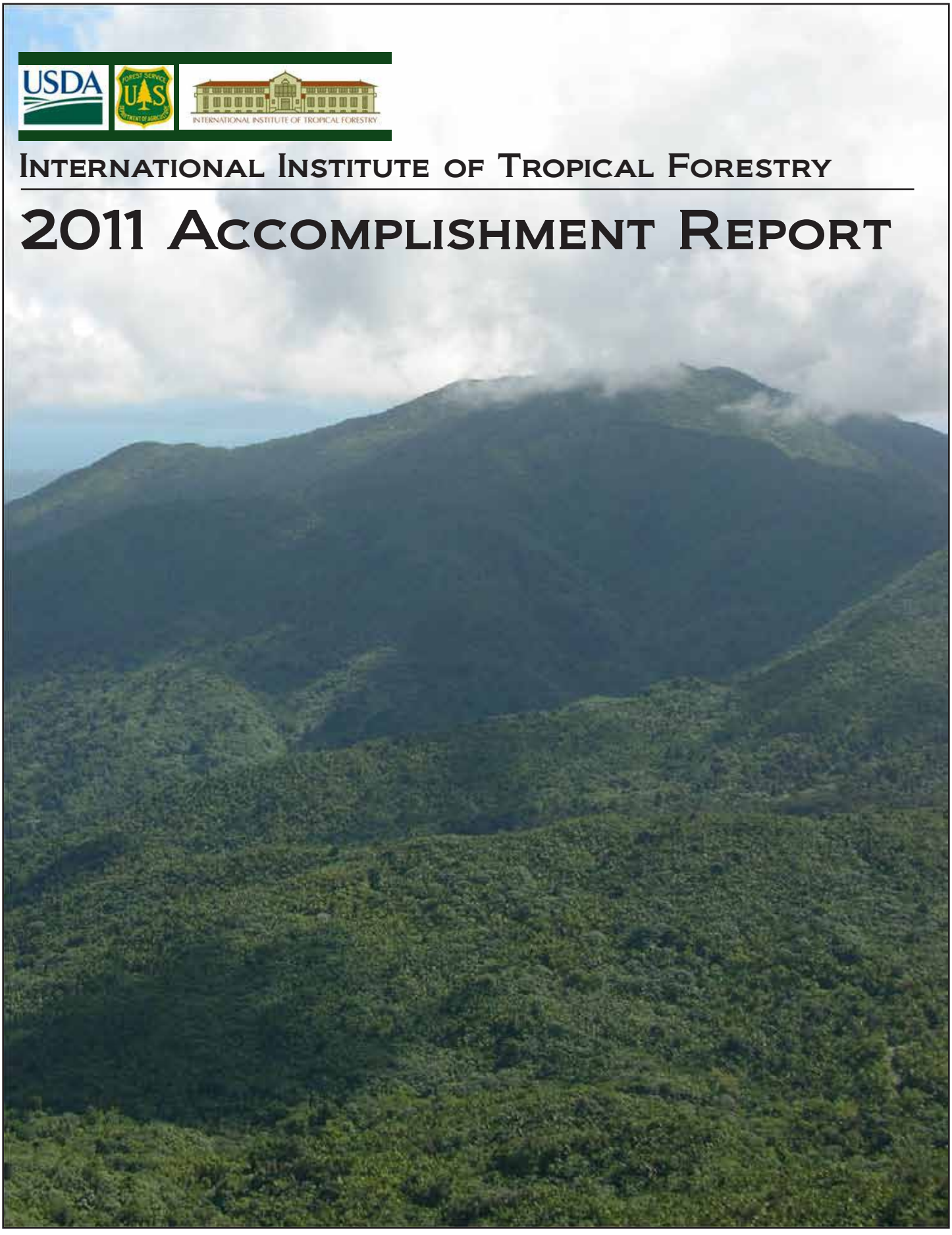

USDA

INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY

International Institute of Tropical Forestry

2011 Accomplishment Report

Cover image: view of the Luquillo Experimental Forest. Photo by Tana Wood.
Image on page 4: elfin forest scenery, 900 meters elevation in the Luquillo Experimental Forest. These short, gnarled trees are among the few species endemic to these summits.

Contents

Vision

We are a center for excellence where creativity and accomplishments result in timely products and services that anticipate the needs of society as it mitigates and adapts to environmental change.

Mission

Our mission is to develop and disseminate scientifically based knowledge that contributes to the conservation of forests, wildlife, and watersheds of the American Tropics in the context of environmental change.

Photo: G. Bauer

Editor's Message

Grizelle González

Fiscal year (FY) 2011 was one of renovation at the Institute. I have had the honor of editing this first edition of our Accomplishment Report, which includes all of the Institute's units. I hope you enjoy learning what we accomplished during FY 2011. Happy reading!

Grizelle González
Acting Project Leader, Research Unit

A Message From the Director

An essential responsibility of any government organization, particularly one dedicated to research, is reporting the results of its activities to the public. The Institute serves all tropical America and from its establishment in 1939 its mission included research, education, and the transfer of information to the region (Wadsworth 1995). Between 1940 and 1964, the Institute published the Caribbean Forester, a forestry journal that served the region by disseminating 200 research articles from Puerto Rico and foreign tropical areas. Afterwards and until today, the Institute disseminated its research findings through the Annual Letter, which we mailed to an extensive list of stakeholders, clients, and collaborators. We also continue to publish Acta Científica, a journal for science teachers now in its 23rd year of publication. With this publication we turn another page in our history of communicating results to the public. The Accomplishment Report aims at presenting a more holistic view of the programs at the Institute. In the past we focused mostly on our research program, but since 1993 the Institute programs have expanded to include State and Private Forestry as well as International Cooperation. We also established an Administration unit to support the expanded program. While remaining a small organization within the U.S. Forest Service, the Institute is now a more complex organization than in the past, with a wider span of coverage encompassing its many forestry programs and an expanded number of facilities and specialized laboratories. Not everything that we do is included in this report, but the report is inclusive of the kinds of things we do. We are quite excited about this new format, which will allow all our friends and collaborators to better understand the scope of our activities. We invite reactions and suggestions to this report so that we can continue to improve its content and allow us to better address the needs of the community of interests that we serve.

Ariel E. Lugo

Ariel E. Lugo
Institute Director

Panoramic view of El Yunque National Forest (also known as the Luquillo Experimental Forest).

Photo: P.L. Weaver

A Look at the International Institute of Tropical Forestry

The Setting

The International Institute of Tropical Forestry (the Institute) is a tropical forestry research and technology transfer institute. It is located in Río Piedras, Puerto Rico (Fig. 1), and has a long and productive history. Created in 1939 as the Tropical Forest Experiment Station in cooperation with the University of Puerto Rico, the Institute has been in operation continually for 72 years. The Institute serves as a focal point for bringing external research and educational resources to bear on issues affecting tropical forests and grasslands. Because of the high diversity of tropical landscapes and the multicultural and multilingual user base, Institute employees must have specialized knowledge and skills in several fields. Our assets include an exceptional cadre of bilingual and trilingual scientists, natural resources managers, professionals, technicians, state-of-the-art facilities, laboratories, experimental research forests, an excellent tropical forestry library, a long tradition of collaborations, and constituents who are highly supportive of our mission and programs.

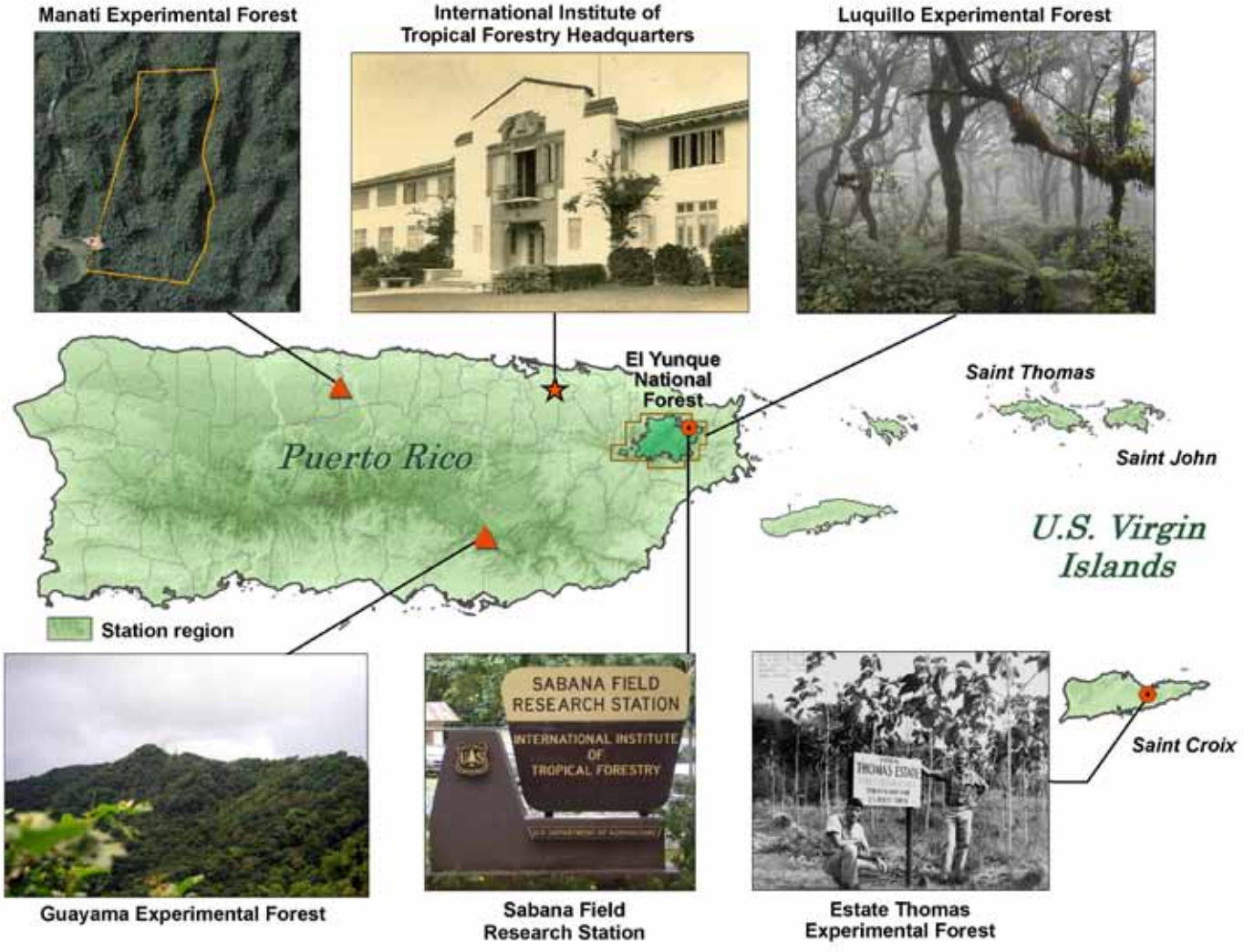

Figure 1. Experimental forests and facilities of the International Institute of Tropical Forestry.

A Look at the International Institute of Tropical Forestry

New Experimental Forests

On June 30, 2010, the Institute became the custodian of two new properties transferred from the USDA Farm Service Administration. These properties are now known as the Guayama Experimental Forest and the Manatí Experimental Forest.

The Guayama Experimental Forest is located on the south side of Puerto Rico where the Guayama, Cayey, and Salinas municipalities meet (Fig. 2). This property has an area of approximately 141 hectares with steep topography which translates to diverse vegetation in the area. Quebrada del Palo crosses the Guayama Experimental Forest from east to west. There are several intermittent streams that feed Quebrada del Palo inside this experimental forest. The property has a small network of old, unpaved farm roads that provide access from its east side. The internal unpaved roads will be useful for supporting future research programs at this experimental forest. There is also an unpaved road north of the property through Cayey that provides access to the Guayama Experimental Forest. The property is currently being surveyed.

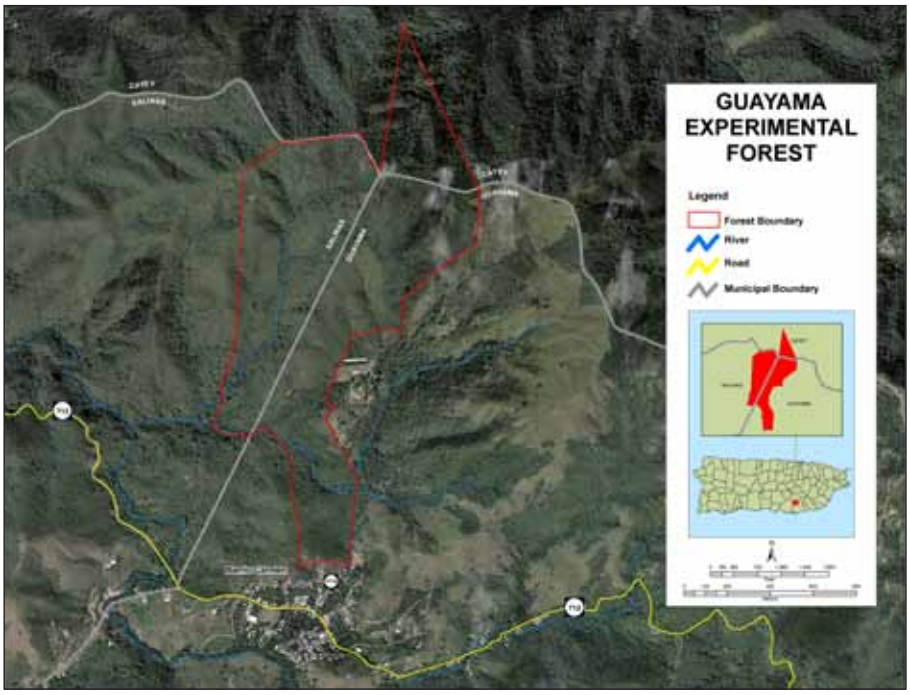

Figure 2. Guayama Experimental Forest.

The Manatí Experimental Forest is a 27-hectare property located along the boundary of the Manatí and Florida municipalities. The property is located in the northern part of the island's karsts area (Fig. 3). Surveys of this area will be scheduled once the Guayama Experimental Forest survey work is complete. We have not explored this property but aerial and satellite photos show closed secondary forest cover. This land will provide a location to study secondary moist forest on karst in contrast with karstic dry forests in Guánica and secondary forests on other substrates in the Luquillo Experimental Forest.

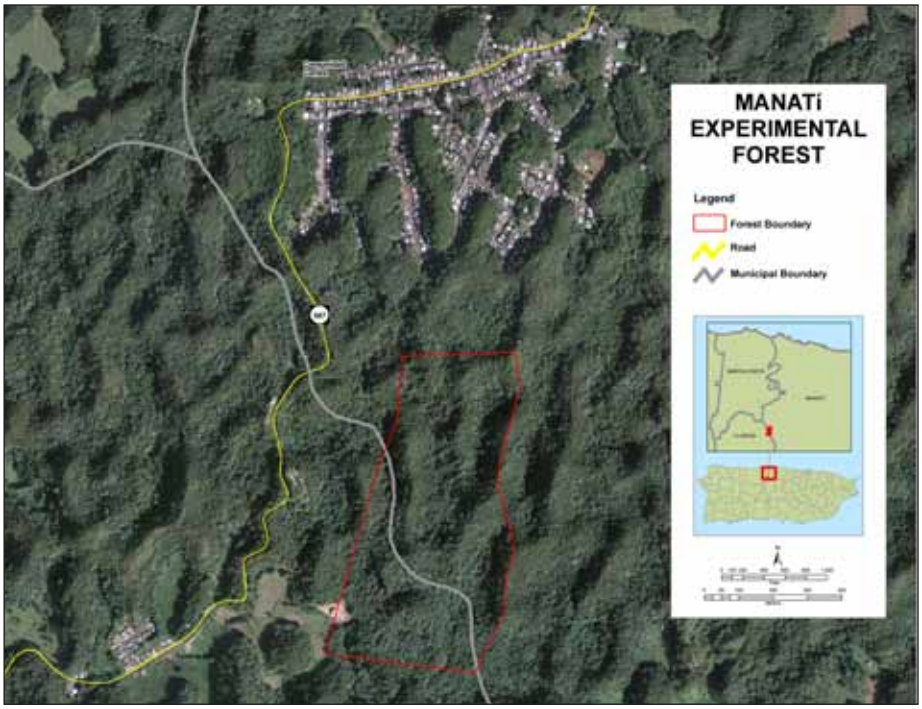

Figure 3. Manatí Experimental Forest.

Contact: Carlos D. Rodríguez Pedraza, crodriguez@fs.fed.us

Description of the Institute's Facilities

Headquarters

The Institute Headquarters has 50,000 square feet of modern, state-of-the-art facilities that are secure, functional, accessible, and which service the scientific community of the Institute and its collaborators. The Headquarters complex is located in Río Piedras, Puerto Rico, and houses:

- 1The Institute's Headquarters building—an historical building currently under full restoration and modernization including conversion into a high performance sustainable building.

Gisel Reyes, technical information specialist, working at the Forest Service National Library at the Headquarters Complex.

- 1A Forest Service National Library recently remodeled, containing major publications in English and Spanish on forestry, ecology, management, and utilization of tropical forests as well as other documents and materials related to tropical forests around the world.
- 1A Chemistry Laboratory focusing on analytical chemistry of plant tissues, water, soils, and air. In a typical year, about 50,000 analyses on samples collected from tropical ecosystems around the world are completed by laboratory personnel.

Chemistry laboratory in the Headquarters Complex.

Conference center in the Headquarters Complex.

Storage of water samples.

A Look at the International Institute of Tropical Forestry

- 1A Remote Sensing Laboratory to study landscape ecology using Geographic Information Systems (GIS), remote sensing, and field studies. This laboratory develops information, methods, and products using spatial data and analyses at multiple scales, which are made available through maps, publications, and training.
- 1 A technology transfer conference center with capabilities for multiple use combinations for meetings, trainings, and conferences. This facility has a food serving area and accessible restrooms.
- 1A multipurpose building that houses a dormitory, a gym, general storage area, office space, and lunch area.
- 1An area for sample preparation and long-term storage of samples.
- 1Three back-up generators to ensure that electrical power is available for continuous operation during power blackouts, and a 3,400-gallon potable water tank that can provide drinking water during water shortages.

Institute personnel working in the GIS and Remote Sensing Laboratory in the Headquarter Complex. From left to right: William A. Gould, Gary Potts, Maya Quiñones, Maria I. Herrera, Patricia Rincón, Olga M. Ramos, Carlos D. Rodríguez, Mariano Solórzano, and Suhey Ortíz.

Sabana Field Research Station

The Sabana Field Research Station is a short drive from the Bisley Long-term Ecological Research watersheds and about a 1-hour drive from the Headquarters complex in Río Piedras. The Sabana Station includes nine buildings:

- 1Administrative building housing all administrative support;
- 1Laboratory building for water analyses;
- 1Storage building;
- 1Back-up generator to ensure that electrical power is available for continuous operation during power blackout, and two potable water tanks that can provide drinking water during water shortages;
- Office building for scientists and technicians;
- 1Communications and physical security building;
- Multipurpose building that includes office space, laboratory space, oven room, sample preparation room, storage areas, laundry room, and flammable storage area;
- 1Dormitory building, with restrooms, kitchen, living and balcony areas; and
- 1Mycology laboratory.

Contact: Miriam Salgado Herrera, msalgado@fs.fed.us

The Sabana River is adjacent to the Sabana Field Research Station, located in Luquillo, Puerto Rico.

Support and Administration

Professional, technical, and administrative employees support Research and Development and other programs at the Institute. Our professional and technical staffs include biologists, foresters, ecologists, chemists, technicians, and other specialists who work with our scientists and provide assistance to field and laboratory studies. Administrative and support staffs include: Budget, Engineering, Contracting and Procurement, Facilities and Property Management, Grants and Agreements, and Reception.

Administrative Specialist: Adolfo Menéndez, *amenendez@fs.fed.us*

Finances and Workforce

The funding allocation for the Institute not only supports the workforce, but also its functions, programs, and operations. The numbers that follow are for fiscal year 2011 (October 1, 2010, to September 30, 2011):

Incoming Funding

- Research and Development Appropriations: $ 4.05 million
- State and Private : $1.9 million
- International Cooperation: $550,000
- Administration: $1.45 million
- Total Funding: $7.95 million

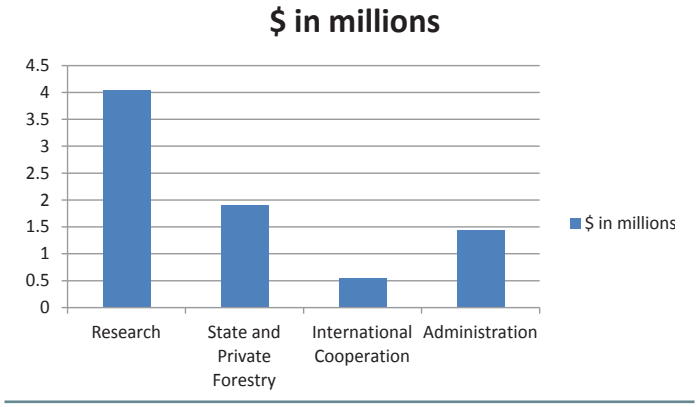

Figure 4. FY2011 Institute Funding.

Distribution of Funds

- Salaries: $3.99 million (50 percent)
- Support and Operations: $2.07 million (26 percent)
- Distributed to Cooperators: $1.88 million (24 percent)

*Does not include American Recovery and Reinvestment Act (ARRA) funds.

Workforce Statistics

- Total Institute workforce: 69
- Permanent workforce: 44
- Temporary workforce: 25
- Of the total workforce: 9 (13 percent) are scientists

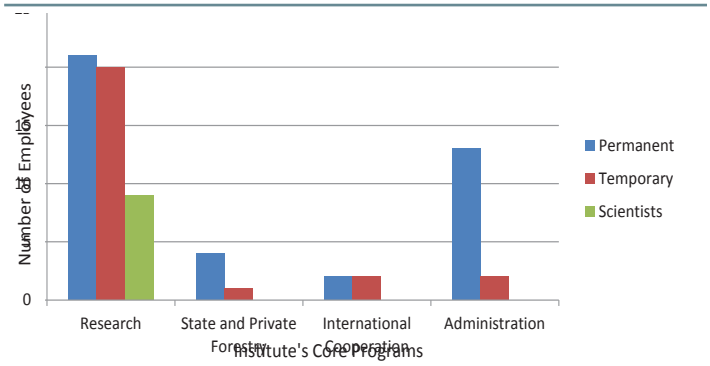

Figure 5. Number of Institute employees.

Support and administrative personnel stationed at IITF, Headquarters Complex. From left to right: Mildred Alayón, Maricarmen Parrilla, Amelia Dávila, Adolfo Menéndez, Janet Rivera, Sharleen M. Ortíz, Rosa Y. Ávila, and Lía Sánchez.

Funding Partners for FY 2011

Cooperators Who Received Funding From the Institute

Non-Governmental Organizations

- 1Centro Para La Conservación del Paisaje
- 1Consejo Asesor para la Forestación Urbana y de Comunidades de Puerto Rico, Inc.
- 1Ciudadanos del Karso
- 1El Caribe Resource Conservation and Development
- 1International Society of Tropical Foresters
- 1Mesoamerica Ecotourism Alliance
- 1Misión Industrial
- 1National Ecological Observatory Network
- Paso Pacífico
- 1Puerto Rico Conservation Foundation
- 1Puerto Rico Conservation Trust Foundation
- 1Southern Group of State Foresters
- 1Sustainable Alliances, Inc. DBA Alianza Mesoamericana de Ecoturismo
- 1The Natural History Society of Puerto Rico
- 1The Research Foundation of State University of New York
- 1University of Georgia Research Foundation Inc.
- 1Winrock International
- 1Virgin Islands Resource Conservation and Development Council, Inc.

Private Industry and Individuals

- 1 The Greenleaf Group, Inc.
- 1 Dr. James Grogan

Universities

- 1 Ave Maria University
- 1 Colorado State University
- 1 Duke University
- 1 Florida International University
- 1 Indiana University
- 1 Miami University at Ohio
- 1 Oregon State University
- 1 Southern Illinois University
- 1 Universidad Metropolitana
- 1 University of California - Berkeley
- 1 University of Idaho
- 1 University of Indiana
- 1 University of Missouri
- 1 University of New Hampshire
- 1 University of Pennsylvania
- 1 University of Puerto Rico–Agricultural Extension Service
- 1 University of Puerto Rico–Research Division
- 1 University of Rhode Island

State Government

- 1 Puerto Rico Department of Natural and Environmental Resources
- 1 Puerto Rico Department of Transportation and Public Works*
- 1 Puerto Rico Fire Department*
- 1 U.S. Virgin Islands Department of Agriculture
- 1 Virgin Islands Fire Service

**These partners received ARRA Funds.*

Cooperators Who Provided Funds to the Institute

- 1 Environmental Management Authority, Trinidad and Tobago
- 1 La Romana Bayahibe Hotel Association
- 1 National Ecological Observatory Network
- 1 National Park Service
- 1 Puerto Rico Department of Natural and Environmental Resources
- 1 U.S. Army Corps of Engineers
- 1 U.S. Fish and Wildlife
- 1 U.S. Geological Survey

American Recovery and Reinvestment Act

The American Recovery and Reinvestment Act 2009 (Recovery Act) was signed on February 17, 2009 by President Barack Obama. The Recovery Act is an effort to preserve and create jobs and promote economic recovery through a variety of measures. The Institute received funds for 11 projects totaling about $7.4 million. Of this, $4.138 million was dedicated to hurricane and fire prevention and mitigation projects and $3.765 million was dedicated to capital investments and maintenance. An estimated 125 people have been employed with funds that the Institute has provided to contractors and cooperators. From the total recovery funding obligations, 45.3 percent have been spent.

The islands of Puerto Rico and the U.S. Virgin Islands (USVI) are subject to hurricanes and tropical storms and wildfires. Fallen trees and broken branches cause downed power lines, flooding in storm sewers and streams, and a variety of physical safety hazards. Wildfires can affect human health and safety, cause property damage, and increased erosion and sedimentation. The State and Private Forestry unit is administering three projects to mitigate these impacts. Two Institute Economic Recovery Act projects are focused on reducing risks along roadsides and a third focuses on fuels reduction in fire-prone landscapes.

Hurricane and Fire Prevention and Mitigation Projects

Puerto Rico Hurricane and Hazardous Fuel Mitigation Project

The State and Private Forestry unit is administering a grant of $1,167,000 to the Puerto Rico Department of Transportation and Public Works (DTOP) to implement the Puerto Rico Hurricane and Hazardous Fuel Mitigation Project. The project involves training, roadside tree inventory, management planning, and plan implementation. The management plan will address existing risks, retention of structurally sound trees, and species selection to meet site objectives. Implementation activities will include pruning to improve tree health and structural conditions, removal of hazard trees, and tree planting.

The project is intended to extend across 2,169 kilometers of secondary roadways. Roads were selected based on the degree to which they provide access to municipalities or emergency facilities, or whether they have a history of public safety incidents such as trees falling and endangering people or property. Research and empirical evidence from other locations has established that proactive roadside tree planting and its management help communities achieve a more effective allocation of resources and reduce costs and inconvenience following storms or other natural disasters.

A unique aspect of this project is that DTOP helped to establish Cooperativa Vías Lindas, a cooperative of employees displaced by Government Attrition. A training plan was worked on by DTOP, the Institute, and the Cooperative to expand the knowledge and skills of the members. To date, 18 members have taken training in 20 topics including chainsaw operation, safety, tree biology, soils, tree identification, inventory techniques, planting and establishment, street tree maintenance, and business management. Once the project is completed, the cooperative will have a workforce with the professional and technical skills needed to participate fully in today's marketplace.

Contact: Magaly Figueroa, mafigueroa@fs.fed.us

Tree inventory along St. Croix, U.S. Virgin Islands roads.

St. Croix, USVI, Hurricane and Hazardous Fuel Mitigation Project

The State and Private Forestry unit is also administering a grant of $404,000 to the Virgin Islands Resource Conservation and Development Council to implement the St. Croix Hurricane and Hazardous Fuel Mitigation Project. The main objective is to reduce hurricane- and fire-related risks along roads on the island of St. Croix, U.S. Virgin Islands. A GIS data-base is being created from roadside

American Recovery and Reinvestment Act

inventories. A management plan will be developed and trees are being grown to demonstrate principles of proper tree and site selection.

The GIS database captures attributes of individual trees such as species, diameter, canopy, distance to the road, and location, and an assessment of tree health based on the condition of the tree canopy, stems, roots, and presence of insects or disease. Tree proximity to power lines, poles, utilities, and roads is recorded to establish the risk of the tree becoming a hazard. Utility pole locations and the power line heights facilitate the development of a comprehensive roadside tree management plan. The inventory is 75 percent completed. To date, 416 kilometers of roadsides have been assessed and 4,778 trees are included in the inventory.

Trees are grown for inplanting demonstrations, and training has been provided to public and private employees to improve the pool of skilled workers in hazard tree evaluation and tree management practices such as pruning, tree removal and safety, GIS, GPS, and planning.

Contact: Constance Carpenter, conniecarpenter@fs.fed.us

Puerto Rico fire crews "mop up" after fires to ensure no burning embers can reignite fires once they leave.

Prescribed Fire on Puerto Rico State and Private Forestry Lands

The State and Private Forestry unit granted $2,064,000 to the Puerto Rico Fire Service to employ, equip, and train two new wildland firefighting crews for about 2 years. The Fire Service has historically cross-trained structural firefighters in wildland firefighting techniques. This project represents their first effort to stand up crews to work exclusively on wildland firefighting, fire prevention, and mitigation.

The ultimate goal is to reduce the acreage of burned land. This is accomplished by educating people on fire prevention, reducing fuel loads before they are ignited, and ensuring that manpower is available to suppress fires before they are able to spread. Other benefits are a reduction in the use of emergency funds to suppress fires, and a reduction in funds needed to mitigate fire effects on agricultural land, or to restore natural and protected areas affected by fire.

Training for crew members meets national interagency standards for wildland fire fighting that entail both classroom and experiential requirements. Participants have received training in the incident command system, safety, fire behavior, basic and intermediate fire fighting, and other topics. Several individuals completed an in-depth prescribed burn course to prepare for the use of prescribed burning. The Fire Service recently received permission from the Environmental Quality Board to conduct prescribed burns in fire prone areas. Frequent precipitation has thwarted plans so far but this will be a useful tool for future fire control and training.

Contact: Constance Carpenter, conniecarpenter@fs.fed.us

Capital Investments and Maintenance

A highlight of the Institute recovery projects are the new dormitory facilities and laboratory / woodshop building in the Sabana Field Research Station located in Luquillo, Puerto Rico. Projects included:

Sabana Dormitory

The Luquillo Experimental Forest enables long-term research on wildlife, climate change, the effects of hurricanes on ecosystems, and other critical issues. To facilitate this research, the Institute built a 24-person dormitory at the Sabana Field Research Station to replace the use of a 1938 structure that had housed many of visiting scientists, students, and volunteers. This project will minimize human health risks by supplying improved sleeping, restroom, dining, and living facilities. The project will increase the capacity of the research station to receive visitors. The project will also increase the efficiency and productivity of the research program in the Luquillo Experimental Forest.

Project Cost**:** $646,000
Estimated completion date: 11/19/2011

American Recovery and Reinvestment Act

Sabana Dormitory in July 2011.

Sabana Dormitory in November 2011.

Woodshop Renovation

This project includes the partial demolition of a woodshop and its renovation into a multipurpose building. The woodshop was obsolete and space was needed to provide research program support. The renovated facility will have office space, storage, a laboratory for sample preparation, ovens, restrooms, and laundry facilities.

Project Cost: $552,000
Estimated completion date: 03/19/2012

Employment

The total employment for the Sabana dormitory and the woodshop renovation has been up to 24 people, including the main contractor and sub-contractor employees.

Contact: Adolfo Menéndez, amenendez@fs.fed.us

Old woodshop building—prior to the remodeling ARRA project, in the Sabana Field Research Station, Luquillo, Puerto Rico.

Sabana Multipurpose building in April 2011.

Sabana Multipurpose building in November 2011.

Awards and Training

Awards

Guaynabo School Celebrates Earth Week with Tree Nursery Inauguration

On April 28, 2011, the Rafael Martínez Nadal Middle School of the Guaynabo School District in Puerto Rico dedicated a school tree nursery to Carlos Domínguez Cristóbal, State and Private Forestry Conservation Education Coordinator and Historian. The nursery was made possible through a "Green Project" award of $10,000 from ACE, a Swiss-based global insurance company. Though Domínguez worked with math teacher and 4-H Club advisor Magda López and others to prepare the application, he had no idea that the school planned to name the facility after him.

Visitors appreciating the variety of plantings in the nursery. Carlos Domínguez Cristóbal at far right.

The students take turns weeding and watering the plants in the nursery. They have started seedlings of several native tree species and are producing herbs, peppers, tomatoes, lettuce, and eggplant. "Who said kids don't like vegetables?" One mother said that her son didn't like school but he couldn't wait to go after he started working in the nursery and even on Saturday morning he would rush her out the door to get to the nursery.

Domínguez defers credit for the nursery to López, with whom he has worked since 2001. She often provides outdoor activities on her own time, taking students to pick oranges and coffee, camping, and on treks through the mangrove forest. In 2002 she began working with Domínguez and Frank H. Wadsworth, retired forester and Institute emeritus scientist, on the development of a school forest and curriculum to use in an outdoor classroom. Wadsworth provided guidance and support on tree selection and management. Domínguez adapted the successful schoolyard program that targets high schools,

Ribbon-cutting at the inauguration of the school tree nursery. Carlos Domínguez Cristóbal far left, Magda López at center, students, parents and local ACE representatives.

to meet the needs of the middle school. Support was also provided by the municipal government and the private sector.

Today students like to take visitors on tours to show off the nursery. Students know the names of the trees, the local birds nesting there, and insects, too. They practice different math and science skills with data they collect from the forest, and language skills by writing essays and poems in Spanish and English.

Magaly Figueroa—Publically Recognized at the Caguas Arbor Day Celebration

Magaly Figueroa, State and Private Forestry, Natural Resource Specialist, was publically recognized at the Caguas Arbor Day celebration on April 29, 2011for her support in the establishment and growth of the city's Urban Forestry program. Caguas has been designated a Tree City USA and has an active street tree management program.

Carlos Domínguez—Gifford Pinchot Excellence in Interpretation and Conservation Award

Carlos Domínguez, Historian and Conservation Education Specialist at the Institute, received this award for the enduring nature of his conservation education activities. For more than 30 years, Carlos has brought local officials, community groups, and students together to celebrate their forest treasures. He is also well-known for his conservation education manual, which meets math and science requirements, and is used in outdoor schoolyard programs in high schools and middle schools.

Magaly Figueroa—2011 Chief's Award for Conserving Open Space

Magaly Figueroa, a part of the Agency-wide team for the Forest Legacy Program, won this award for protecting private forest lands through the Forest Legacy Program.

Natural Resource Specialist Magaly Figueroa is presented a copy of the Manifesto declaring April 29 Caguas Arbor Day, by Caguas Mayor William Miranda Torres.

Training

Senior Leadership Program

Grizelle González, Research Ecologist, graduated from the U.S. Forest Service, Senior Leadership Program, Class 8–2011 on November 3, 2011, in a ceremony celebrated in Washington, DC. Angela Coleman, U.S. Forest Service Assistant Deputy Chief for Research and Development, described the effort: "Our new graduates did an outstanding job of representing Research and Development in this year-long training program, which is one of the agency's premiere leadership training opportunities. It convenes senior leaders from around the country who commit to a year of leadership training and development".

Middle Leadership Program

Carlos D. Rodríguez Pedraza, the Institute Safety and Occupational Health Manager / Lands Manager, graduated from the U.S. Forest Service's Middle Leadership Program 2011.

This year's crop of actively engaged student conservationists.

Research and Development

Research has been the cornerstone of the Institute's program since its inception. Early research focused on reforestation, plantation forestry, tropical species identification, forest inventory methods, endangered species, and carbon sequestration. Currently, the Institute's research programs are focused on forest ecology, disturbance ecology, ecosystem functions and services, urban ecology, watershed dynamics, migratory species, climate change, and policy science to better understand the effect of natural and human-induced pressures on tropical forests and the landscapes in which they are found. Our research provides key information on forest structure and function, land cover change, and governance to inform the development of sustainable land use practices and policy. Research will continue to focus on the Luquillo Experimental Forest and its Bisley Long-term Ecological Research watersheds, the San Juan Urban Long Term Research Area, the Guánica Biosphere Reserve, various novel secondary forests, and other ecosystems in Puerto Rico; the Estate Thomas Experimental Forest in St. Croix U.S. Virgin Islands; the Brazilian Amazon; and throughout the Western Hemisphere in collaboration with partners in the region.

Acting Project Leader: Grizelle González, *ggonzalez@fs.fed.us*

Network Science—Collaborative Programs

Forest Inventory and Analysis (FIA)

The U.S. Forest Service inventories the forests of the United States and its territories. For Puerto Rico and the U.S. Virgin Islands, the inventory and related research are funded and managed jointly by the Institute and the Southern Research Station's Forest Inventory and Analysis (FIA) Program. The field crew includes employees of both the Institute and the Southern Research Station, and they conduct the inventory out of the Institute's Headquarters in Río Piedras, Puerto Rico. The Institute's Chemistry Laboratory dries, processes, and analyzes all soil and litter samples. Maps of land cover and forest types for the region, which Institute scientists have produced with Landsat satellite imagery, help to refine the FIA forest cover estimates that come from the plot data. These maps also estimate the areas of forest and land-cover types with limited extent, like mangroves, which are not well-represented by the inventory plots given the systematic inventory design. The Institute also contributes to setting priorities for the inventory and its design, and it maintains a species taxonomy database for the inventory.

The goal of the Institute investment in the Caribbean FIA Program is forest ecology research in four main areas: stand dynamics and diversity; land-cover and climate change; methods for remote sensing and mapping of forest attributes; and biogeochemical cycling. Research on stand dynamics and diversity investigates controls on tree species richness and diversity (succession, competition, productivity, dispersal, and functional traits) from stand to landscape scales, and on the structuring of the tree species communities that regrow after large-scale clearing. Remote sensing and mapping research develops and tests approaches for mapping forest attributes through integrating Caribbean Forest Inventory and Analysis Program data with remotely sensed data, particularly multispectral and hyperspectral imagery and lidar, and through modeling of future climate and land-use scenarios. Example forest attributes that the Institute is mapping or modeling in this way include forest structure, growth, phenology and leaf traits, productivity, species composition and diversity, species distributions, nutrient cycling, and

María M. Rivera, professional technician, working in the Soil Ecology Laboratory.

Mayssá Ittayem, chemist, examining a ground sample of soil before performing nutrient analyses.

other attributes. The Institute also plans to project potential changes in forest attributes, such as the distributions of tree species, forest types, and ecological zones that may occur with climate change. Research considers the influence of current and historical landscape structure, including forest fragmentation, on stand dynamics, structure, wildlife habitat, element cycling, diversity, and species composition. Another goal is to evaluate the combined impacts in these landscapes of land-use and land-cover changes and global climate change in the context of existing protected areas and reserves.

Contact: Eileen Helmer, ehelmer@fs.fed.us

Luquillo Long Term Ecological Research (LUQ)

The goal of Luquillo Long Term Ecological Research Program (LUQ) is to understand how forest and stream ecosystems, and the services that they support, are changing in Puerto Rico, thereby providing guidance for management of change in the tropics. We focus on understanding the key role of disturbance in determining ecosystem functions, processes, and their services. In the first phases of LUQ (1988–2006), degrees and mechanisms of resistance and resilience were studied, especially after the passage of hurricanes. This background led to more recent work on response to human disturbance and climate change, both likely to cause long-term, directional change in ecosystems and services.

The LUQ also identified ecosystem trends over its 23 years of existence (Peters et al. 2012) and synthesized results in several books. Major achievements included leading the establishment of the National Ecological Observatory Network (NEON), Critical Zone Observatory (CZO), Integrative Graduate Education and Research Traineeship (IGERT), and San Juan Urban Long Term Research Areas-Exploratory (ULTRA-Ex) programs in Puerto Rico, thereby creating a broad, strong synergy toward sustainability science in the tropics. Over the years, LUQ has also given a commanding perspective on tropical ecology, resulting in numerous synthetic works. A site-synthesis book (Brokaw et al. 2012), for example, contains chapters whose content ranges from theory to management and reflects the benefit of long-term research toward understanding resistance and resilience of tropical systems in a changing disturbance regime. This research program also contributed to syntheses of LTER Network contributions (Robertson et al. 2011) and long-term trends (Peters et al. 2011).

Ridges and valleys in the Luquillo Experimental Forest.

Contact: Grizelle González, ggonzalez@fs.fed.us

The National Ecological Observatory Network (NEON)

The Institute is a major collaborator of the National Ecological Observatory Network (NEON). NEON has been under development for many years, but recently $434 million in construction funding was provided to the program by the National Science Foundation. NEON will be the first continental ecological research platform and promises to change the way ecological research is accomplished. Data will be collected on biodiversity, disease and pathogens, nutrients, water, pollutants, and greenhouse gases at more than 60 sites spread from Alaska and Hawaii across the United States to Puerto Rico. A very ambitious crow flying to the four corners of the network would cover more than 14,000 miles. The sites in Puerto Rico will be the southern and eastern-most in the network. Unique features of the NEON program are that it will use a single protocol to collect all data sets nationwide, rather than different instruments or protocols from site to site as other research networks have done. The data collected will also be freely available to scientists and the public in near-real time; since no one owns the data, they will be available for everyone. Having vast amounts of baseline data available will allow scientists to design studies that build from that platform, without having the costs and efforts needed to collect baseline data. NEON will also provide the first truly standardized continental network of research sites dedicated to being able to describe and forecast ecological trends at such a large scale.

Puerto Rico was chosen to represent the Atlantic Neotropical domain after the Institute, academic, and other scientists and educators came together to inform NEON on the advantages and opportunities of using the island as an observational site. Guánica Forest will be the core "wildland" site for the Observatory and will anchor

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a land use gradient that includes the Lajas Agricultural Experiment Station, an urban forest in Ponce, and stream sites near San Germán and Adjuntas. Sampling and instrumentation are planned to remain in Guánica for 30 years and in the other sites for 5–10 years. Installation of equipment is projected to begin in 2012–13. Geotechnical, environmental assessment, and permitting work are already completed or currently underway, as is planning for specific locations for instrument arrays. Local scientists are facilitating permitting, science decisions, and site access for the central NEON staff.

More information on the NEON project can be found at *www.neoninc.org*.

Guánica Dry Forest looking southwest from visitors' center.

San Juan ULTRA-Ex: Understanding the Socio-Ecology, Sustainability, and Future of the City

The city of San Juan has been selected as part of a national initiative for interdisciplinary scientific research in cities, the Urban Long Term Research Areas-Exploratory (ULTRA-Ex). A collaborative program between the National Science Foundation, the Puerto Rican Conservation Foundation, and the Forest Service, the ULTRA-Ex seeks to address how an increasingly urban landscape affects natural and human communities. With more than half of the world's population already living in cities, it is crucial that we develop scientific knowledge that contributes to the long-term quality of life and environmental health, or the sustainability, of cities. San Juan ULTRA-Ex scientists seek a holistic understanding of how environmental, social, and economic factors interact in the city of San Juan as a socio-ecological system—the perspective that cities are products of human-nature interactions. This approach will help us understand what aspects of the city are more vulnerable to local and global risks, such as extensive development, climate change, and global economic changes, among others.

With a focus on San Juan's urban watershed, the Río Piedras River Watershed, we have multiple ongoing projects that address various aspects of the socio-ecology of the urban watershed, including: hydrology; urban forests and biodiversity; soil nutrients; water quality and ecology; riparian restoration; environmental history of the watershed; flooding risks; residents' perceptions and behavior towards sea-level rise, yard practices, and streams; decision-makers' perspectives, knowledge, and roles in governing the urban environment; land use and land cover change; and energy use. These projects are linked through a common network of sampling points across the watershed that was selected to meet both social and ecological criteria (Fig. 6).

Our scientists collect both quantitative and qualitative data within the same sampling points and use diverse ecological and social methods, such as vegetation and water quality sampling, questionnaires and interviews (see photo) and modeling approaches. This integrated network allows us also to examine the watershed from various scales including spatial scales (i.e., household and river scale, to community and watershed scale), as well as temporal (i.e., historical, contemporary, and future visions and scenarios). In this process we have had the contribution of numerous graduate and undergraduate students from a diverse set of disciplines.

ULTRA-Ex research scientists and students, from both natural and social sciences, conducting household surveys in various communities within the Río Piedras River Watershed. The objective of the household surveys is to measure residents' perceptions and practices of their yards and surrounding green areas and streams.

More than an interdisciplinary scientific effort, San Juan ULTRA-Ex seeks transdisciplinarity where, through the engagement of non-science stakeholders (city managers, communities, NGOs, and other social groups) in different phases of the research process, we hope to provide policy-relevant knowledge to city planners and administrators. We have engaged approximately 32 different organizations and community leaders through various stages of research, including framing problems and questions, providing feedback and critique to products, and participating in mapping workshops to develop land use scenarios. We have also developed the San Juan ULTRA-Ex Web Database and Mapping Portal as a tool to facilitate collaboration among our researchers and partners by making data, documents, events, and other information, accessible. Overall, our objective is to put science at the service of city residents to collectively work toward improving life in our cities.

For more information please visit the website *www.sanjuanultra.org*.

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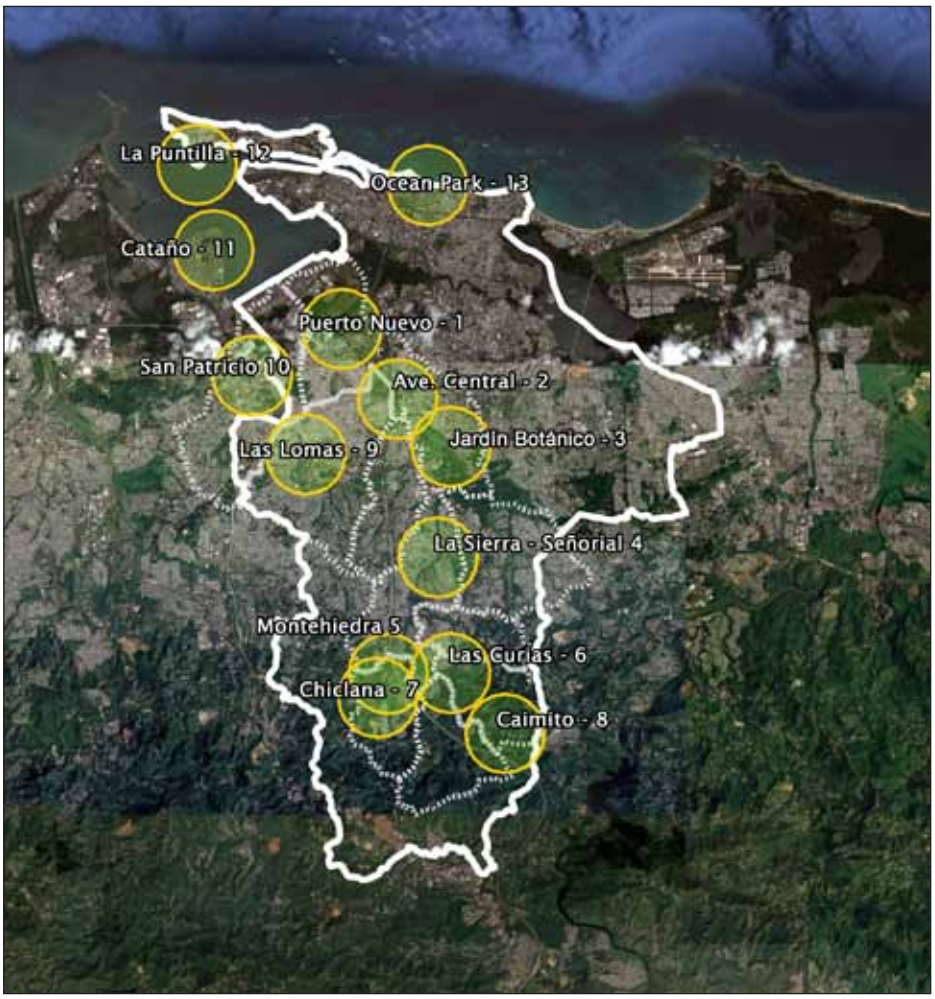

Figure 6. Network of socio-ecological sampling points for San Juan and the Río Piedras River Watershed. The orange boundary delineates the Municipality of San Juan, and the blue boundaries delineate the watershed and sub-watershed of the Río Piedras River Watershed. The 13 circles are the half-kilometer buffer surrounding each point.

Luquillo Critical Zone Observatory (LCZO)

The "Critical Zone" is defined as the outer layer of the Earth that directly sustains human life. It extends from the lower atmosphere into the underlying bedrock and includes all the physical, chemical and biological processes that shape and transform the Earth's surface. The Luquillo Critical Zone Observatory (LCZO) is one of six National Science Foundation-supported observatories designed to provide an integrated platform for collaborative studies that will provide the scientific basis for the long-term management of critical zones.

How critical zone processes, water balances, and mass fluxes differ in landscapes with contrasting bedrock lithology but similar climatic and environmental histories is the overarching focus of the LCZO. Our infrastructure, sampling strategy, and data management system are designed to use the natural laboratory of northeastern Puerto Rico as a platform whereby collaborators can quantify and contrast how critical zone processes differ in watersheds underlain by quartzdiorite and volcaniclastic bedrock. The two main study watersheds, the Río Mameyes and the Río Blanco, drain the Luquillo Experimental Forest (Fig. 1, earlier) and have similar climates and environmental histories but differing lithology. The Mameyes watershed is primarily underlain by volcaniclastic bedrock that weathers to produce clay-dominated soils and boulders. The Río Blanco watershed is underlain by quartzdiorite, which weathers into a saprolite composed of sand and large corestones. These differences in weathering patterns have a profound influence on forest composition, landslide frequency, chemical weathering, and the morphology of streams and hillslopes. LCZO research is based around seven broad hypotheses that address the following main questions:

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- 1 How are soil carbon, redox, and nutrient cycling coupled and decoupled from lithology, landscape position, and climate?
- 1 How does weathering vary with regolith thickness and landscape position?
- 1 How does lithology influence sediment supply and the residence time and routing of water and solutes across the landscapes?
- 1 How do the morphology, biogeochemistry, and vegetation of riparian zones vary with lithology, climate, and basin size?
- 1 How does basin lithology influence depositional environments and stratigraphic resolution of the coastal and fluvial sediments?

The LCZO is supported by a $4.4 million, 5-year grant from the Earth Science Division of the National Science Foundation. It also receives additional technical and infrastructure support from the U.S. Geological Survey-Water, Energy, and Biogeochemical Budget Program, and the Institute. The principal researchers and students involved in the LCZO are from the University of Pennsylvania, Pennsylvania State University, the University of California at Berkeley, the University of New Hampshire, Brown University, the University of Puerto Rico, the U.S. Geological Survey, and the Institute. The Observatory also provides facilities for collaborators from a host of U.S. and international research institutions and works closely with the Luquillo Long Term Ecological Research Program. In the first 2 years of existence, more than 40 individuals have actively participated in LCZO research.

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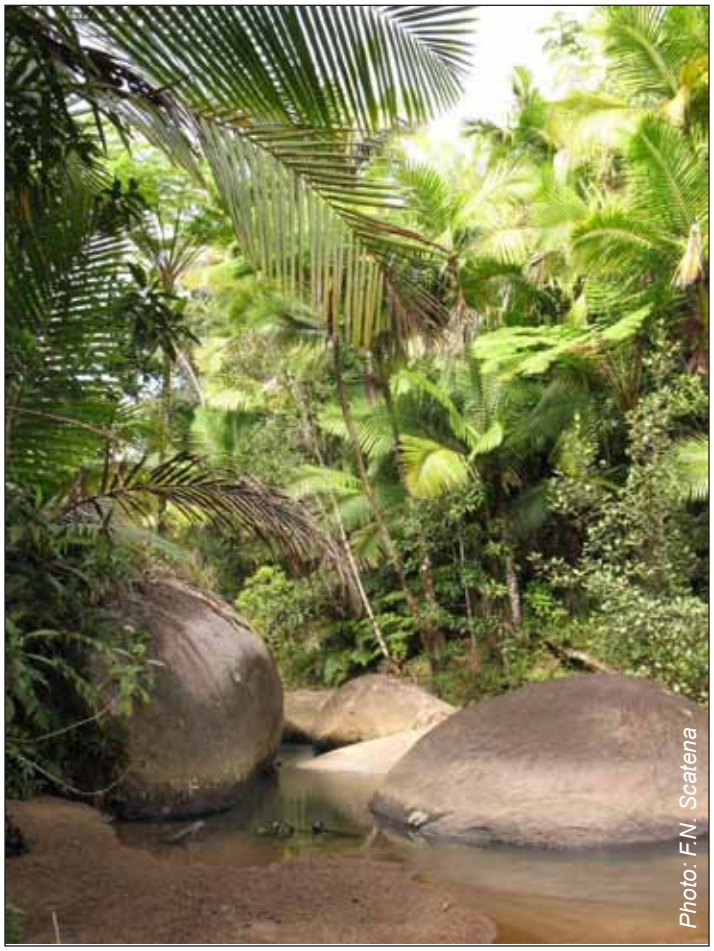
For additional information, data, and publications, see the LCZO web site *www.sas.upenn.edu/lczo* or contact Luquillo-CZO@sas.upenn.edu.



Stream draining quartzdiorite in the Luquillo Mountains.

Stream draining volcanoclastics in the Luquillo Mountains.

Caribbean Landscape Conservation Cooperative (CLCC)

The Institute has been working with a number of other Federal and local agencies to establish a Caribbean Landscape Conservation Cooperative (CLCC), which was initiated this year as part of a national network of 22 landscape conservation cooperatives. Landscape conservation cooperatives are applied conservation science partnerships among State and Federal agencies, regional organizations, tribes, non-governmental organizations, universities and other entities within a geographic area. They are designed to provide science to inform resource management decisions in an integrated fashion across landscapes—at a broader scale than any individual partner's responsibility. Landscape conservation cooperatives consider landscape-scale stressors including climate change, habitat fragmentation, urban sprawl, invasive species, and water availability in order to assess the conservation status of species and habitats and provide a vision for sustainable landscapes under future scenarios. The Caribbean Landscape Conservation Cooperative includes the Puerto Rican archipelago and the U.S. Virgin Islands (Fig. 7), and recognizes the connectivity of these islands with the greater Caribbean and the continental regions through shared species, habitats, and conservation opportunities and goals. The purpose of the CLCC is to provide a regional context to conduct conservation planning and management at different scales, from decisions on site management to understanding the implications of management actions regionally, nationally and globally. It is a platform for partners to integrate information, perform regional assessments of conservation status, assess future scenarios, and collaborate in applied conservation science. The CLCC mission is providing science and technology for conservation planning and action – addressing the need to restore and sustain natural resources in Caribbean land and seascapes.

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Collaborating Institutions: U.S. Fish and Wildlife Service, U.S. Geological Survey, National Oceanic and Atmospheric Administration, and Puerto Rico Department of Natural and Environmental Resources.

Figure 7. The extent of the Caribbean Landscape Conservation Cooperative. Map colors represent developed land (black), forested land (green), shrubland (brown), and grassland (light tan).

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Research Highlights By Scientist

I. Tropical Ecosystem Dynamics

1. Characterization of lichen communities along an elevation gradient in Puerto Rico

While studies of lichens in Puerto Rico have been historically discontinuous, the lichen biota is probably among the best known in the region. Recent work has shown that there are about 1,181 documented lichen species in Puerto Rico, while another effort suggests that there actually could be as many as 1,600 species. This indicates that at least 26 percent of our lichen species are yet to be discovered. Furthermore, since only one work has explored the interaction between lichens and environmental conditions in Puerto Rico, ecological dynamics of lichens in these ecosystems are still mostly unknown. To address these issues, we are carrying out a comprehensive survey of lichen species occurrence and abundance in a series of plots established along an elevation gradient of eight forest types in northeastern Puerto Rico. We expect to see differences in the composition and structure of lichen communities among these forest types with differences in environmental conditions such as precipitation, and temperature as factors explaining most of the variation observed between these communities. While the study is ongoing, we have already developed an extensive collection of photographs showing the diversity of lichens at these forests. Other expected outcomes include a compilation of methods and guidelines for long-term monitoring of forest health using lichens as indicators, and increased interest in the study of lichens of Puerto Rico and their potential use as bioindicators of the environment.

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The foliose lichen Leptogium azureum growing in the trunk of a palm (Prestoea montana) in the Palma de sierra forest in El Yunque National Forest.

Lichenologist Joel A. Mercado collecting crustose lichens growing in the trunk of a tree. To collect this kind of lichen, part of the living tissue of the bark needs to be removed.

Collaborating Institutions: Institute State and Private Forestry Program, University of Puerto Rico, Río Piedras Campus (Eugenio Santiago-Valentín)

2. Disturbance ecology in the Bisley Experimental Watersheds

A. Vegetation dynamics under the canopy

Hurricanes strongly influence short-term patterns of plant community structure, composition, and abundance, and are a major contributor to the maintenance of plant diversity in many forests. Previous research in the Bisley Experimental Watersheds had focused on the immediate and long-term effects of hurricane disturbance on tree species composition, number of species, and diversity, while far less attention has been given to other types of vegetation that dominate under the canopy. Yet the non-tree understory community is where the majority of plant species reside. With measurements from a unique 20-year dataset, the response and recovery of forest herbs, shrubs, and vines were tracked through multiple storms, hurricanes, and droughts. Changes in number of species, ground cover, biomass, and diversity of the non-tree community were analyzed following Hurricane Hugo (1989) and Hurricane Georges (1998) in a mature secondary subtropical wet forest of the Bisley Experimental Watersheds. Our results demonstrate that hurricanes caused an immediate, but transient, increase in overall number of species, ground cover, and diversity. Over the 20-year study period, the non-tree community exhibited pronounced and persistent changes in composition, including a dramatic increase in abundance and number of

fern and vine species and a decrease in forbs and shrubs. In the 2010 census, the understory composition and relative abundance of understory vegetation was significantly altered from previous censuses, as proportions of shrubs, herbs, ferns, and vines had drastically changed. Currently, the ferns and vines combined are 75 and 90 percent of total understory ground cover and biomass, respectively (compared to 35 to 45 percent 20 years ago). These results for the non-tree community contrast sharply with previous studies from the Bisley Experimental Watersheds that considered the same study period and area, but found that hurricanes rarely altered dominant tree species composition over the long-term. These results suggest that the role of hurricane disturbance in structuring plant diversity may be even more important than previously thought, particularly as the non-tree community contains most of the vascular plant species in tropical forests.

Contact Tamara Heartsill-Scalley, theartsill@fs.fed.us

Collaborating Institutions: Northern Research Station; University of Pennsylvania

B. Leaf litter dynamics in headwater streams.

Leaf litter that falls from the forest into streams is broken down into smaller particles. This broken-down leaf litter is then transported downstream in varying amounts and with different nutrient composition, to be consumed by native aquatic fauna. Leaf litter in streams is also known as coarse particulate organic matter (CPOM), and it is the basic energy source of forested headwater streams. Analysis of 18 years of data from the Bisley Experimental Watersheds showed there were various annual peaks in the quantity of CPOM exported instead of the single annual export pulse observed in temperate deciduous systems. The variation in the quantity and quality of exported material depended on traits of particular events (storms, hurricanes), season, and the successional status of forests. The quality (chemical composition) of exports varies temporally, with proportion of carbon to nitrogen (low quality for consumers) being highest in the driest months and lowest (high quality for consumers)during rainy months. These results signal that more attention should be given to changes in precipitation seasonality in the tropics. Changes in rainfall patterns could not only affect the timing of new leaf and flower production and stream discharge, but also increase the seasonal range in quality of organic matter exports to reach streams. Changes in the quality of organic matter resources in streams can potentially alter ecosystem processes and aquatic food webs.

In terms of quantity, median daily exports were similar before and after hurricane Hugo (September 18, 1989). However, after 16 years of forest succession following this hurricane, the moderate and high stream flows still exported less CPOM than what was exported in the 2 years prior to the hurricane. Median daily amounts of CPOM export had been observed to occur following hurricanes, but it seems that several decades are required for high storm flow exports to return to pre-disturbance conditions. Thus, the state of development of vegetation in the watershed limits how much material can be exported during a storm independently of the steepness of hillsides or amount of stream runoff. The synergy between hurricane intensity and frequency and level of vegetation maturity defines the long-term pattern of high CPOM exports in these watersheds. Forested headwaters continuously provide leaf litter and retention structures such as fallen logs and branches, and these can create and maintain pools along with natural litter traps that facilitate processing of organic matter in headwaters. Our observations in these forested watersheds have shown that most of the leaf litter that reaches these streams is processed in place and only very small amounts (0.024 percent) are exported. However, headwaters under non-forested land cover conditions may not be able to retain and process large percentages of leaf litter inputs, and this in turn can affect water quality and resource availability for aquatic ecosystems downstream.

Samuel Moya, professional technician, measuring throughfall in the Bisley Watersheds in Luquillo, PR.

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3. Long-term forest dynamics in the Caribbean: assessment of long-term forest dynamics in the Caribbean

Recent discussions during regional Caribbean foresters meetings highlighted a need for a regional workshop to synthesize results on regional forest dynamics from individual studies in permanent forest plots across the Caribbean. The main question to be addressed by the workshop is the detection of change in forest stands as a result of environmental change, particularly hurricane effects and climate change. Specific targets of inquiry are changes in: (1) stem or biomass turnover, (2) tree growth rates, (3) structural attributes, and (4) species composition.

Our challenge is to have all collaborators at the same starting point before the workshop. From our initial contacts, the conditions of permanent-plot data sets in the region vary substantially, from data in file cabinets to data sets with metadata in database programs, and thus our pre-workshop work has begun. The range of permanent plot descriptions, based on the participants' metadata provided, will be our first available product. The next steps in pre-workshop activities are the development of a Webpage and initial permanent plot site description products for sharing among the group. We expect to host a workshop aimed at synthesizing data in mid 2013.

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Collaborating Institutions: The Puerto Rico Conservation Foundation http://www.caribbeanforesters.org/, and others

4. Forest dynamics

Three studies were carried out in the Luquillo Experimental Forest to explore forest structural and species site relationships. The first used plots on ridge, slope, and ravine topography within the lower montane rain forest of the Espíritu Santo and Mameyes watersheds between 350 and 570 meters elevation (Weaver 2010a). Canopy height in the upper Espíritu Santo watershed (leeward of the El Yunque to Mt. Britton ridge) was greater than in the Mameyes watershed (windward of the ridge); canopy height tended to decline from ridge to slope to ravine topography for sampling sites in both watersheds. Within both watersheds, total aboveground biomass was greater on ridges than in ravines, and stem density decreased from ridges and slopes to ravines. *Prestoea montana* (R. Grah.) Nichols and *Dacryodes excelsa* Vahl accounted for about 30 percent of the 1,400 stems and 69 species that were tallied. Correspondence analysis showed that species abundances for 37 species with ≥ 6 occurrences (94 percent of all stems), varied by watershed and topographic position. Moreover, the Mameyes plots contained some tree species associated with forest types at higher elevation. Hurricanes affect the Luquillo Experimental Forest with sufficient frequency to maintain all forest types in various stages of recovery. Forest composition at any site is a function of environmental gradients, major climatic events, and tree species attributes.

The second study was in elfin forest at the summits of the Luquillo Experimental Forest above 880 meters in elevation, where tree cover was explored by aspect and topographic positions (Weaver 2010b). Mean stem density for all topographic positions decreased from ridge to ravine, whereas the opposite was true for canopy height. Biomass was greater on ridges and slopes than in ravines, regardless of aspect.

Tabebuia rigida Urban was the most abundant species, accounting for 23 percent of the 3,620 stems encountered. *Eugenia borinquensis* was the best distributed, occurring on 90 percent of the plots. One-half of the 42 recorded species accounted for less than 2 percent of all stems. Climatic, edaphic, and physiological factors account for elfin forest, which is adapted to survive under rigorous environmental conditions. Elfin forest provides numerous benefits, including critical habitat for many endemic flora and fauna, valuable water supplies, panoramic vistas, and recreational opportunities.

Scaffold tower reaches the canopy tops in the Bisley Watershed in the Luquillo Experimental Forest.

The last study was in the El Toro Wilderness, which was designated by Congress in 2005. El Toro occupies 36 percent of the Luquillo Experimental Forest and is the only tropical wilderness managed by the U.S. Department of Agriculture. The wilderness extends from 370 to 1074 meters in elevation and is occupied by four forest types that are characteristic of mountainous Caribbean islands: lower montane rain forest, montane rain forest, palm brake, and elfin forest (Weaver 2011). The Luquillo Experimental Forest contains: 225 tree species with 45 endemic to Puerto Rico and several to the Luquillo Experimental Forest alone; 150 species of ferns, 79 species of orchids, 11 native bats, 100 birds, 19 native reptiles, 14 native amphibians,

Elfin forest scenery: short, gnarled, epiphyte laden trees of relatively few species endemic to the summits grow above 900 meters elevation in the Luquillo Experimental Forest. Forest trails provide scenic vistas and recreational opportunities for visitors.

and 6 fish species. Most of these species are also present within the wilderness. The Luquillo Experimental Forest is surrounded by a dense human population and is under multipurpose management. Future activities in El Toro will involve the demarcation of wilderness boundaries, determination of wildlife habitats, and long-term monitoring. El Toro provides visitors with solitude, an uncommon resource elsewhere on the island.

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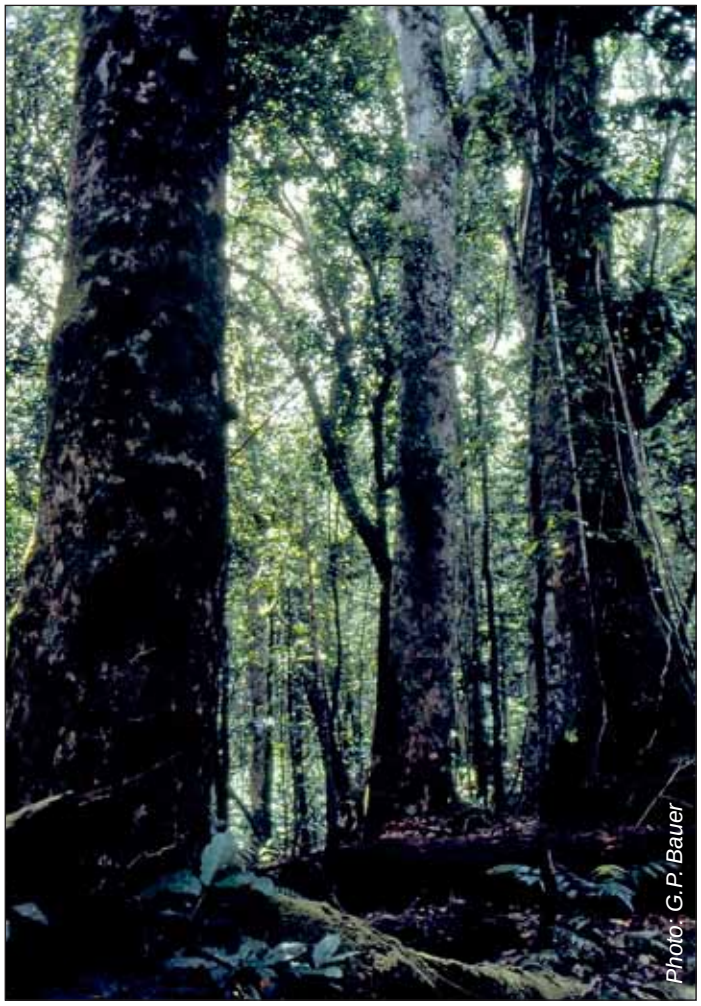
5. Dry forest research in southwestern Puerto Rico

Recent research in Guánica Forest and the surrounding area has focused on determining how native species respond to wildfires and on techniques that can be used to help re-establish native species in degraded areas. In their native state, Puerto Rican dry forests do not have natural ignition sources and appropriate ground-level fuel structure to carry wildfires across the landscape. However, the island's agriculture history has resulted in the introduction of a vast number of pasture-grass species that provide excellent fuel for fires in the dry season. This fuel, combined with careless or malicious human activities that provide sparks, results in wildfires that threaten native tree species. Our research has shown experimentally that peak fire temperatures from 150 to 300˚C will kill a majority of saplings. Lower temperatures (i.e., lower than 150˚C) kill



Lower montane rain forest: Dacryodes excelsa (tabonuco tree) is the dominant species that grows mainly at elevations < 600 meters within the Luquillo Mountains. Tabonuco favors ridge topography, where it sometimes exceeds 30 meters in height and 1 meter in diameter.

saplings when fires occur in the afternoon, presumably because the morning dew has evaporated by then and does not absorb the heat from a wildfire. In areas where we did controlled burns, about 75 percent of the saplings incurred temperatures above 300˚C. In experimental plots where we planted native saplings, fires from controlled burns killed about 65 percent of the saplings (representing 13 native species and *Leucaena leucocephala*, an introduced species) and subsequent summer drought killed additional saplings, resulting in total mortality of 96 percent. Of the 13 native species that we planted, *Bursera simaruba* (almácigo or turpentine tree) and *Erythoxylon areolatum* (indio) had the best combination of growth and survival after fires. The conclusion is that reforestation projects that attempt to re-establish trees in grass-dominated locations either need to prevent fire or reduce grass cover, both requirements can be costly or labor-intensive.

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One species that had acceptable post-fire survival and growth rates was *Leucaena leucocephala*, a species brought to Puerto Rico more than 200 years ago. We planted saplings of native species using *Leucaena* as a "nurse tree" and prevented the occurrence of fire. Survival of native saplings under *Leucaena* was not different than when planted in open areas, but growth of saplings under *Leucaena* was 50 percent higher. Thus, *Leucaena* did show a nurse tree effect. Previous work had established that *Leucaena* canopies suppressed grass biomass and density, and protected native saplings planted in *Leucaena* stands by reducing fire effects (Santiago et al. 2008). Because of the time and expense required to control grass and fire, it may be a better strategy to establish a more fire-resilient forest dominated by *Leucaena* and then underplant native species once canopy cover is established.

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El Toro Wilderness: The Luquillo Mountains as viewed from PR Route 2, which parallels the north coast. The northern part of the El Toro Wilderness Area extends left to right through the upper middle part of the photo. El Yunque Rock is visible at the upper right.

6. Caribbean vegetation mapping: Tropical forest associations and land cover for Trinidad and Tobago mapped from multiseason, multidecade, gap-filled Landsat.

Drawing upon field plots labeled as to forest assemblage, field data collected by foresters from the Trinidad and Tobago Forestry Division, and unique historical work by J.S. Beard (1944, 1946), investigators teamed up to produce the most detailed maps of wetlands, forest types, and land cover that have ever been available for conservation and management in Trinidad and Tobago (Figs. 8 and 9). Unlike most previous work, in which tropical forests were mapped only to physiognomic class (e.g., evergreen, deciduous, montane, etc.), the Institute and collaborators have shown for the first time that old tropical forests can be mapped to the level of species assemblage with gap-filled Landsat imagery. In gap-filled imagery, image gaps from clouds or scan-line failure are filled with imagery taken on various dates.

Earlier maps of Trinidad and Tobago show forest types for public lands only. No previous maps detailed forest types and land cover. The team learned that many forest associations are identifiable in the multiseason, fine resolution view of forest canopies that is viewable on Google Earth. Decision tree classification models of forest habitats were 59 to 99 percent accurate for individual classes, based on a randomly-selected 10 percent of reference pixels. Accuracy improved when ~20-year-old gap-filled images representing late dry season phenology, including drought phenology, supplemented recent gap-filled imagery from the early dry season. The synthetic multiseason imagery that they produced from these old dry-season images significantly improved model predictions by 14 to 21 percent for deciduous, 7 to 36 percent for semi-evergreen, and 3 to 11 percent for seasonal evergreen associations; and by 5 to 6 percent for secondary forest. The team also established that Tobago's "xerophytic rain forest" is associated with ultramaphic geology. Like the State Forests of Susúa and Maricao in Puerto Rico, which also have ultramaphic geology and serpentine substrates, this forest type exhibits more xerophytic features, including more sclerophyllous leaves than other forests with just as much rainfall.

In addition to digital data for land cover and forest type, the project designed and printed 45 cartographic products for Trinidad and Tobago, including island-wide maps as well as 41 maps at 1:25,000-scale that correspond to the topographic maps for the country. These maps show and label land cover and forest type, roads, rivers, towns,

Vegetation along the grass-forest interface. The grass shown here is good fuel in the dry season, and future fires will kill trees in the picture, resulting in additional encroachment of grassland into the forest.

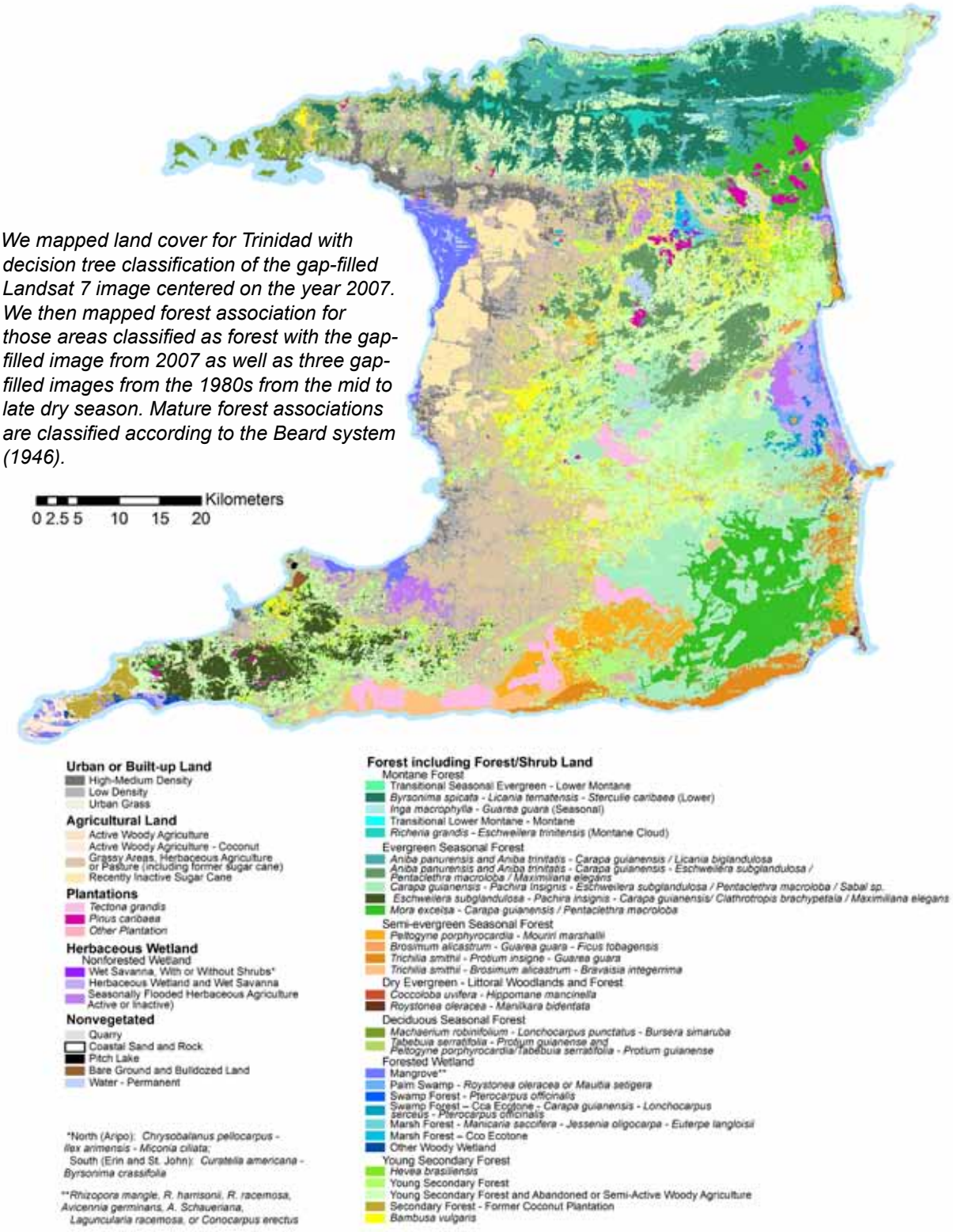

Figure 8. We mapped land cover for Trinidad with decision tree classification of the gap-filled Landsat 7 image centered on the year 2007. We then mapped forest association for those areas classified as forest with the gap-filled image from 2007 as well as three gap-filled images from the 1980s from the mid to late dry season. Mature forest associations are classified according to the Beard system (1946).

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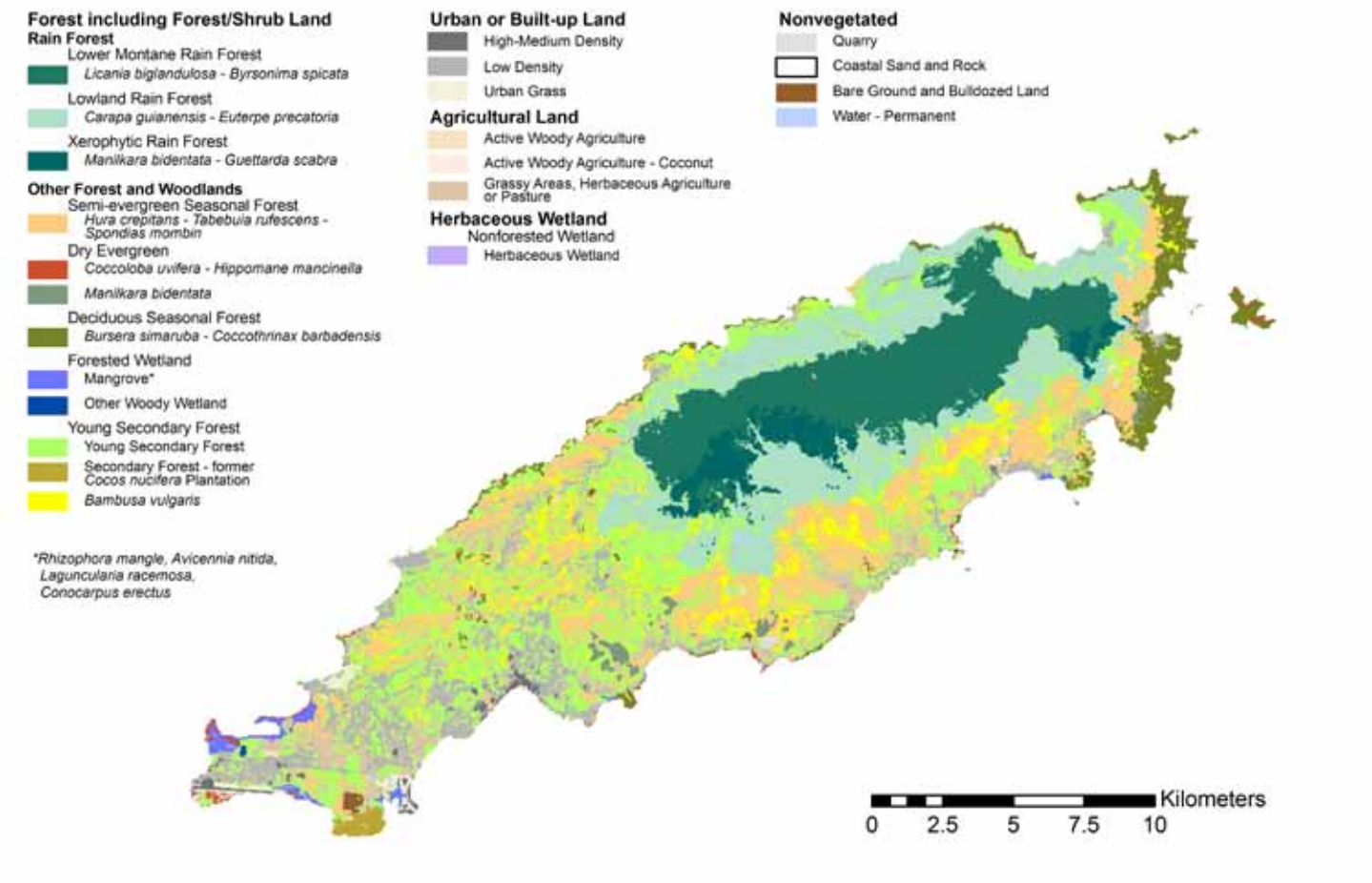

Figure 9. We mapped land cover and forest type for Tobago with decision tree classification of the gap-filled Landsat 7 image centered on December 16, 2007, which is the early dry season. Mature forest associations are classified according to the system of Beard (1944).

topography, forest and wildlife reserves, and management boundaries. The GIS data for roads and topographic contours required considerable development work. The project also included a month of hands-on training in remote sensing and GIS for two staff members from the Trinidad and Tobago Forestry Division.

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Collaborating Institutions: Colorado State University, Trinidad and Tobago Forestry Division, and Fanning Software Consulting

II. Global Change

Biodiversity

1. (A)Avian diversity among agroscapes in Nicaragua's northern highlands.

Nicaragua's highland forests are threatened by continual wood extraction and encroaching agriculture. Nicaraguan students and the lead researcher used fixed-width point counts to characterize bird assemblages in agroforestry systems under five land uses. Overall species richness and abundance were higher in coffee plantations and forest fallows, whereas disturbance-sensitive species were more abundant in secondary and riparian forest (Fig. 10). Species and foraging guilds characteristic of closed-canopy forest were found in coffee plantations, but only at points near forest remnants. To conserve and manage agroscapes as well as natural habitat, land stewards should maintain woodland strips and hedgerows bordering streams, remnant forest tracts and an arboreal component, including over- and understory, within the landscape matrix.

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(B) New species and notes on distributions of Nicaragua's avifauna.

Nicaragua's avifauna may be the least understood in Mesoamerica because the ecology, life history, and distribution of most species remain little known. However, in the past decade local and international biologists have

made several important contributions to Nicaraguan bird distribution, including more than 90 new species recorded and noteworthy range extensions for the country. We recently reported (Sandoval and Arendt 2011) the first records of striated heron (*Butorides striata*) and brown-capped tyrannulet (*Ornithion brunneicapillus*) from Nicaragua and range extensions and abundance of 29 additional species in the Atlantic Region and the Paso del Istmo Biological Corridor.

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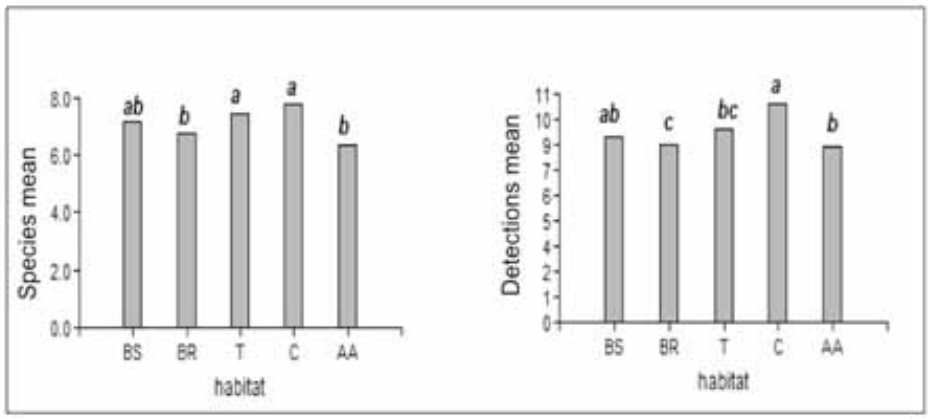

Figure 10. Means for the number of species and detections among five land-use types within a landscape matrix in the Nicaraguan highlands: AA = open area or grassland; BS = secondary forest; BR = riparian forest; C = coffee plantation; T = forest fallow. Distinct letters above each bar indicate a statistical difference at α ≤ 0.05.

2. Egg Laying patterns of the pearly-eyed thrasher in the Luquillo Experimental Forest.

Temporal aspects of egg deposition are important factors governing avian reproductive success. I documented hourly egg-laying patterns of the pearly-eyed thrasher (1979 to 2000). The first eggs laid each day were in the early morning (median 06:42 a.m.) and almost half of the eggs were laid by 7:23 a.m. Many times, however, the last two eggs of a clutch were laid later in the morning and some not until mid afternoon (2:29 p.m.), thus extending egg laying to 8 hours. Delayed laying of the last eggs in a clutch may be an adaptive strategy triggering brood reduction to ensure survival of older and more robust siblings during periods of physiological stress and food shortages. A delay in the hatching of younger siblings, even by just a few hours, results in a growth and development advantage of older nestlings. Consequently, their survivability is increased over that of the younger, under-developed, and less fit siblings when resources are scant (Arendt 2011).

Pearly-eyed thrasher.

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3. Collapse of a winter resident bird community in the Guánica Dry Forest.

Most North American migrants spend the non-breeding season in Mexico, the Caribbean, and Central America. The declines in migrant-bird population may first become apparent on the wintering grounds, where they occur in high concentrations. Collaborators and I documented an approximately 40-year decrease in both abundance and diversity of winter-resident birds, with a precipitous decline recorded during the past decade. Constant-effort mist-netting captures only about one-third as many birds as it did 20 years ago. Statistical modeling confirms a population decline and predicts local extirpation by 2033. Species richness estimates also decreased during our study, with average species richness estimated at 12.3 species during 1991 to 2001, but only 7.6 species during 2007 to 2011 (Fig. 11).

Populations of the three most common species that historically constituted 75 percent of winter resident captures are declining dramatically (Fig. 12). Black-and-white warbler (*Mniotilta varia*) declined from more than 250 birds in 1991 to fewer than 50 birds for the past 4 years. American redstart (*Setophaga ruticilla*) averaged 150 to 200 birds during 1990 to 2004, but since 2005 has been fewer than100 birds; and ovenbird (*Seiurus aurocapilla*) also declined. It is critical that we accelerate on-the-ground

Research and Development

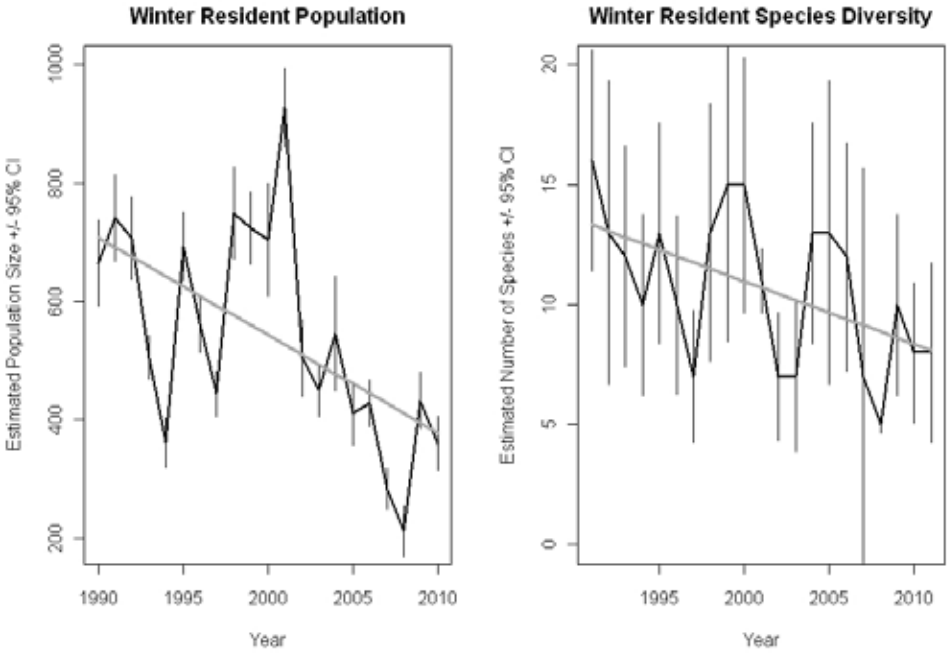

Figure 11. Annual variation in estimates of total winter resident birds and estimated species richness for winter residents with fitted negative trends from capture/recapture data gathered from nine netlines in the Guánica Forest, Puerto Rico, from 1991 through 2011; error bars are 95 percent confidence intervals.

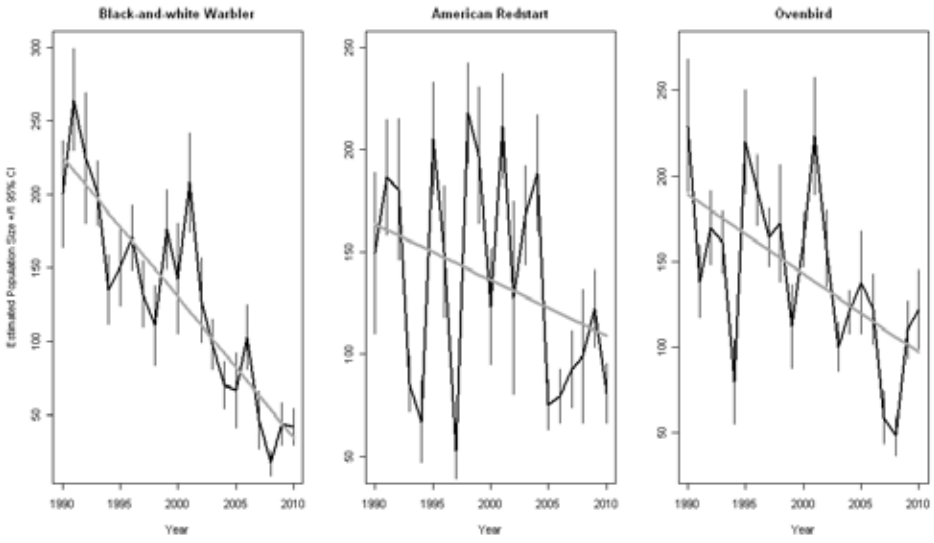

Figure 12. Declining population estimates for the three most common species captured in our study, computed using MARK. Error bars are 95 percent confidence intervals.

conservation for migrant as well as resident birds and support research that attempts to understand these declines.

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Collaborating Institution: University of Missouri

4. Avian studies and research opportunities in the Luquillo Experimental Forest.

In commemoration of 100 years of avian research in U.S. Forest Service experimental forests, a special symposium was held at the American Ornithologists Union meeting in Philadelphia, PA, in August 2009. As a result of this symposium, participants were invited to submit manuscripts reviewing avian studies from their respective experimental forests to be considered for publication in a special section on avian studies in Forest Ecology and Management. As a result of this invitation, Joe Wunderle and Wayne Arendt submitted a manuscript reviewing avian studies from the Luquillo Experimental Forest (LEF), which was recently published (Wunderle and Arendt 2011). In their review, Wunderle and Arendt emphasized avian studies with management implications and noted opportunities for future studies, especially those that would help managers respond to local and global changes, which may affect the forest's ecosystems and avifauna.

As one of the most active ecological research sites in the Neotropics, the Luquillo Experimental Forest has a rich history of ecological studies on which to base future avian studies. As is typical of an island ecosystem, the Luquillo Experimental Forest has low avian species richness, as represented by only 23 bird species that breed in the forest and another 76 species, mostly migrants, that are known to occur. The role of birds in the food web of the lower elevation tabonuco forest has been especially well-studied as part of a larger investigation of the rainforest's food web. The forest is

noted for its remarkably high densities of Anolis lizards and Eleutherodactylus frogs, which may depress insect and spider densities, thereby contributing to the forest's low species richness and densities of most insectivorous birds. The endangered Puerto Rican parrot has become the symbol of the forest, in part, because it has been the focus of intensive long-term research and management efforts, which have stimulated research on other associated species. The spin-off studies from the parrot recovery effort are many, including long-term studies of the pearly-eyed thrasher and botfly parasitism. Given the high frequency of hurricane disturbance to the Luquillo Experimental Forest and studies providing a baseline for comparisons, research has provided substantial contributions to an understanding of hurricane effects on forest ecosystems including bird populations and their resources. Censuses conducted over a 20- to 30-year period have documented disturbing population declines in sharp-shinned and broad-winged hawks and the elfin-woods warbler in the forest. These and other studies are summarized in Wunderle and Arendt's (2011) review of more than 150 publications pertaining to avian studies from the Luquillo Experimental Forest, which will be a useful reference for others interested in conducting research at this site.

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5. Winter ecology of the endangered Kirtland's warbler.

Field work on the winter ecology of the endangered Kirtland's warbler and its habitat continued for the ninth winter (November 2010 to May 2011) on the island of Eleuthera, The Bahamas. The Kirtland's warbler ranks as one of North America's rarest songbirds and has been the focus of an intensive state and federal recovery effort on its North American breeding grounds. Yet despite these efforts little was known of the nonbreeding biology of the species and its habitat requirements and potential conservation needs on its wintering grounds in the Bahamas. At the request of the Kirtland's Warbler Recovery Team, the Institute wildlife program has focused much of its research on the winter ecology of this species. This work currently focuses on: (1) elucidating factors controlling the occurrence of Kirtland's warbler habitat on the island of Eleuthera, The Bahamas, and (2) examining effective means of creating, enhancing, or managing Kirtland's warbler habitat in disturbed areas.

Research findings to date indicate that Kirtland's warblers require early successional habitats, derived mostly from anthropogenic disturbance, and therefore habitat disturbance is required to produce winter habitat for the warbler. Thus the challenge for wintering grounds conservation is the need to work with private landowners (given limited public lands) and the requirement for re-occurring habitat disturbance to produce Kirtland's warbler habitat. To addresses these challenges the research program now focuses on answering the question: How can we tweak re-occurring habitat disturbances for the benefit of the Kirtland's warbler in a cost-effective manner on private lands? Re-occurring disturbances are typical of areas where brush is controlled for the maintenance of utility corridors, boundary lines, fire breaks, and rights-of-ways, and these areas are also known to provide habitat for the Kirtland's warbler. Therefore, the research goal is to devise management strategies that allow maintenance of Kirtland's warbler fruit plants in these managed sites without compromising the original management objectives of the landowner.

Collaborating Institutions: The Nature Conservancy-Michigan and Bahamas programs, Bahamas National Trust, Southern Forest Research Station (Athens, GA), and Forest Products Laboratory (Madison, WI)

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The endangered Kirtland's warbler.

Changing climate

1. Tropical forest carbon balance in a warmer world.

Tropical forests are likely to experience a significant and permanent increase in temperature over the next 2 decades. Given the importance of tropical forests to the global carbon budget, understanding the potential for these forests to adapt to an unprecedented temperature regime is critical to our ability to accurately predict feedbacks to future climate. In response to a recognized need to understand the tropical forest response to increased temperatures, the International Institute of Tropical Forestry is leading a collaborative effort to develop a whole-forest warming experiment in Puerto Rico. This experiment will enable us to determine the resilience and adaptability of tropical forests to increasing temperatures and will provide valuable insight into mechanisms controlling the uptake and storage of carbon in these systems.

Research and Development

In October 2010, the Institute hosted a 3-day workshop that involved 10 scientists from university and government institutions to discuss the development of a whole-forest warming experiment in Puerto Rico. This collaborative effort led to the production of an expansive literature review of the response of tropical forests to increased temperature (currently in review for publication in Biological Reviews). The institute's scientists and collaborators also led an organized oral session at the 96th annual Ecological Society of America Meeting in Austin, TX, USA, August 2011, titled "From Leaf to Biosphere: The Effects of a Warming Climate on Tropical Rain Forests." This session was one of just three selected to develop a meeting report for publication in the journal New Phytologist.

The U.S. Forest Service awarded the Institute funds to begin development of a full-scale prototype for the warming experiment. Equipment to begin production of the prototype is ordered and we anticipate construction will begin in 2012. This will be the first tropical forest warming experiment and the first experiment to warm at the whole-forest-scale for any forested ecosystem.

Two solar panels were installed above the forest canopy on existing towers to power an automated soil respiration system (Li-Cor LI-8100/8150) in karst forest at El Tallonal.

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Collaborating Institutions: University of California-Berkeley; Michigan Technological University; U.S. Geological Survey, UT; Lawrence Berkeley National Laboratory; USDA-Agricultural Research Service, AZ; Environmental Improvement Systems Inc., PR; Brookhaven National Laboratory, NY; Oak Ridge National Laboratory, TN; California State University-San Marcos; University of Puerto Rico; and The Puerto Rico Conservation Foundation

2. Assessing the carbon balance of a non-native forest stand in the karst region of Puerto Rico.

In the face of a rapidly changing world, understanding the functional role of non-native species is critical to the development of effective forest management strategies. We are investigating the net carbon balance of a forest stand dominated by the introduced species, Castilla elastica. As part of this assessment, we installed an automated soil respiration system in February 2011, to evaluate soil respiration with high temporal resolution. This research builds on the master's research of Jessica Fonseca Da Silva and the work of high school students during the Puerto Rico Math and Science Partnership program of the National Science Foundation. The results of the combined research program established a baseline of forest structure and carbon dynamics in replicated long-term plots. Studies are conducted at the privately owned El Tallonal Reserve, where two canopy towers and climate stations are available for the carbon balance research. Results from this study will provide information on net soil carbon loss from this forest with high temporal resolution.

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Collaborating Institutions: University of California-Berkeley; Citizens for the Karst; The Puerto Rico Conservation Foundation; and University of Puerto Rico-Río Piedras

3. Preserving the nighttime environment for future generations in Puerto Rico.

Preserving dark skies and the nighttime environment has recently become a focus of researchers studying the effects of light pollution in Puerto Rico.

In Puerto Rico, which spends an estimated $3,700 million annually on electricity for its 3.7 million residents, artificial illumination is the main cause of light pollution. Light pollution not only makes it more difficult to see the stars, but it also adversely affects sensitive nocturnal species and increases energy costs and carbon emissions. Expansion of the San Juan Metro Area and other urban corridors is encroaching on upland and protected areas, causing a marked decrease in night sky quality. Currently, scientists

from the Institute are monitoring artificial light pollution in Puerto Rico by customizing nighttime remote sensing imagery and map products for local use and directly monitoring nighttime lightscape conditions in the field for research, policy, and mitigation. On the periphery of the El Yunque National Forest, the only tropical rainforest in the National Forest System, light pollution is obvious at uphill locations. Numerous community outreach presentations have been offered to educate children and adults about ecological and astronomical effects of light pollution in Puerto Rico, especially in the vicinity of the El Yunque National Forest. Light pollution also greatly diminishes the visibility of the island's three main bioluminescent water bodies where high concentrations of bioluminescent microorganisms make the bays glow. Since 2006, the Forest Service has worked with the Conservation Trust of Puerto Rico Light Pollution Task Force to implement a light pollution management strategic plan for the Bioluminescent Lagoon Demonstration Project at Las Cabezas de San Juan Nature Reserve in Fajardo, Puerto Rico. The task force and management plan aim to safeguard the resources in the Reserve and to protect local economic revenues derived from tourists visiting these globally unique locations.

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Collaborating Institutions: Conservation Trust of Puerto Rico, Sociedad de Radioastronomía del Caribe, and University of Puerto Rico-Humacao

4. Effects of experimental warming and snow manipulation in Alaskan tundra.

Increases in global air temperatures are predicted to increase vascular plant productivity in the Arctic through temperature effects on key ecosystem processes such as soil microbial respiration, organic matter decomposition, and nutrient availability. However, little is known about the effect that increasing precipitation

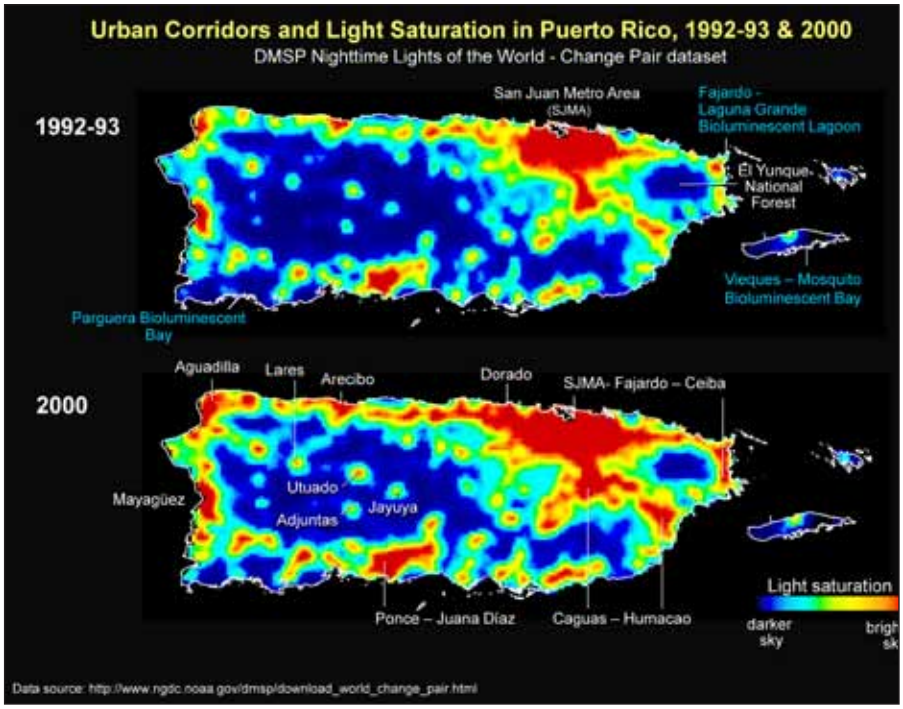

Figure 13. Changes in nightlight coverage on the islands of Puerto Rico, Vieques, and Culebra, 1992/93 to 2000. Global data source accessible from NOAA NGDC Earth Observation Group (EOG) Defense Meteorological Satellite Program (http://www.ngdc.noaa.gov/dmsp/download_world_change_pair.html).

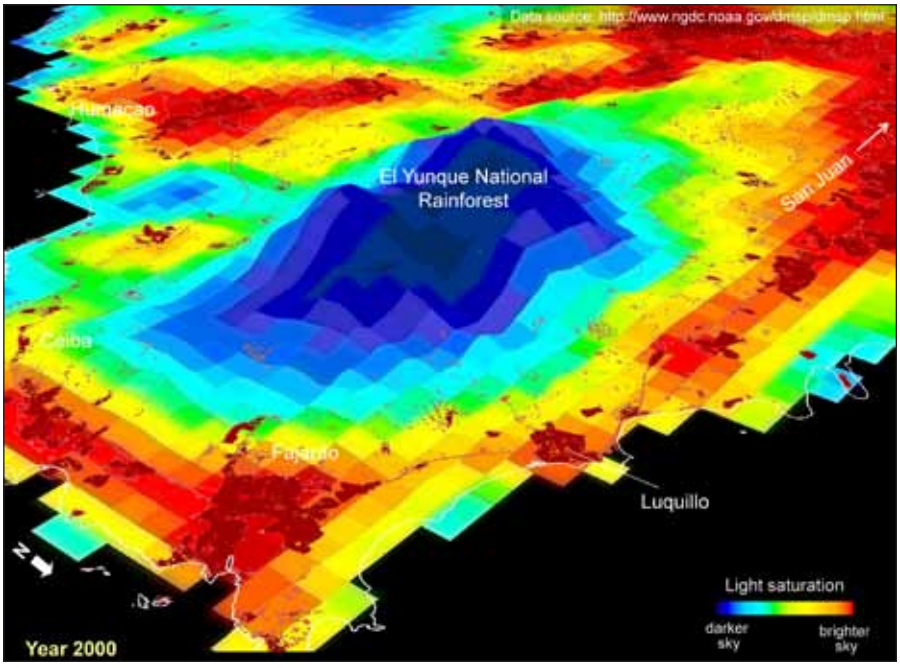

Figure 14. A 3-D perspective of the light pollution footprint in the vicinity of El Yunque National Forest. Data source: http://www.ngdc.noaa.gov/dmsp/dmsp.html

Research and Development

or the interaction of warming and precipitation may have on tundra ecosystems. We established a long-term experimental study to shed more light on these interactions (Mercado Díaz 2011). The study involved manipulating snow depths and warming plots of tundra vegetation, and comparing growth and composition of vegetation with control plots. Two common Alaskan Arctic ecosystem types were manipulated, dry heath and moist-acidic tussock tundra. These sites have been exposed to warming and snow manipulations since 1994 and responses have been measured periodically. Changes in snow regimes had the largest effects on vegetation. Most common changes associated with increasing snow depths included increases in canopy height and shrub abundance and decreases in species diversity and lichen cover. Increases in air temperature had few measurable effects on vegetation; however, differences between control and warmed plots were more noticeable over time in terms of the abundance of shrubs at the moist site. Responses of vegetation in terms of canopy height and total vegetation cover varied over time within and between ecosystem types, suggesting diverging long-term responses of ecosystems within this tundra region to climate change (Figs. 15 and 16).

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Collaborating Institutions: University of Puerto Rico, The Puerto Rico Conservation Foundation, and Florida International University

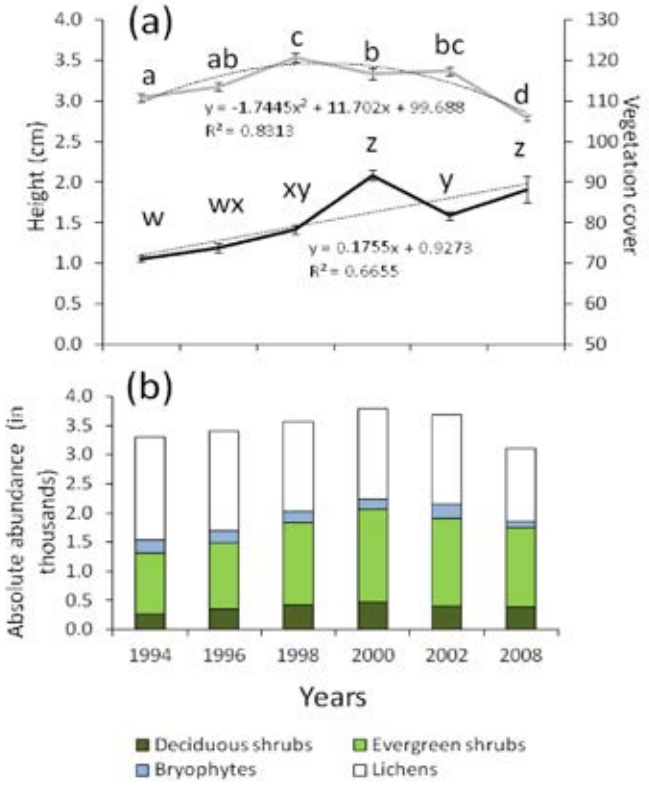

Figure 15. (a) Trends in canopy height (black line) and vegetation cover (grey line), and (b) absolute abundances of main growth forms at the dry site from 1994 to 2008. Vegetation cover estimated as mean number of overall vegetation hits. Lower case letters represent significant differences among years (a, b, c for vegetation cover and w, x, y, z for canopy height).

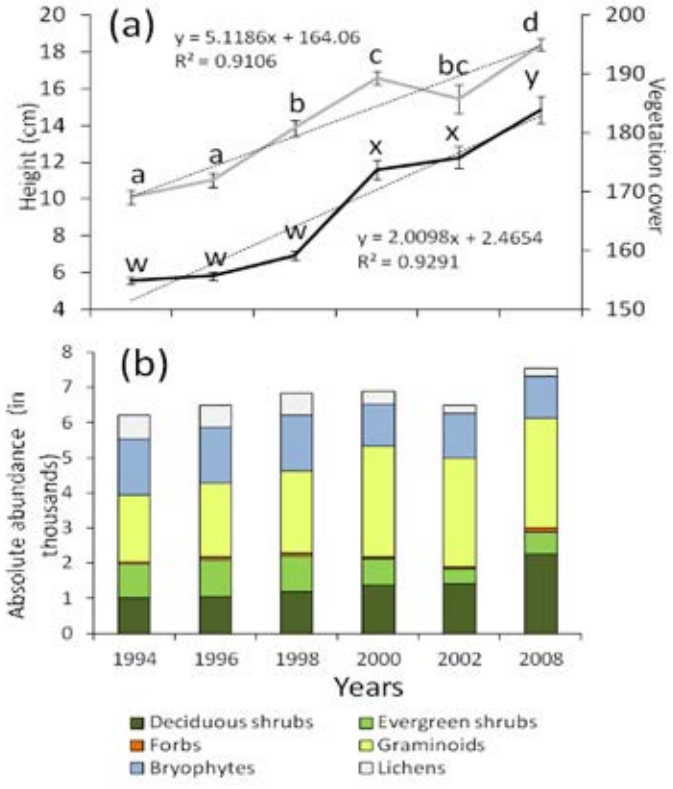

Figure 16. (a) Trends in canopy height (black line) and vegetation cover (grey line), and (b) absolute abundances of main growth forms at the moist site from 1994-2008. Vegetation cover estimated as mean number of overall vegetation hits.

Biodiversity assessment and conservation

1. Mapping protected natural areas of Puerto Rico. Conservation of natural resources is a balance of protection, managed use, restoration, and sustainable development.

Effective planning and management of protected areas for biodiversity conservation integrates local, regional, and global concerns with scientific research assessing the extent and status of protected areas. We have developed a map that portrays 115 terrestrial and marine protected areas—public and private lands designated for biodiversity conservation—in Puerto Rico (Gould et al. 2011). The commonwealth of Puerto Rico owns and manages the greatest area of protected lands (58 percent), followed by the Federal government (28 percent) and non-governmental organizations or other private entities (14 percent). Eight percent of the island has some degree of legal protection for conservation, while nearly 92 percent of the island has no biodiversity protection. Protected areas are concentrated on the high peaks of the Central and Luquillo Mountains, the wetlands of the coastal plains, and the lesser islands and cays of the Puerto Rican Archipelago. These areas are relatively well-protected. Under-protected areas include non-wetlands of the coastal plain, the karst limestone hills in northwestern Puerto Rico, and the coastal hills and lower slopes—which form an important hydrological and ecological link between the upper mountains, the coastal wetlands, and the near shore marine areas. The map we developed is a product of the Puerto Rico Gap Analysis Project, supported by the Institute and the United States Geological Survey National Gap Analysis Program. The information was primarily gathered through interviews with protected area management officials and through literature review. The map is part of the Forest Service Research Map (RMAP) series recently developed at the Institute.

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Collaborating Institutions: University of Puerto Rico, The Conservation Trust of Puerto Rico, The Puerto Rico Department of Natural and Environmental Resources, and The USGS National Gap Analysis Program

Figure 17. An excerpt from a new map product in the recently inaugurated Forest Service Research and Development Research Map Series (RMAP). Darker green areas are managed by the Commonwealth government, intermediate green are managed by the Federal government, and light green are managed by non-governmental agencies. Gray lines represent the marine protected areas for Puerto Rico.

Research and Development

2. Integrated Gap Analysis Project—modeling and mapping sea turtle distributions.

The Integrated Gap Analysis Project for Puerto Rico and the U.S. Virgin Islands is evaluating the conservation status of 237 animal species and habitats in order to identify "gaps" in conservation. Sea turtles, including the hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*), were prioritized in this analysis because of their endangered or critically endangered status (IUCN 2010) and essential ecological role in marine ecosystems. We developed a comprehensive set of databases including natural history information, local species distribution, potential habitat identification, and conservation status of sea turtles in the region. We have developed habitat suitability models and mapped predicted distributions for different turtle activities and parts of the life cycle, such as nesting and feeding activities, and juvenile or adult distributions (Fig. 18).

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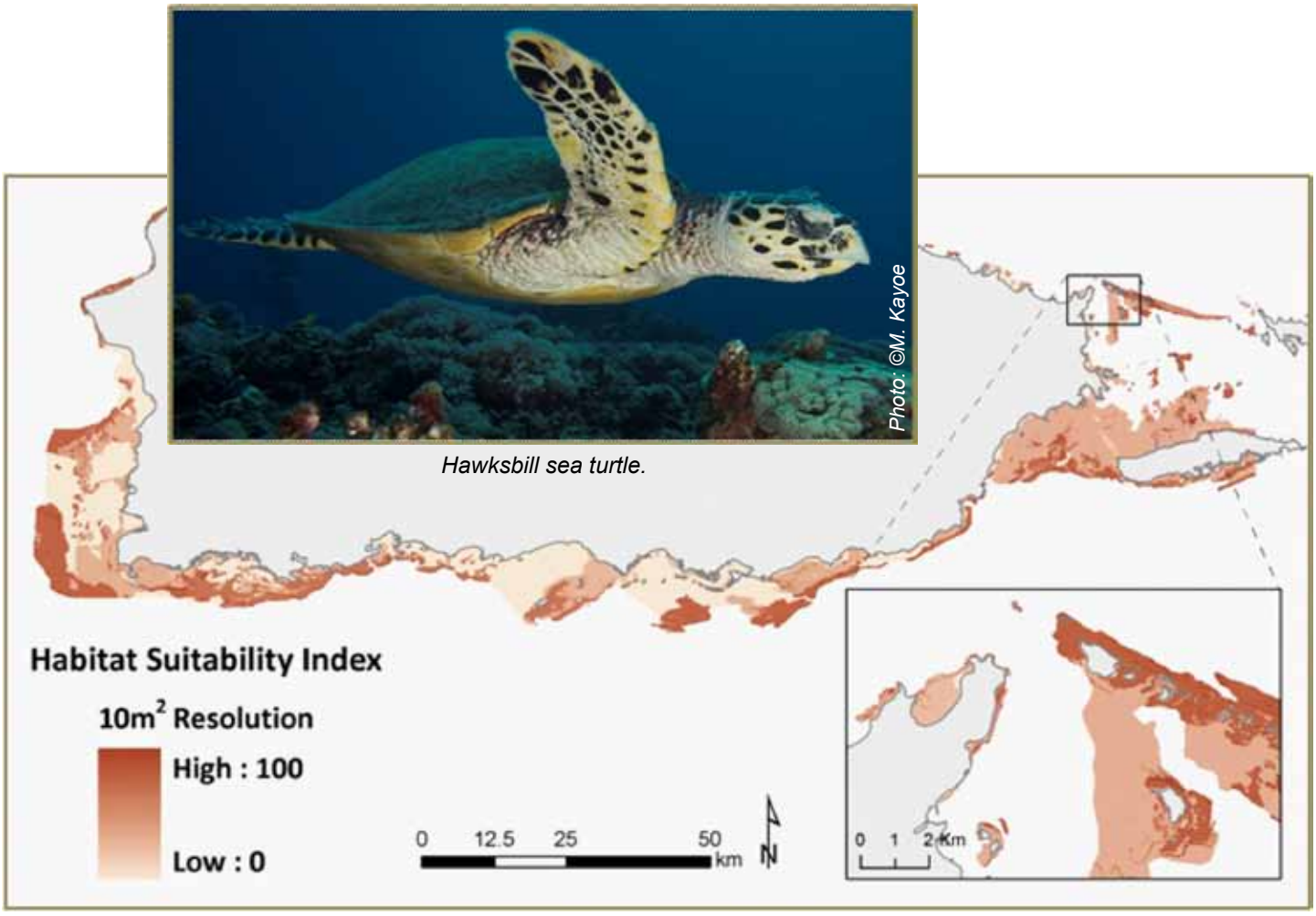
Collaborating Institutions: U.S. Geological Survey, and Puerto Rico Department of Natural and Environmental Resources



Hawksbill sea turtle.

Figure 18. This model depicts the suitability of in water habitats for the hawksbill turtle based on habitat associations. Some areas remain blank because some of the layers (e.g., bathymetry) do not cover the whole extent of the study areas. The equation used for modeling of hawksbill habitat affinities includes information on the habitat structure (reef type), location within that structure, and surface roughness.

III. Working Lands

1. Advancing tropical forest management through governmental and non-governmental forest policies

Tropical forests are increasingly valued for the goods and services that they provide at local to global levels, yet they continue to be degraded and lost at alarming rates. Governmental forest regulation and non-governmental forest certification are policy approaches used throughout the tropics to promote and advance forest sustainability, but they are often criticized for failing to curtail continuing rates of tropical forest degradation and loss. Regulation generally encompasses guidelines, rules, and/or restrictions on forest use and extraction. Certification is a fairly new, non-governmental market-driven policy tool that aims to promote sound forest management through market-based incentives. With collaborator Fred Cubbage, the effectiveness of governmental forest regulation and non-governmental forest certification in Costa Rica, Guatemala, and Nicaragua was analyzed. We found that sufficient human, financial, and technical resources and capacity are fundamental for adequate implementation of both policy approaches, but in most tropical settings, resources and capacity are often substantially limited, particularly for governmental forest regulation. The findings also show that innovative arrangements for promoting, verifying, and enforcing regulatory compliance can compensate for limited governmental resources and processes. In particular, forest sustainability was enhanced where combinations of policy tools and actors beyond the traditional command-and-control approach were used to promote forest sustainability, including economic incentives for sustainable forest management, technical assistance for forest owners and managers, development and participation of private-sector forest 'stewards,' and support for sustainable forest management from nongovernmental organizations. The results also shed light on the mitigating effects of local-level inducements and constraints to governmental and non-governmental forest policy adoption and compliance, such as forest size and composition, management resources and capacity, and attitudes toward forest policy and implementers. Overall, the research and its results help policy- and decision-makers as well as forest owners and users by identifying key factors to consider in developing and implementing policies to promote sustainable forest management in the tropics.

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Collaborating Institution: North Carolina State University

2. Integrating research, education, and traditional knowledge in ecology: a case study of biocomplexity in Arctic ecosystems

Integrating research and education is a fundamental goal of institutions and agencies supporting science because of the benefits to society of a more informed population. The value of engaging public interest in ecological research is to maintain support for and integrate science in solutions to environmental problems. For environmental scientists there can be some costs to developing programs that address broader impacts. For example, while there is a call for environmental scientists to broaden their activities to engage in outreach (i.e., have broader impact), there are few venues or incentives to report on these activities in ways that would enhance an environmental scientist's research career. Publishing examples of successful integration in environmental research journals can help researchers and institutions evolve better mechanisms to achieve goals beneficial to society, including improved public understanding of science, greater diversity of research and stakeholders, and better application of current scientifically based information to managing environmental issues. In that spirit, we present as an example an effort that integrates an interdisciplinary research project investigating the interactions of climate, vegetation, and permafrost in the study Biocomplexity of Arctic Tundra Ecosystems with a university field course, Arctic Field Ecology, and with indigenous Inuit students and elders (Gould et al. 2010). The integration allowed university students and native community members to participate with the research team, drawn by the opportunity to gain education and experience. This participation has had synergistic benefits with the research agenda and diversified the pool of stakeholders involved in the research.

The arctic field ecology youth-elder-science camp involved such diverse activities as (top) stretching hides of caribou recently harvested by the elders and (bottom) observing microscopic soil invertebrates.

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Collaborating Institutions: Kitikmeot Inuit Association, University of Alaska-Fairbanks

Research and Development

3. Sustainable management of big-leaf mahogany in the Brazilian Amazon

Big-leaf mahogany is by far the most valuable timber species in seasonally dry forests across the southern rim of the Amazon Basin, but much of it is unsustainably managed. Our research supports sustainable management through better understanding of mahogany life history and population dynamics in natural forests. Local economies and livelihoods will benefit from forest industries invested in active management of long-term timber production from standing forests.

The Mahogany Project seeks to understand what makes big-leaf mahogany 'tick' in natural forests across southern Brazilian Amazonia by monitoring vital rates for all stages of its life cycle, from seeds to senescent adults, across temporal and spatial scales relevant to each life phase. With steady support from the IITF since 1995, the Mahogany Project has addressed a long list of basic and applied research questions, as demonstrated by more than 30 mahogany-related scientific articles and book chapters published to date. Project researchers have contributed directly to Brazilian national forest policy through participation in working groups and seminars to revise and improve industry harvest practices. Based on 16 years (1995 to 2010) of annual censuses of more than 600 trees and many thousands of seedlings and saplings scattered across nearly 5,000 hectares of forest, project researchers have developed demographic models that simulate both short- and long-term population responses to forest management practices such as minimum diameter felling limits, commercial tree retention rates, and vine cutting. One of these, the Big-Leaf Mahogany Growth and Yield Model, is a highly interactive and user-friendly computer application that can be operated on-line at www.swietking.org or downloaded with complete instructions for use on office or home computers. The model can be run based on pre-installed example populations from project sites in southeast and southwest Amazonia, or forest managers can upload data from actual management sites. Transforming unsustainable harvest practices into sustainable management systems through better understanding of mahogany life history and population dynamics in natural forests will benefit local economies and livelihoods as forest industries invest in long-term timber production from standing forests under active management.

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Collaborating Institutions: ISCIENCES, Middlebury College, HJ Andrews Experimental Forest, Oregon State University, Instituto Floresta Tropical–IFT (Brazil), ESALQ/Universidade de São Paulo (Brazil)

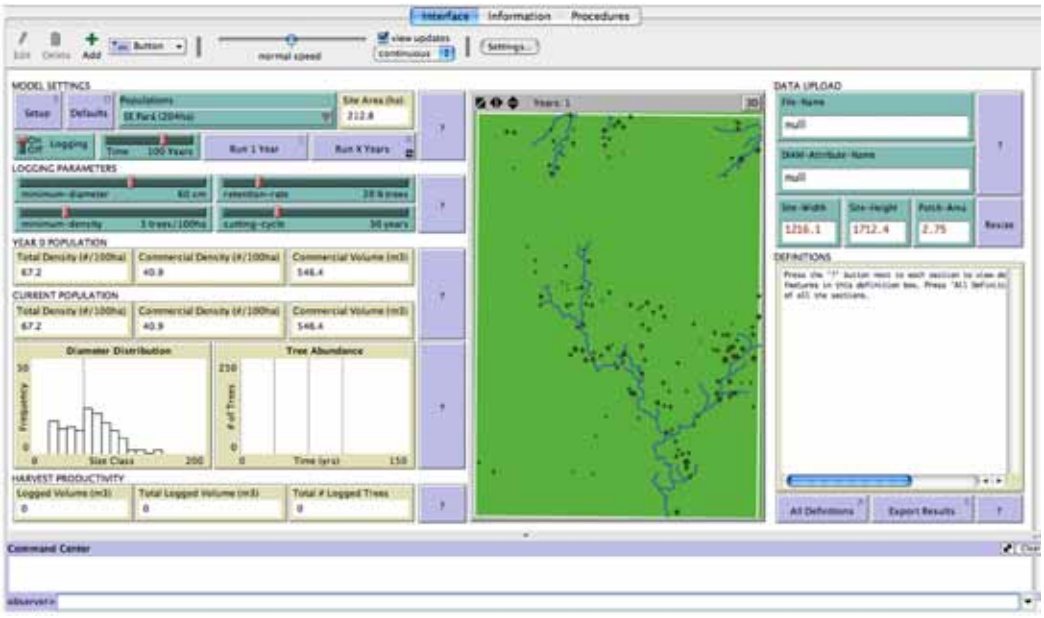

Figure 19. Screen shot of the Big Leaf Mahogany Growth and Yield Model user interface. The model is available at www.swietking.org.

State and Private Forestry

The Institute has a long tradition of information exchange with government agencies, universities, and local communities in Central and South America and the Caribbean. Through the State and Private Forestry Program (S&PF), the Institute provides professional, technical, and financial assistance to local communities and private landowners in Puerto Rico and the U.S. Virgin Islands (St. Thomas, St. Croix, and St. John). Through focused technical and financial assistance and conservation education, Federal resources are leveraged to protect and support sustainable management of the islands' forests and ecosystems to produce goods and services that are important to many communities. This assistance is focused on cooperative forestry, cooperative fire protection, forest health, urban and community forestry, and landowner and legacy assistance programs. Key issues addressed by this program include: rapid urbanization and residential development and its sprawl into natural areas; ecological restoration of natural and built-up areas; water quality (including storm water runoff, and restoration of natural areas); soil protection and watershed management; sustainable urban forestry programs at the local level; damage of reefs and over-fishing of key species; and sustainable tourism development in small communities.

Program Manager: Constance Carpenter, *conniecarpenter@fs.fed.us*

Forest History

The Institute's historian, Carlos Domínguez Cristóbal, in 2008 completed a book on policies affecting mangroves in Puerto Rico during the 19th century (La política forestal del manglar en Puerto Rico durante el siglo XIX). The 200-page volume is based on an analysis of information on the historical impact of specific policies and programs affecting the use of mangroves and a study of 31 mangrove forests. Included is information on the draining and conversion of mangroves to produce sugar cane. It also relates interactions between the coastal communities, land use decisions, and the extent and benefits of mangrove forests.

Another interesting historical work is Árboles municipales oficiales de Puerto Rico. This document presents information on the historical relevance of the official trees designated in 37 municipalities. In the process it raises awareness of the historical role of forests and trees in the culture and economy of Puerto Rico. Each municipality used its own unique process to select and officially designate the tree. Those involved have included schools, communities and social and cultural organizations.

From left to right: Magaly Figueroa, natural resources specialist; Bruce Drapeau, cooperative fire (El Yunque shared services); Gisel Reyes, publications assistant (U.S. Forest Service National Library); Carlos Domínguez Cristóbal, history and conservation education; Constance Carpenter, Cooperative Programs manager; Christian Torres Santana, forest health specialist; Aixa Mójica, program support.

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Conservation Education

If every school were able to establish an area for long-term ecological study near their schools, it would be a dream come true for teachers and students alike. Carlos Domínguez Cristóbal, S&PF conservation education coordinator, published a conservation education manual called Forestry Research: an Interdisciplinary Guide based on his experience working with students in just such a setting for nearly 30 years (Domínguez-Cristóbal 2011). In the forward to the manual, Institute Director Ariel E. Lugo says, "… the exercises involve the application of botany, zoology, ecology, mathematics, chemistry and social science concepts. Even more interesting, this guide contains a strong dose of history and toponymy that make it more innovative and distinctive than any guide I've seen throughout my career." The next step is to transform the dream into reality.

The Institute hopes the manual will help spur the adoption of forest schoolyards and outdoor classrooms throughout Puerto Rico and the U.S. Virgin Islands. A forest schoolyard is a dynamic laboratory of life. Sample exercises in the manual help teachers guide students into an encounter with nature, and many incorporate idiosyncrasies unique to Puerto Rico's history and its tropical setting. Spanish and English versions of the manual were developed, which expands its utility as a model for programs in other tropical countries and for Spanish-speaking students in the United States and elsewhere.

Two schools in Puerto Rico—the urban elementary school Juana A. Méndez in Carolina and the rural middle

school Eugenio Maria de Hostos in Arecibo—have recently expressed their intention to take students into outdoor classrooms. The middle school is located near the Cambalache State Forest, which has the potential to provide numerous opportunities for students to explore forest research questions.

The 2011 Conservation Education Bulletin was dedicated to student accomplishments at Francisco Morales High School in Naranjito, Puerto Rico. The number of schools with outdoor classrooms and research projects is increasing; therefore, future issues will seek to incorporate the latest news and field results from as many schools as possible. The bulletin is an important tool for sharing information among schools, the community, and partners

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Juan Ponce de León High School (Florida, Puerto Rico) students identifying forest insects on a plot in the karst region.

More Kids in the Woods: Kids Discovering the Santa Ana Forest

The future of natural resources conservation depends on future generations. Since 2007, the Forest Service has invested $3 million in diverse, partnership-based More Kids in the Woods projects that get "more kids in the woods" to learn about and experience the natural environment. In 2011, the More Kids in the Woods challenge-cost share program competitively funded 21 projects that help children establish a lifelong connection with nature and develop outdoor skills and interests, and healthy lifestyles. Kids Discovering the Santa Ana Forest was one such project that won funding through this competition.

Even though Puerto Rico is a small island with many beautiful forest resources, some kids have never had the opportunity to visit and enjoy the experience of observing and touching the natural features and creatures found here. Recognizing that we need to provide educational opportunities to those kids, the Natural History Society of Puerto Rico applied for a grant from the U.S. Forest Service More Kids in the Woods Program for the Kids Discovering the Santa Ana Forest project.

Implementation of the project was a big success, enabling children from underserved communities to have their first encounter with a tropical forest. Children from schools active under the No Child Left Behind initiative were invited to spend one day at the Santa Ana Nature Center. The project targeted teachers and students from the first through the sixth grades, but more advanced students were also included.

The Nature Center has about 100 acres and is part of the Monagas Park, which is a recreational facility managed by the Puerto Rico National Parks Company. The kids were greeted by the Santa Ana Nature Center staff, Eliezer Nieves and Dayamaris Candelario, who gave a brief overview of the events of the day. Activities included observation, studies, environmental games, and educational talks on conservation initiatives in general and the forest ecosystem they were visiting in particular. The students completed a pre-test at the beginning of the day to assess their knowledge about forests, endemic species, and parts of a tree. A post- test assessed what the kids learned and any changes in their attitudes regarding nature.

Then the fun began. The children walked through the trails of Santa Ana Forest and began their exploration. Once there, the students had the opportunity to observe some of the 50 different tree species present and the herbaceous plants that are part of the ecosystem. They were introduced to bird-watching and were told about both endemic and exotic species that live in the Santa Ana Forest. Reptiles such as the Puerto Rican boa, and lizards and amphibians were observed. The Santa Ana Forest has a huge variety of insects for students to discover; among these are butterflies, walking sticks, bees, and mantis.

Each student received the basic equipment needed to perform a variety of field studies. For example, each student got a magnifying glass to examine the parts of trees and insects; portable weather stations and soil thermometers to collect information on temperature and humidity; and measuring tapes and clinometers to measure tree diameter and height. Hands-on experience taught the kids how to identify the different parts of a tree, insects and animals of the forest, benefits of the forest's ecosystems, and how wonderful nature is. The kids were excited about sharing their discoveries with each other.

Each group collected information, which was logged into the Nature Center database. The database also includes results of inventories of the forest biota, information on tree growth, and observations of wildlife behavior. That information is filed in the Santa Ana Forest data inventory and is used to develop educational fact sheets and to prepare presentations.

Back at the pavilion the students had the opportunity to discuss what they saw and how it made them feel. They talked about how forests work, their benefits, and how the interaction with nature benefits both physical and mental health. They discussed the fact that even though the forest is surrounded by heavily developed land it is still in good shape and provides environmental services to the surrounding neighborhoods. The students learned about the importance of conserving the forest environment and the sustainability of ecosystems.

Richard Louv's (2005) Last Child in the Woods book was an inspiration for the project. Louv explained that children exposed to nature show intellectual, spiritual, and physical improvement compared to those who have passive lifestyles and dedicate their time to video games and watching television. Also, kids from schools that have nature-based experiential education show improvement in social studies, language, arts, math, and science.

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Collaborating Institutions: The Puerto Rico Department of Education, Puerto Rico National Parks Company, Department of Natural and Environmental Resources, University of Puerto Rico, the Interamerican University, and the Natural History Society

Kids discovering the Santa Ana. Photo courtesy of Santa Ana Nature Center, Natural History Society of Puerto Rico.

Forest Health

During FY 2011, the State and Private Forestry unit hired Christian Torres Santana to coordinate the Institute's Forest Health Program, to provide technical assistance to partners, and to assist with implementing projects in Puerto Rico and the U.S. Virgin Islands. The Forest Health Program focuses on providing technical, professional, and financial assistance to stakeholders monitoring forest pests, diseases, and other biotic and abiotic factors that may cause detrimental changes to the health of Puerto Rican and U.S. Virgin Islands' forests. This year we have been closely working with the Puerto Rico Department of Natural and Environmental Resources to establish a Statewide Forest Health Monitoring Program, to develop a Forest Health Conditions report, and to form an integrated Forest Health Committee. Under collaborative agreements we are working with the University of Puerto Rico at Mayagüez Plant Diseases and Pests Diagnostic Clinic to develop fact sheets of important forest pests and diseases and to provide training to University of Puerto Rico at Mayagüez Agricultural Extension Service agents. From this project, an Integrated Management of Forest Pests and Diseases Website (http://sea.uprm.edu/forest/index.html) was developed to provide an accessible mechanism for the general public, biologists, arborists, managers, students, and scientists. The Website contains information on major forest pests/diseases and those of potential introduction, pest management, and basic identification in Puerto Rico.

The Forest Health Program specialist has joined the Harrisia Cactus Mealybug (*Hypogeococcus pungens*) Interagency Task Force. The mealy bug is a serious forest health concern in Puerto Rico's dry forest. The task force has developed an informative brochure in Spanish to make visitors aware of this pest in the dry forests, on the main island as well as Vieques, Culebra, and other islands (Fig. 20).

We are also working with the U.S. Forest Service's Forest Health Technology Enterprise Team to include Puerto Rico as part of the Pest Event Reporter database and to be able to develop risk maps for major pests and diseases.

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Eliezer Ríos and Dayamaris Candelario show kids the wonders of the forest. Photo courtesy of Santa Ana Nature Center, Natural History Society of Puerto Rico.

State and Private Forestry

Mario Francis, Virgin Islands UCF Council, presents the "We Plant Native Trees" campaign t-shirt.

Urban and Community Forestry Program: All About Capacity Building

Both the Puerto Rico Statewide Forest Resources Assessment and the Strategies for Puerto Rico and the U.S. Virgin Islands identified urban forests and green spaces as important elements of urban scenarios that contribute to livable cities and a healthy urban environment. Capacity building is the strategy proposed to improve the condition of urban forests and increase the environmental benefits and services those resources offer. During Fiscal Year 2011, the Virgin Islands Department of Agriculture, Virgin Islands Urban and Community Forestry (UCF) Council, and the Puerto Rico Urban and Community Forestry Council invested their time and effort to build capacity among the communities and professional groups in areas related to the establishment, creation, management, and protection of the urban forests and green infrastructure.

The Virgin Islands Urban and Community Forestry Council, with the support of the Forest Service Urban and Community Forestry Program, adopted the campaign "We Plant Native Trees" and offered educational talks to kids and community groups and exhibitions that reached thousands of individuals during big events such as the Virgin Islands Ag Fair, and the Environmental Fairs in St. Croix and St. Thomas. The Council also contributed to the newspapers by sending articles covering aspects related to the importance of urban forests resources, and participated on radio talk shows. Professional tree managers and certified arborists of the International Society of Arboriculture in the Virgin Islands had the opportunity to participate in two specialized training sessions. The Council also continued with the enactment of a local Tree Law. The scope of this policy will determine applicable regulations for the protection and conservation of the forest resources in the urban areas. Although the process has not been easy, the Council effectively reached important political figures to get their support for the law.

The Puerto Rico Urban and Community Forestry Council hosted the 13th Caribbean Urban and Community Forestry Conference in December 2010, featuring the theme of Green Economy: Law, Community, and Capacity Building. The event was attended by more than 120 people from the Virgin Islands, Puerto Rico, St. Lucia, Dominica, Venezuela, and the United States. The Arbor Day Foundation made presentations about the Tree City

Kids discovering termite mounds in the Santa Ana Forest. Photo courtesy of Santa Ana Nature Center, Natural History Society of Puerto Rico.

After visiting the forest kids are invited to express what they learned through drawing. Photo courtesy of Santa Ana Nature Center, Natural History Society of Puerto Rico.

USA and Tree Campus USA programs to the group; both of these programs promote planning, protection, and proper management of urban forest resources, education, and healthy communities. Representatives of municipalities, communities, and universities of both Puerto Rico and the Virgin Islands showed their interest in participating in those programs. Attendees represented urban foresters, law enforcement, planners, ecologists, foresters, horticulturists, and wildland firefighters.

The Puerto Rico Urban and Community Forestry Council also sponsored five specialized training sessions for tree management professionals and ISA certified arborists. The topics covered by those trainings were: bucket truck operation and safety, first aid, tree climbing, electrical hazards and tree management, and chainsaw operation.

The Centro para la Conservación del Paisaje received a grant to provide training sessions to the municipalities of Puerto Rico on the use of iTree, which is a software developed by the U.S. Forest Service that provides urban forestry analysis and benefits assessment tools. With iTree, communities should be able to determine environmental services provided by their urban trees through the analysis of the condition and structure of those trees, along with their location and health. The first step is collecting information on a tree inventory and then using the information to run the different extensions of iTree. Centro para la Conservacion del Paisaje hosted two training sessions, one in Caguas, the other in Cabo Rojo. The group will provide technical assistance to the participants on the implementation of iTree in their municipalities.

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Forest Stewardship Program in Puerto Rico

The Forest Stewardship Program provides targeted technical and planning assistance to enable active, long-term forest management on important private landscapes. Landowners who implement forest stewardship management plans are in a much better position to participate in incentive programs, including U.S. cost-share and State tax abatement. The Forest Stewardship Program contributes to the following overarching goals.

1. Serves as the primary, most extensive (in reach and scope) private forest owner assistance program;
2. Successfully sustains a vast, effective network of forestry technical assistance providers and programs;
3. Provides comprehensive management plans (forest stewardship management plans) to landowners and offer education and technical assistance opportunities to landowners;
4. Establishes strong and effective partnerships with State foresters, conservation districts, and many more partners to provide for broader forest landowner participation in USDA conservation programs.

The Puerto Rico Statewide Assessment and Strategies for Forest Resources identified the priority landscapes for Puerto Rico. State and Federal agencies and non-government partners established conservation priority landscapes as an opportunity to leverage resources. This initiative includes the preparation of forest stewardship management plans that promote watershed conservation by managing existing forests, restoring or creating riparian buffers, and establishing agroforestry practices. It encourages the implementation of landscape-scale and multi-landowner planning and streamlined processes to increase private forest landowners' participation in cost-share programs through collaboration with USDA agencies and the U.S. Department of the Interior, Fish and Wildlife Service.

Humacao Joint Priority Landscape

The Humacao Joint Priority Landscape is located in the southeastern corner of Puerto Rico. The area is threatened to be converted to non-forest uses due to urban sprawl. The Natural Resources Conservation Service, the Department of Natural and Environmental Resources, the U.S. Fish and Wildlife Service, and the U.S. Forest Service endorsed the collaborative effort to bring the communities within the area into a conservation effort. Landowner organizations and other groups supported this initiative.

Figure 21. Humacao Joint Priority Landscape. Dark areas present Federal and State protected lands in southeastern Puerto Rico. Dashed area represents the Humacao Joint Priority Landscape.

State and Private Forestry

Benefits

1. Habitat improvement for Puerto Rico endemic bird species such as the Puerto Rican parrot (*Amazona vittata*), Puerto Rican sharp-shinned hawk (*Accipiter striatus venator*), Puerto Rican broad-winged hawk (*Buteo platypterus brunnescens*), Puerto Rican screech owl (*Megascops nudipes)*, elfin-woods warbler (*Dendroica angelae*), yellow-shouldered blackbird (*Angelaius xanthomus*), and Puerto Rican plain pigeon (*Patagioenas inornata wetmore*).
2. Habitat improvement for Puerto Rico reptile species such Puerto Rican boa (*Epicrates inornatus*) and Culebra giant anole (*Anolis roosevelt*); and amphibians such as Puerto Rican rock frog (*Eleutherodactylus cooki*), and golden coquí (*Eleutherodactylus jasper*).
3. Watershed conservation, restoration and improvement of forest health on properties within the Río Blanco, Río Grande de Loíza, and other important watersheds located in eastern Puerto Rico.
4. Promote conservation of forest cover in properties located within the buffer and protection boundaries of the El Yunque National Forest, Puerto Rico State Forests, Natural Refuges, and other important ecosystems.
5. Conservation practices to reduce soil erosion and improve water quality.
6. Tree planting, forest improvement practices, and education are the main strategies to promote forest conservation, habitat restoration, reduction of pests and diseases occurrence, improvement of soil condition, carbon sequestration, and improvement of degraded ecosystems.

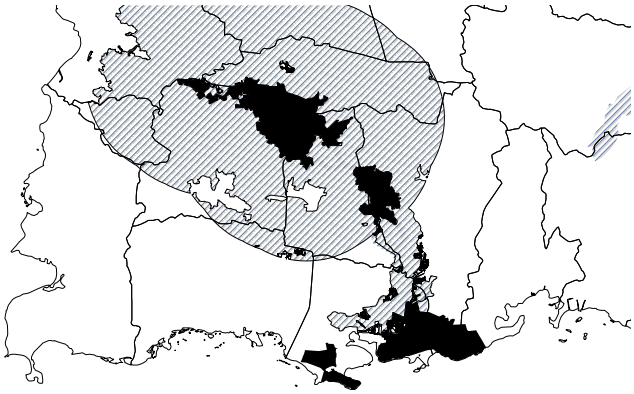

Figure 22. Guánica-Maricao Joint Priority Landscape. Dark areas present State forests and natural reserves managed by the Department of Natural Resources and Environment in southwestern Puerto Rico. Dashed area represents the Guánica-Maricao Joint Priority Landscape.

The Guánica-Maricao Joint Priority Landscape

The Guánica-Maricao Joint Priority Landscape was identified as a priority area by the NOAA Coastal Zone Management Program, USDA Natural Resources Conservation Service, Puerto Rico Department of Natural and Environmental Resources, U.S. Fish and Wildlife Service, and the U.S. Forest Service. Landowners' organizations such as the Puerto Rico Soil Conservation Districts and other groups supported this initiative.

Benefits

1. Habitat restoration for the reintroduction of the Puerto Rican parrot (*Amazona vittata*). With this reintroduction, the Puerto Rican parrot natural populations will increase to three (El Yunque National Forest, Utuado, and Maricao).
2. Improve habitat for Puerto Rico endemic bird species: Puerto Rican nightjar (*Caprimulgus noctitherus*), Puerto Rican bullfinch (*Loxigilla portoricensis*), Puerto Rican screech owl (*Megascops nudipes*), Puerto Rican lizard cuckoo (*Coccyzus vieilloti*), elfin-woods warbler (*Dendroica angelae*), green mango (*Anthracothorax viridis*), and Puerto Rican woodpecker (*Melanerpes portoricensis*).
3. Improve Río Loco Watershed condition as part of the Guánica Bay and Río Loco Watershed Restoration Project lead by NOAA and other State and Federal agencies.
4. Implement conservation practices to reduce soil erosion and improve water quality.
5. Establish shade on coffee plantations to reduce pests and disease occurrence, improve product quality and soil condition, and contribute to carbon sequestration.

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Knowledge and Perception of Forest Benefits and Drivers of Ecosystem Change: The Case of the Northern Karst and the Río Piedras Watershed

Forests provide a full suite of goods and services that are vital to human health and well-being. These natural assets we call ecosystem services. The U.S. Forest Service's State and Private Forestry program partnered with Misión Industrial, a local non-governmental community organization, to better understand local perceptions of forest-based ecosystem services in two regions of Puerto

Rico: the Río Piedras Watershed (a mainly urban site) and the Northern Karst (a mainly rural site). Misión Industrial asked a variety of community members in each area open-ended questions intended to allow them to express the values they attach to forests in their own words.

Río Piedras Watershed

Human well-being and the quality of life of urban populations greatly depend on urban forests and green areas. Forested lands in urban areas are also important for supporting other resources such as water. However, population growth and increases in built-up areas put pressure on these urban forests. Hence, it is important to increase public knowledge and understanding about the benefits provided by urban forests, the factors affecting them, and the means of conserving and making wise use of such forests. The Río Piedras watershed hosts a variety of urban forests and is the main watershed for the city of San Juan.

Key findings

- Language matters—half of the participants could define urban forests, but more than half had never heard of the term "watershed."
- 1Temperature regulation, oxygen production, and air purification were the most cited and considered the most important forest benefits. 1
- 1Few participants noted the connection between urban forests, rivers, and water.

Floodwaters at the Río Piedras.

Communities in the Northern Karst

The unique Northern Karst region of Puerto Rico contains some of the best examples of karst habitat in the Caribbean and supports numerous endemic species, an extensive track of mature forest, and Puerto Rico's largest freshwater aquifer. Yet this region is also threatened by

View from Cueva Ventana (Window Cave, name as translated in English) of the northern karst in Arecibo, Puerto Rico.

human activities and unplanned development, making it important to increase awareness and understanding of the benefits that karst forests provide.

Key findings

- Language matters—more than half of the participants could define "forest." It is important to consider other terms for forests such as "monte." However, 75 percent of participants had never heard of the term "karst."
- Forest products, temperature regulation, and fauna and flora were the most cited forest benefits among participants. Air purification and oxygen production ranked as most important.
- There was less connection with water-related benefits of forests.

The results from this collaboration will help the State and Private Forestry program and other governmental and non-governmental organizations develop targeted environmental educational strategies, awareness campaigns, and outreach initiatives aimed at increasing people's knowledge about forests and their benefits in Puerto Rico, particularly in karst and urban forests.

- The following short information sheets on these findings are available from the State and Private Forestry staff:
- 1Public Knowledge and Perceptions About Karst Forests
- Karst Forests and Their Benefits: A Comparison Between Local and Expert Knowledge
- 1Public Knowledge and Perceptions About Urban Forests in a Watershed Context

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International Cooperation

The International Cooperation (IC) Unit promotes the mission of exchanging knowledge critical to the sustainability of tropical ecosystems through development, training, and technical assistance programs throughout Central and South America, the Caribbean, and other parts of the world. Project topics include forest, park, and protected area management; environmental education and interpretation; sustainable nature-based tourism; long-term forest monitoring; and environmental and biological assessments. Staff members regularly participate in technical assistance and training for the development and implementation of international activities.
International Cooperation had a very active year working mostly in Central America and the Caribbean Regions. Our primary areas of focus were Nicaragua and the Dominican Republic, although we supported the Central America Free Trade Agreement–Dominican Republic (CAFTA-DR) and other U.S. Aid International Development (USAID) activities throughout the region.

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Global Activities

- Provided a grant to the International Society of Tropical Foresters [www.istf-bethesda.org] for production and worldwide distribution of a newsletter.

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Regional Activities

- Participated in the CAFTA-DR regional meeting in Washington, DC, with USAID, U.S. Department of State, other Federal agencies, and CAFTA-DR Focal Points from all CAFTA-DR countries. Also, IC staff participated in an International Migratory Bird Act activity in Washington, DC, with partners from throughout the region.
- Participated in the Mesoamerican Society for Biology and Conservation at their annual conference held in San Jose, Costa Rica. International Cooperation sponsored the environmental communications pre-conference workshop and a photo/film festival—"MesoAmerica Es…"—during the conference, and a seminar on biological corridor management in Mesoamerica, where several technical presentations were made from throughout the region.
- Organized the Fifteenth Caribbean Foresters Meeting, held June 14–18 in Guadeloupe, and compiled and edited the Proceedings of the Fifteenth Meeting of Caribbean Foresters.

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Nicaragua Activities

In coordination with the Institute's Wildlife Unit, we continued with our technical assistance and technology transfer to Nicaragua with support to long-term biomonitoring, sustainable tourism development, and sampling for mercury and other of persistent toxic substances in shade coffee and cloud forest within the Mombacho Volcano Natural Reserve (Granada, Nicaragua).

USAID Director Dr. Alexander Dickie receiving the Guegüense Excellence in Tourism Award from the Nicaragua Chamber of Tourism. This award was given to the Institute for high-quality technical assistance in the "Conservation and Sustainable Tourism in Critical Watersheds" project that was funded by USAID.

Birdwatchers at the La Bastilla EcoLodge, Jinotega, Nicaragua. The Institute provided technical assistance to design the ecolodge, construct trails, and train nature guides.

Gerald Bauer, Program Manager of International Cooperation at the Institute stands at the Jimenoa Waterfall in Jarabacoa. The Institute through its International Cooperation unit provided technical assistance to the Dominican Republic Ministry of environment and local communities to conduct assessments of sites such as this waterfall in the Salto Jimenoa National Monument to help improve their ecotourism products.

Our primary partners in Nicaragua were the Ministry of Environment and non-governmental organizations CLUSA, Paso Pacífico, and Fundación Cocibolca. Long-term plots were measured in agroforestry systems under five land uses (secondary and riparian forests, forest fallow, coffee plantations, and 'open lands,' e.g., grasslands and pasturelands with scattered trees) in the northern highlands and the same above-cited agroforestry systems, with the exception of coffee plantations, in southern coastal areas within the Paso del Istmo biological corridor. Several manuscripts, technical reports, and presentations were generated from this work.

Other significant accomplishments in Nicaragua from IC and our international partners included:

- 1 The non-governmental organization Paso Pacífico was invited for the second consecutive year to participate in the Clinton Global Initiative.
- 1 International Cooperation provided technical assistance and guidance to the Academy for Educational Development to set up management of a sustainable tourism project in Nicaragua. The Academy asked advice on local talent, staffing, technical needs for specific communities and/or protected areas, etc.
- 1 International Cooperation provided technical assistance to local partners to establish eco-consulting businesses to serve conservation non-governmental organizations and development projects in Protected Area buffers zones that would provide benefits to economically disadvantaged Hispanic community members.

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Dominican Republic Activities

International Cooperation completed a 2-year agreement with USAID/Dominican Republic and signed a new agreement to continue to provide leadership, mentorship, and technology transfer to Dominican Republic (DR) partners in biodiversity conservation and sustainable tourism activities in local, underserved and disadvantaged Hispanic communities, and tourism clusters, in coordination with the Dominican Sustainable Tourism Alliance and the Dominican Consortium for Tourism Development (Consorcio Dominicano de Competitividad Turística). The Institute also signed a Memorandum of Understanding with the Dominican Republic Ministry of Tourism to strengthen cooperation over the next few years.

The primary focus in the Dominican Republic was to assist Dominican Republic tourism clusters with biodiversity conservation and sustainable tourism development, through on-the-ground technical assistance and training programs. The following activities were undertaken:

Provided technical assistance to underserved, disadvantaged Hispanic local communities and non-governmental organizations to encourage economic benefits by helping to establish eco-businesses in protected areas and their buffer zones in La Caleta Marine National Park, Laguna Bávaro Wildlife Refuge, Samaná Bay, and local communities in Jarabacoa (Sonido de Yaque) and Constanza (Salto Aguas Blancas).

Designed environmentally friendly souvenir products to promote biodiversity conservation and to encourage economic benefits for local underserved Hispanic

International Cooperation

communities and non-governmental organizations to sell in gift shops and at major hotels. More than 25 products were designed, including logos, keychain fobs, posters, post cards, t-shirts, caps, coffee mugs, and bird guides.

Completed seven technical reports to help provide for conservation of biodiversity in protected areas and buffer zones, including:

- 1 Análisis de Sitio y Recomendaciones para el Desarrollo Ecoturístico del Sendero Padre Nuestro, Parque Nacional del Este, Bayahibe, República Dominicana.
- 1 Plan de Señalización del Parque Nacional del Este, Bayahibe, República Dominicana.
- 1 Taller sobre Diseño, Construcción y Mantenimiento de Senderos, Parque Nacional del Este, Sendero Padre Nuestro, República Dominicana.
- 1 Taller sobre Diseño, Construcción y Mantenimiento de Senderos, Parque Nacional Valle Nuevo, Salto Aguas Blancas, República Dominicana.
- 1 Recomendaciones para Senderos de Observación de Aves en Dos Parques Urbanos en la República Dominicana.
- 1 Recomendaciones para Turismo y Conservación de Biodiversidad en el Refugio de Vida Silvestre de Laguna Bávaro, República Dominicana.
- 1 Desarrollo de Turismo de Kayak en Laguna Bávaro, Punta Cana, República Dominicana.

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Whale watching in the Samaná Bay is an important economic generating activity for local tour guides. The Institute through its International Cooperation unit helps train nature guides and park rangers who protect these unique resources.

Publications — Fiscal Year 2011

For electronic versions of Institute publications, please go to Treesearch at www.treesearch.fs.fed.us. For hard copy versions, please contact greyes@fs.fed.us, or write to:

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Jardín Botánico Sur
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