sup>2</sup> (195 people/km <sup>2</sup> )
Urban sprawl	40%	Low-density construction and areas with significant land consumption.

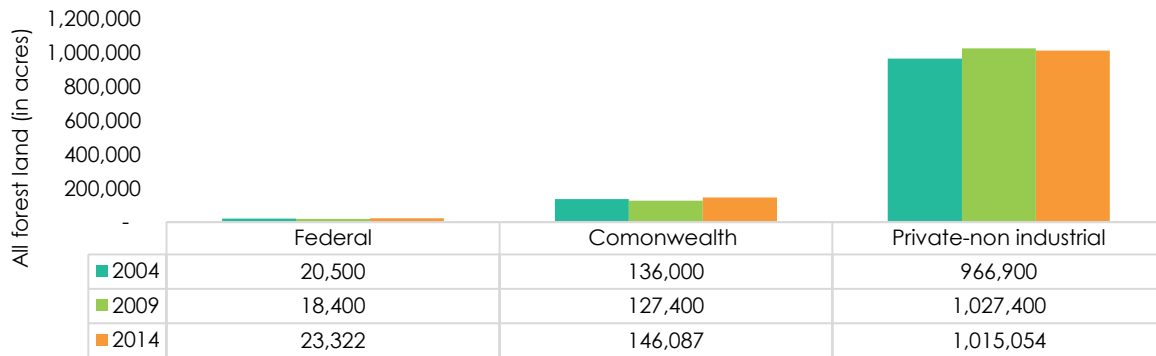
Source: Martinuzzi, S., W. Gould, and O. M. Ramos. 2007. Land development, land use and urban sprawl in Puerto Rico integrating remote sensing and population census data. *Landscape and Urban Planning* 79: 288-297.

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).

### 3. Forest ownership

According to the 2014 FIA, most of the forested lands in Puerto Rico are under private ownership. Approximately 83% of forested lands in Puerto Rico, including Vieques and Culebra, are in private hands, the Commonwealth government has custody of about 13%, and federal agencies have custody of about 4% (Marcano-Vega, 2017).

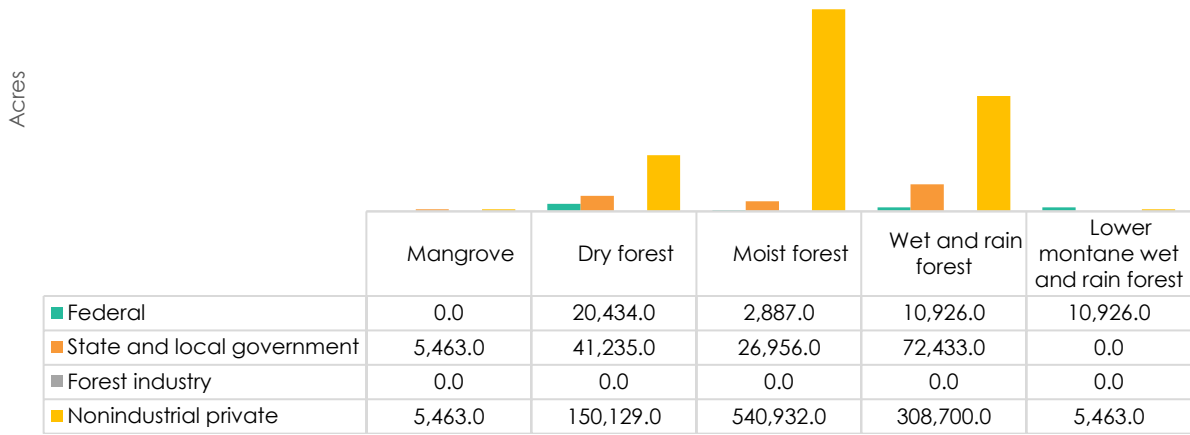
**Figure 13. Area of forest land by ownership class and land status, Puerto Rico (Mainland, Vieques, Culebra), 2004, 2009 and 2014**



Source: Table 2—Area of forest land by ownership class and land status. Forest Inventory years: 2003, 2009 and 2014. Marcano-Vega, Humfredo. (2017). Forests of Puerto Rico, 2014.

Marcano-Vega (2014) found that there are noticeable differences in the types of forest representativeness by tenure. For example, about 5% of the humid forest (10,909 ha out of a total of 230,985 forested ha) is managed by the Commonwealth through the DNER and other agencies. While 67% of the very humid/low montane rain forest area (4,422 ha of 6,633 ha forested) is owned by the federal government, as part of El Yunque National Forest.

**Figure 14. Area of forest land by forest-type and ownership group, Puerto Rico, Vieques and Culebra, 2014**



Source: Marcano-Vega, Humfredo. (2017). Forests of Puerto Rico, 2014.

### III. IMPACTS OF HURRICANES IRMA AND MARIA ON PUERTO RICO FORESTS

After the most recent FIA, Puerto Rico was impacted by two consecutive hurricanes. In 2017, Hurricanes Irma and María made landfall in Puerto Rico, the latter being the worst natural disaster in the island's recent history. Hurricane María, a category 4 hurricane on the Saffir-Simpson scale (Pasch, 2017), caused major disturbances across the island's forest ecosystems (Resetar et al., 2020).

María caused extensive damage by uprooting trees, defoliating forest canopy, and depositing massive amounts of litterfall (Hosannah et al., 2020). Preliminary estimates suggest that Hurricane María caused mortality or severe damage to 23 - 31 million trees (Feng et al., 2018).

Rapid assessments made after the hurricane, demonstrated that 75% of significantly impacted wetlands were stressed mostly due to debris, tree defoliation, disease, damage, and changes in hydrology (COR3, 2018). An assessment of five urban coastal forested wetland sites found an overall mangrove mortality of 53%, with some sites reporting over 90% of dead mangrove habitat (Branoff, n.d.).

A research that compared data of tree damage in the same forest in Puerto Rico after hurricanes Hugo (1989, category 3), Georges (1998, category 3), and María (2017, category 4), found that María killed twice as many trees as Hugo, and broke 2- to 12-fold more stems than the other two storms for all but two species (Uriarte et al., 2019, p. 2).

Among forests, higher disturbance was observed in sierra palm, transitional, and tall cloud forests; seasonal evergreen forests with coconut palm; and mangrove forests (Feng et al., 2018). This last ecosystem is a vital resource, as it not only acts as a natural barrier that protects communities, but it also receives influx from mountain forests via watershed processes, which results from and interacts with hurricane effects (López-Marrero, 2019).

Both hurricanes, Irma and María, reduced a quarter of the biomass contained in Puerto Rico's trees (Krajick, 2020; Hall et al 2020). The study concluded that storm-related rainfall, including soil water storage capacity, caused more forest damage than maximum wind speeds (Hall et al., 2020).

Forest damage across the island also contributed to a loss of ecosystem services, including reductions in species diversity, habitat for animal species, water quality and storm water runoff control, land stabilization, urban heat island effect mitigation, recreation, as well as economic opportunities.

Urban forests were assessed focusing on changes in ecosystem services provided in the municipalities of San Juan, Ponce, and Mayagüez. It was found that tree cover declined by nearly 25% in San Juan, approximately 6% in Ponce, and approximately 4% in Mayagüez (Meléndez-Ackerman, 2018 as cited in Resetar, 2020). Loss of ecosystem services included: air pollution removal, carbon storage, and carbon sequestration.

In the municipality of San Juan, specifically in the Santurce Peninsula Meléndez-Ackerman (2018) estimated a 39% tree cover loss, causing a reduction in pollution removal of 45%, valued at \$42,600 loss per year; a reduction in carbon sequestration of 24% per year, with an estimated loss of \$790,000; a decreased in oxygen production by 13 % with a loss of \$29,000 per year; and avoided runoff by 49%, with a loss of \$162,000 per

year. The assessment found that overall replacement costs for trees were estimated at \$4.8 million.

At the Río Piedras watershed Meléndez-Ackerman also assessed the impacts of hurricane María in 69 residential yards and found a 27% loss in the number of trees. Ecosystem services were reduced at 26% for pollution removal, 15% for carbon storage, 48% for carbon sequestration, 32% for oxygen production, 39% for avoided runoff, and a 67% for loss in the structural value of the tree cover (Resetar, 2020).

In the aftermath of hurricane María, there was an unprecedented volume of down, dead, and damaged timber in Puerto Rico (Resetar, 2020). It is estimated that 1.74 million cubic meters (about 60%) of all debris was vegetative material.<sup>13</sup> There were thousands of logs with economic value that were lost. The USACE estimated that there were approximately 45,000 logs, considering that there was one valuable log per 50 cubic yards of vegetative debris collected, but there were more not documented on lands that were not part of the USACE's vegetation removal activities (Resetar, 2020). Unfortunately, valuable hardwoods were mixed with general debris and ended in landfills.

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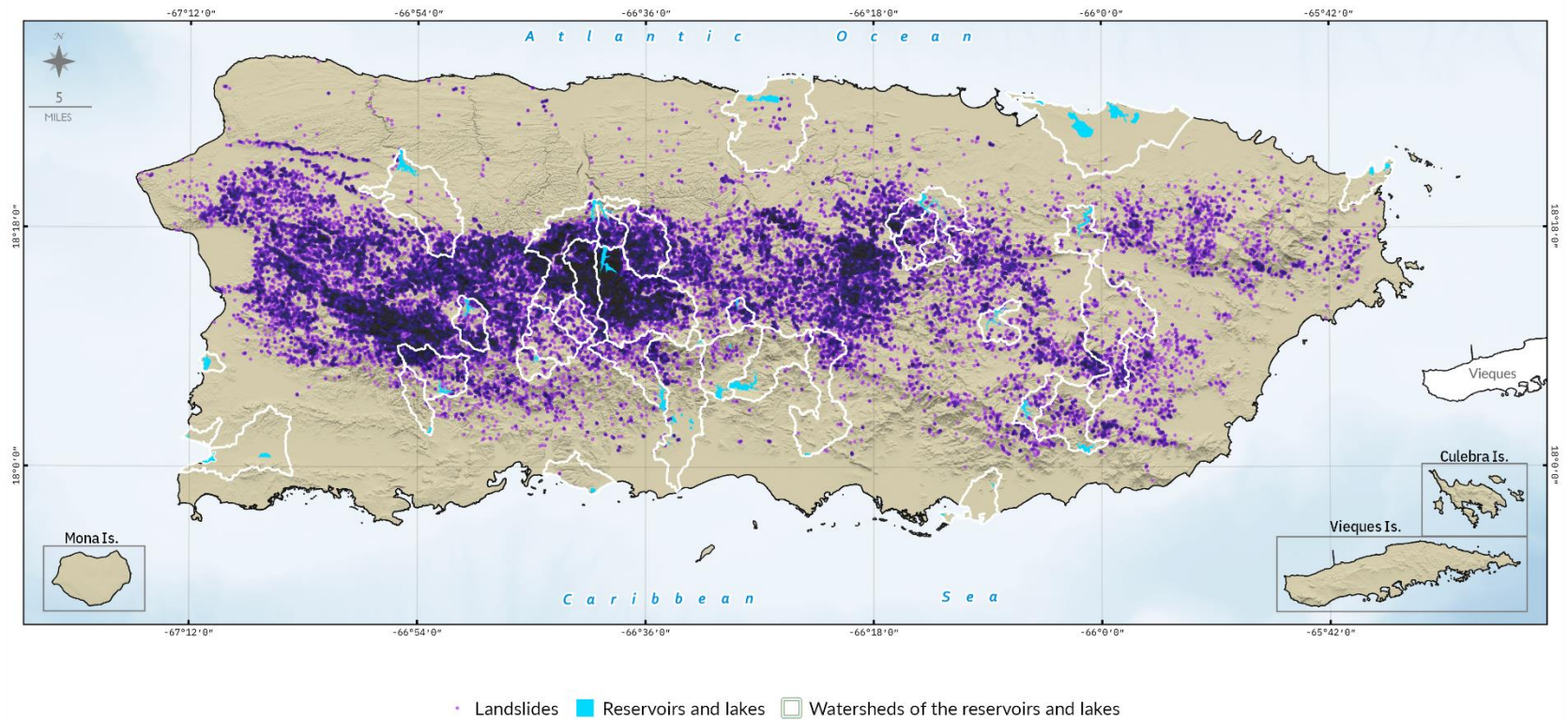
<sup>13</sup> The USACE estimates that there were 2.91 million cubic meters of debris, which included vegetative materials, among other.



**Figure 15. Almost 60% of all debris collected in the aftermath of hurricane Maria was vegetative material**

Hurricane María also triggered more than 40,000 landslides in Puerto Rico. According to a USGS report, the number of landslides that occurred during this hurricane was two orders of magnitude greater than those reported from previous events. Figure 16 shows landslides associated with hurricane María in relation to the main reservoirs in Puerto Rico. A high concentration of landslides occurred in the Caonillas and Dos Bocas reservoirs watershed, which, as previously indicated, are an important source of water in Puerto Rico. Management strategies, including reforestation would be required to restore and enhance these areas to protect these sources of water.

Figure 16. Landslides associated with hurricane María and Puerto Rico's reservoirs



Source: Landslides from Map of slope-failure locations in Puerto Rico after Hurricane María, USGS,(2019); Watersheds and Reservoirs from OPA, DNER.

Hurricane Maria also caused extensive damage to the protected natural areas forests and infrastructure. Preliminary assessments documented forest canopy damage, in addition to blocked trails and roads, and damaged infrastructure and recreational facilities (Resetar, 2020).



**Figure 17. Wetlands in the Punta Tuna Nature Reserve were severely destroyed by hurricane Maria**

Hurricane María also damaged the 14 tree nurseries that existed in Puerto Rico, of which 11 are public and three are operated by Para La Naturaleza, a local NGO. DNER nurseries include Cambalache, Los Caños, Arecibo, Mayagüez, Ponce, and Guayama.

The Cambalache nursery, which is the largest in the DNER, experienced damages on its seedling protection structures (hoop houses and coverings), and in the ground irrigation, caused by debris. Also equipment was damaged and seed storage system was destroyed because of electricity loss (Resetar, 2020). Damages severely limited the tree nursery capacity to support an island wide tree planting efforts (Resetar, 2020).

#### IV. LAND CONSERVATION AND MANAGEMENT IN PUERTO RICO

Spain recognized the importance of forests and forest products. During the last quarter of the 19<sup>th</sup> 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 DNER's administration. 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. Puerto Rico's land surface is approximately 8,934 square kilometers (km<sup>2</sup>) or 3,449 square miles (mi<sup>2</sup>) of which 16.1% is protected by the Commonwealth and federal governments, and local Non-Government Organizations (NGOs) (Castro-Prieto et al., 2019). There are 159 terrestrial protected areas in Puerto Rico, of which 90% are public and 10% are privately owned by NGOs<sup>1</sup> or individuals (Castro-Prieto et al, 2019).

Commonwealth protected areas include in addition to state forests, nature reserves, wildlife refuges, natural corridors, and national parks, which are administered by the DNER. Federal protected natural areas include El Yunque National Forest and other lands owned by the USDA Forest Service (USFS), and five national wildlife refuges, administered by the US Fish and Wildlife Service (USFWS).

Not all protected lands are publicly owned. It is estimated that only 4% (357 square kilometers or 138 square miles) are owned by the DNER, USFS, USFWS, and private conservation NGOs

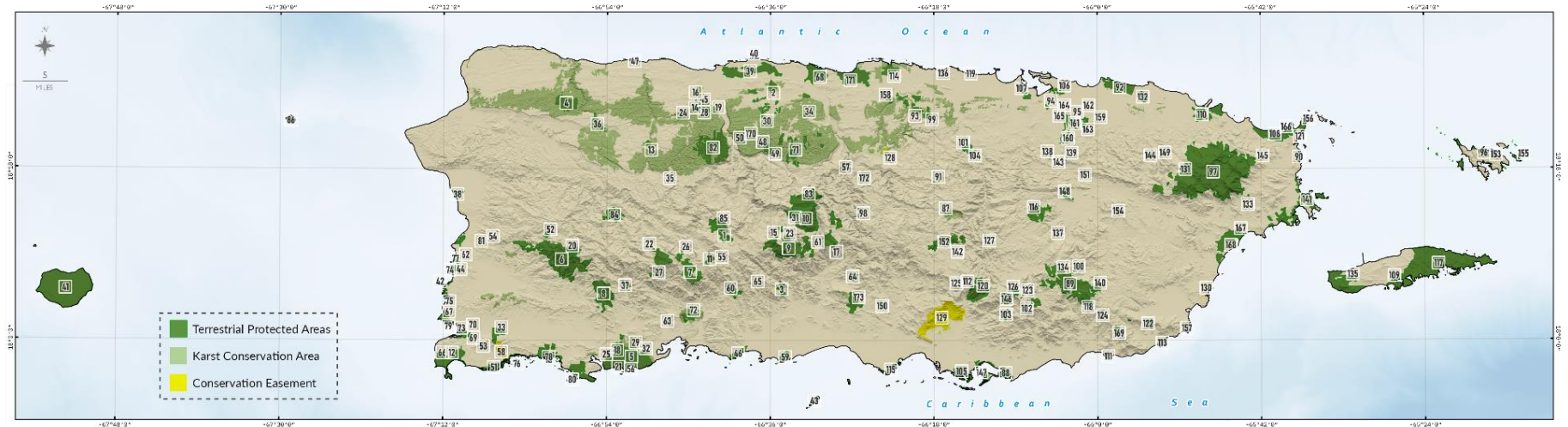
(Castro-Prieto et al., 2019). The rest of the protected lands are either privately owned or are owned by public corporations such as the Puerto Rico Industrial Development Company, Lands Authority, the University of Puerto Rico, the Puerto Rico Electric Power Authority (PREPA), among other entities.

The following map shows the terrestrial protected areas. Overall, protected areas are scattered and fragmented not only in the FLA, but throughout the territory. Management plans for many protected 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).

A spatial assessment of key biodiversity areas inside and outside the current network of protected areas in Puerto Rico estimated that 70% of the protected natural areas in Puerto Rico encompass high or very high landscape diversity associated with an expected high diversity of habitats and species, despite their relatively small size (Castro Prieto et al., 2016).

These researchers analyzed forest structure in protected areas to estimate forest quality as forests are the main habitat for most terrestrial species in Puerto Rico (Gould et al. 2007, as cited in Castro-Prieto 2016). Forests were classified according to their coverage and their relevance for planning purposes. Forests classified as core are the focus class for biodiversity conservation and are the least fragmented. These occupied 3,412.96 km<sup>2</sup> in Puerto Rico, of which 16% (543.74 km<sup>2</sup>) were in protected areas (Castro Prieto et al., 2016). This was the most abundant class in protected areas and accounted for 91.74% of the total protected forest area. Other abundant classes were edge (forests in the outer core area, where some species prefer to dwell in the foreground/background interface); and perforation (forests similar to edges, but correspond to the inner boundary of the core, these perforations inside core habitat are a sign of fragmentation).

Figure 18. Protected Natural Areas in Puerto Rico (Federal, Commonwealth, Municipal NGO)



- |  |   |  |  |  |
|--|---|--|--|--|
| 1 Bosque del Pueblo de Adjuntas                                      | 36 Refugio de Vida Silvestre Lago Guajataca                         | 71 Área Natural Protegida Río Encantado                                | 106 Reserva Natural Caño Martín Peña                             | 141 Área Natural Protegida Medio Mundo y Daguao                      |
| 2 Bosque Estatal de Cambalache                                       | 37 Refugio de Vida Silvestre Lago Luchetti                          | 72 Área Natural Protegida Cuevas el Convento                           | 107 Reserva Natural Ciénaga Las Cucharillas                      | 142 Servidumbre de Conservación Centro Espíritu Santo                |
| 3 Bosque Estatal de Corrillos  | 38 Reserva Natural Caño La Boquilla                                 | 73 Refugio de Vida Silvestre Iris Alameda de Boquerón / BE de Boquerón | 108 Reserva Natural Corredor Ecológico del Noreste               | 143 Área Natural Protegida San Juan Park                             |
| 4 Bosque Estatal de Guajataca  | 39 Reserva Natural Caño Tiburones                                   | 74 Reserva Natural Cayo Ratonés/ BE de Boquerón                        | 109 Reserva Natural de las Bahías Bioluminiscentes de Vieques    | 144 Área Natural Protegida Luz Martínez de Benítez                   |
| 5 Bosque Estatal de Guánica  | 40 Reserva Natural Cueva del Indio                                  | 75 Reserva Natural Finca Belvedere/ BE de Boquerón                     | 110 Reserva Natural del Río Espíritu Santo                       | 145 Servidumbre de Conservación Finca Gulín                          |
| 6 Bosque Estatal de Maricao  | 41 Reserva Natural de Isla de Mona y Monito                         | 76 Reserva Natural La Parguera/ Bosque Estatal de Boquerón             | 111 Reserva Natural Humedal de Punta Vientos                     | 146 Área Natural Protegida Jajome                                    |
| 7 Bosque Estatal de Monte Guilarte                                   | 42 Reserva Natural Finca Belvedere                                  | 77 Reserva Natural Laguna de Joyuda/ BE de Boquerón                    | 112 Reserva Natural Las Piedras del Collado                      | 147 Área Natural Protegida Punta Pozuelo                             |
| 8 Bosque Estatal de Susúa  | 43 Reserva Natural Isla Caja de Muertos                             | 78 Reserva Natural La Parguera   | 113 Reserva Natural Manglar de Punta Tuna                        | 148 Área Natural Protegida Río Bairoa                                |
| 9 Bosque Estatal de Toro Negro                                       | 44 Reserva Natural Laguna de Joyuda                                 | 79 Reserva Natural Punta Guaniquilla/ Bosque Estatal de Boquerón       | 114 Reserva Natural Pantano de Cibuco                            | 149 Área Natural Protegida La Pitahaya                               |
| 10 Bosque Estatal de Tres Picachos                                   | 45 Reserva Natural Mata de Platano Field Station                    | 80 Reserva Natural La Parguera   | 115 Reserva Natural Punta Petrona                                | 150 Área Natural Protegida Los Llanos                                |
| 11 Bosque La Olimpia   | 46 Reserva Natural Punta Cucharas                                   | 81 Río Hondo Community Forest  | 116 Reserva Natural Sistema de Cuevas y Cavernas de Aguas Buenas | 151 Área Natural Protegida Hacienda Lago                             |
| 12 Cabo Rojo National Wildlife Refuge                                | 47 Finca Nolla  | 82 Bosque Estatal de Río Abajo   | 117 Vieques National Wildlife Refuge                             | 152 Área Natural Protegida Cañón San Cristóbal                       |
| 13 Cavernas del Río Camuy  | 48 Forest Legacy Program acquisition - Finca CDK1_Guillermety       | 83 Reserva Natural del Río Ciallitos                                   | 118 Las Casas de la Selva  | 153 Área Natural Protegida Carro Feliz                               |
| 14 El Tallón   | 49 Forest Legacy Program acquisition - Finca CDK2_Negrón            | 84 Área Natural Protegida Hacienda Margarita                           | 119 Reserva Natural Playa Grande El Paraíso                      | 154 Área Natural Protegida Quebrada Janer                            |
| 15 Finca G. Ulínas & Co.   | 50 Forest Legacy Program acquisition - Finca M Rodriguez            | 85 Área Natural Protegida Hacienda Pellejás                            | 120 Reserva Natural Planadas - Yeyesa                            | 155 Culebra National Wildlife Refuge/ Culebrita Lighthouse           |
| 16 Finca José Santiago   | 51 Bosque Estatal de Boquerón                                       | 86 Desecho National Wildlife Refuge                                    | 121 Reserva Natural Finca Seven Seas                             | 156 Reserva Natural Las Cabezas de San Juan                          |
| 17 Finca Luis A. Zayas   | 52 Área Natural Protegida Río Maricao                               | 87 Área Natural Protegida Cañón Las Bocas                              | 122 Área Natural Protegida Sierra la Pandura                     | 157 Reserva Natural Inés Mendoza (Punta Yeguas)                      |
| 18 Forest Legacy Program acquisition - Finca A Matos                 | 53 Área Natural Protegida El Conuco                                 | 88 Bosque Estatal de Aguirre   | 123 Área Natural Protegida Culebras                              | 158 Reserva Natural Freddie Ramirez                                  |
| 19 Forest Legacy Program acquisition - Finca Banco Popular de PR     | 54 Área Natural Protegida Cerro Las Mesas                           | 89 Bosque Estatal de Carite  | 124 Área Natural Protegida Marín Alto                            | 159 Bosque Los Capuchinos/ CESJ                                      |
| 20 Forest Legacy Program acquisition - Finca Busigó Maricao          | 55 Servidumbre de Conservación Foreman                              | 90 Bosque Estatal de Ceiba   | 125 Servidumbre de Conservación Siembra Tres Vidas               | 160 Arboretum de Cupey/ CESJ   |
| 21 Forest Legacy Program acquisition - Finca El Pitirre, Inc. #16    | 56 Reserva Natural Punta Ballenas/ BE de Guánica                    | 91 Bosque Estatal de Monte Choca                                       | 126 Área Natural Protegida La Robicda                            | 161 Bosque Urbano del Nuevo Milenio/ CESJ                            |
| 22 Forest Legacy Program acquisition - Finca Fratelli Guilarte       | 57 Área Natural Protegida Río Toro Negro                            | 92 Bosque Estatal de Pinones   | 127 Servidumbre de Conservación El Rabanal                       | 162 Bosque Urbano Doña Inés Mendoza/ CESJ                            |
| 23 Forest Legacy Program acquisition - Finca Gripijas Toro Negro     | 58 Servidumbre de Conservación Finca María Luisa                    | 93 Bosque Estatal de Vega  | 128 Servidumbre de Conservación El Tambor                        | 163 Corredor Ecológico de San Juan (CESJ)                            |
| 24 Forest Legacy Program acquisition - Finca Hernández Dairy (3)     | 59 Área Natural Protegida Punta Cabullones                          | 94 Bosque Urbano de San Patricio                                       | 129 Servidumbre Escénica Montes Oscuros                          | 164 Jardín Botánico de la Universidad de Puerto Rico/ CESJ           |
| 25 Forest Legacy Program acquisition - Finca J. Gutiérrez            | 60 Área Natural Protegida Hacienda Buena Vista                      | 95 Bosque Urbano del Nuevo Milenio                                     | 130 Servidumbre de Conservación Bosque Tropical Palmas del Mar   | 165 Antiguo Acueducto del Río Piedras/ CESJ                          |
| 26 Forest Legacy Program acquisition - Finca La Nuez Guilarte        | 61 Servidumbre de Conservación Finca Ledesma Moulter                | 96 Culebra National Wildlife Refuge                                    | 131 Finca El Verde   | 166 Reserva Natural Finca Seven Seas/ RN Corredor Eco del Noreste    |
| 27 Forest Legacy Program acquisition - Finca Mogotes Guilarte        | 62 Área Natural Protegida Cordillera Sabana Alta                    | 97 El Yunque National Forest   | 132 Área Natural Protegida Los Frailes                           | 167 Reserva Natural Bosque Pterocarpus                               |
| 28 Forest Legacy Program acquisition - Finca North Inv. & Prop., Inc | 63 Área Natural Protegida Cerro La Tuna                             | 98 Finca Geraldo Colón   | 133 Área Natural Protegida Shapiro                               | 168 RN Pantano Bosque Pterocarpus Lagunas Mandry y Sta Teresa Humacá |
| 29 Forest Legacy Program acquisition - Finca P Hernández             | 64 Área Natural Protegida Río Too Vacca                             | 99 Finca Las Orquídeas   | 134 Área Natural Protegida Jorge Sotomayor del Toro              | 169 Área Natural Protegida Río Jacoboa                               |
| 30 Forest Legacy Program acquisition - Finca San Andrés Dairy        | 65 Servidumbre de Conservación Picafor                              | 100 Finca San Salvador Fasc I  | 135 Refugio Natural de Vida Silvestre El Bucay                   | 170 Zona de Conservación del Corso                                   |
| 31 Forest Legacy Program acquisition - Finca Sucesión Bauzá          | 66 Bosque Estatal de Boquerón/ Cabo Rojo National Wildlife Refuge   | 101 Finca Vizcarondo   | 136 Área Natural Protegida Bosque de Pterocarpus de Dorado       | 171 Reserva Natural Laguna Tortuguero                                |
| 32 Forest Legacy Program acquisition - Finca Suñ. López              | 67 Reserva Natural Punta Guaniquilla                                | 102 Forest Legacy Program acquisition - Finca Mikasobe Carite          | 137 Área Natural Protegida Paraíso de las Lunas                  | 172 Área Natural Protegida Río Sana Muerto                           |
| 33 Laguna Cartagena National Wildlife Refuge                         | 68 Reserva Natural Hacienda La Esperanza                            | 103 Guayama Research Area  | 138 Área Natural Protegida Río Guaynabo                          | 173 Área Natural Protegida Ojo de Agua                               |
| 34 Manatt Research Area  | 69 Finca Este/ RVS Iris Alameda de Boquerón/ BE de Boquerón         | 104 Refugio de Vida Silvestre Lago La Plata                            | 139 Área Natural Protegida Hermanas Sendra                       |  |
| 35 Parque Ceremonial Indígena de Caguana                             | 70 Finca Mar Sin Barreras/ RVS Iris Alameda de Boquerón / BE de Boq | 105 Reserva Nacional de Investigación Estuarina de Bahía de Jobos      | 140 Área Natural Protegida Ulpiano Casal                         |  |

Source: Protected Areas Conservation Action Team, 2018. Puerto Rico Protected Areas Database (version of December, 2018). GIS data, San Juan, PR.

Landscape diversity was also assessed based on the vegetation cover and ecological life zones according to the Holdridge classification scheme. Results indicate that it was varied among the protected areas, using both variables.<sup>14</sup> However, almost all protected areas (90-95% of all protected natural areas assessed) have very low or low landscape diversity based solely on the Holdridge life zones classification scheme.

The study also found that the regions with the highest species richness, or that are classified as critical or important wildlife areas are not well represented within the network of protected areas (Castro Prieto et al., 2016).<sup>15</sup> It is estimated that 38.98% of Puerto Rico has a very high to high species richness.<sup>16</sup> Less than a quarter (23.74%) of this very high to high species richness is in protected natural areas.<sup>17</sup> The study found that unprotected regions with high species-richness, and that are classified as Critical Wildlife Areas (CWA) or Important Bird Areas (IBAs) occurred in lands adjacent to existing protected areas (Castro Prieto et al, 2016).

## V. ADDITIONAL PLANNING MECHANISMS FOR LAND PROTECTION

Public and private lands in Puerto Rico are protected through other planning mechanisms in addition to the designation as a protected natural area. These are the Puerto Rico Land Use Plan (PRLUP) and the Karst Special Planning Area.

### 1. The Puerto Rico Land Use Plan

The PRLUP classifies the territory in three basic categories: urban, developable, and rustic land, from which other classifications are derived. The PRLUP classified 13.3% of the territory in Puerto Rico as urban land (294,213 acres), 0.77% as developable land (16,973 acres), of which 60.7% are programmed (10,303 acres) and 39.3% are non-programmed (6,669 acres). Likewise, it

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<sup>14</sup> Results ranged from 70 protected areas with a very high and high landscape diversity, 11 intermediate, and 14 with very low and low landscape diversity.

<sup>15</sup> The researchers determined the proportion of high and very high species-richness areas, predicted habitats for threatened species under protection in Puerto Rico, and estimated the proportion of terrestrial critical wildlife areas (CWAs) and Important Bird Areas (IBAs) inside protected areas.

<sup>16</sup> Very high species-richness regions in Puerto Rico occupied approximately 1,200 km<sup>2</sup>, and high 2,270 km<sup>2</sup>.

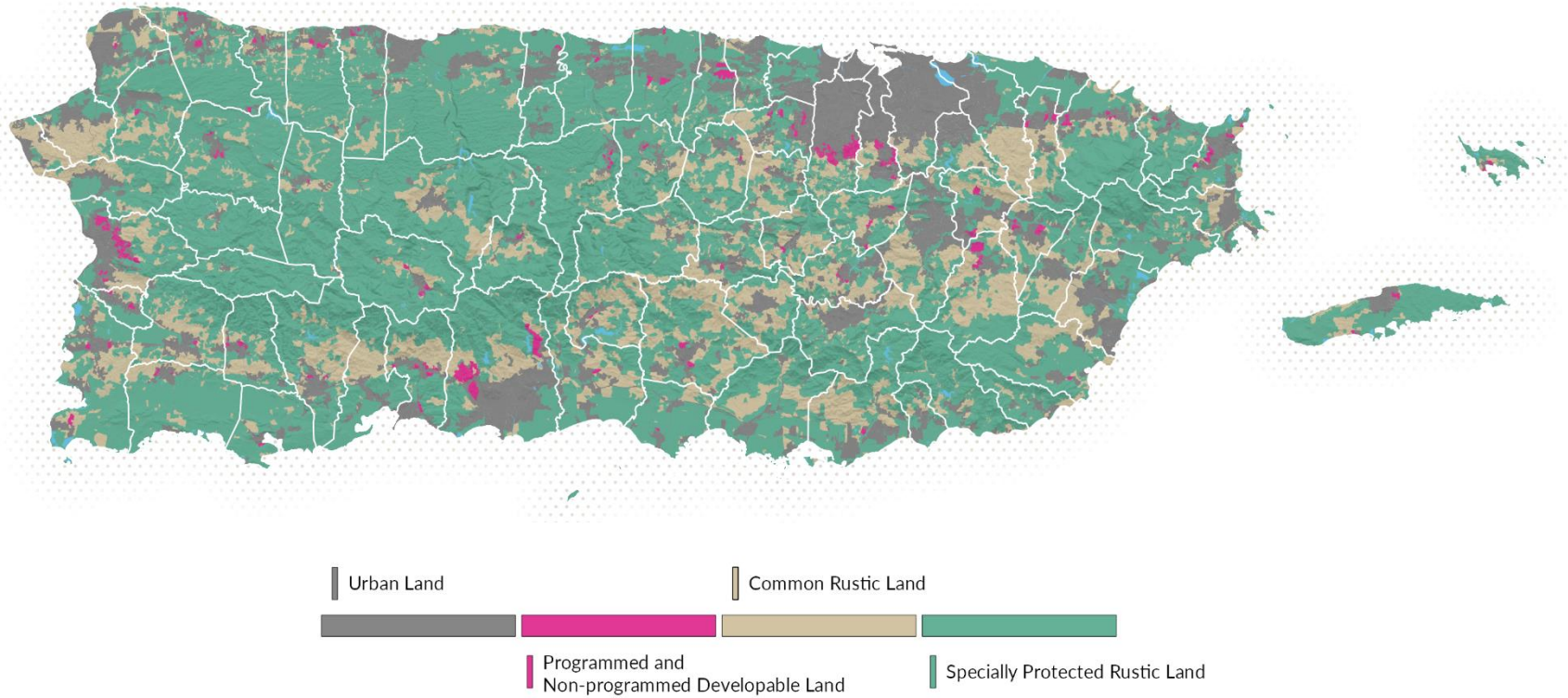
<sup>17</sup> It is estimated that 10.55% (126.55 km<sup>2</sup>) of the very high and 13.19% (299.34 km<sup>2</sup>) of the high species richness.

classified 20% as common rustic land (442,206 acres) and 60.1% as specially protected rustic land (1,339,939 acres)

Specially protected rustic land is a classification through which lands are protected due to their ecological, hydrological, aesthetic and/or agricultural values. However, these are mostly private lands. The common rustic lands are also of importance. For the past decades, most new development inquiries occurred in the "Common Rustic Land" (Martinuzzi et al 2007).

Developable lands are scattered through the territory, mostly contiguous to urban lands. The next map shows the distribution of the general land use classes throughout Puerto Rico.

Figure 19. Land use classifications according to the Puerto Rico Land Use Plan



Source: Puerto Rico Planning Board, 2015. Puerto Rico Land Use Plan. Map prepared by Estudios Técnicos, Inc.

## 2. The Karst Special Planning Area

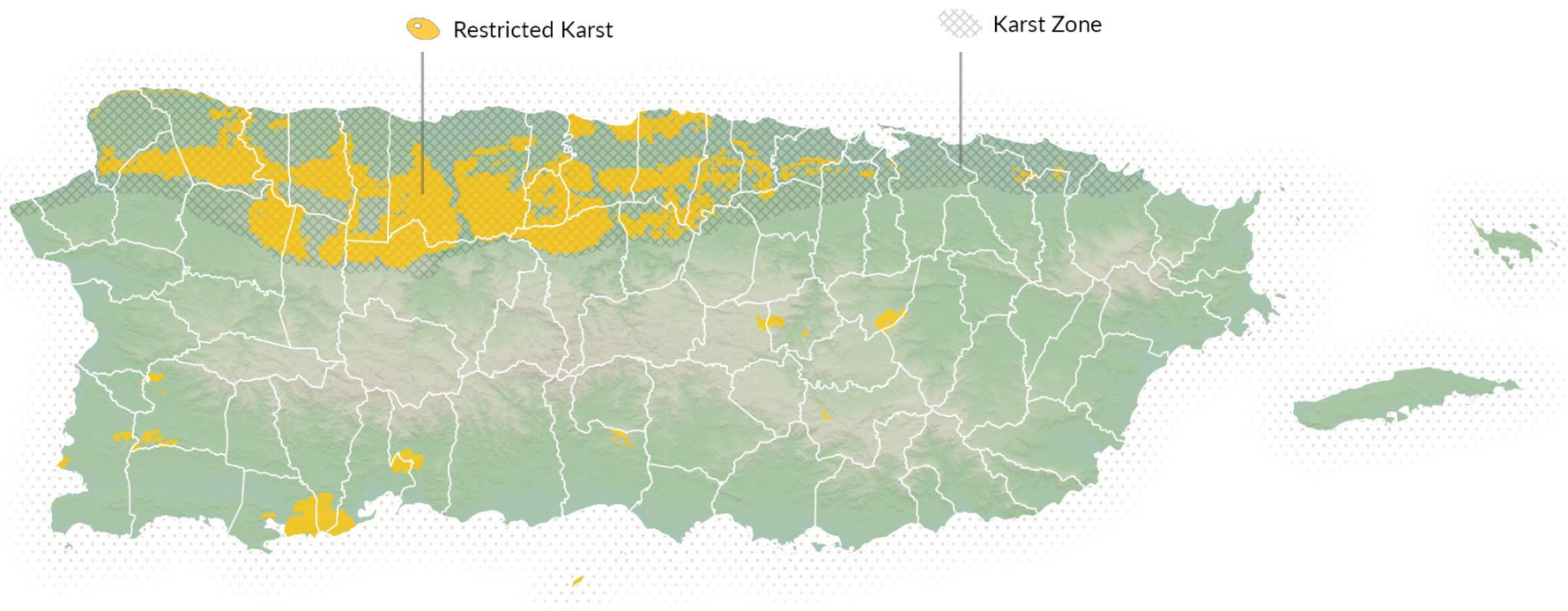
In June 2014, the Plan and Regulation for the Karst Special Planning Area (SPA) was approved.<sup>18</sup> This SPA covers 236,138 acres where proper land use practices are promoted to protect forest and water resources in the region. This SPA includes the northern limestone region, which contains Puerto Rico's most extensive freshwater aquifer, largest continuous expanse of mature forest, and largest coastal wetland, estuary, and underground cave systems (Lugo et al., 2001).

The restricted karst is protected for its ecological, geological, and hydrological values, and covers public and private lands. It protects most of the karst belt and other disperse areas throughout Puerto Rico. The karst belt covers 142,544 ha or 65% of the northern limestone (Lugo et al., 2001). The karst belt is extremely diverse and unique due to its multiple landforms concentrated in a relatively small area. Karst forests contain the largest reported number of tree species per unit area in Puerto Rico (Lugo et al., 2001). The area provides habitat and refuge for many rare, threatened, endangered, and migratory species.

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<sup>18</sup> This plan and regulation were prepared by the DNER and the Puerto Rico Planning Board in compliance with the "Act for the Protection and Conservation of Puerto Rico's Karst Physiography (Law 292-1999)".

Figure 20. Karst Special Planning Area



Source: Puerto Rico Planning Board. Layers: Special Planning Area – Karst Restricted; Special Planning Area – Karst Zone. 2015. Map prepared by Estudios Técnicos, Inc.

### 3. *The Model Forest: a landscape approach to forest management*

The Puerto Rico Model Forest was designated to protect and manage forested lands at a large scale by including the communities and economic activities within these lands (PRCWS, 2015). The Puerto Rico Model Forest is not a protected area but connects 26 protected natural areas. It covers 378,639 acres of public and private forested lands, across 17 municipalities, accounting for 17% of the Commonwealth's territory.

With the approval of the Puerto Rico Model Forest Act (Law No. 182 of 2014), these lands were identified as a priority for planning and sustainable development, and the role of citizens in landscape conservation was recognized. Voluntary conservation practices and the sustainable use of the landscape are to be promoted, such as sustainable tourism, education, and agriculture. Additional information is included in section III(a)-2 of this plan.

## VI. FOREST RESOURCES AND BENEFITS

Puerto Rico forests are a mix of native and non-native naturalized species, which together create novel plant and animal communities (DNER, 2015). These forests provide public benefits that include wildlife habitats, mitigate species extinctions, and provide ecosystem services such as soil stabilization, temperature regulation, nutrient transformation, and water and carbon cycling (Lugo, 2004 as cited in DNER, 2015).

### 1. 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 influences 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.

According to the Puerto Rico State Wildlife Action Plan: Ten Year Review (PRSWAP), Puerto Rico has approximately 5,847 native wildlife species (DNER 2015). Native species include: 51 reptiles (Rivero 1998), 18 amphibians (Rivero 1998), 5,573 insects (Torres and Medina-Gaud 1998), 190 birds (Raffaele 1989), and 15 mammals (DNER 2015).

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 New Wildlife Law 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 2015). The DNER classifies priority species according to risk of extinction (DNER 2015). There are 317 species of greatest conservation need subdivided into the following categories: 48 critically endangered (CR), 41 endangered (EN), 47 vulnerable (VU), 24 low risk (LR) and 156 data deficient (DD) (DNER, 2015).

The U.S. Caribbean is considered a biodiversity hotspot area with 78 federally listed species, and 11 at-risk species including the proposed *Atlantea tulita*, *Solanum conocarpum*, and *Pterodroma hasitata*. Of these 78 federally listed species, 75 occur in Puerto Rico.

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 need by taxon included in the PRSWAP (DNER 2015)**

Taxon	CR	EN	VU	DD	LR	Total
Amphibians	3	1	4	1	0	9
Birds	7	5	5	9	1	<b>27</b>
Reptiles	3	6	3	5	0	<b>17</b>
Marine Mammals	0	1	1	0	0	2
Terrestrial Mammals	0	0	3	2	1	<b>6</b>
Fresh Water Fishes	2	1	1	0	0	<b>4</b>
Invertebrates	2	0	1	8	8	<b>19</b>
Plants	30	15	3	0	0	<b>48</b>
<b>Total</b>	<b>47</b>	<b>29</b>	<b>21</b>	<b>25</b>	<b>10</b>	<b>132</b>

CR - Critically Endangered, EN - Endangered, VU - Vulnerable, LR - Low Risk, DD - Data Deficient. DNER, 2015.

The DNER identifies lands in Puerto Rico that are critical to wildlife and those that should have conservation priority. The Critical Wildlife Areas (CWAs) represent important compendiums of species and habitats of concern, emphasizing on endangered and/or endemic species occurrence, presence of critical habitat, and level of threat on habitats and species. These cover approximately 853.13 km<sup>2</sup> (9.58%) of lands in Puerto Rico (Castro et al., 2016). The DNER defines these areas to protect critical wildlife habitat from degradation due to incompatible land uses (DNER, 2015).

The DNER also identifies Priority Conservation Areas in Puerto Rico which include habitats for endangered species, wetlands, important areas for migratory species, ecologically important natural communities, and areas that have been identified to be declared as Nature Reserves. There are 97 priority conservation areas, covering approximately 696, 461 acres (31.7%) of Puerto Rico.

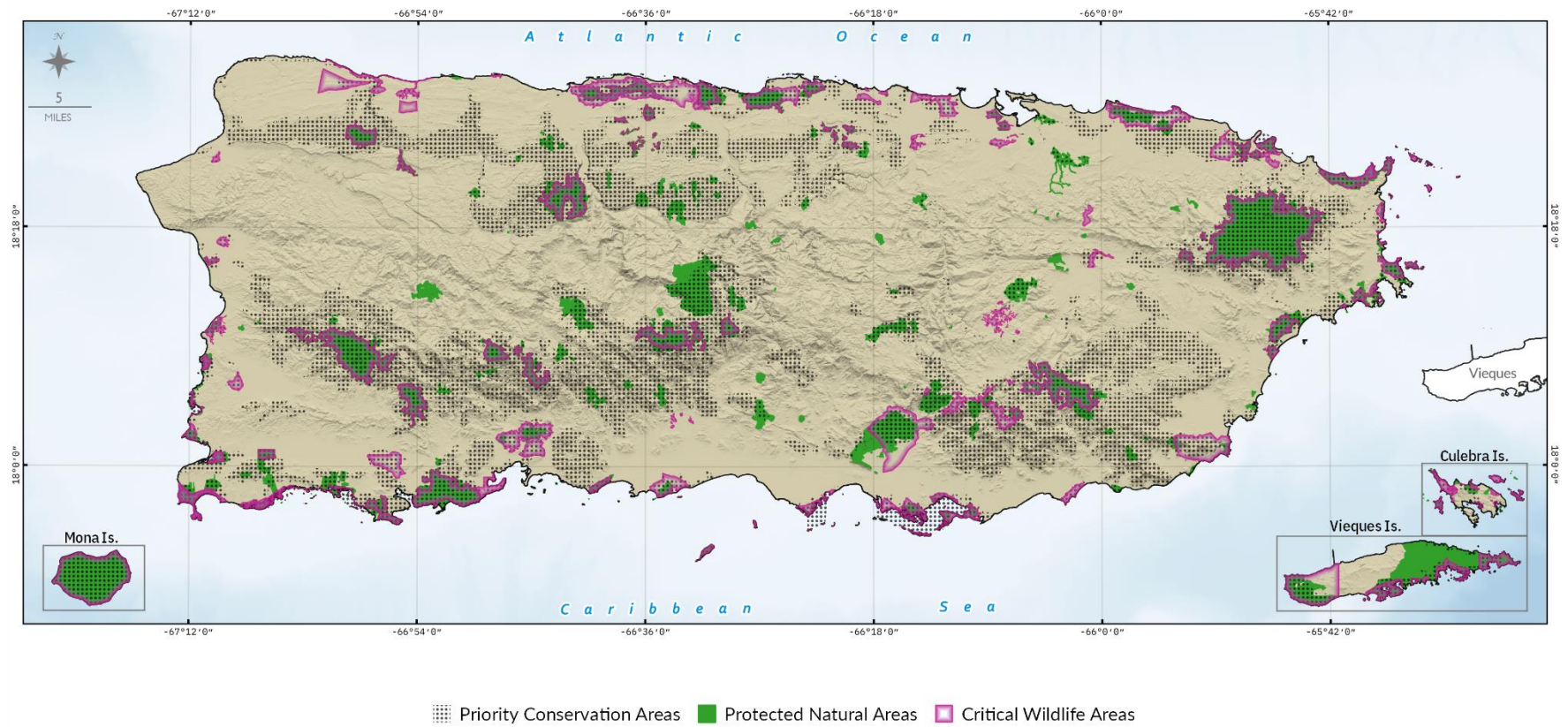
Figure 21 shows the system of protected natural areas, together with the CWAs and the Priority Conservation Areas. The PRSWAP identifies these as the wildlife conservation areas, which are the lands where the DNER should focus conservation actions and efforts according to the habitat types of interest (DNER, 2015).

Many of these areas, especially in the coastal zone are wetlands. 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.

Mangrove forests 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. Recent studies show that coastal habitats have a significant influence in wave reduction, where mangroves can reduce on average up to thirty-one percent of coastal wave

intrusion (Narayan et al. 2016). Also, mangrove forests fix and store significant quantities of carbon and play an important role in the carbon sequestration process. According to Zarate-Barrera and Maldonado (2015), it is estimated that these ecosystems absorb around 25.5 million tons of carbon per year. Although mangrove forests play an important role in the global carbon cycle, the loss of 35% of these ecosystems around the world over the past two decades has led to the emission of large quantities of stored carbon and therefore, contributed to global warming (Zarate-Barrera et al. 2015). These characteristics distinguish mangrove forests as coastal systems of high ecologic and economic value. Between 70% and 90% of marine life of commercial or recreational value uses these forests for at least part of their respective life cycles (DNER 2003). Mangrove forests are also part of the habitat for native and migratory birds, including birds that are on the federal list of endangered species.

Figure 21. Terrestrial Wildlife Conservation Areas (CWA& PCA) and Protected Natural Areas



Source: DNER Heritage Program; Protected Areas Conservation Action Team. 2018. Puerto Rico Protected Areas Database [version of December, 2018]. GIS data, San Juan, PR.

## 2. Water resources

Forest cover is fundamental for the amount and quality of water of the rivers, reservoirs, and aquifers. Puerto Rico has 224 rivers, 553 named streams, and 39 reservoirs (DNER, 2016d). The largest river is the Río Grande de Loíza, draining an area of 767 square kilometers (296 square miles). There are only seven rivers on the island with drainage areas greater than 259 square kilometers (100 square miles), although more than 100 streams discharge into the ocean. The large number of drainage basins in the island results in a surface hydrology characterized by a multitude of small watersheds and catchments.

All rivers in Puerto Rico rise in the forested mountainous central area of Puerto Rico. The headwaters of these rivers supply most of the island's reservoirs, which provide water to meet domestic, industrial, and agricultural consumption. For example, the headwaters of eight major rivers rise in El Yunque forest and provide water for domestic purposes and hydroelectric power for many communities in eastern Puerto Rico, including the Vieques and Culebra islands (Miller & Lugo, 2008; Waide et al, 2013).

There are fifteen (15) major dams providing water and electricity on the island. Sedimentation also increases water treatment costs. Most sediment is transported to reservoirs during extreme events, such as heavy rainfall or hurricanes, leading to a potential long-term water-supply problem. High sedimentation rates occur in the north and east watersheds where the rainfall is high, and the watersheds are more developed (ASCE, 2019). Reservoirs which's capacity has been reduced by more than 50% are the Loco, Carraízo, Lucchetti and Dos Bocas (ASCEPR, 2019). The Dos Bocas life expectancy is less than 35 years given its current sedimentation rate. This, along with Caonillas and four other reservoirs, are part of the North Coast Superaqueduct which supplies more than 50 mgd of drinking water to approximately 600,000 residents in the San Juan Metropolitan Area and municipalities in the northern region (ASCEPR, 2019). Low life expectancy is documented also for the Loco, Carraízo and Lucchetti, with fewer than 15, 45 and 50 years, respectively (ASCEPR, 2019). Lucchetti Reservoir in Yauco, which supplies drinking water and to the Lajas irrigation system, is affected by a

sedimentation problem (DNER, 2016c). This is identified by the USGS as a principal watershed.

The different regions in the following map show areas upstream of existing reservoirs and hydrological reserves identified by the DNER and the Office of the Land Use Plan of the Puerto Rico Planning Board (PRPB) in 2008. Its primary objective is to maintain and/or restore sufficient forest cover to extend the lifespan of existing water supply reservoirs (DNER, 2016d).

Figure 22 shows the associated reservoirs for these dams, which are the main surface water source in Puerto Rico (DNER 2008a). Jointly, reservoirs account for 55% of freshwater extraction on the island. Therefore, protection of reservoirs' capacity is an important DNER management objective (DNER, 2016d).

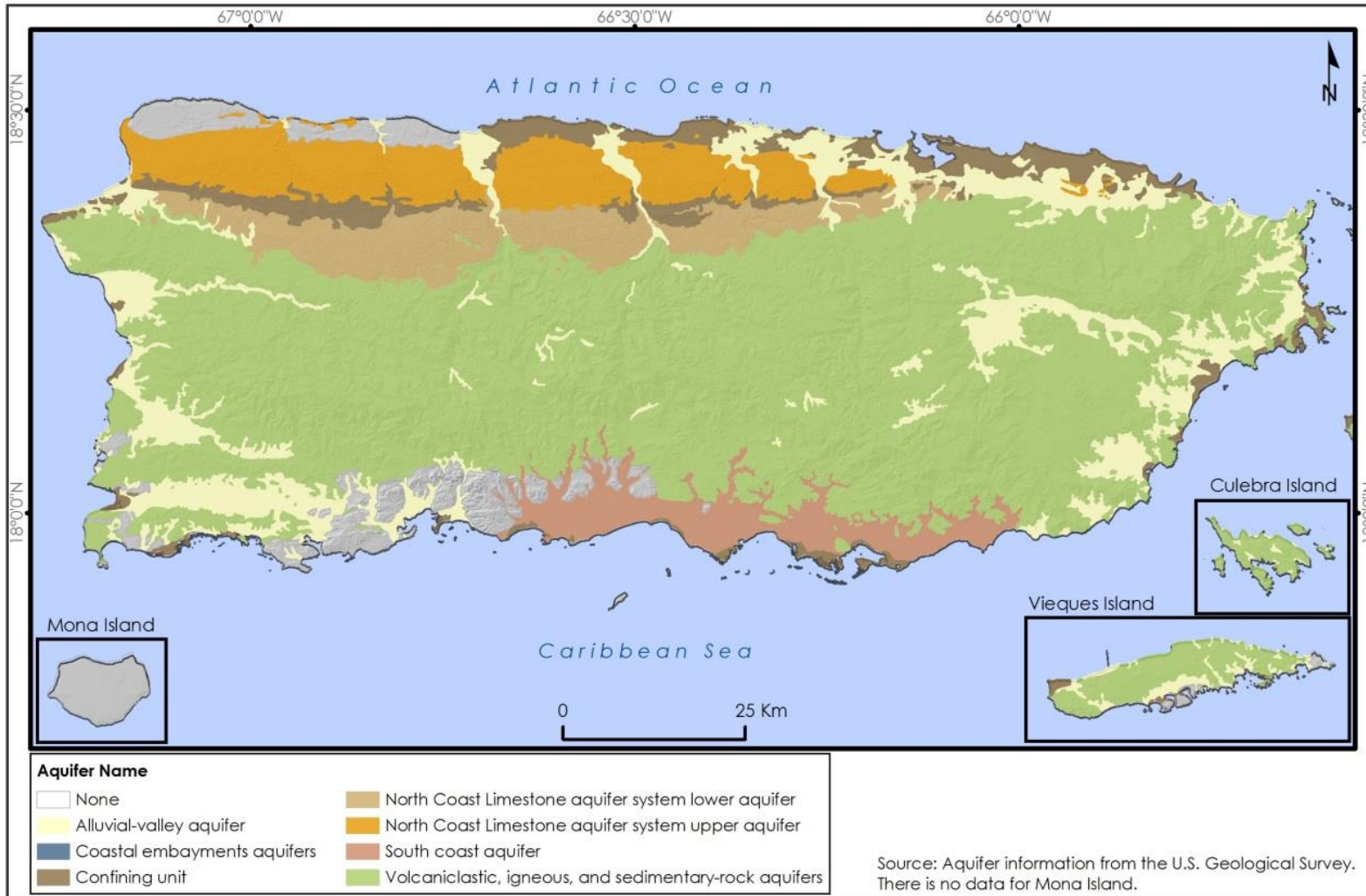
Sedimentation has decreased reservoirs' capacity to store water and has reduced water quality for human and wildlife consumption. High erosion and sedimentation rates result from the combination of steep soils, intense rains, and extensive land use in Puerto Rico (DNER 2008a). There is a large variation 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 2008a).

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Figure 23. Classification and location of the aquifers in Puerto Rico, Vieques, and Culebra



Aquifers are another important source of water in Puerto Rico. An aquifer is a saturated geological formation, of regional and economic significance. 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.

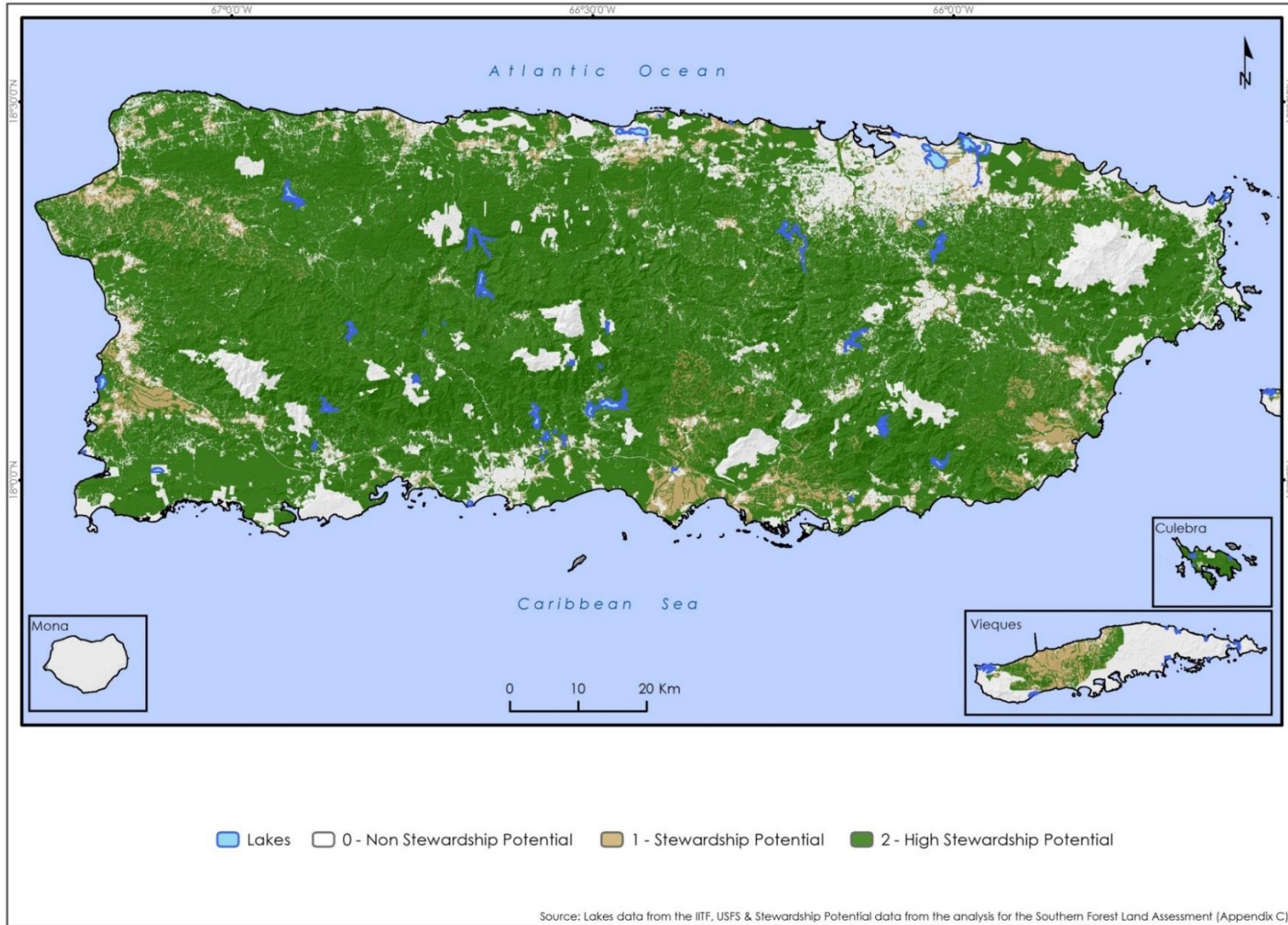
The main aquifers in the island include those formed of limestone and alluvium on the North Coast; the alluvial aquifers in the inland valleys of Caguas, Juncos, Cayey, and Cidra valley, and the south coast aquifer. The latter is the main source of potable water for the municipalities of Salinas, Santa Isabel, Coamo, and Guánica (DNER, 2016c). It is also the freshwater source that sustains habitats in the Jobos Bay National Estuarine Reserve, the only in Puerto Rico and the Caribbean (DNER 2016d). There are also minor aquifers in the river valleys in the west and east of the island. Classification and location of the different aquifers in the island are presented in Figure 23.

Underground water quality and quantity depend on the forest cover, precipitation, runoff, permeability of soils and sea level change. Aquifer's recharge depends to a greater or lesser extent on the water that infiltrates through the soil. All these provide the water that supports ecosystems functions and services, and for human consumption (industrial, commercial, and residential uses). However, development activities increase the proportion of impervious surfaces within a watershed, increasing the amount of rainwater that runs directly into streams rather than infiltrating into the soil and recharging groundwater aquifers.

Overall, 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 24 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 C).

Figure 24. Water bodies in Puerto Rico, Vieques, Culebra and Mona Island and their relationship to Forest Stewardship Potential



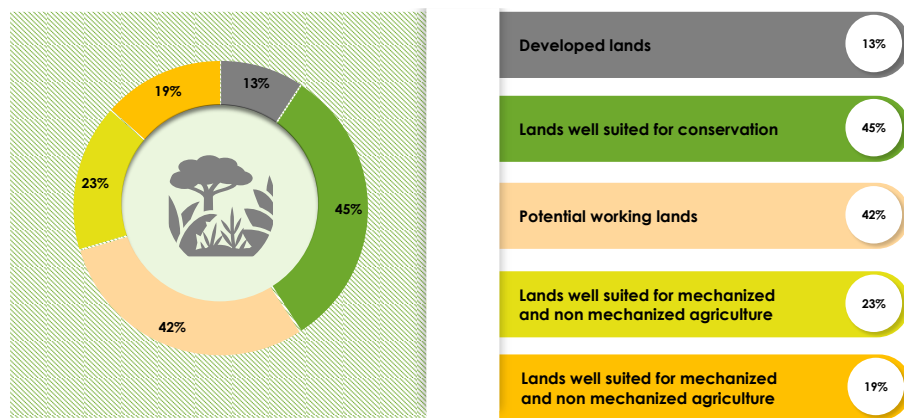
### 3. Economic benefits from forests

#### a. Forest products and timber management opportunities

In 2017, Gould and collaborators classified 42% (933,777 acres) of lands in Puerto Rico as “potential working lands”, which include lands suited for mechanized and non- mechanized agriculture and lands suitable for forestry production.<sup>19</sup> The study found that forest cover, biodiversity and ecosystem services can be maintained while increasing agricultural productivity on flatter lands and lower slopes, and integrating agroforestry, shade coffee, low impact timber harvest, and non-timber forest product uses on steeper slopes (Gould et al., 2017). The authors recognized the importance of keeping key watersheds and mountain slopes forested to increase sustainability and productivity on all working lands, and to include best practices, such as water and nutrient management, in all agricultural operations to improve productivity.

The next figure shows the potential land for conservation, agriculture and forestry in Puerto Rico as defined by Gould et al. (2017). Figure 26 shows the distribution of these categories across the island.

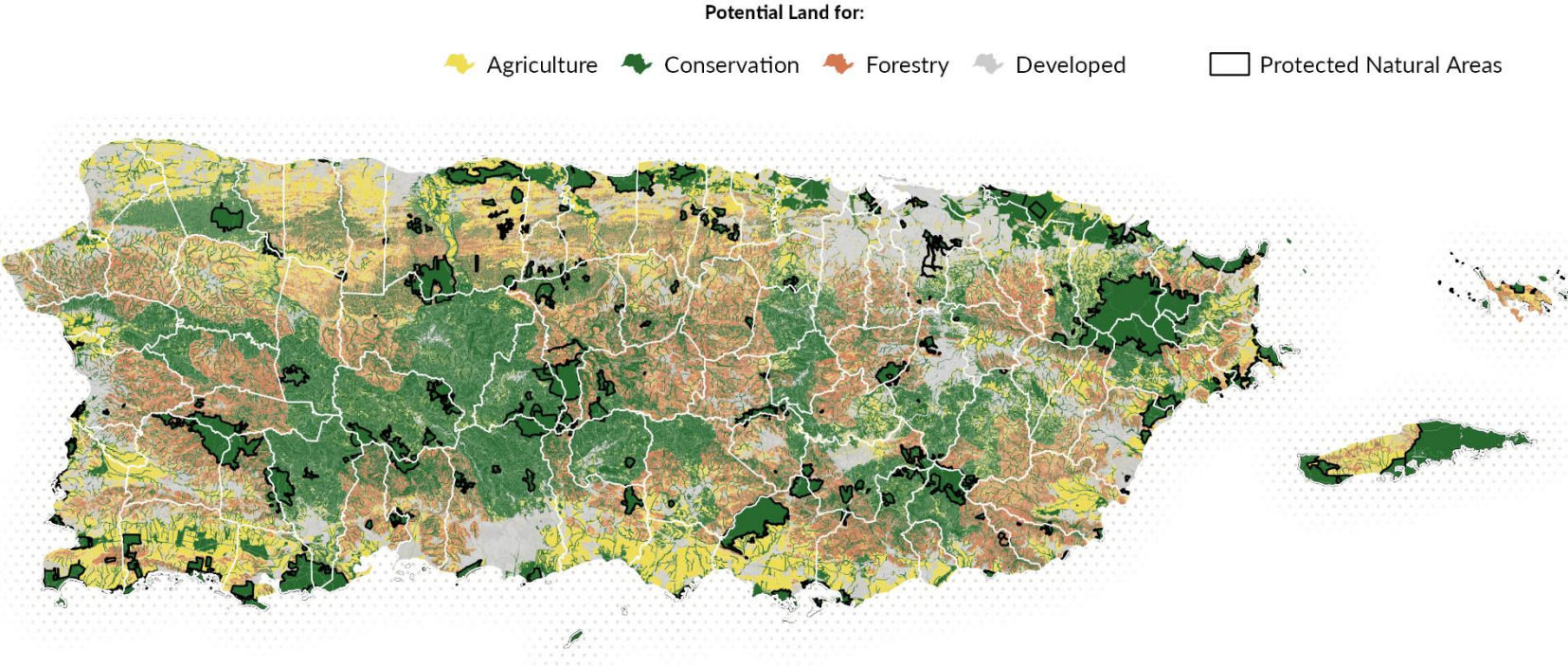
**Figure 25. Land well-suited for conservation, agriculture, and forestry in Puerto Rico (Gould et al., 2017)**



Source: Gould, et al., 2017. Land Use, Conservation, Forestry, and Agriculture in Puerto Rico.

<sup>19</sup> They did not include the following areas as areas suitable for timber production: protected areas, wetlands, developed land surface, natural barrens, riparian zone 50 m buffers, or watersheds that contain reservoirs because of their role in reducing sedimentation and protecting important water sources for the island.

Figure 26. Potential for conservation, agriculture, and forestry in the FLA (Gould et al., 2017)



Lands well suited for conservation, which occupy 45% of Puerto Rico, include protected areas, riparian buffers, lands surrounding reservoirs or sub watersheds, wetlands, beaches, and barrens such as salt and mudflats, slopes greater than 50% and water bodies (Gould et al., 2017). Lands that are suited for forestry are those where timber and non-timber products, agroforestry and shade coffee can be grown. These are observed in like a wide belt in the center of the island (yellow and orange colors). Lands suitable for forestry production cover 19% of Puerto Rico. In these, timber and non-timber products, agroforestry<sup>20</sup>, and shade coffee can be cultivated (Gould et al., 2017).

Gould and collaborators (2017) found that the municipalities with the greatest amount of land with forestry potential are Arecibo, Coamo, San Germán, and Corozal. These have steeper slopes where timber production may be integrated with agroforestry, shade coffee, non-timber forest product uses, or other forms of sustainable activity that maintain a high degree of forest cover.

#### b. Timber

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 caribaea*), 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.  $\geq 5$  inches (Brandeis and Turner 2013).

The most recent FIA estimated that there are 39.4 million cubic meters (1.39 thousand cubic feet) of commercial wood in the forests of Puerto Rico (including Culebra and Vieques)

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<sup>20</sup> According to Food and Agriculture Organization (FAO) "agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components". Retrieved from: <http://www.fao.org/forestry/agroforestry/80338/en/>

(Marcano-Vega, 2017). Most of this volume (83.3%) was found in private lands. The assessment also found that most of the commercial quality wood of large diameter is in the interior of the moist and wet/pluvial forests.

The FIA also reported that the net volume of some wood species used to make furniture and crafts in Puerto Rico increased during the 2004–2014 period. The sum of the net volume of native timber species, such as *Cordia alliodora* (capá Prieto), *Ocotea leucoxylon* (guaraguao), *Tabebuia heterophylla* (white oak), *Andira inermis* (moca) and *Cecropia schreberiana* (yagrumo hembra), experienced an increase of 57.8 percent from 2004 to 2014. However, most of such commercial quality timber is found in large diameter stands where trees larger in diameter still represent a relatively low percentage of the total number of trees. The FIA indicated that these findings highlight the need to develop plans consistent with sustainable forest management and wildlife conservation on private lands being considered for timber harvesting

These conditions were before hurricane María impacted the island, which left millions of downed trees in Puerto Rico, much of which were high value tropical hardwood species. However, there is an increasing interest in developing wood products.

In the Caribbean economies, commodity wood production plays a minimal to nonexistent role (McGinley et al, 2017). In Puerto Rico, however, the majority of the growing stock tree species were hardwoods with sound wood properties suitable for a variety of uses including construction, joinery, furniture, crates and boxes, flooring, fuel, poles, and turning (Forero-Montaña, 2015)

During 2005-2013, Puerto Rico imported more than 2.5 billion dollars of a wide variety of solid wood products from 83 countries and six territories, being furniture the most important item accounting for more than 55 percent of the transactions with an annual average value greater than 156 million dollars (Forero-Montaña, 2015). However, the production and sale of wood products is important to individuals and can serve as an inducement for forest landowners to conserve and/or manage their forests. During 2005-2013 Puerto Rico also exported wood and manufactured wood products to 72 countries and 15 territories for an annual average value of more than 24 million

dollars (Forero-Montaña, 2015), representing a small fraction of the amount of wood products that were imported. According to Forero-Montaña (2015), in terms of annual volume increment the island could cover almost its total current demand for imported sawn-wood (149,222 m<sup>3</sup>) using local wood, which accounts for 11 percent of the transactions with an average annual value of U.S. \$30 million. There is a need for more information on existing and potential wood product markets. Potential sources of this information include local craftsmen, oral tradition, available inventories in governmental agencies, updated sawmill information, and commercial suppliers of wood and non-wood materials used for arts and crafts. Currently some local artisans are using native wood and other locally grown wood to produce musical instruments, carvings and other crafts. Inventories could help link landowners with desirable trees to those who would use them.

### c. Agriculture

Gould and collaborators (2017) identified lands suitable for mechanized and non-mechanized agriculture, based on slope, the presence of protected natural areas, wetlands and other conditions. These cover 23% of Puerto Rico, and include lands suitable for row and specialty crops, livestock, dairy, hay, pasture, and fruits (Gould et al., 2017). These are in the coastal plains and the interior valleys.

According to Marcano-Vega (2017), fruit trees within the secondary forests of Puerto Rico offer an opportunity for the promotion of agroforestry systems and guarantee ecosystem services. The FIA has been assessing four species of fruit trees and recently found that for example, the mango tree population figures as the fourth species of highest biomass in Puerto Rico with a total of 5.1 million stems in 2014 (Marcano-Vega, 2017). The FIA also documented an increase from 7.6 million in 2004 to 11.2 million in 2014 in the total number of mangos (*Mangifera indica*), panapén (*Artocarpus altilis*), china (*Citrus × sinensis*) and avocado (*Persea americana*).

Although shade grown coffee has multiple ecological benefits, *Coffea arabica* and *Coffea canephora* are the species most cultivated in Puerto Rico. These are grown predominantly in the mountainous regions of the island by small-holding farmers with limited resources (ICC 2009 as cited in Fain et al., 2017). Figure

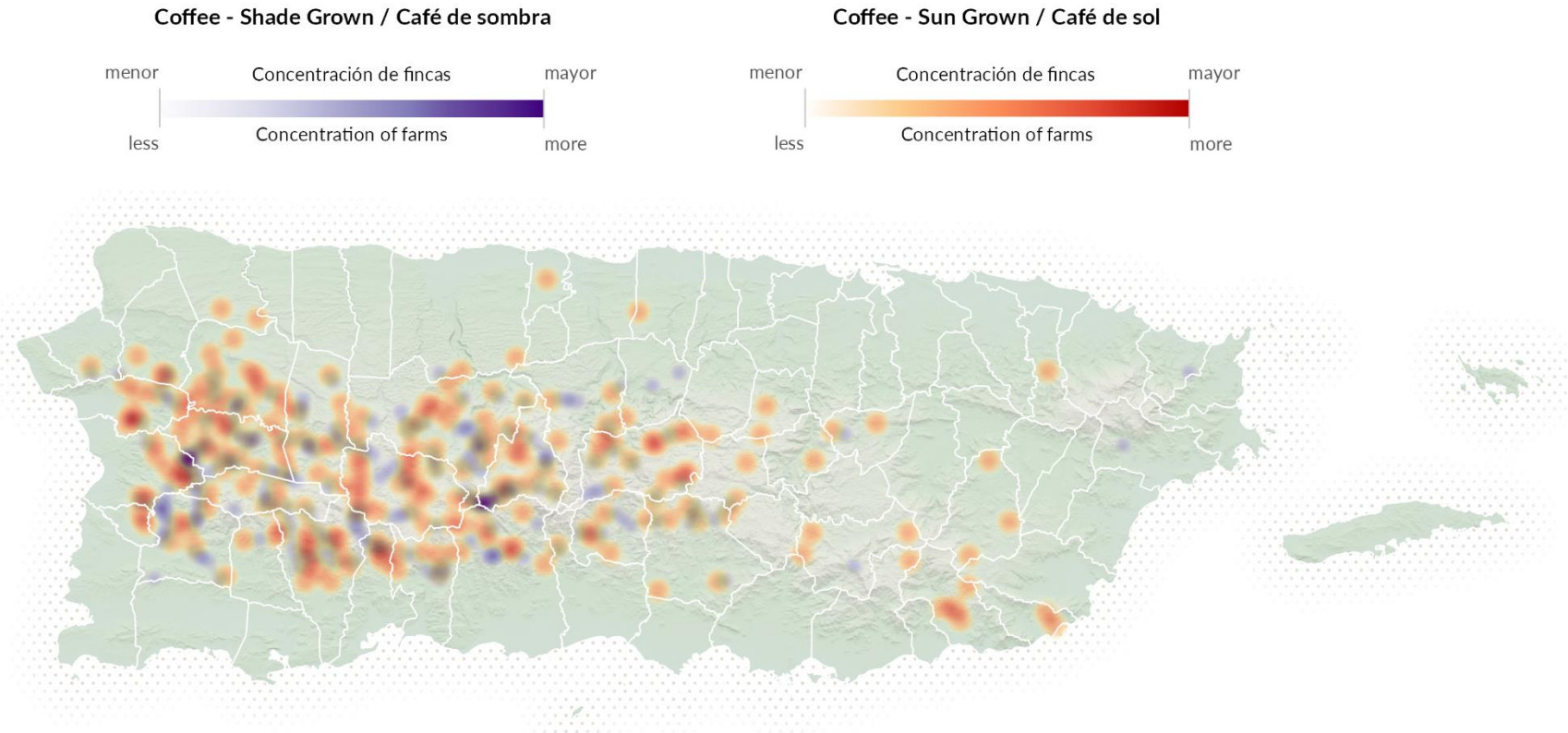
27 shows the concentration and distribution of shade grown coffee versus sun grown coffee in Puerto Rico. According to the most recent Census of Agriculture, there are 818 farms that cultivate coffee grown in the shade. These cover 780.8 acres in Puerto Rico. Many of these are owned by individuals or families. These farms also produce fruits and coconuts, root crops or tubers, among other (USDA, 2018).

It was estimated that almost 90% of shade coffee plantations were lost due to hurricane María. Through Supplemental funding, the USDA-IITF, the NRCS, the USFWS, the DNER and other partners assisted private landowners, providing technical assistance and forest management planning to accelerate restoration and plan for future climate risks and threats (USDA, 2021). In addition, private landowners are receiving technical assistance and forest management planning to restore agroforestry practices and to improve wildlife habitat.

It should be noted that Borkhataria and collaborators (2012), found the willingness of coffee farmers to return to shaded plantations if given similar incentives to those received for farming sun coffee. Overall, they were happier with their cultivation practices (89.3% satisfied) than growers of sun coffee (60.9% satisfied), valued biodiversity.

Through the Forest Stewardship Program, management plans have been prepared for more than 7,436 acres of lands in Puerto Rico. This provide private landowners the opportunity to apply for various incentives available in NRCS, the USFWS, among other.

Figure 27. Shade Grown and Sun Grown Coffee distribution in Puerto Rico Concentration of sun grown coffee vs shade grown coffee.



Source: Caribbean Climate Hub, Puerto Rico Department of Agriculture. Coffee Crop data from 2016. Map prepared by Estudios Técnicos, Inc.

#### 4. Public recreation opportunities

The climate, diversity and proximity of ecosystems in Puerto Rico allow outdoor recreational activities to be carried out throughout the year. Approximately 87.2% of Puerto Rico's residents practice outdoor recreation activities such as hiking, biking, bird watching among other (DRD, 2020). In addition, Puerto Rico visitors reported engaging in over 20 different activities in the island, being the hiking/biking, camping, sightseeing, watching wildlife and beach going the most common activities (Leeworthy et al, 2018).

The DNER has recreational infrastructure in several of its protected areas. The natural areas under the USFWS, the USFS, and NGOs such as Para La Naturaleza and Casa Pueblo also provide recreational opportunities. In addition, during the past years, citizens, particularly organizations that group cyclists, have opened trails in forested public and private properties. These trails are not only used by MBT, but by hikers as well. This provides the opportunity for people to enter and enjoy forested areas, but proper management in natural areas and in areas important for wildlife is needed. In addition, social media has exposed many forested lands that are used for recreation and visitation has increased.

This reflects an increased demand of natural areas and forested lands for recreation, but also constitutes a liability issue for private landowners. This was one of the main outdoor recreation issues identified in the Puerto Rico's outdoor recreation plan (DRD, 2020). With the physical distancing measures associated with the COVID 19 Pandemic, there has been a substantial increase in the use/demand of open spaces for recreation.

The diversity of forests in Puerto Rico, the topography, and the proximity of the ecosystems of the interior, the karst and the coast offer a unique scenic and aesthetic value. Taking advantage of the aesthetic and landscape values, various scenic routes have been designated or are proposed throughout the island. In addition, several viewpoints have been developed which are important for tourism and recreation.

## 5. Hazard and climate change mitigation

Forests provide other valuable services such as air purification; carbon sequestration; natural protection and increased resilience against storm surges, floods, and hurricanes; and mitigation against landslides, soil erosion, and sedimentation (Resetar et al, 2020).

An example has been documented in the Municipality of Caguas. The municipality calculated that retaining tree cover saved them from spending \$63,486,739 on runoff control infrastructure like culverts, sewer lines, among other (Glogiewicz et al. 2008).

The most recent FIA reported that the biomass and total carbon dioxide accumulated in Puerto Rico's forests (including Vieques and Culebra forests) increased by 27.6% between 2004 and 2014 (Marcano-Vega, 2017). These increases in concentration were observed in the different types of forests.

Marcano-Vega (2017) estimated that the 23 Mg, carbon dioxide removed from the atmosphere and accumulated in Puerto Rico's forests mitigated the emissions of cars in Puerto Rico for eight (8) years, or the emissions of the barrels of oil consumed for three (3) and a half year.

Climate change is not only an overarching threat to America's forests, but also a source of new opportunities. Already, it is creating new markets for carbon storage and biomass energy that should be utilized (Tidwell, 2010). However, increases in the intensity and frequency of tropical cyclones may reduce the ability of tropical forests to sequester carbon (Hall, 2020).

Overall, there is a need to educate the public about the multiple benefits and economic value provided by forestry resources in Puerto Rico.

## C. 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 above (Martinuzzi et al 2007). 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.

The most recent FIA reported a relative steadiness in forest cover (Marcano-Vega (2017)). This could be due, among other, to the fact that during the decades of 1990 and 2000 there was a substantial increase in the construction activity in the coastal areas of Puerto Rico, including the main island, Vieques and Culebra. As this occurred, the forest cover in the central mountains of the island continued to recover. In 2006, Puerto Rico began to experience an economic contraction, and a reduction in its population. Both factors have reduced construction activity, and consequently the pressure on forest resources was reduced. However, a rebound in construction is being observed<sup>21</sup>, which is why it is necessary to protect forest resources.

Even with forest steadiness, forest fragmentation and loss of forested wetlands, especially in the coastal areas remain an issue of concern. According to the PRLUP, for almost four decades, vacant lands on the periphery of the cities and metropolitan areas were urbanized at a rate higher than population growth, which resulted in an excess in the offer or housing inventory. Population in the urban centers declined, while urban expansion occurred in the peripheral areas. Based on the Land Cover Map, the PRPB estimated that 14.4%<sup>22</sup> of Puerto Rico was developed in the decade of 2010. Approximately 9.9% of the island was developed before 1977, which indicated that it took almost 500 years to develop 105,221

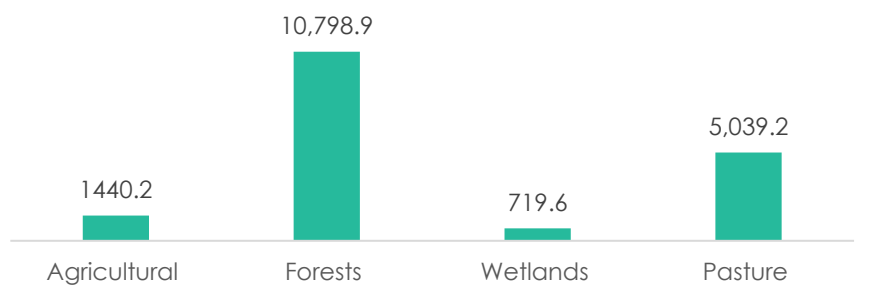
<sup>21</sup><https://www.elnuevodia.com/negocios/construccion/fotogalerias/se-reactiva-la-construccion-nueva-en-puerto-rico/>

<sup>22</sup> 319,398.9 acres

ha (11.65%) and 33 years to develop 24,035 (or 2.66% of Puerto Rico).

If this trend of urbanization continues, despite the population reduction, the PRLUP estimated that an additional 7,283.5 ha will be urbanized by 2025, being the lands covered by forests the most impacted, as shown in the following figure.

**Figure 28. Habitats to be impacted according to projected land uses in the PRLUP (in acres)**



Source: PRPB. 2015. Land Use Plan. Territorial Ordinance Guidelines.

The assessment made for the PRLUP concurs with the findings of Gould, Martinuzzi and Parés (2012) who identified a sharp decline in agriculture; the conversion of grassland, woodland, and shrubland to closed forest; and the urbanization of the landscape as the principal trend in land use and landcover patterns during the last decades in Eastern Puerto Rico. They found that in the last seven decades, the most noticeable change was the shift from a non-forested to a forested landscape and the intensification of the ring of urbanization surrounding El Yunque National Forest. The loss of natural land cover specially in the coastal areas make it necessary to protect the coastal hills and plains and the matrix of habitats that include the mangrove forests and river systems of the coastal area (Gould, Martinuzzi and Parés, 2012).

Certainly, this urbanization process is observed around many other protected areas. A research published in 2017, found that although population in Puerto Rico is decreasing, the number of housing units around protected areas continued to increase (Castro-Prieto, 2017).

Site location consultations (*consultas de ubicación*) are used as an indicator of the development pressure in Puerto Rico. Data provided by the Puerto Rico Planning Board (PRPB) from 2015-2021 shows that site location consultations are disperse

throughout Puerto Rico, especially watersheds of reservoirs that are important for water supply, such as the Río Grande de Arecibo Watershed, La Plata Watershed and the Río Grande de Loíza Watershed, as presented Figure 29. The intense growth pattern in land use has also impacted geographic zones associated to the recharge areas of the main aquifers in Puerto Rico, causing soil erosion and sedimentation of water bodies and reservoirs (DRNA 2008-a). These development trends contribute 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.

Many of these lands where site consultations and new development inquiries are requested are classified as common rustic land<sup>23</sup> (Martinuzzi et al. 2007). 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.

Forest 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. 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. 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

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<sup>23</sup> Common rustic land is a land use classification used for those lands not contemplated for urban or developable use in a territorial plan due, among others, to the fact that the lands classified as urban or developable are sufficient to accommodate the expected urban development (Municipal Code, 2020).

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.

Figure 29. Locations of consultations related to commercial, industrial, residential, and other development in Puerto Rico.



Source: Consultations from Puerto Rico Planning Board (2015-8/2021); Watersheds from USGS National Hydrography Dataset (2019).

## II. HYDROMODIFICATIONS

As indicated in section IIb-1, coastal forests have been impacted by hydromodifications that altered the vegetation cover and species composition. Evidence of such modifications have been documented at the Efrain Archilla Nature Reserve in Humacao, where the Río Antón Ruiz flood control project altered a mangrove forest close to the Boca Prieta channel and *Pterocarpus officinalis* trees adjacent to the mangroves (DNER, 2009a).

Yu and collaborators (2019) also analyzed mortality and recruitment in a freshwater swamp dominated by *Pterocarpus officinalis* in the context of landscape saltwater intrusion and drought. They found that saltwater intrusion and drought increased tree mortality during 2003–2015 compared to 1994–2003. Saltwater intrusion had a more significant negative effect on tree recruitment than on mortality in this *Pterocarpus* forest. The authors found that coastal wetlands are facing challenges to their persistence at current locations due to accelerated sea level rise, limited coastal lands, and a modified hydrological regime.

As part of the hurricane Maria recovery efforts, multiple flood control projects have been proposed throughout Puerto Rico, including channelization of water bodies and levees. These have the potential to adversely affect coastal wetlands, which are already under multiple natural and anthropogenic stressors.

## III. CONVENTIONAL-LARGE SCALE AGRICULTURAL PRACTICES

Conventional and mechanized agricultural production may result in a threat to forest causing forest fragmentation and clearing specially to coastal forests. In addition, traditional large scale agricultural practices use large amount chemical fertilizers and pesticides, which affect wildlife and water supplies, posing additional stressors to forest ecosystems.

In Puerto Rico, shade grown coffee was mostly replaced by intensive full-sun techniques which significantly increased the crop's vulnerability to storm damage and climate change effects such as increases in annual mean temperature (Fain et al., 2017).

In addition, new uncertainties have risen about how much and where to grow more food (Gould et al. 2017 as cited in Castro-

Prieto, 2019). This conflict was evident in 2013 when approximately 950.3 acres of wetlands were cleared or filled for an agricultural project in Guánica (El Nuevo Día, 2013). It was estimated that 45.8 acres of secondary forest were cleared (El Vocero, 2013).

#### IV. CLIMATE CHANGE

Climate change poses a major threat to Puerto Rico's forest ecosystems which include changes in biodiversity, in carbon cycling, forest composition and structure, decreases in primary productivity, changes in ecosystems processes, and nutrient and water cycling (Waide et al., 2013; Gould et al., 2018).

The Puerto Rico Climate Change Council (PRCCC, 2013) identified major climate change stressors that are likely to affect Puerto Rico's forests. These are sea level rise, increased severity of tropical storms, decreased precipitation, increased drought, increased surface and extremes. These stressors will likely alter the flowering and fruiting phenology of all forest types, and the establishment and survival of seedlings, which would lead to changes in species composition, distribution, and abundance (PRCCC, 2013). Also, the PRCCC has stated that the delivery and flow of important forest ecosystem services may be compromised by climate-induced alterations, with potentially detrimental effects for the human communities that depend on them (PRCCC 2013). Table 4 presents a summary of outcomes/consequences of climate change stressors on Puerto Rico's dominant forest types prepared by the PRCCC.

**Table 4. Summary of outcomes/consequences of climate change stressors on Puerto Rico’s dominant forest types prepared by the PRCCC.**

Forest Type		Stressors				Biophysical Outcomes						Societal Consequences
		Sea level rise	Increased storm severity	Decreased precipitation/ increased drought	Increase in surface temperature	Salt water intrusion	Increased seasonality/ changes in flowering & fruiting phenology, seedling establishment	Increased wildfires	Elevated cloud condensation level	Changes in species composition, distribution, and abundance	Novel plant and animal assemblages with unique structure and function	Altered quantity and quality of forest ecosystem services (e.g., provision of clean water, carbon storage, economic and recreation opportunities)
Pterocarpus forests		●	●	●		●	●			●	●	●
Lowland moist forest & woodlands		●		●		●	●			●	●	●
Dry forests		●	●	●	●	●	●	●		●	●	●
Karst forests			●	●	●		●	●		●	●	●
Lower montane forests		●	●	●	●		●		●	●	●	●

Source: PRCCC, 2013. Puerto Rico's State of the climate 2010-2013: Assessing Puerto Rico's Social-Ecological Vulnerabilities in a Changing Climate.

According to the 4<sup>th</sup> National Climate Assessment (4<sup>th</sup> NCA), projected decreases in rainfall will change the distribution of ecological life zones, as relative increases in dry life zones are estimated, and the shrinkage and disappearance of wetter life zones (Gould et al., 2018). As temperatures continue to increase, montane species are shifting their ranges upslope and may reach upper elevational limits (Gould et al., 2018).

Model simulations show a robust drying pattern for all Caribbean islands that is generally larger for Puerto Rico (25% annual rainfall reduction for some life zones). These project substantial increases in temperature and decreases in precipitation for all life zones within Puerto Rico by 2050 (Bowden et al., 2020).

Vulnerable life zones such as the unique rainforest habitats in the Luquillo Mountains could be affected, which during the past decades have been impacted by anthropogenic stressors resulting from urban expansion (Gould et al., 2018; Gould, Martinuzzi and Parés, 2012; López-Marrero, and Hermansen-Báez, 2010). In addition to land use changes, climate change represents a threat to the cloud forest ecosystem in the Luquillo Mountains (Beusekom- Van, González and Scholl, 2017).

Climate change can also cause significant damage to forested wetlands due to sea level rise. Yu and collaborators (2019) analyzed coastal wetland changes in Puerto Rico under two scenarios: a one (1) and (2) meter sea level rise by 2100. They found that the areas currently covered by other saltwater and freshwater wetlands would be replaced by mangroves and estuarine water, and saltmarsh would encounter the most relative loss among wetland types (Yu et al, 2019). A 1-meter sea level rise scenario would allow the expansion of mangroves as the saltmarsh and freshwater wetlands would decrease. While in 2-meter sea level rise scenario, the distribution of all vegetated wetlands would be reduced and mostly replaced by estuarine water.

Coastal swamps characteristic of lower saline intrusion such as bloodwood swamps (*Pterocarpus officinalis*) and pond apple swamps (*Annona glabra*) would be severely affected. All these coastal forests act as nurseries for fish, habitat for other wildlife, and sediment filters for runoff. Research conducted on *Pterocarpus* forests has shown that increased soil and water salinity affects litter, flower, and fruit production and that

salinities above fourteen percent (14%) can kill populations of these trees (Eusse and Aide 1999; Rivera-Ocasio et al. 2007).

Puerto Rico, like other islands, receives many of the impacts of climate change. However, Puerto Rico also contributes emissions that cause global warming. Puerto Rico's CO<sub>2</sub> emissions from fossil fuels in 2018 were 20 million metric tons.<sup>24</sup> Climate warming is mainly caused by increasing CO<sub>2</sub> emissions in the atmosphere. Carbon sequestration by forests is one way to mitigate ambient greenhouse gasses, such as CO<sub>2</sub>, 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 enhancing 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.

## V. HURRICANES

Islands in the northern Caribbean are vulnerable to extreme weather-related disasters (Bowden et al., 2020). The hurricane cycle in the Atlantic has shaped Puerto Rico's forests for approximately 10 million years at a rate of 0.45 hurricanes hitting the island per year (Joglar, 2005). Atmospheric events like storms or hurricanes cause major recurrent ecosystem disturbances in

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<sup>24</sup> <https://www.eia.gov/state/data.php?sid=RQ#CarbonDioxideEmissions>

Puerto Rico, from there, other natural disasters emerge like floods and landslides.

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).

Hurricane effects vary based on forest structure and characteristics, such as forest age and forest type, environmental gradients, topographic location, stand characteristics, tree size, and species characteristics such as wood density (Tanner et al. 1991; Basnet et al. 1992).

As previously indicated, hurricanes Irma and María combined knocked down a quarter of the biomass contained in Puerto Rico's trees (Hall et al., 2020). Researchers found that an unsuspected key factor, more than wind, was massive rainfall and that future hurricanes stoked by warming climate may be even more destructive to forests than projected (Hall et al., 2020).

According to the 4th National Climate Assessment, climate models project an increase in the frequency of strong hurricanes (Categories 4 and 5) in the Atlantic Basin, including the Caribbean (Gould et al, 2018). It is essential to provide long-term, comprehensive, coordinated strategies for conserving, protecting, and enhancing forests in Puerto Rico to protect them and increase resilience to future natural disturbances. These strategies may include: 1) developing and implementing strategies at the watershed scale to promote a comprehensive management approach and reduce the impact on forest ecosystems; 2) establishing public and private collaborations to restore the function and structure of rural protected forests, ecological corridors, private forested lands, agroforestry, and urban forests; 3) applying green infrastructure in urban areas to mitigate floods and wind damage; 4) managing hurricane-induced debris, such as high-quality wood gathered during the vegetation waste removal process, to support and boost the

local wood product industry; and 5) using structural approaches to stabilize soils and slopes and protect these area during future storms.

## VI. DROUGHT

The most severe drought event recently experienced in Puerto Rico occurred during the period of 2013-2016. Atypically dry conditions were observed since the end of November 2013, especially in the southern region of Puerto Rico (DNER, 2016a). During the spring-summer of 2014, drought conditions was experienced in the central part of the island and in the municipalities of the north-central-west coast. During 2015, conditions intensified in the eastern half of the island, as the municipalities of the north central-west coast experienced a marked increase in the amount of rainfall. By January 2016, extreme drought conditions were observed in the southern region of Puerto Rico, while 59% of the island presented drought conditions. In October 2016, drought conditions persisted in 12.7% of the territory. Impacts on State Forests include changes in the behavior of birds specially in the Toro Negro State Forest. In the Jobos Bay National Estuarine Research Reserve (JBNERR) lack of water caused the death and stress of vegetation, especially in the mangrove forests (DNER, 2016a).

Droughts are another factor affecting forests that will worsen with climate change. Although many forest species in Puerto Rico can adjust to drought, hotter and longer droughts could affect their tolerance, causing long term effects, such as changes in plant communities and loss of species (Crausbay et al., 2018). In estuaries, the compound effects of climate change, urbanization and competing uses for the surface and underground waters may cause changes in the dominant wetland plants that provide the primary structure of estuaries. This has been documented in the South Coast Aquifer, where the availability of water that is required to sustain the mangrove forests in the southeast coasts of Puerto Rico, especially in the Jobos Bay National Estuarine Research Reserve and the Aguirre Forest has been compromised. This has caused the death of the mature black mangrove forest (DNER, 2016d).

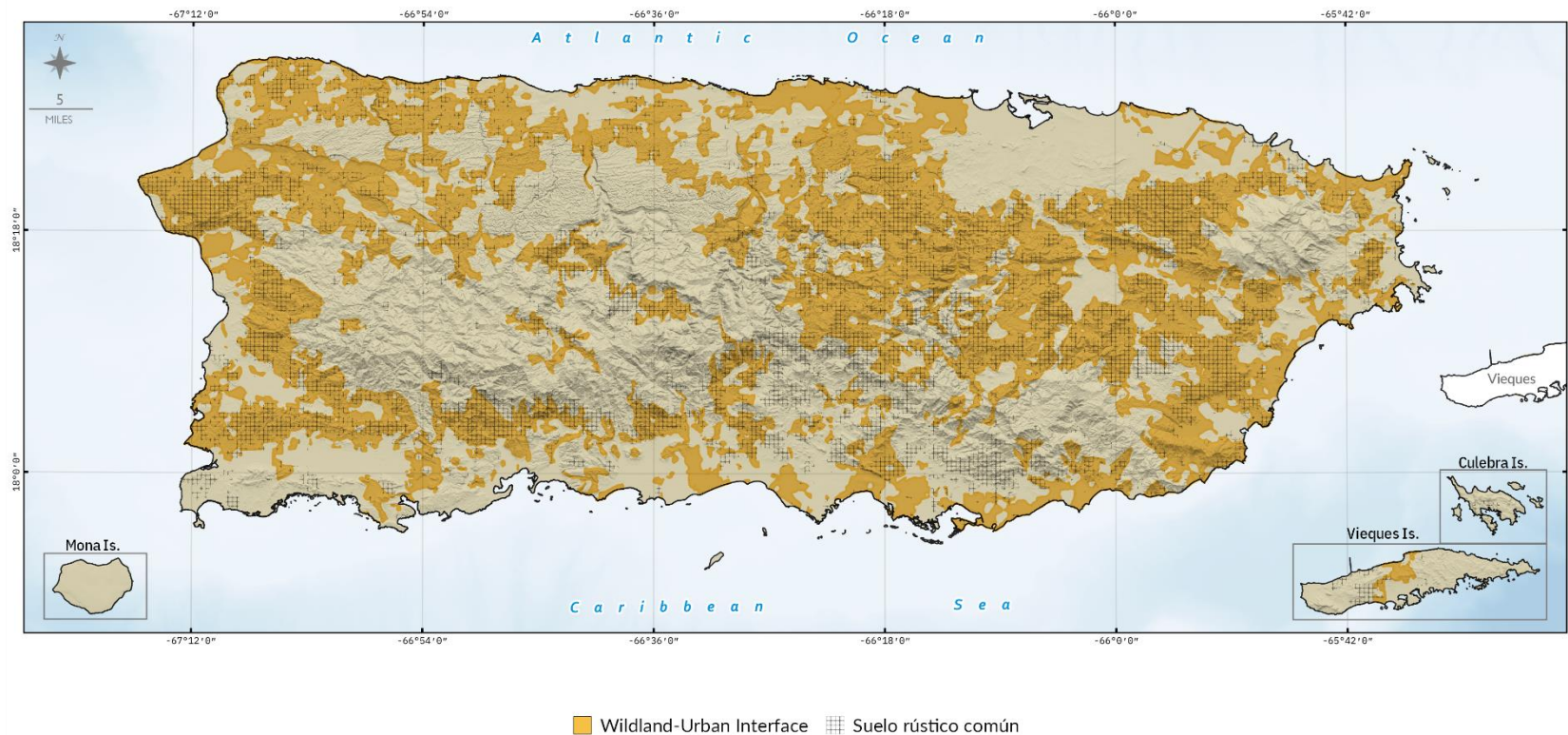
## VII. WILDFIRES

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 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 most fires in Puerto Rico are set by people (Gould 2008). Research and monitoring of fires in our region have 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).

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).

Figure 30. Intersection of wildland urban interface and "Common Rustic Lands" zoning according to Puerto Rico



Source: Urban and rural land use in Puerto Rico. USDA Forest Service, International Institute of Tropical Forestry, Martinuzzi, S.; Gould, W.A.; Ramos González, O.M.; Quiñones, M.; Jiménez, M.E. 2008; Puerto Rico Planning Board, Land Use Plan, 2015.

According to the Puerto Rico Firefighters Bureau (PRFB) statistics, between 2018 through 2020 a total of 7,099 wildland fires were reported throughout Puerto Rico. The highest incidence of fires occurred in 2020 with a total of 5,077. The PRFB regions with the highest numbers of fires were Ponce, Guayama and Mayagüez.

In terms of the incidence in the DNER Protected Natural Areas, a higher number of fires were documented in 2019, as compared with 2018, affecting areas such as: Guánica State Forest, Boquerón Wildlife Refuge, Punta Cuchara Natural Reserve, Caño Tiburones Natural Reserve and Tortuguero Lagoon Natural Reserve. Most of those fires were related to anthropogenic causes such as: campfires, cigarettes, torching, burning of trash and inappropriate prescribed burning of pastures.

The high incident of wildland fires in Puerto Rico requires the development of appropriated educational and outreach activities in order to raise public awareness. These activities, in addition to active management and a landscape conservation approach could reduce the incidence of fires and other stressors to forest ecosystems.

## VIII. 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.

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 nonnative 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).

A recent study held in Puerto Rico and the Virgin Islands (PRVI), revealed that the alien flora in PRVI consists of 1,032 species, which represent a third of total plant diversity in the islands and are classified in the following manner: thirty-eight percent as casuals, forty-five percent as naturalized and seventeen

percent as invasive (Rojas-Sandoval and Acevedo-Rodríguez 2014). Poaceae and Fabaceae are the families with the highest numbers of naturalized and invasive species, a fact that is not surprising since these two families are among the more diverse plant families of the world as well as among other Caribbean floras (Acevedo-Rodríguez and Strong 2012).

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

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

#### **IX. PESTS AND DISEASES**

The Agricultural Extension Service of the University of Puerto Rico in Mayagüez has been able to compile over time a list of native and nonnative 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 systems (Martorell 1945; Almodovar 2008). Table 7 shows a list of the concerned species considered pests in Puerto Rico forests and their host woody plants (Martorell 1982).

**Table 5. Natives and nonnatives insect species detected in Puerto Rico considered harmful to local tree or shrub species**

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
<i>Apate monacha</i>	the apate borer/ "escarabajo taladrador del tallo"	<i>Bixa orellana</i> ; <i>Bucida buceras</i> ; <i>Casuarina equisetifolia</i> ; <i>Delonix regia</i> ; <i>Inga vera</i> ; <i>Eugenia jambos</i> ; <i>Linociera domingensis</i> ; <i>Melia azedarach</i> ; <i>Persea americana</i> ; <i>Picramnia pentandra</i> ; <i>Salix chilensis</i> ;
<i>Aphis gossypii</i>	"áfido"	no information available
<i>Aspidotus destructor</i>	the coconut scale/ "la queresa del coco"	<i>Cocos nucifera</i> ; <i>Annona glabra</i> / <i>Barringtonia speciosa</i> ; <i>Grevillea robusta</i> ; <i>Mammea americana</i> ; <i>Persea americana</i> ; <i>Phoenix dactylifera</i> ; <i>Psidium guajava</i> ; <i>Terminalia catappa</i>
<i>Chlorida festiva</i>	the mango borer/ "el barrenador del mangó"	<i>Albizia lebbek</i> ; <i>Casuarina equisetifolia</i> ; <i>Mangifera indica</i> ; <i>Stahlia monosperma</i>
<i>Chrysomphalus aonidum</i>	the Florida red scale	no information available
<i>Diaprepes abbreviatus</i>	sugarcane weevil/ "vaquita de la caña"	<i>Albizia lebbek</i> ; <i>Andira jamaicensis</i> ; <i>Byrsonima spicata</i> ; <i>Cedrela mejicana</i> ; <i>Cedrela odorata</i> ; <i>Ceiba pentandra</i> ; <i>Chrysophyllum cainito</i> ; <i>Coccoloba uvifera</i> ; <i>Cordia alliodora</i> ; <i>Delonix regia</i> ; <i>Ficus stahlii</i> ; <i>Guaicaum officinale</i> ; <i>Inga vera</i> ; <i>Lagerstromia speciosa</i> ; <i>Melicocca bijugata</i> ; <i>Thespesia grandiflora</i> ; <i>Persea americana</i> ; <i>Psidium guajava</i> ; <i>Swietenia macrophylla</i> ; <i>Swietenia mahogani</i> ; <i>Tamarindus indica</i> ; <i>Terminalia catappa</i>
<i>Eulepte concordalis</i>	the roble leaf-webber/ "tejedor de la hoja del roble"	<i>Tabebuia argentea</i> ; <i>Tabebuia heterophylla</i> ; <i>Tabebuia lucida</i> ; <i>Tabebuia rigida</i> ; <i>Tabebuia schumaniana</i> ; <i>Crescentia cujete</i> ; <i>Spathodea campanulata</i>
<i>Exophthalmus roseipes</i>	the green bug/ "la vaquita verde"	<i>Andira inermis</i> ; <i>Chrysobalanus icaco</i> ; <i>Coccoloba uvifera</i> ; <i>Conocarpus erectus</i> ; <i>Dalbergia ecastophyllum</i> ; <i>Elaeodendrum xylocarpum</i> ; <i>Hymanea courbaril</i> ; <i>Inga vera</i> ; <i>Inga laurina</i> ; <i>Terminalia catappa</i>
<i>Homaledra sabalella</i>	the palm leaf- webber/ "tejedor de las hojas de las palmas"	<i>Cocos nucifera</i> ; <i>Prestoea montana</i>
<i>Iceria montserratensis</i>	no official common name; at first glance it looks as the cottony cushion scale ("queresa algodonosa")	<i>Byrsonima spicata</i> ; <i>Callophyllum calaba</i> ; <i>Casearia sylvestris</i> ; <i>Casuarina equisetifolia</i> ; <i>Chrysophyllum argenteum</i> ; <i>Cocos</i>

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
		nucifera; Ficus nítida; Inga vera; Inga laurina; Mammea americana; Psidium guajava; Samanea saman
<i>Icerya purchasii</i>	the cottony cushion scale / "queresa algodonosa"	Casuarina equisetifolia; Erythrina glauca; Senna emarginata; Prosopis juliflora; Pithecelobium dulce
<i>Ischnaspis longirostris</i>	the black red scale	no information available
<i>Megalopyge krugii</i>	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 guajava; Rhizophora mangle; Sciacassia siamea; Spondias purpurea; Terminalia catappa; Triplaris caracasana
<i>Nasutitermes costalis</i>	common termite/ "comején"	Albizia lebbeck; Albizzia procera; Andira inermis; Artocarpus communis; Bucida buceras; Bursera simarouba; Callophyllum calaba; Canagium odorata; Capparis portoricensis; Casuarina equisetifolia; Cecropia peltata; Cedrelaodorata; Ceiba pentandra; Cocoloba 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
<i>Oiketicus kirbyi</i>	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; Terminalia catappa; Thuja orientalis; Tabebuia spp.
<i>Pachylia ficus</i>	the ficus sphinx	Ficus nitida; Castilla elastica
<i>Pectynophora gossypiella</i>	the pink bollworm	Thespesia grandiflora; Thespesia populnea
<i>Phyllophaga portoricensis</i>	may beetle/ "caculo de mayo"	Cocoloba uvifeera; Schefflera morototoni; Lagerstromia speciosa; Bucida buceras; Cordia alliodora; Cordia sebestena; Grevillea robusta; Sterculia apétala; Sterculia foetida; Swietenia mahogani; Swietenia macrophylla; Terminalia catappa

Insect scientific name	Insect common names	Tree or shrub species affected, present in Puerto Rico
<i>Pseudalcapasis pentagona</i>	west indian peach scale	Calatropis procera; Clibadium erosum; Erythrina poeppigiana; Fraxinus sp.; Gleditsia triacanthos; Mammia americana; Mangifera inindica; Thespessia grandiflora; Hibiscus tiliaceum; Salix chilensis; Trema lamarkiana; Trema micrantha
<i>Pseudococcus adonidum</i>	mealybug/ "chinche harinosa"	Barringtonia speciosa; Callophyllum calaba; Erythrina glauca; Hibiscus tiliaceus
<i>Psychonoctua personalys</i>	mangrove stem-borer/ "barrenador del mangle"	Eugenia jambos; Laguncularia racemosa; Rhizophora mangle
<i>Saissetia oleae</i>	black sacale/ "la queresa negra"	Andira inermis; Annona muricata; Cedrela mejiicana; Cordia alliodora; Cordia sulfata; Crescentia cujete; Erythrina berteroaana; Erythrina glauca; Erythrina poeppigiana; Ficus laevigata; Ficus nitida; Gleditsia triacanthos; Guarea trichiloides; Guazuma ulmifolia; Isandrina emarginata; Eugenia jambos; Lagerstromia speciosa; Manilkara bidentata; Thespessia 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 lamarkiana; Trema micrantha; Zanthoxylum flavum
<i>Selenothrips rubrocinctus</i>	cacao thrips/ "candelilla del cacao"	Anacardium ; occidentale; Bixa Orellana; Chrysobalanus icaco; Coccoloba laurifolia; Mangifera indica; Psidium guajava; Spondias bombim; Terminalia catappa; Zanthoxylum monophyllum
<i>Sericocerina krugii</i>	sea grape wasp/"avispa de la uva de playa"	Coccoloba uvifera; other Coccolobba spp; Triplaris surinamensis
<i>Spodoptera frugiperda</i>	the fall armyworm/ "el gusano de ejército de otoño"	Seedlings of Eucaliptus robusta
<i>Xyloborus affinis</i>	ambrosia beetle	Albizzia lebeck; Cocos nucifera; Inga vera; Inga laurina

Exotic pests include non-native microorganisms, plants, insects, and other animals that cause or transmit diseases, displace native species, or diminish the economic or aesthetic value of a product or the environment. These pests not only have an impact on forest health but may also have a serious impact on species of high agricultural value. Table 6 lists detected exotic agricultural invasives pests species in Puerto Rico.

**Table 6. Puerto Rico Exotic Agricultural Pests Invasive Species**

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

## D. 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 DNER 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	<ul style="list-style-type: none"> <li>-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.</li> <li>-Promotes the conservation of soil, water, flora and fauna through the protection and effective management of private forest land.</li> <li>-Promotes greater participation of owners in the programs.</li> <li>-Develops projects that are aimed at improving water quality through the protection and conservation of watersheds and forest areas.</li> </ul>
Urban and Community Forestry, U&CF	<ul style="list-style-type: none"> <li>-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.</li> <li>-The program has an Advisory Council composed of representatives of various sectors of society, whose primary function is to advise the director of the BMNPFS in the process of implementing the program. Provide technical and financial assistance to communities, public and private entities and</li> </ul>

Program	Purpose
	municipalities on the management of urban forest resources to promote a sustainable ecosystem.
<b>Forest Legacy Program, FLP</b>	-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 with other states for funding of this program, which should provide a matching 25% of the state.
<b>Community Forest and Open Space Conservation Program, CFP</b>	-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.
<b>Forest Health Management</b>	-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.
<b>Forest Health Monitoring</b>	-Monitors the forests of the United States to determine detrimental changes or improvements to forest health that occur over time.
<b>State Fire Assistance</b>	-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.

Program	Purpose
<p><b>Volunteer Fire Assistance</b></p>	<p>Provides financial, technical and other assistance to rural communities with a population of less than 10,000 matched on a 50-50 basis either by the state or community. The State Foresters and their staff deliver this program. Some benefits include:</p> <ul style="list-style-type: none"> <li>  Available funding to renovate equipment obtained through the Federal Excess Personal Property Program</li> <li>  Improved fire protection capabilities and capacity in rural areas to protect lives and other rural investments</li> <li>  Improved effectiveness of fire protection in wildland urban interface areas</li> <li>  Complements state and federal firefighting forces to optimize fire protection across ownerships</li> <li>  Complements the Rural Fire Assistance Program provided by the Bureau of Land Management</li> </ul>
<p><b>Good Neighbor Authority (FY 2014 Appropriations Act and the 2014 Farm Bill)</b></p>	<p>These authorities encourage the USFS to enter into Good Neighbor Agreements with the States, the Commonwealth of Puerto Rico, and State Forestry Agencies to carry out authorized forest, rangeland, and watershed restoration and protective services when similar and complementary projects are being performed on adjacent State or private lands, and on and off National Forest System lands. (CFR 2015)</p>

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

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

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

Program	Purpose
<b>Environmental Quality Incentives Program, EQIP</b>	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.
<b>Partners for Fish and Wildlife, PFW and Coastal Program, CP</b>	These programs provide financial and technical assistance for voluntary, on-the-ground habitat restoration and protection projects through locally based field coordinators. The programs recognize the need to balance residential, tourist, commercial, agriculture, and industrial needs with conservation of important habitats and species, and work closely with other Federal, Territorial, non-governmental organizations, and private partners to carry out restoration projects. The mission of these programs is to protect and recover Federal Trust Species (threatened and endangered species, migratory birds, and inter-jurisdictional fish species) by supporting restoration of high priority habitats to restore important fish and wildlife species in private and public lands of Puerto Rico and U.S. Virgin Islands.
<b>Conservation Reserve Program, CRP (Farm Service Agency)</b>	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.
<b>Conservation Stewardship Program, CSP</b>	A voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner by: <ul style="list-style-type: none"> <li>  Undertaking additional conservation activities; and</li> <li>  Improving, maintaining, and managing existing conservation activities,</li> </ul>

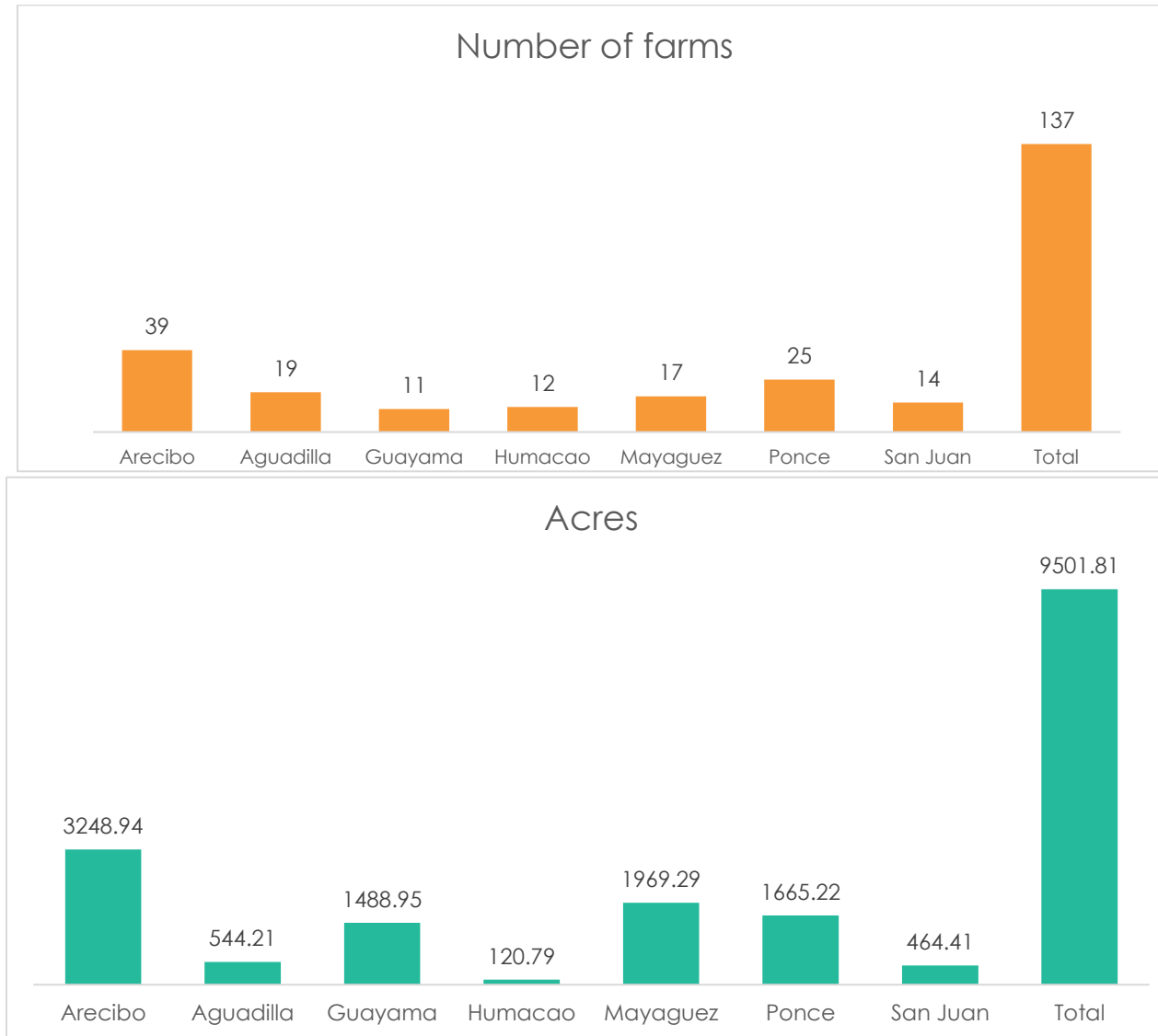
Program	Purpose
<p><b>Regional Conservation Partnership Program, RCPP</b></p>	<p>Partners with agricultural producers, farmers, state or local governments, NGOs, and higher education institutions to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale by restoring or sustaining natural resources such as:</p> <ul style="list-style-type: none"> <li>  Clean and abundant water</li> <li>  Healthy, productive soils</li> <li>  Enhanced, wildlife and pollinator habitat</li> </ul>
<p><b>Agricultural Conservation Easement Program, ACEP</b></p>	<p>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.</p>
<p><b>Healthy Forests Reserve Program, HFRP</b></p>	<p>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.</p>

### 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. As of 2021, there are 137 farms and 9,502 acres of lands in Puerto Rico participating in the Program.

Figure 31. Number of farms and acres of lands participating in the DNER state auxiliary forest programs.





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

**Table 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 Forestry Regulations for Puerto Rico,	It requires a DNER permit for cutting and grooming trees on public or private land in Puerto Rico.
Commonwealth Law No. 144 of 1976, as amended	Law for the extraction and excavation of Earth's crust components	It prohibits the issuance of Earth's crust components extractions and excavations in natural resources “reserves” (includes Commonwealth Forests).
Commonwealth Law No. 136 of 1976 (Also known as the “Water Act”)	Act for the Conservation, Development and Use of the Water Resources of Puerto Rico	It assigns to DNER the faculty of planning and ruling the usage, conservation and development of water resources in the Commonwealth, those superficial as much as subterranean.
Commonwealth Law No.29 of 1976	Department of Natural and Environmental Resources Rangers Corp Act	It creates DNER Rangers Corp who is supposed to enforce all the Commonwealth statutes available

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

# III. PUERTO RICO STATE-WIDE STRATEGIES FOR FOREST RESOURCES

## A. STRATEGIES OVERVIEW

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

- 
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

Forest fragmentation, specially of large forest parcels due to urbanization and development is an issue of concern. This causes other problems such as the increase in wildland fires, and in pests. The fragmentation of forests due to the construction of telecommunications towers is an issue in various areas of Puerto Rico. Another concern is the loss of public open space.

Forest connectivity will improve climate change adaptation and resilience not only for species but also for communities. Despite the uncertainties of ecosystems' responses to climate change, forested corridors facilitate species movement, as landscape fragmentation inhibits a species' migration capacity (Keeley et al., 2018a; Keeley et al., 2018b).

### 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.

Landslides associated with hurricane Maria and the loss of forest cover may have compromised important reservoirs. It is necessary to prioritize the reforestation of these watersheds to protect water supplies and associated wildlife.

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

The people of Puerto Rico are aware about the conservation of its natural resources and to develop new initiatives among government agencies, Non-Governmental Organizations (NGO's) and citizen groups, but additional supporting information still needed. 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 and climate change (hurricanes, floods, fires, pests, etc.)*

Climate change will exacerbate the impacts of hurricanes, droughts, pests, floods, fires among other disturbances that affect forests. Undoubtedly, sea level change will impact the estuarine and palustrine coastal forests. Reducing the stressors and fragmentation of forest ecosystems could help decrease the impacts on these resources.

#### *5. Hurricane and natural disturbance preparedness and response*

Hurricane Maria highlighted the importance of working on preparedness, response and recovery of forests and timber resources to the impacts of atmospheric events. As previously described, valuable hardwoods were mixed with general debris and ended in landfills, which in turn compromised the useful life of this infrastructure. This is a pressing issue that should be avoided in the future.

A comprehensive preparedness, response and recovery strategy is needed to manage the waste stream following storm events. This includes rapidly assess downed woody debris across Puerto Rico, develop a standardized process for removing woody debris from public and private lands, and increase sawmilling capacity (Resetar, 2020).

#### *6. Economic opportunities and alternative market development*

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

A comprehensive market research for wood products is needed, not only to properly manage climate events, but also to support a sustainable forest product industry in Puerto Rico.

#### *8. Active management of public and private forests*

As previously indicated, many of the state forests and other protected areas with important forest resources do not have

management plans. In addition, most of the forested lands are private. There is a need to continue working with private landowners in developing management plan and strategies for the protection and sustainable use of forest resources.

### 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.

## 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

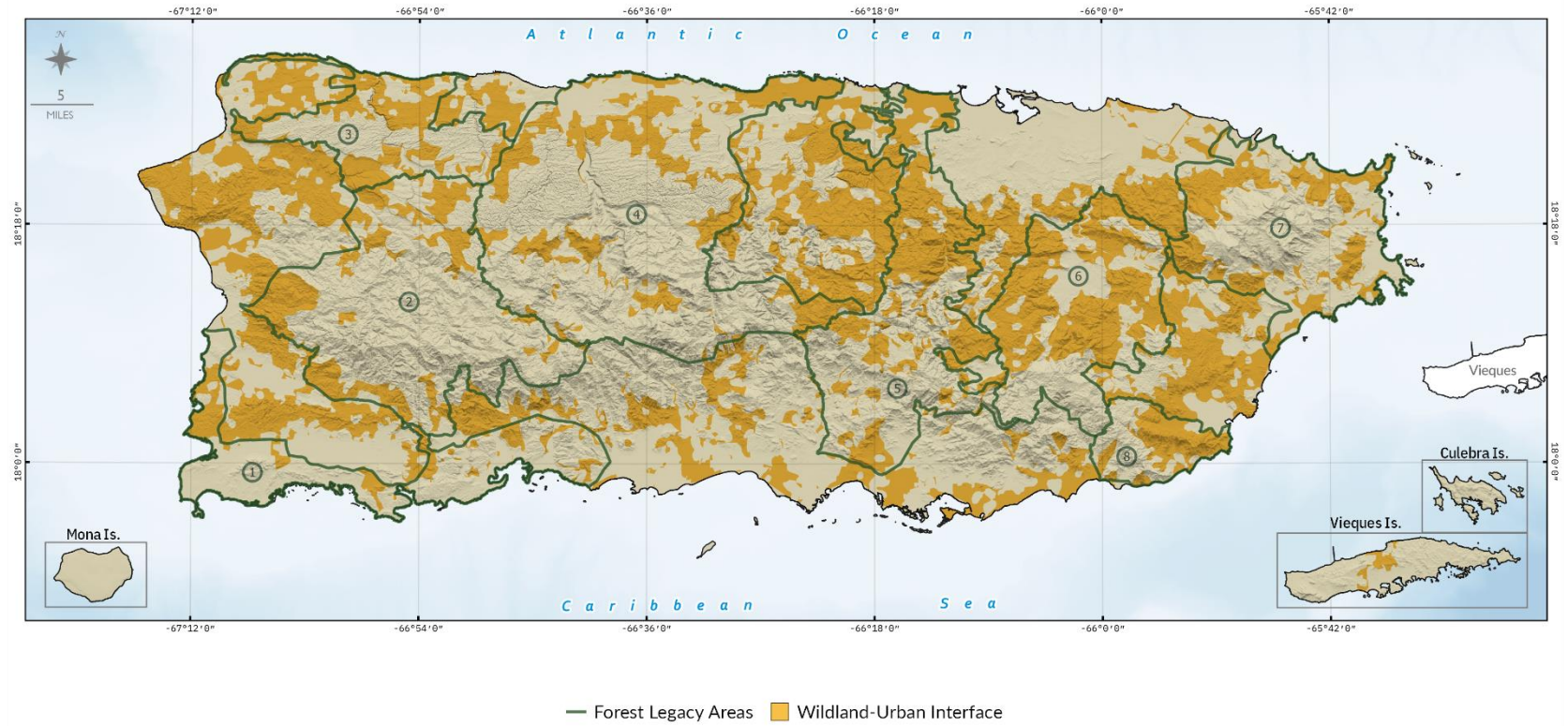
objective. It also requires the provision of guidelines as to how the goal contributes to the management of the issues. For each goal a matrix of strategies has been provided that address the issues. These strategies are meant as guides to the process of managing Puerto Rico forest resources into the near future.

### 1. Interface Landscape

The DNER will focus on acquiring land and easements in the Forest Legacy Areas (Figure 32). 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 B).

The Forest Legacy Program (FLP) is a volunteer land acquisition and conservation easement program that is administered by USFS and implemented cooperatively with the DNER. At present, eight Forest Legacy Areas have been identified based on the following criteria: fish and wildlife habitat, aesthetic and scenic value, public recreation opportunities, outstanding geological features, soil productivity, watershed values, including water quality protection and climate change mitigation and adaptation. These Forest Legacy Areas are: Guánica, Caonillas–Dos Bocas, El Yunque, La Plata-Coamo, Maricao, Maunabo, Quebradillas, Río Grande de Loíza.

Figure 32. Overview of urban wildland interface zones (Martinuzzi et al. 2007) and Forest Legacy Areas in Puerto Rico.

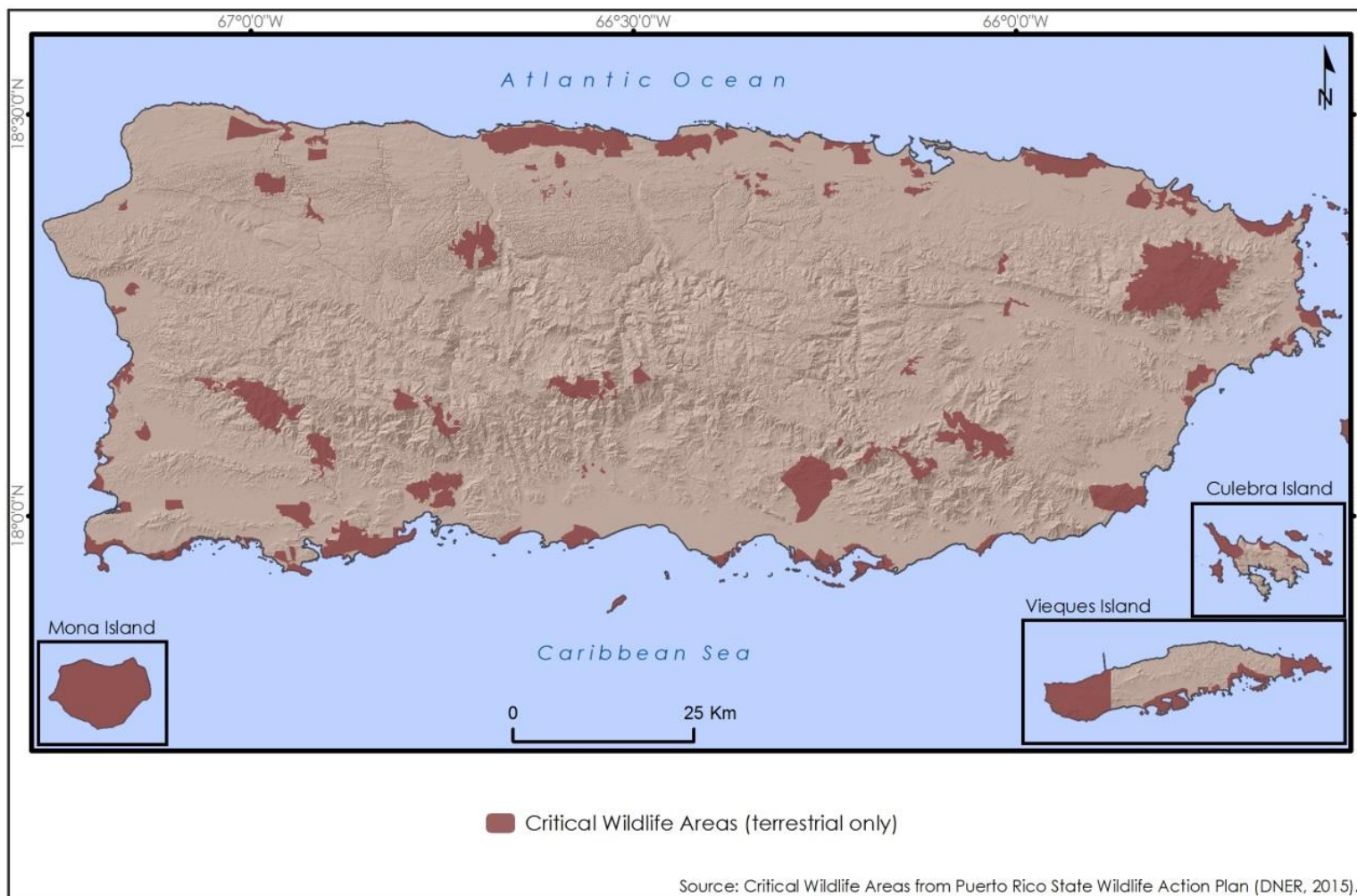


Source: Urban and rural land use in Puerto Rico. USDA Forest Service, International Institute of Tropical Forestry, Martinuzzi, S.; Gould, W.A.; Ramos González, O.M.; Quiñones, M; Jiménez, M.E. 2008.

## 2. Critical Wildlife Areas (CWA's)

Figure 33 Figure 1 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 area is found in the Appendix E. The DNER will work to manage their own land to meet this need, to prepare private forest management plans that consider wildlife objectives, and to educate community.

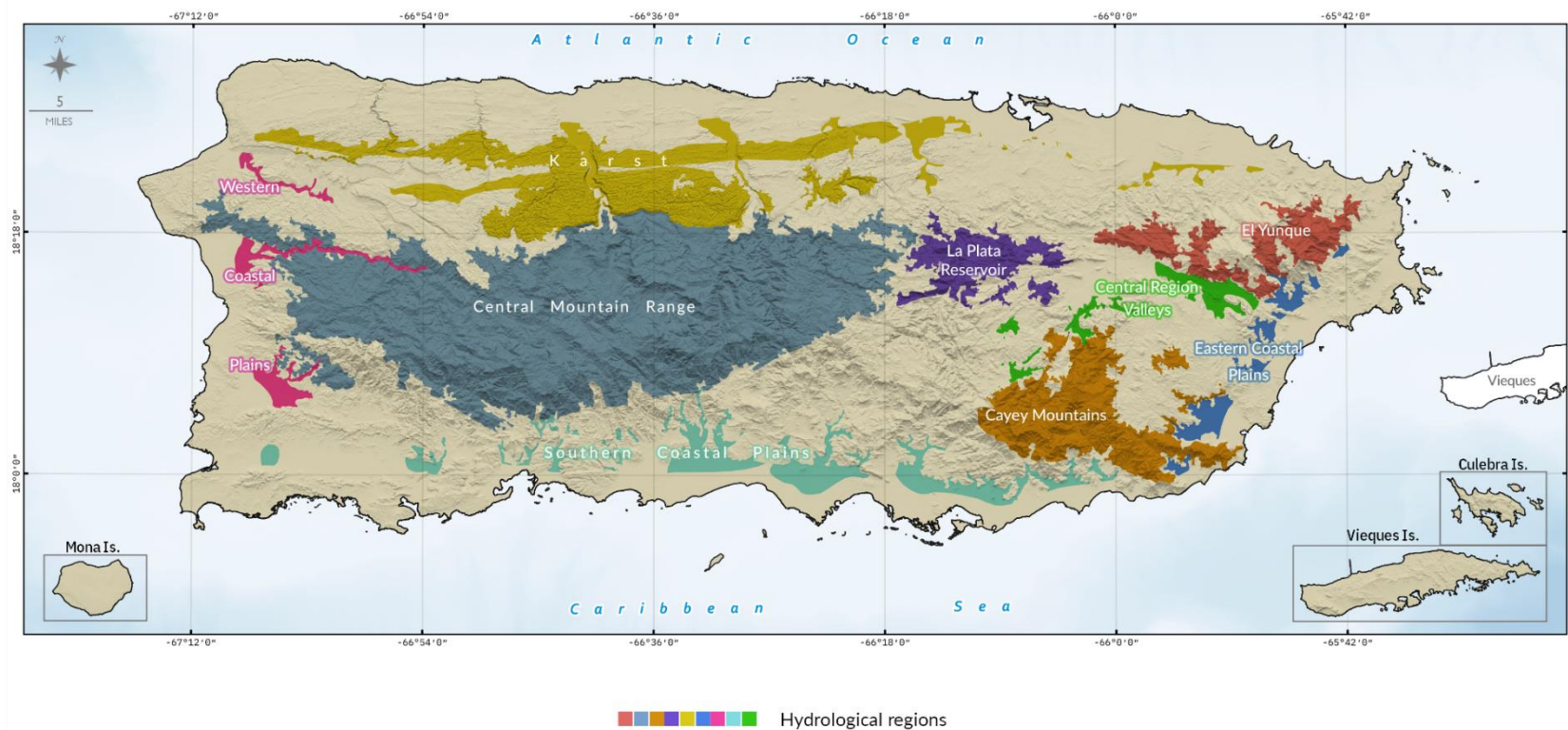
Figure 33. CWA's of Puerto Rico and their respective geographical locality obtained from PRSWAP (DNER 2015)



### 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 34) as well as Hydrological Reserves (Table 10. Hydrological Reserves). 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 34. Hydrological regions in Puerto Rico recommended for water quality protection by DNER and the Puerto Rico Planning Board (PRPB).



Source: DNER.

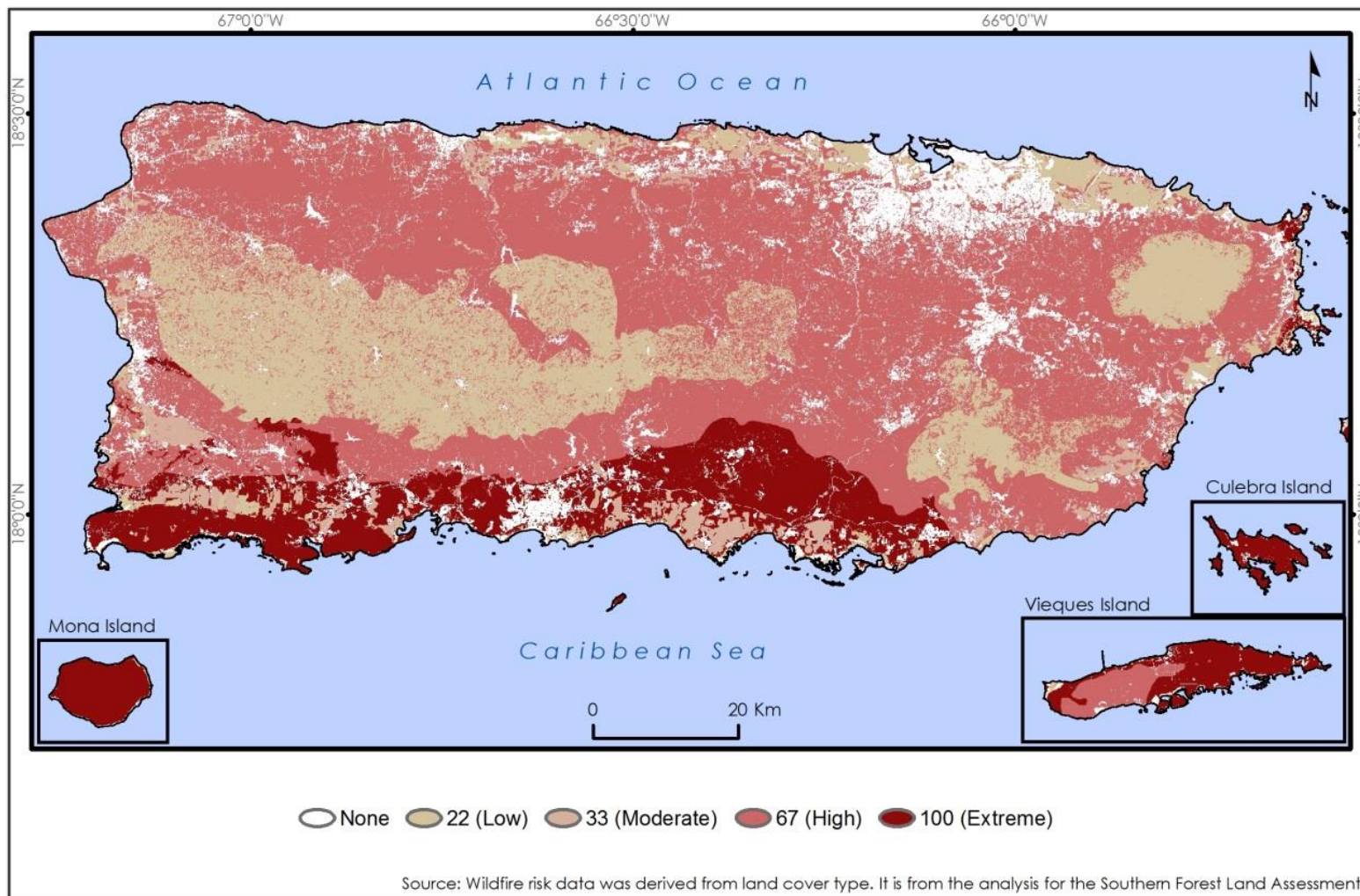
**Table 10. Hydrological Reserves**

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

#### 4. Fire Prone Landscape

The area in red on Figure 35. Overview of areas of Puerto Rico, Vieques, and Culebra under different levels of wildfire incidence according to SFLA 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 Mayagüez and Ponce Administrative Regions.

Figure 35. Overview of areas of Puerto Rico, Vieques, and Culebra under different levels of wildfire incidence according to SFLA



## 5. Riparian corridors

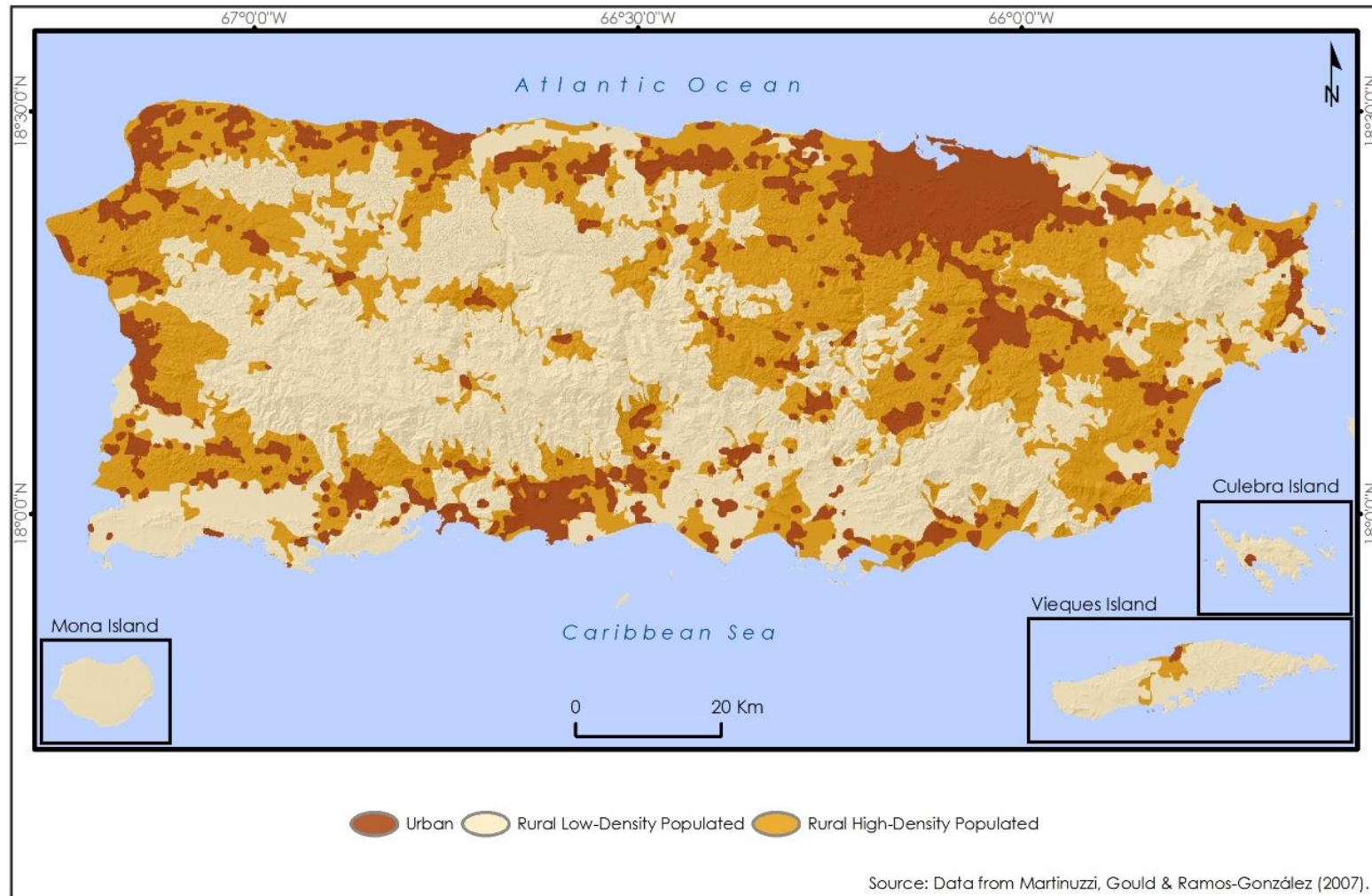
Riparian areas are the lands adjacent to a body of water, stream, river, marsh, or shoreline and a high priority for forest conservation and management. They have unique ecological attributes. Restoration and management of forest cover in riparian areas adjacent to reservoirs, agricultural fields and 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, as presented in Figure 12.

## 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 36). 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 36. 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 37). The Guanica/Maricao joint priority landscape has leveraged Federal, State, cooperative, and independent efforts. Several conservation and restoration projects supported by these entities are currently in progress within public and private lands in this region. These projects are focused on a "ridge-to-reef" approach to conserve and restore habitats along the entire watershed. For example, the NOAA Coastal Zone Management Program is working to protect the coral reef system, NRCS is promoting sustainable agricultural practices with local farmers in the Río Loco watershed to improve water quality, reduce sedimentation and reduce soil erosion. Moreover, NRCS, PRDNER and USFWS, in collaboration with private landowners, are implementing conservation practices such as forest enhancement, forest enrichment, establishment of riparian buffers, and the conversion of sun-grown coffee to shade-grown coffee within private lands of the Río Loco watershed, and areas surrounding the Maricao Commonwealth Forest to benefit local and Federal trust species. In addition, EPA is focusing on a major estuary restoration effort, the USFS and the BMNPAFS are jointly

promoting riparian buffers and other practices through forest stewardship plans and the Puerto Rico Fire Department (PRFD) and State Forests are working on wildland fire strategies in this landscape.

| The Humacao joint priority landscape

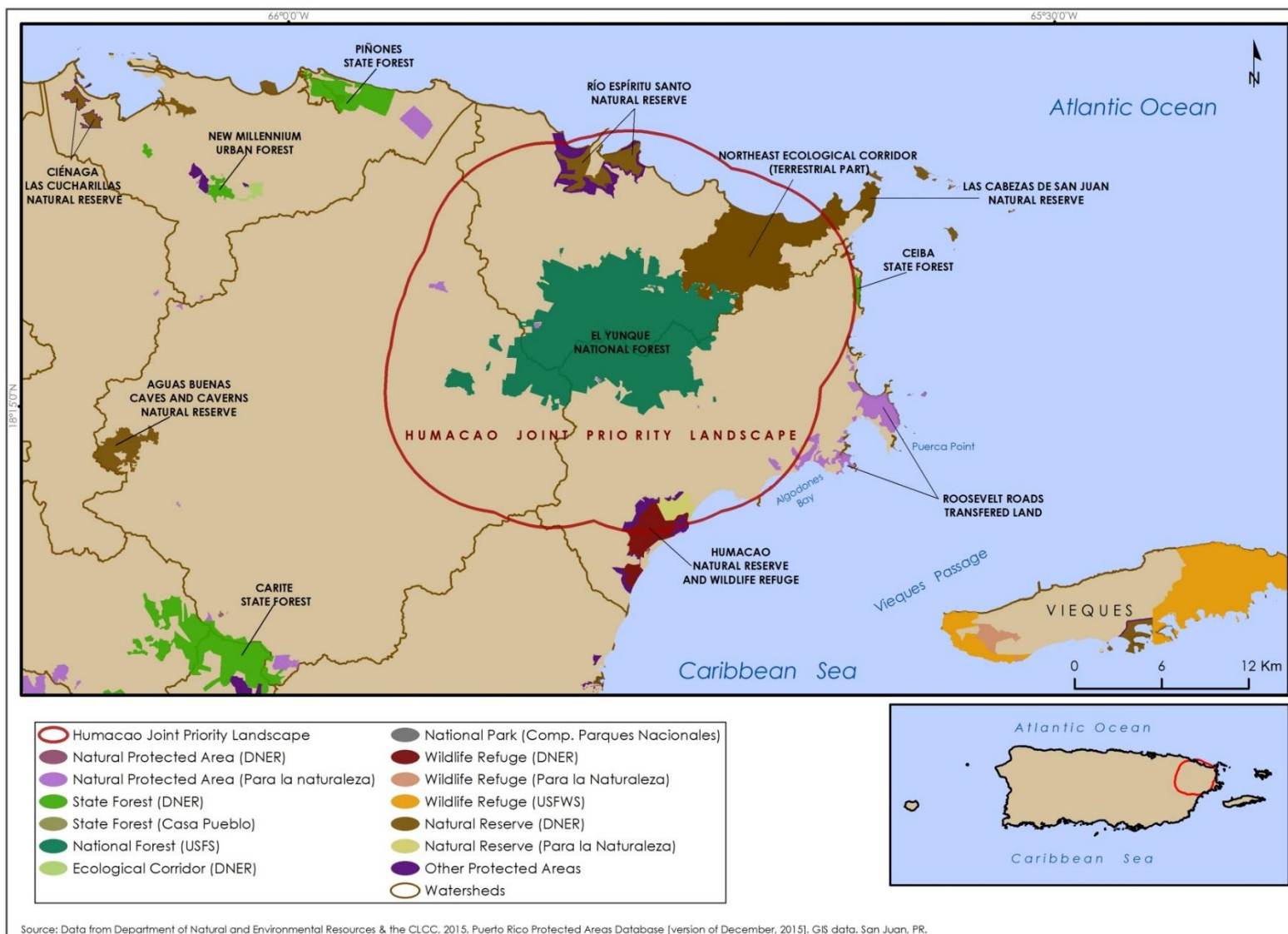
This area is located in the southeastern corner of mainland Puerto Rico in an area of urban sprawl. The area includes a 5-mile buffer zone, which encompasses the Northeast Ecological Corridor, Ceiba State Forest, El Yunque National Forest, Medio Mundo y Daguao Natural Protected Area, and the Natural Reserves of Río Espíritu Santo and Humacao (Figure 38). The Northeast Ecological Corridor was established in 2012 under Act No. 126, as amended, and is distinguished by containing most of the general types of coastal wetlands classified in Puerto Rico.

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

Figure 37. Overview of the Guánica/Maricao joint landscape



Figure 38. Overview of the Humacao joint priority landscape



## 8. The Model Forest of Puerto Rico

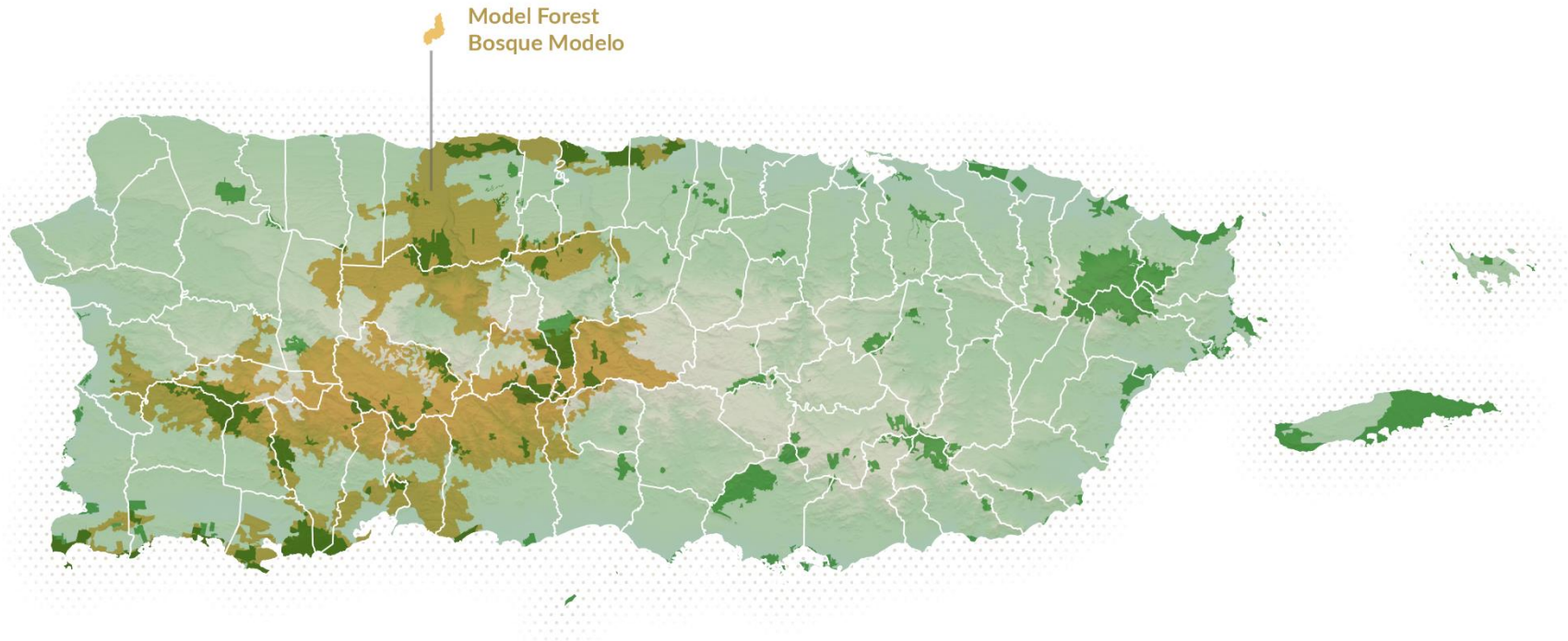
According to the International Model Forest Network model forests are based on an approach that combines the social, cultural and economic needs of local communities with the long-term sustainability of large landscapes in which forests are an important feature. People with differing interests and perspectives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

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

By 2014, the Commonwealth of Puerto Rico established the Puerto Rico Model Forest Act under Commonwealth Law Num. 182, being the first country to establish a Model Forest through legislation. This law recognizes the ecological value of the area, by establishing an umbrella effect on ecosystems and associated diversity of these areas, and the role of citizens in landscape conservation by declaring the Model Forest of Puerto Rico as a priority area for planning and a geographic sustainable development platform to promote criteria for management and conservation, sustainable tourism, education, and agriculture when implementing regional programs. The Model Forest of Puerto Rico interconnects

nineteen (19) protected areas; including *Bosque del Pueblo*, Toro Negro, Tres Picachos, La Olimpia, among others; throughout 378,777 acres of land from the north coast to the southern dry zone between Guánica and Cabo Rojo (Figure 39). 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 39. Overview of the Model Forest of Puerto Rico



Source: Puerto Rico Planning Board. 2015.

## B. GOALS AND STRATEGIES

### I. GOAL 1: CONSERVING WORKING FOREST LANDSCAPE

This goal encompasses the need to preserve 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):

<b>1</b>	<b>Continue land acquisition programs of key private forested land by available mechanisms (e.g. FLP)</b>	→ recreation and tourism; wood products, water conservation, climate change adaptation
<b>2</b>	<b>Promote conservation easements on private forested land</b>	→ recreation and tourism; wood products
<b>3</b>	<b>Provide adequate conservation management to private forests through FSP</b>	→ recreation and tourism; water conservation
<b>4</b>	<b>Develop forest and wildlife interpretation trainings</b>	→ recreation and tourism
<b>5</b>	<b>Develop management information on agroforestry practices suitable to the Río Loco Watershed at Guánica Bay Watershed.</b>	→ agroforestry products; wood; fruits; medicinal products; craft products; coffee, energy conservation, air quality improvement
<b>6</b>	<b>Increase capacity of community to manage trees (i.e. promote municipal tree boards)</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety, energy conservation, air quality improvement
<b>7</b>	<b>Increase tree canopy cover and condition</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; energy conservation, air quality improvement

8	<b>Acquire community open spaces to protect key forested areas</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; water conservation
9	<b>Hazard tree mitigation</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; energy conservation, air quality improvement
10	<b>Increase use of native plant material (native tree propagation and use)</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety, energy conservation, air quality improvement
11	<b>Develop nursery quality standards (Work with nursery growers to provide quality nursery stock)</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; energy conservation, air quality improvement.
12	<b>Develop educational programs and activities (i.e. demonstration of forests projects)</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety, energy conservation; air quality improvement
13	<b>Introduce agroforestry concepts</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; economic opportunities
14	<b>Promote arboriculture in universities curricula</b>	→ shade; aesthetics; climate control; mental health; wood products; mulch; wildlife; green infrastructure; recreation; safety; trained professionals

**Table 11. Goal 1: Conserving Working Forest Landscapes**

Benefits	Priority landscape	Strategies	Resources	Performance Measures
<ul style="list-style-type: none"> <li>-Recreation</li> <li>-Tourism</li> </ul>	<ul style="list-style-type: none"> <li>-Public lands</li> <li>-Surrounding private lands</li> </ul>	<ul style="list-style-type: none"> <li>-Continue land acquisition of key forested land by available mechanisms (USFS FLP).</li> <li>-Promote Conservation Easements on private forest land.</li> <li>-Provide adequate conservation management to private forests through FSP.</li> <li>-Develop forest and wildlife interpretation trainings.</li> </ul>	<ul style="list-style-type: none"> <li>-USFS FLP</li> <li>-DNER PR Natural Heritage Program</li> <li>-DNER PR High Ecological Value Land Acquisition and Conservation Fund</li> <li>-USFS FSP</li> <li>-NRCS HFRP</li> <li>-USFWS State Wildlife Grant</li> <li>-PR Conservation Trust Land Acquisition Initiative</li> </ul>	<ul style="list-style-type: none"> <li>-High priority forest ecosystems and landscapes are protected from conversion (acres-annual and cumulative).</li> <li>-Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship Management Plan</li> <li>-Number of interpretation trainings offered to private landowners and community members.</li> </ul>
<ul style="list-style-type: none"> <li>Wood products</li> </ul>	<ul style="list-style-type: none"> <li>Area around Toro Negro State Forest due to high risk of development.</li> </ul>	<ul style="list-style-type: none"> <li>-Continue land acquisition of key forested land by available mechanisms (USFS FLP)</li> <li>-Promote Conservation Easements on private forest land</li> </ul>	<ul style="list-style-type: none"> <li>-USFS FLP</li> <li>-DNER PR Natural Heritage Program</li> <li>-DNER PR High Ecological Value Land Acquisition and Conservation Fund</li> <li>-USFS FSP</li> </ul>	<ul style="list-style-type: none"> <li>-High priority forest ecosystems and landscapes are protected from conversion (acres-annual and cumulative).</li> <li>-Number of acres in forest areas being managed sustainably as defined by current Forest Stewardship</li> </ul>

Benefits	Priority landscape	Strategies	Resources	Performance Measures
		-Provide adequate conservation management to private forests through Forest Stewardship plans	-NRCS HFRP -USFWS State Wildlife Grant -PR Conservation Trust Land Acquisition Initiative -PRIDCO PR Arts and Crafts Development Program	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.
-Shade -Aesthetics -Climate control -Mental health -Wood products	Urban Areas and wildland urban interface.	-Increase capacity of communities to manage trees (i.e. promote municipal tree boards).	-USFS U&CF Community Cost-share Grants  -NGOs Education Programs	-Number of cities protecting urban forests after working with U&CF to develop management plans and ordinances.

Benefits	Priority landscape	Strategies	Resources	Performance Measures
<ul style="list-style-type: none"> <li>-Mulch</li> <li>-Wildlife</li> <li>-Green infrastructure</li> <li>-Recreation</li> <li>-Safety</li> <li>-Energy conservation</li> <li>-Air quality improvement</li> </ul>		<ul style="list-style-type: none"> <li>-Increase tree canopy cover and condition.</li> <li>-Acquire community open space to protect key forested areas.</li> <li>-Hazard tree mitigation.</li> <li>-Increase use of native plant material (native tree propagation and use).</li> <li>-Develop educational programs, activities (i.e. demonstration forests projects).</li> <li>-Develop nursery quality standards.</li> <li>-Introduce agroforestry concepts.</li> </ul>	<ul style="list-style-type: none"> <li>-Tree City USA</li> <li>-PR Via Verde Program</li> <li>-DNER Reforestation Programs</li> <li>-USFS Community Forest and Open Space Conservation Program</li> <li>-International Society of Arboriculture</li> <li>-Municipalities</li> <li>-Universities</li> <li>-DNER</li> <li>-PR U&amp;CF council</li> </ul>	<ul style="list-style-type: none"> <li>-Number of cities and communities managing their urban forest.</li> <li>-Number of Municipal Tree Boards.</li> <li>-Number of cities participating of the Tree City USA Program.</li> <li>-Number of ISA Certified Arborists (private and public sector).</li> <li>-Number of communities participating of the Open Space Community Forest Program.</li> <li>-Number of nursery growers improving nursery protocols.</li> </ul>

Benefits	Priority landscape	Strategies	Resources	Performance Measures
		<p>-Promote arboriculture in University curricula.</p>	<p>-University of Puerto Rico (UPR) Extension Service</p> <p>-PR Association of Professional Arborists</p> <p>-College of Architects and Landscape Architects.</p> <p>-PR Correctional and Rehabilitation Department</p>	<p>-Number of nurseries producing high quality nursery stock.</p> <p>-Number of demonstration projects using high quality plant material and native species.</p> <p>-Number of arboriculture courses offered at the UPR in Mayaguez, College of Agriculture</p>

## II. GOAL 2. PROTECT FORESTS 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 that could potentially affect present forest resources in the island have been identified by the original publication of the present document, previously referred as “Puerto Rico Statewide Assessment of Forest Resources”. These threats are hereby presented, followed by 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	Utilize the Fire Danger Rating System to identify the areas prone to 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	Engage in wildland fire suppression activities through collaboration among wildland fire crews from DNER, USFWS, USFS, PRFD, among others.
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 wildfire suppression.
9	Develop an effective communication strategy between partners involved in the suppression of wildfires.
10	Serve as members of the core team drafting the “Caribbean Cohesive Wildland Fire Management Strategy”.
11	Continue having a fire management officer from DNER actively participating in the Caribbean Multi-Agency Coordination Group.

### B. Insect pests and diseases

1	Establish a Forest Health Monitoring Program at the BMNPAFS.
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	<p>Protect developed large contiguous forest areas and corridors to insure connectivity by:</p> <ul style="list-style-type: none"> <li>(1) Land acquisition (see Appendix A)</li> <li>(2) Conservation easements</li> <li>(3) Adequate land use zoning</li> <li>(4) Voluntary protection</li> </ul>
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	<p>Increase programs availabilities for the East side of the Islands by:</p> <ul style="list-style-type: none"> <li>(1) Increase outreach,</li> <li>(2) Increase Water Conservation</li> <li>(3) Enhance Forest Diversity,</li> <li>(4) Enhance all restored riparian habitats.</li> </ul>
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### 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. (See Development; urban sprawl; fragmentation, Hurricane/storms and Flooding)

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

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

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
		<ul style="list-style-type: none"> <li>-Wildland Fire suppression</li> <li>-Tree planting and resource restoration in areas affected by fires</li> <li>-Acquire, maintain, and pre-position essential equipment and supplies for wildland fire suppression.</li> <li>-Develop an effective communication tool between partners involved in the suppression of wildland fires</li> </ul>		<ul style="list-style-type: none"> <li>(2) Upgraded or new fire suppression equipment obtained, or</li> <li>(3) Formation of a new fire department or expansion of an existing department involved in wildland fire fighting.</li> </ul>
<p><b>Insect pests and disease</b></p>	<ul style="list-style-type: none"> <li>-Loss and displacement of wildlife</li> <li>-Decreased reproduction</li> <li>-Stained wood</li> <li>-Poor tree form</li> <li>-Aesthetics</li> <li>-Hazard trees</li> </ul>	<ul style="list-style-type: none"> <li>-Establish a forest health monitoring program at the DNER</li> <li>-Encourage early detection and rapid response from forest managers</li> <li>-Provide professional training to forest managers</li> <li>-Promote public education about possible detrimental effects on forest floristic components</li> </ul>	<ul style="list-style-type: none"> <li>-USFS Forest Health Monitoring Program</li> <li>-UPR Extension Service Forest Health Clinic and Diagnostics Lab</li> <li>-DNER Forest Health Program</li> </ul>	<ul style="list-style-type: none"> <li>-Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects, diseases and plants.</li> <li>-Percent of population living in communities developing or managing programs to plant, protect and</li> </ul>

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
	-Increase fire risk  Fragmentation	-Maintain adequate urban tree inventories and management practices  -Promote Integrated Pest Management	-UPR  -USFS	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 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,	-USFS FLP  -USFS FSP  -Professionals who evaluate zoning, planning and permits  -Municipalities  -USFS CFP  -USFS U&CF Program  -PR U&CF Council  -International Society of Arboriculture	-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 and maintain their urban and community trees and forests.  -Number of acquisitions completed that are instrumental for corridor protection.  -Number of communities

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
		(2) Increase Water Conservation, (3) Enhance Forest Diversity, (4) Enhance all restored riparian habitats.	-PR Association of Professional Arborists	participating of the CFP.
<b>Hurricanes/storms</b> (Island-wide)	-Biodiversity  -Wildlife  -Urban forest  -Forest products  -Recreation experiences  -Coastal resources	-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 software application (adapted to tropics) -FEMA Programs -PR Conservation Trust	-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 and maintain their urban and community trees and forests.

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
	Island-wide	<ul style="list-style-type: none"> <li>-Develop a comprehensive hurricane preparedness, response, and recovery plan to manage wood debris and hardwoods for wood products</li> <li>- Conduct a market study for wood products</li> <li>-Increase capacity and facilities to manage wood debris and hardwood products</li> </ul>	<ul style="list-style-type: none"> <li>-DNER</li> <li>-USFWS</li> <li>-Municipalities</li> <li>-PR Department of Transportation and Public Works</li> <li>-PREPA/LUMA Energy</li> <li>-FEMA</li> <li>-COR3</li> </ul>	<ul style="list-style-type: none"> <li>-Development of the Plan</li> <li>Development of the market analysis for wood products</li> <li>-Number of facilities that can manage wood products (sawmills)</li> </ul>
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	<ul style="list-style-type: none"> <li>-Corridors for tree migration</li> <li>-Increase carbon storage through increases in tree cover</li> <li>- Urban forest inventory</li> <li>-Tree Management plan development</li> <li>-Hazard tree mitigation</li> </ul>	<ul style="list-style-type: none"> <li>-USFS U&amp;CF Program</li> <li>-USFS FSP</li> <li>-USFS FLP</li> <li>-USFS Community Forest and Open Space Conservation Program</li> <li>-International Society of Arboriculture</li> <li>-PR Association of Professional Arborists</li> <li>-Tree City USA</li> </ul>	<ul style="list-style-type: none"> <li>-Population of communities benefiting from S&amp;PF activities designed to contribute to an improvement in air quality.</li> <li>-Population of communities benefiting from S&amp;PF activities that result in energy conservation.</li> </ul>

Threats (risk map)	Resources (affected/resource effects)	Strategies	Resources	Performance Measures
		-Tree selection	-ITree (adapted to tropics) -PR Conservation Trust -UPR Marine Science Department	
<b>Flooding</b>	-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.
<b>Drought</b> (See fire, see climate change)				
<b>Invasive plants</b>	-Biodiversity  -Wildlife  -Displacement of indigenous species	-Professional and public education  -Promote native and other suitable species  -Early eradication	-Nursery growers and buyers, -DNER -Puerto Rico Forest Health Advisory Committee	-Number and percent of forest acres restored and/or protected from (1) invasive and (2) native insects, diseases and plants (annual).

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

### 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	Forest products benefits to incentivize protecting and enhancing forest cover		

**Table 13. Goal 3: Enhance public benefits associated with trees and forests**

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

Benefits	Priority area	Strategy	Resources	Performance measures
<b>Wildlife Habitat</b>	<ul style="list-style-type: none"> <li>-Coastal upland forest remnants</li> <li>-Mature forest habitats</li> <li>-Corridors that link mature forest areas (i.e. riparian areas along streams)</li> <li>-Corridors required under Commonwealth Law Number 14 of 1999</li> <li>-Threatened and Endangered Species habitat.</li> </ul>	<ul style="list-style-type: none"> <li>-Private forested land acquisition by several means including FLP</li> <li>-Encourage Conservation Easements</li> <li>-Promote voluntary private land conservation management.</li> <li>-Provision of proper management on public forested lands</li> <li>-Continue land acquisition programs to conserve mature forest</li> <li>-Promote and Encourage agroforestry practices (sun coffee plantations to shade grown coffee)</li> <li>-Establish Maricao Commonwealth Forest and a 5</li> </ul>	<ul style="list-style-type: none"> <li>-UFSF FLP</li> <li>-DNER PR Natural Heritage Program</li> <li>-DNER PR High Ecological Value Land Acquisition and Conservation Fund</li> <li>-USFS FSP</li> <li>-NRCS EQIP</li> <li>-USFWS PFW</li> <li>-Federal and State agencies management</li> <li>-NRCS HFRP</li> </ul>	<ul style="list-style-type: none"> <li>-High priority forest ecosystems and landscapes are protected from conversion (acres- annual and cumulative).</li> <li>-Number of acres in forest areas being managed</li> <li>Sustainably as defined by current Forest Stewardship Management Plan</li> <li>-Detectable increased in frequency numbers of priority critical species for WHIP.</li> <li>Establishment of wild reproductive couples of Puertorrican Parrot in Maricao Commonwealth Forest.</li> <li>-Increase of riparian forests under conservation practices.</li> <li>-Reduction of predator numbers on Maricao Commonwealth Forests and it 5 mile buffer zone.</li> <li>-Increase the number of ecological corridor created between public and private forested land.</li> </ul>

Benefits	Priority area	Strategy	Resources	Performance measures
		mile buffer (it includes Susúa Commonwealth Forest)		
<b>Plant biodiversity</b>	Public forested lands	<p>Private forested land acquisition by several means including FLP</p> <p>-Promote voluntary private land conservation management.</p>	<ul style="list-style-type: none"> <li>-USFS FLP</li> <li>-USFS CFP</li> <li>-Conservation Easement Commonwealth Law</li> <li>-DNER Puerto Rico Natural Heritage Program</li> <li>-DNER High Ecological Value Land Acquisition and Conservation Fund</li> <li>-NRCS HFRP</li> <li>-USFS FSP</li> <li>-USFWS State Wildlife Grant</li> </ul>	<ul style="list-style-type: none"> <li>-High priority forest ecosystems and landscapes are protected from conversion (acres- annual and cumulative).</li> <li>-Number of acres in forest areas being managed</li> <li>Sustainably as defined by current Forest Stewardship Management Plan</li> </ul>
<b>Carbon Sequestration</b>	Private forested land	<ul style="list-style-type: none"> <li>-Retain forest cover</li> <li>-Manage for forest health and growth</li> </ul>	<ul style="list-style-type: none"> <li>-USFS FSP</li> <li>-USFS FLP</li> <li>-USFS CFP</li> <li>-Conservation Easement Commonwealth Law</li> <li>-NRCS HFRP</li> </ul>	<ul style="list-style-type: none"> <li>-Population of communities benefiting from S&amp;PF activities designed to contribute to an improvement in air quality.</li> <li>-Population of communities benefiting from S&amp;PF activities that result in energy conservation.</li> </ul>

Benefits	Priority area	Strategy	Resources	Performance measures
		-Forest products benefits to incentivize protecting and enhancing cover		

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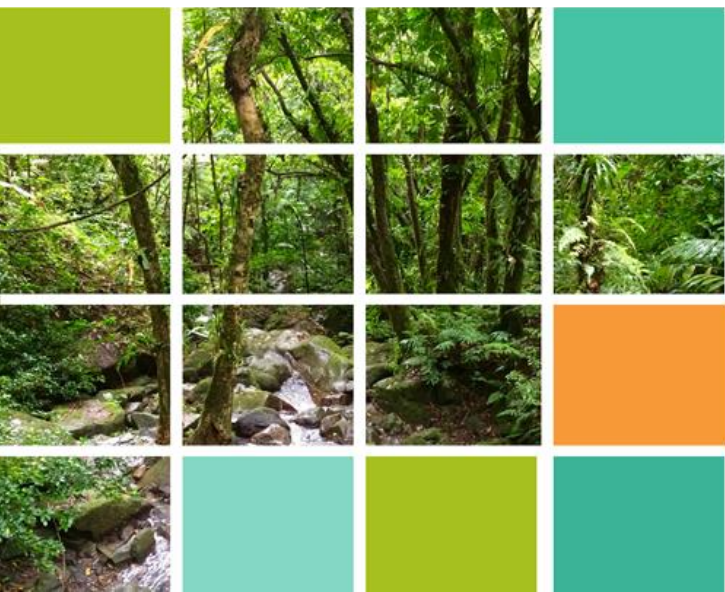
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# APPENDIX A: COASTAL CHANGE ANALYSIS PROGRAM

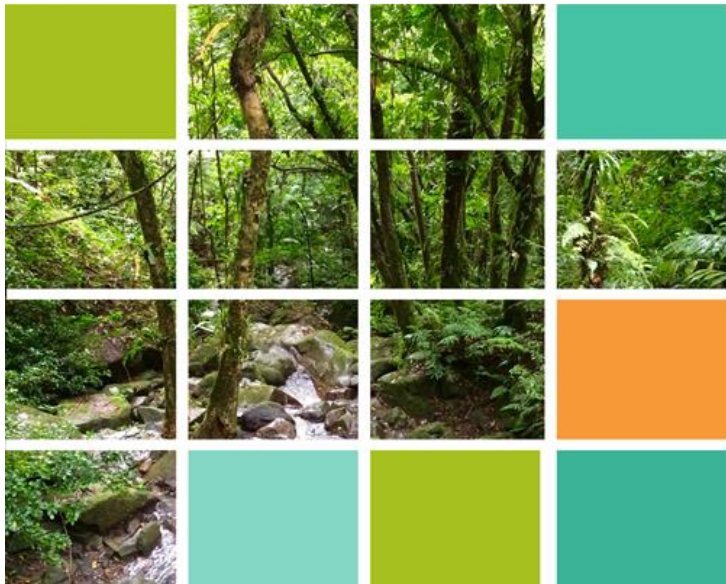
Land Cover classes		Description	Área (m <sup>2</sup> )	%
Developed land	2	Impervious Anthropogenic features such as buildings, parking lots, and roads developed from concrete, asphalt or other construction material that does not allow infiltration from precipitation.	832,358,156	9.40%
	5	Developed , Open space Contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Constructed surfaces account for less than 20% of total land cover.	281,314,184	3.20%
Agricultural land	6	Cultivated crops Contains intensively managed areas to produce annual crops. Crop vegetation accounts for more than 20% of total vegetation. This class also includes all land being actively tilled.	287,807,620	3.20%
	7	Pasture/Hay Contains areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture / hay vegetation accounts for more than 20% of total vegetation.	586,555,856	6.60%
Grassland	8	Grassland Contains areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.	302,661,720	3.40%
Forest land	11	Mixed forest Contains areas dominated by trees generally greater than 5 meters (16 feet) tall, and greater than 20% of total vegetation cover. <i>Both coniferous and broad-leaved evergreens are included in this category.</i>	5,200,756,256	58.60%
Scrub land	12	Scrub/shrub Contains areas dominated by shrubs less than 5 meters (16 feet) tall with shrub canopy typically greater than 20% of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.	761,009,416	8.60%
Palustrine wetlands	13	Palustrine Forested Wetland Includes tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters (16 feet) in height, and all such wetlands that occur in tidal zones in which salinity due to ocean-derived salts is below 0.5%. Total vegetation coverage is greater than 20%.	205,044,336	2.30%
	14	Palustrine Scrub/Shrub Wetland Includes tidal and non-tidal wetlands dominated by woody vegetation less than 5 meters (16 feet) in height, and such all wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation coverage is greater than 20%. <i>Species</i>	32,576,332	0.40%

Land Cover classes		Description	Área (m <sup>2</sup> )	%	
Estuarine wetlands		<i>present could be true shrubs, young trees and shrubs or trees that are small or stunted due to environmental conditions.</i>			
	15	Palustrine Emergent Wetland	Includes tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses, or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation cover is greater than 80%. <i>Plants generally remain standing until the next growing season.</i>	91,364,464	1.00%
	16	Estuarine forested wetland	Includes tidal wetlands dominated by woody vegetation greater than or equal to 5 meters (16 feet) in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.	78,521,512	0.90%
	17	Estuarine scrub/shrub wetland	Includes tidal wetlands dominated by woody vegetation less than 5 meters (16 feet) in height, and all such wetlands that occur in tidal areas in which salinity due ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.	19,748,552	0.20%
	18	Estuarine emergent wetland	Includes all tidal wetlands dominated by erect, upright and rooted emergent hydrophytes (lichens and mosses excluded). These occur in tidal areas where salinity due to salts derived from the ocean is greater than or equal to 0.5%. The total vegetative cover is greater than 20%.	24,587,912	0.30%
Barren land	19	Unconsolidated shore	Contains material such as silt, sand or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneer plants that become established during brief periods when growing conditions are favorable.	16,661,528	0.20%
	20	Barren land	Contains areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earth material. Generally, vegetation accounts for less than 10% of total cover.	55,688,216	0.60%
Water and submerged lands	21	Open water		93,652,888	1.10%
	22	Palustrine aquatic bed	Includes areas of open water, generally with less than 25% cover of vegetation or soil. Includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.	1,183,372	0.01%

Land Cover classes	Description	Área (m <sup>2</sup> )	%
 23 Estuarine aquatic bed	Includes tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.	84,316	0.00%
Background	Areas within the image file limits but containing no data values.		
Unclassified	Unclassified Areas in which land cover cannot be determined; these include clouds and deep shadow.	7,828,952	0.10%
<b>Total</b>		<b>8,871,576,636</b>	<b>100.00%</b>



**APPENDIX B:**  
PUERTO RICO FOREST  
LEGACY ASSESSMENT  
OF NEEDS



**APPENDIX C:**  
THE SOUTHERN FOREST  
LANDS ASSESSMENT

## Appendix C. The Southern Forest Lands Assessment

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

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

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

All data information layer used had been previously published. These maps reflect forest resource priorities according to this model and give base for the spatial analysis and for the identification of potential areas of concern, while at the same time offering a

benchmark, to assess program effectiveness in protecting such forest resources. The results are organized by different S&PF programs, and DNER administrative region. Each of these layers was assigned a level of importance (weight), originally developed by the leaders of the Southern Region of the NASF. Please refer to Table 14 for weight values utilized.

Figure 40. High priority landscape areas as indicated by the SFLA

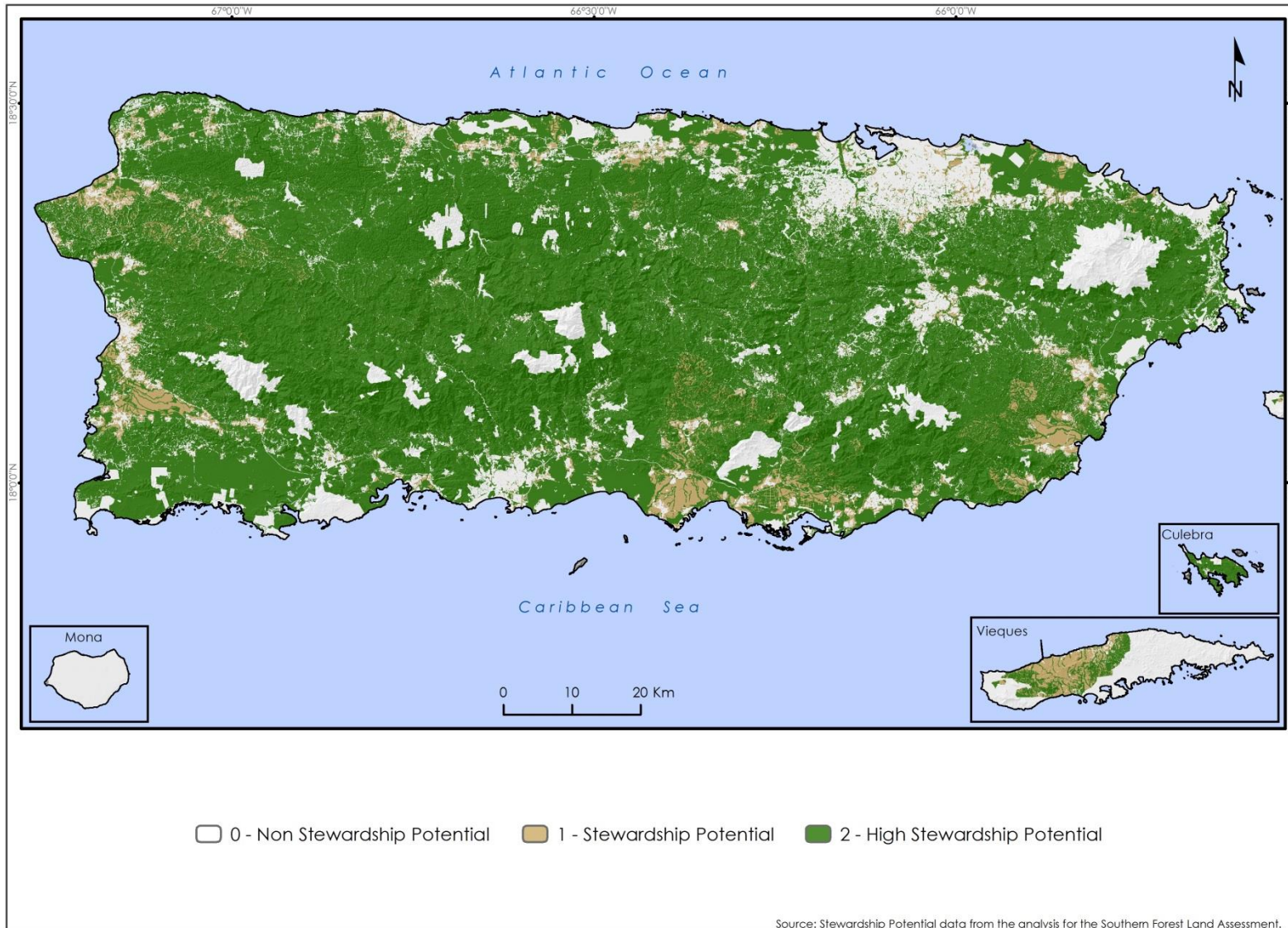
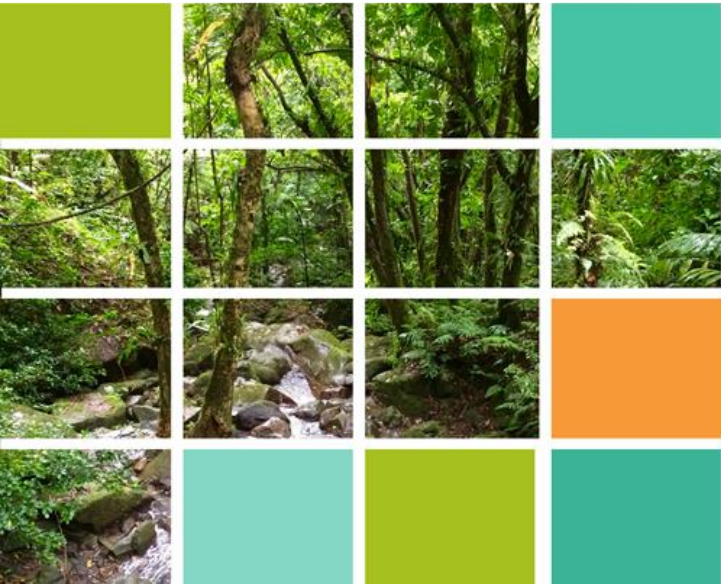


Table 14. Geographic layers weighted according to importance in analysis

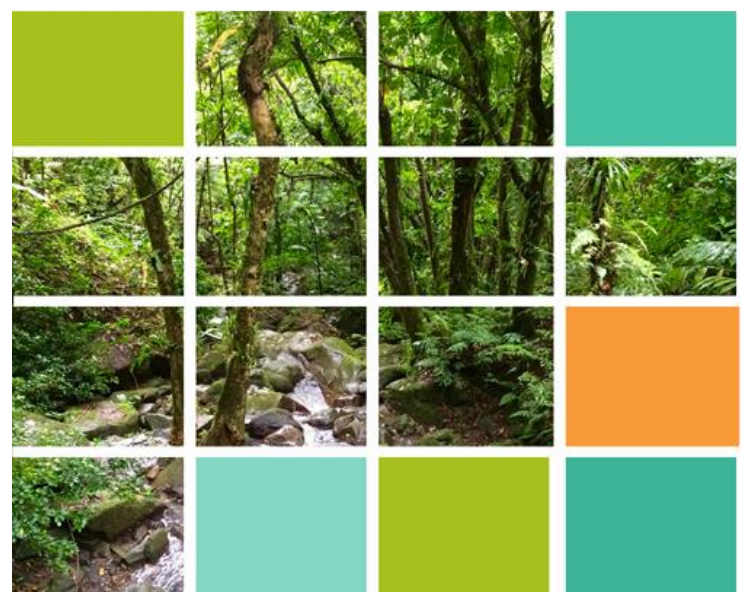
<b>Layer</b>	<b>Weights</b>
<b>Forestland</b>	<b>11.1</b>
<b>Development Level</b>	<b>11.1</b>
<b>Riparian Areas</b>	<b>11.1</b>
<b>Wildfire Risk</b>	<b>2.5</b>
<b>Public Drinking Water</b>	<b>11.1</b>
<b>Priority Watersheds</b>	<b>11.1</b>
<b>Forest Patches</b>	<b>7.4</b>
<b>Forested Wetlands</b>	<b>0.8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



**APPENDIX D:**  
IDENTIFICATION OF  
PUBLIC ISSUES AND  
CONCERNS

## **Appendix D. Identification of Public Issues and Concerns**

This Appendix will be updated in october-november 2021



**APPENDIX E:**  
FOREST LAND  
ANALYSIS PROJECT  
(FLAP)

## 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 15). During the meetings each participant was rotated through three small group discussion sessions (Table 18). Lists of meeting participants are available in the BMNPFS office.

Table 15. FLAP public meeting schedule

<b>REGION</b>	<b>DATE</b>	<b>LOCATION</b>	<b>TIME</b>
<b>HUMACAO</b>	September 9, 2008	UPR, Humacao Campus	7:00 pm
<b>GUAYAMA</b>	September 10, 2008	UPR, Cayey Campus	7:00 pm

REGION	DATE	LOCATION	TIME
<b>PONCE</b>	September 23, 2008	Interamerican University, Ponce	7:00 pm
<b>ARECIBO</b>	September 24, 2008	Ernesto Ramos Antonini Theater, Barceloneta	7:00 pm
<b>AGUADILLA</b>	October 22, 2008	UPR- Aguadilla Campus	7:00 pm
<b>MAYAGUEZ</b>	October 23, 2008	Rebekah Colberg Sports Complex, Cabo Rojo	7:00 pm
<b>SAN JUAN</b>	October 28, 2008	Environmental Building, Río Piedras	7:00 pm

#### FLAP Group A Questions

When was the last time you visited a forest managed by the DNER? What do you remember of the experience?

What activities do you enjoy out in the woods?

How do you understand that forests can benefit your benefit or quality of life and your community?

#### FLAP Group B Questions

In your experience, what are the characteristics of a forest? What is a forest for you?

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

What recreational activities would include among the services and opportunities for visitors of our forests?

What ideas, programs or understand incentives could benefit land owners so that they keep them like a forest?

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](http://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](mailto: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 41. Humfredo Marcano (USFS) reporting FIA data at the Guayama public meeting.

terms of specific tasks within the Bureau.

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 BMNPAFS also analyzed results to establish connections between them and possible clustering in

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

- Fragmentation (loss of large patches of forest)
- Water and watershed conservation
- Climate change (what is being done; are there impacts expected)
- Environmental Services (use of forest resources for recreation, therapy, etc.).
- Loss of forests and urban interface within rural areas (remnant, parks, housing subdivisions)

- Disturbances that are affecting forests (hurricanes, floods, fires, plagues, etc.)
- Education on forests and forest functions (desire to know or understand more and better)
- The adverse effects of exotic species on our native ecosystems, their flora and wildlife well-being
- Markets derived from wise uses of forests, including ecotourism (I want to buy souvenirs, photos, brochures, posters, etc.)
- 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 16

**Table 16. Categories and Class of Threats associated with Forest Resources in Puerto Rico as determined by public involvement in the Puerto Rico FLAP process.**

<b>Threat Category</b>	<b>Threat Class</b>
<b>Forest Habitat Conversion: Intentional conversion of natural habitat that is detrimental to wildlife use and survival.</b>	Housing and urban development Agriculture
<b>Forest Habitat Degradation: Degradation of wildlife habitat and available forage.</b>	Intentional fires Illegal dumping Wetland filling Recreation Inadequate forest and woodland management Grazing Poor forest harvest practices
<b>Consumptive Use of Biological Resources: Harvest or use of plant and animal populations in a manner that negatively impacts wildlife.</b>	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 BMNPAFS, 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:**  
NATIONAL PRIORITIES  
SECTION

# STATE ACTION PLAN, 2021

