International Institute of Tropical Forestry

2014-2015 Accomplishments Report

USDA U.S. FOREST SERVICE
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United States Department of Agriculture

This report was produced through the collaborative efforts of many individuals who provided text, photos and constructive feedback. Thanks to all who contributed.

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Photos of *Ceiba pentandra* flowers (front cover) and *Eucalyptus robusta* tree (back cover) by M.M. Rivera-Costa.

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Closed on all Federal holidays and January 6.

I. Vicens

G. Bauer

Institute Research Ecologist Tana Wood measures leaf temperature at El Tallonal, a biological reserve in Arecibo, Puerto Rico.

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Editorial Message

Editorial team: Marinelis Talavera, Administrative Assistant; Gary Potts, Web Content and Data Manager; Grizelle González, Project Leader; Christopher Nytch, Research Program Support.

This edition of the Institute's Accomplishments Report spans fiscal years 2014-2015. The past two years have been exciting and productive! In the following pages you will find numerous and diverse examples of Forest Service personnel striving to carry out the Institute's mission, through the complementary programmatic realms of Research and Development, State and Private Forestry, and International Development. Just a few of the highlights include the establishment of a new experiment to test the projected effects of climatic warming in a tropical forest, the strengthening of international activities throughout the Caribbean and Central America, and the transfer of technical capacity in rural and urban communities alike in support of natural resource monitoring, conservation and education. The results of many of these endeavours have been published in scientific journals, technical reports, and popular media, including print and online formats. A number of Institute staff members and an arts and science collaboration received notable accolades as well. All of this work has been bolstered by a competent administrative support team, and the collaborative efforts of many valued partners. We are proud of what the Institute has achieved, and pleased to share these accomplishments with you. Many thanks to all who contributed to this report, and likewise to the Institute's continued success. Happy reading!

Director's Message

I thank the editorial team for the hard work they have done in preparing this Accomplishments Report. I also express my gratitude to all Institute employees, contractors, and collaborators for their exemplary performance. What a great job everyone has done!

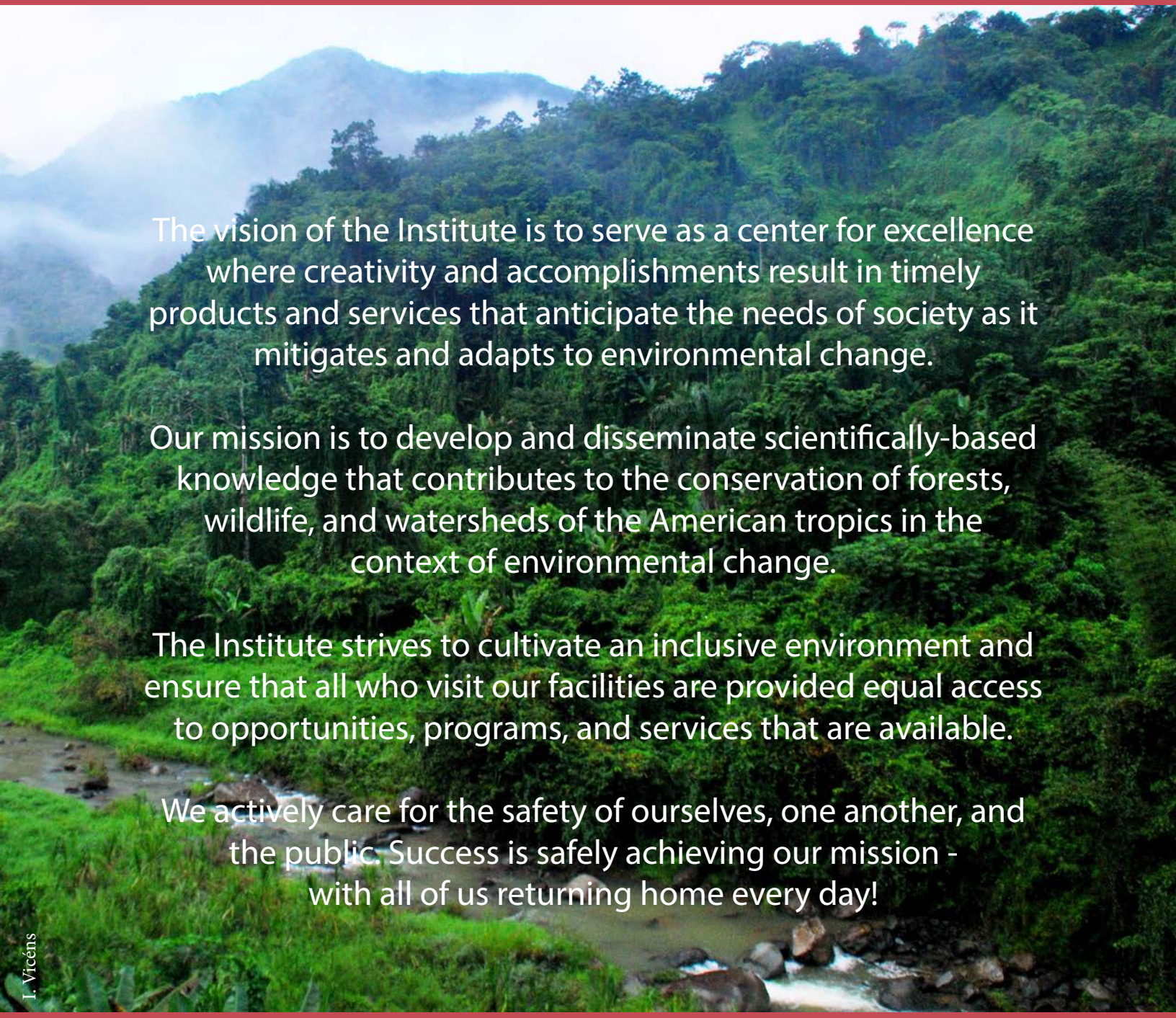
Institute Director, Ariel E. Lugo

As I read this Accomplishments Report, I could not help but reflect that our employees are performing with effectiveness at a time when government resources are becoming scarcer every year, even as the challenge of dealing with natural resources increases in magnitude and complexity. Scientists have formally designated a new geologic epoch to describe the environmental conditions that we face as a human civilization; they call this epoch the Anthropocene. The Anthropocene represents a challenge to all of us because the Earth is responding to human activities in ways that we cannot fully understand or predict with certainty. For scientists, this epoch of human domination over the world represents a tremendous opportunity to advance understanding of social and ecological phenomena, but to do so, we have to re-examine many of the paradigms that worked in the Holocene yet fall short in the Anthropocene. The failure of many Holocene-based conservation paradigms and policies requires a quicker turnaround of information from scientific to policy and public realms. It also requires a different kind of scientific institution.

Dealing with the Anthropocene requires increasing levels of knowledge and understanding that can only be acquired through transdisciplinary activities and strong collaborations among all sectors of society. A scientific institution such as ours cannot operate in isolation from society, particularly if it is going to be effective in influencing the conservation actions of that society. And so, with this Accomplishments Report we disclose our progress towards a collaborative and transdisciplinary organization that is aimed at addressing the challenges of the Anthropocene as it cares for tropical lands and serves its people. I am a biased observer, but I see a lot of progress in our quest, particularly when I compare this Accomplishments Report with past reports. The Institute is rapidly evolving in the scope of its scientific investigations, the breadth of its interactions with people and organizations inside and outside the federal government, and the services it provides society as it confronts the effects of the Anthropocene. I feel pride in leading this adaptive organization and watching how it uses collaborations to overcome the increasing levels of difficulties that result from declining resources in support of our mission.

I invite readers to let us know how we have done and to give us feedback on how to be more effective. We are public servants working for the public good and will listen to your comments and suggestions with the intention of improving our performance and services. In the meantime, MAY THE FOREST BE WITH YOU!

Vision and Mission



The vision of the Institute is to serve as 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.

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.

The Institute strives to cultivate an inclusive environment and ensure that all who visit our facilities are provided equal access to opportunities, programs, and services that are available.

We actively care for the safety of ourselves, one another, and the public. Success is safely achieving our mission - with all of us returning home every day!

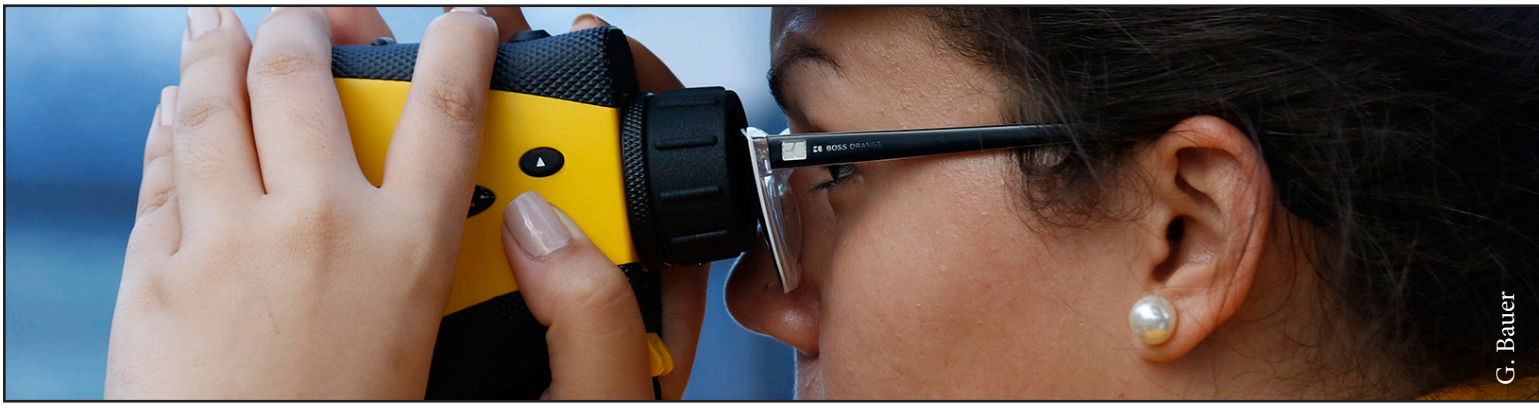
I. Vicéns

About the Institute

The International Institute of Tropical Forestry (Institute), headquartered in Río Piedras, Puerto Rico, is a research and technology transfer institute that is dedicated to advancing tropical forestry on insular, national, and international levels, and developing and exchanging knowledge critical to sustaining benefits of tropical forests and grasslands. The Institute has been in continuous operation since its inception as the Tropical Forest Experiment Station in 1939.

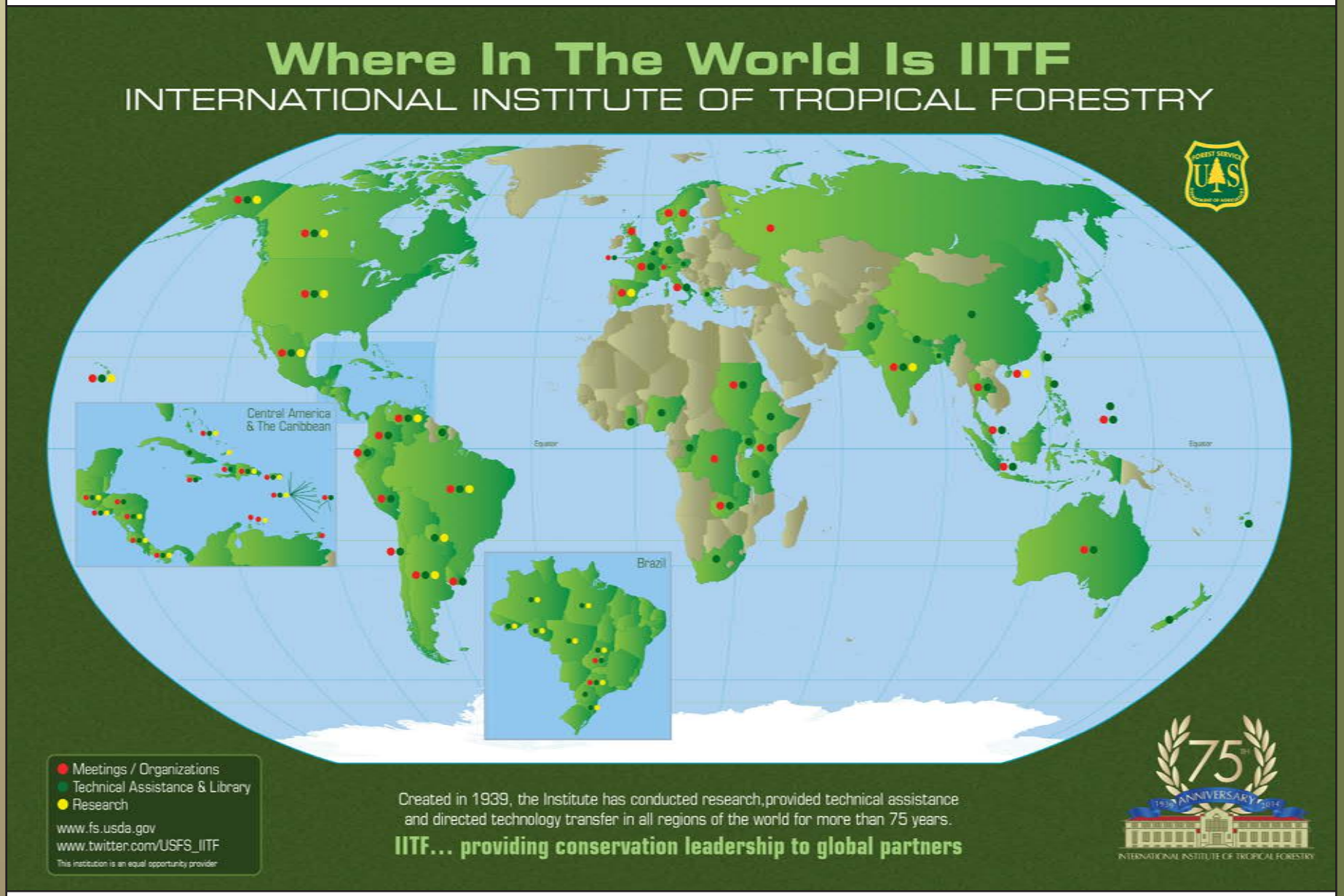
Institute social scientist Tischa Muñoz-Erickson addresses a group of natural resource managers at an iTree workshop in San Juan, Puerto Rico.

Members of our community span a wide range of knowledge and skills, including natural and social scientists, natural resource managers, education outreach and technology transfer specialists, technicians, as well as contracted professionals, students and volunteers. Together these dedicated men and women engage with an equally diverse network of external collaborators from the public, private, and non-profit sectors, in order to carry out our mission and implement our programs.



A demonstration of the use of a range finder.

The influence of the Institute stretches throughout Puerto Rico and the Caribbean, and beyond to several international sites in Latin America and around the globe. We integrate long-term scientific studies with applied investigation, quantitative modeling, and landscape analysis to better understand tropical forest systems and the effects of human-induced pressures, predict future scenarios, devise effective management and governance strategies, and promote sustainable natural resources stewardship.



Map of locations around the globe where the Institute has worked or collaborated over the past 75 years. Image provided by G. Bauer.

INSTITUTE FACILITIES

Among our many physical assets are a historic and sustainable headquarters building, state-of-the art chemistry laboratory facilities, a GIS and remote sensing laboratory, a technology transfer conference center, experimental research forests and scientific equipment, a newly-remodeled field station, and a world-renowned tropical forestry library. Detailed information about all of these resources can be found online at: http://www.fs.usda.gov/iitf/.

Manatí Research Area

International Institute of Tropical Forestry Headquarters (Río Piedras)

Luquillo Experimental Forest (also named El Yunque National Forest)

Guayama Research Area

Sabana Field Research Station

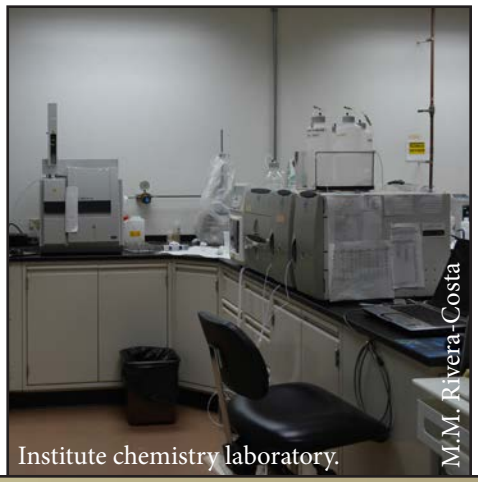
Estate Thomas Experimental Forest

Headquarters

The Institute Headquarters has 50,000 square feet of modern, state-of the art facilities that are secure, functional, and accessible, and that service the scientific community of the Institute and its collaborators. The Headquarters complex is located in Río Piedras, a sector of San Juan, and includes the following amenities:

- The Headquarters building, a historical structure fully restored and modernized into a high-performance sustainable building;
- A Forest Service National Library, containing major pulbications 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.
- A chemistry laboratory that focuses on analytical chemistry of plant tissues, water, soils, and air. In a typical year, more than 50,000 analyses on samples collected from tropical ecosystems around the world are completed by laboratory personnel.
- A spatial analysis laboratory to study landscape ecology using geographic information systems, 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.
- A technology transfer conferece center with capabilities for multiple use combinations for meetings, trainings, and conferences. This facility has a food serving area and accessible restrooms.
- A multipurpose building that houses a dormitory, gym, general storage area, office space, and lunch area.
- An area for sample preparation and long-term storage of samples.
- Three back-up generators to ensure that electrical power is available for continous operation during power blackouts, and a 3,400-gallon potable water tank that can provide drinking water during water shortages.


Forest Service National Library. C. Nytch


Institute chemistry laboratory. M.M. Rivera-Costa


Institute conference room. C. Nytch

Sabana Field Research Station

The Sabana Field Research Station is situated within the El Yunque National Forest/Luquillo Experimental Forest (EYNF/LEF). It was originally established by the Forest Service in 1938 with the objective of maintaining security and surveillance of all surrounding forest areas. Remodeled in 2012, the station has all the amenities to accommodate individuals and groups interested in completing scientific work in the surrounding areas located within the EYNF/LEF, including the nearby Sabana River and Bisley Experimental Watersheds.

Sabana Field Research Station main entrance.

The station's modern facilities include an administrative building and conference room, a laboratory building for wet and dry analyses, a multi-purpose building including office space, laboratory space, oven room, sample preparation room, storage areas, laundry room, and a flammable storage area, research offices and a mycology laboratory, and a dormitory building that sleeps twenty persons, complete with bathrooms, kitchen, living and balcony areas. For more information about Sabana Field Research Station, and for information about making reservations and conducting research at the station, visit: http://www.fs.usda.gov/detail/iitf/research/?cid=FSEPRD486693.

Miriam Salgado, Sabana Station Manager

Field station dormitory.

Field station communal living room.

Field station dry laboratory.

Administration and Support

Administrative Officer: Adolfo Menéndez, amenendez@fs.fed.us

Our Administration and Support staff deliver critical business operations services to the Institute's Research and Development, International Cooperation and State and Private Forestry Programs. Our staff engages in providing technical and administrative support in the areas of budget, engineering and facilities maintenance, contracting and procurement, facilities and property management, mail services, grants and agreements, and reception.

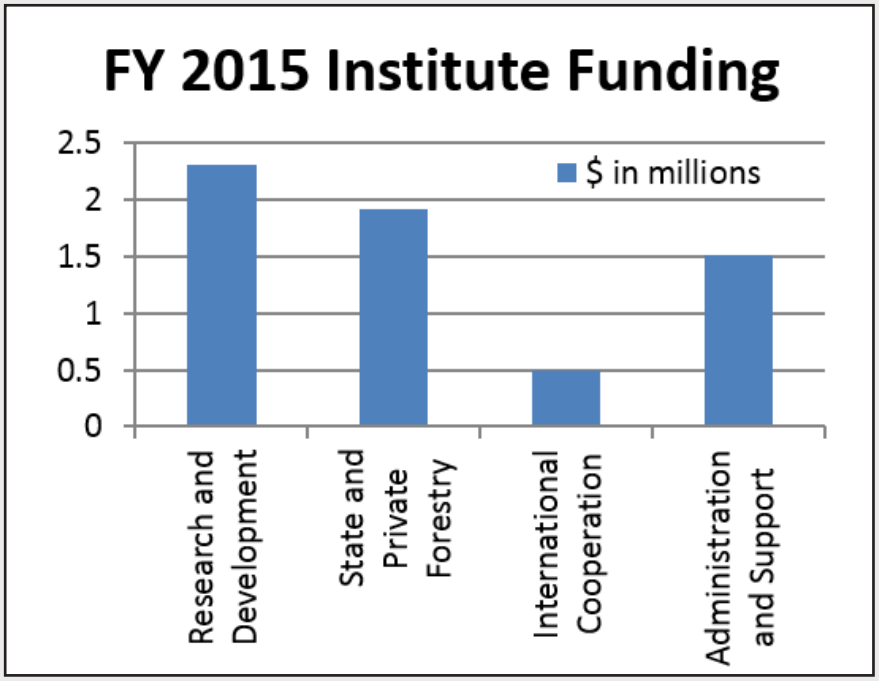
Institute Administration and Support Staff: Adolfo Menéndez, Administrative Officer; Yolanda Padilla, Purchasing Agent; Janet Rivera, Grants Management Specialist; Carlos Esteves, Property Management Technician; Carolyn Pabón, General Engineer; Yanira L. Cortés, Detailed as Staff Assistant; Carmen Plaud, Specialist Support Assistant; absent: Rosa Ávila, Budget Officer; Amelia Dávila, Contracting Specialist.

Finances and Workforce

The budget allocation for the Institute supports the workforce, Business Operations, and programs. The numbers that follow are for fiscal year 2015: October 1st, 2014, to September 30th, 2015.

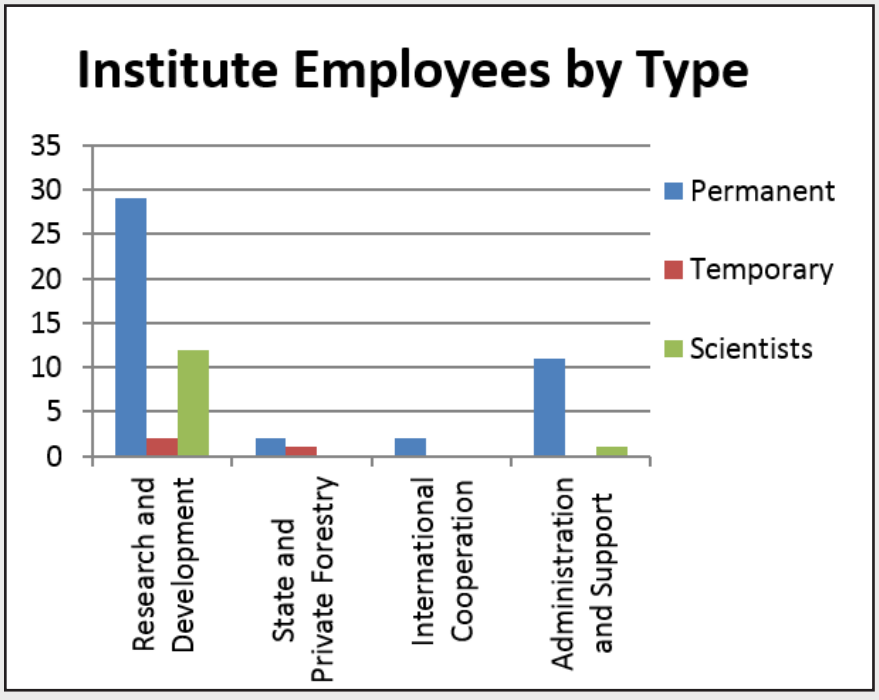
Incoming Funding

- Research Appropriations: $2.305 million
- State and Private : $1.919 million
- International Cooperation: $493,000
- Construction and Related Funds: $119,000
- Administration: $1.39 million
- Total Funding: $6.226



Distribution of Funds

- Employee cost: $3.9 million (63%)
- Support and Operations: $1.4 million (22%)
- Distributed to Cooperators: $1.6 million (25%)



Workforce Statistics

- Total Institute workforce:
- Permanent workforce: 46
- Of the permanent workforce, 10 employees (22%) are scientists.
- Temporary workforce: 2

Funding Partners for Fiscal Year 2015

Cooperators Who Received Funding from the Institute

Non-Governmental Organizations

- Cafi Cultura Puertorriqueña, Inc.
- Consejo Asesor para la Forestación Urbana y de Comunidades de Puerto Rico, Inc.
- Fundación Puertorriqueña de Conservación
- Mayagüez Municipality
- Natural History Society of Puerto Rico
- Paso Pacífico
- Puerto Rico Conservation Trust Foundation (Para La Naturaleza)
- St. Croix Environmental Association
- University of Georgia Research Foundation, Inc.

Private Industry and Individuals

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

Universities

- Clemson University
- Colorado State University
- Michigan Technological University
- North Carolina State University
- Universidad Metropolitana
- University of Missouri
- University of New Hampshire
- University of Puerto Rico–Agricultural Extension Service
- University of Puerto Rico–Research Division
- University of Wisconsin

State Government

- Puerto Rico Fire Department
- Puerto Rico Department of Natural and Environmental Resources
- U.S. Virgin Islands Department of Agriculture
- U.S. Virgin Islands Fire Department

Cooperators Who Provided Funds to the Institute

- Puerto Rico Department of Natural and Environmental Resources
- University of New Hampshire
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- USDA, Climate Change Program Office, Office of the Chief Economist FY15 (USDA, OCE)

Administrative Officer Adolfo Menéndez at a meeting with Institute staff.

M.M. Rivera-Costa

Research and Development

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

The Institute has a long history of research, dating back to the 1920s with the establishment of large-scale trial plantings in El Yunque National Forest with both introduced and native tree species. In the 1930s and 1940s the Institute completed important silvicultural studies with rigorous controls to provide an important basis for tropical forest production. In 1956, El Yunque National Forest was also designated as the Luquillo Experimental Forest, and a forest management plan was developed that prescribed active management of natural stands and the development of plantations. In the 1960s the ecology of unmanaged forests was begun in earnest via long-term ecosystem studies, and experimental research about the fundamental structure and function of tropical forest ecosystems and metabolic processes in response to radiation disturbance. Ecological research strengthened during the 1980s with the establishment of the LEF as a National Science Foundation Long Term Ecological Research (LTER) Program site, and the expansion into topics such as carbon and nutrient dynamics, trophic interactions, and the forcing effects of anthropogenic and non-anthropogenic disturbances. At present, the Institute continues to build upon traditional research strengths, in addition to adding new emphases that focus on watershed and landscape perspectives, assessing the effects of climate and land use/land cover change on tropical ecosystems and their biodiversity, quantifying ecosystem goods and services from novel forest communities and integrated social-ecological systems, and investigating policy and governance dynamics of natural resource management.

The Institute has one research work unit, IITF-4151, titled Tropical American Forest Conservation. The work unit which carries out its agenda through several collaborative programs and projects. These include:

- The Luquillo Long-Term Ecological Research Program
- The Luquillo Critical Zone Observatory
- The San Juan Urban Long-Term Research Area
- The Urban Resilience to Extremes Sustainability Research Network.

Research focal sites extend throughout Puerto Rico, the Caribbean, and parts of Latin America, including:

- Luquillo Experimental Forest, within which are situated the Bisley Experimental Watersheds, East Peak, and El Verde Research Area
- Guánica Biosphere Reserve
- Guayama and Manatí Research Areas
- Estate Thomas Experimental Forest, St. Croix, U.S. Virgin Islands
- Dominican Republic
- The Brazilian Amazon.

Leaf litterfall collection by artist Jaime Suárez in the Luquillo Experimental Forest.

Ecosystem Ecology

Ariel E. Lugo
Institute Director
Assembly and functioning of novel ecosystems; vulnerability and functioning of urban ecosystems; tropical forest response to environmental change.

Wayne J. Arendt
Wildlife Biologist
Disturbance ecology, climate change, conservation and management of neotropical resident and migratory bird communities and invasive species.

William A. Gould
Research Ecologist
Conservation science, biodiversity, ecology, land cover mapping, modeling future scenarios for conservation planning, and field education and outreach.

Soil Ecology

Grizelle González
Project Leader
Soil ecology and biology, ecosystem ecology, tropical ecology, earthworm ecology.

Michael Keller
Research Physical Scientist
Ecology and biogeochemistry of tropical forests, tropical deforestation and forest degradation, and the effects of land use on atmospheric composition.

Tamara Heartsill-Scalley
Research Ecologist
Riparian vegetation, stream dynamics and ecosystem services; monitoring long-term ecosystem responses to disturbance; knowledge and perceptions of wetlands.

Wildlife Ecology

Joseph M. Wunderle
Wildlife Biologist
Conservation biology and management of birds, especially neotropical-nearctic migrants and their response to human and natural disturbances.

Eileen Helmer
Research Ecologist
Tropical forest disturbance and recovery dynamics; monitoring species composition, community structure and phenology, from stand to landscape scales.

Kathleen McGinley
Research Social Scientist
Natural resource and forest policies, institutions, and governance approaches, primarily in Latin America and the Caribbean.

Landscape Ecology

Biogeochemistry

Social Science

Geophysics

Watersheds

Tischa A. Muñoz-Erickson
Research Social Scientist
Institutional arrangements, processes, and tools for facilitating productive, sustainable interactions among research and policy stakeholders, managers, and citizens.

Tana E. Wood
Research Ecologist
Effects of climate and land-use change on soil and ecosystem-level processes, linkages between microbes and the soil environment, and landscape-scale responses.

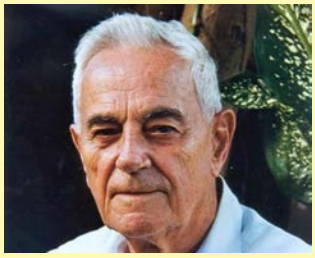
Ashley Van Beusekom
Geophysicist and Hydrologist
Statistical data analysis, computational mathematics, hydrologic modeling, climate change, inverse problems, glaciers, and geomagnetism.

Ernesto Medina
Adjunct Scientist
Physiological ecology of plants in stressful environments, with emphasis on carbon balance, water stress, and nutrient relations.

Whendee Silver
Adjunct Scientist
Effects of land-use practices on carbon losses, carbon sequestration, and biogeochemical cycling; effects of climate and variable redox conditions on ecosystem behavior.

Sebastián Martinuzzi
Adjunct Scientist
Remote sensing, biodiversity conservation and environmental change.

Azad Henareh
Adjunct Scientist
Global effects of climate change, large-scale vegetation and ecosystem change, disturbances and their interactions on landscape structure and ecosystem functions.



Frank H. Wadsworth
Emeritus Scientist
Management and sustainable use of forests and fiber-based products; silviculture and production.

Plant Physiology

Silviculture

TECHNICIANS AND RESEARCH SUPPORT STAFF

Research technicians staff: Carlos R. Estrada Ruíz, Hydrologic Technician; Humberto Robles, Biological Science Technician, María M. Rivera-Costa, General Biologist Specialist; Carlos Torrens, Biological Science Technician; Samuel Moya, General Biologist; absent: Iván Vicéns, Forestry Technician.

Chemical Laboratory research staff: Edgardo Valcarcel, Biological Science Technician; Edwin López, Chemist; Maysaa Ittayem, Chemist; Maribelís Santiago, Chemist; Mary Jean Sánchez, Supervisory Chemist; María del Carmen Marrero, Chemist; absent: Joel S. Olivencia, Electronic Technician.

Geographic Information System (GIS), remote sensing, web development, and Caribbean Regional Climate Sub-Hub staff: William. A. Gould, Caribbean Sub-Hub Director; Jessica Castro, Protected Areas Conservation Action Team; Marixa Maldonado, Caribbean Landscape Conservation Cooperative (CLCC) Administrative Assistant; Maya Quiñones, Cartographer; Gary Potts, Web Content and Data Manager; Isabel K. Parés, Caribbean Sub-Hub Coordinator; absent: Olga Ramos, GIS Analyst; Kasey Jacobs, CLCC Partnership and Outreach Coordinator; Carlos Rodríguez, Ecologist/Safety Officer.

G. Bauer

Caribbean Foresters conference participants measuring a tree trunk in a Dominican Republic dry forest.

Climate and Global Change

Precipitation and temperature trends along an elevation gradient in north-eastern Puerto Rico

Elevation gradient within the Luquillo Experimental Forest.

Tropical ecosystems across the globe are highly sensitive to climate, and individual regions are able to support their diversity of species because of their variability of climate across elevation. Forest Service researchers studied patterns of trends in local climatic conditions along a tropical elevation gradient in an ecologically sensitive area of northeastern Puerto Rico. They examined precipitation and temperature records collected over twelve years at twenty sites, ranging from sea level in the coastal zone of the San Juan Metropolitan area up to 1000 m at the top of the Luquillo Experimental Forest. An analysis of the driest and wettest months of the rainfall seasons revealed that the driest months are getting slightly wetter over time, while no trend was perceived for the wettest months. Precipitation also appears to increase faster at higher elevations. As for temperature, the daily minimum was observed to increase slightly, and the daily maximum decreased, suggesting that the range of temperatures along the elevation gradient is narrowing.

Unlike with precipitation, the pace of temperature change did not vary with elevation position. These results emphasize that differing patterns of climate change across tropical elevation gradients should be explored in order to understand the effects of future climate scenarios on biological life.

Related Publication: Van Beusekom, A.E., González, G. and Rivera, M.M. 2015. Short-term precipitation and temperature trends along an elevation gradient in Northeastern Puerto Rico. Earth Interactions 19: 1-33. www.treesearch.fs.fed.us/pubs/47734

Institute Contacts: Ashley Van Beusekom, ashley.vanbeusekom@gmail.com; Grizelle González, ggonzalez@fs.fed.us

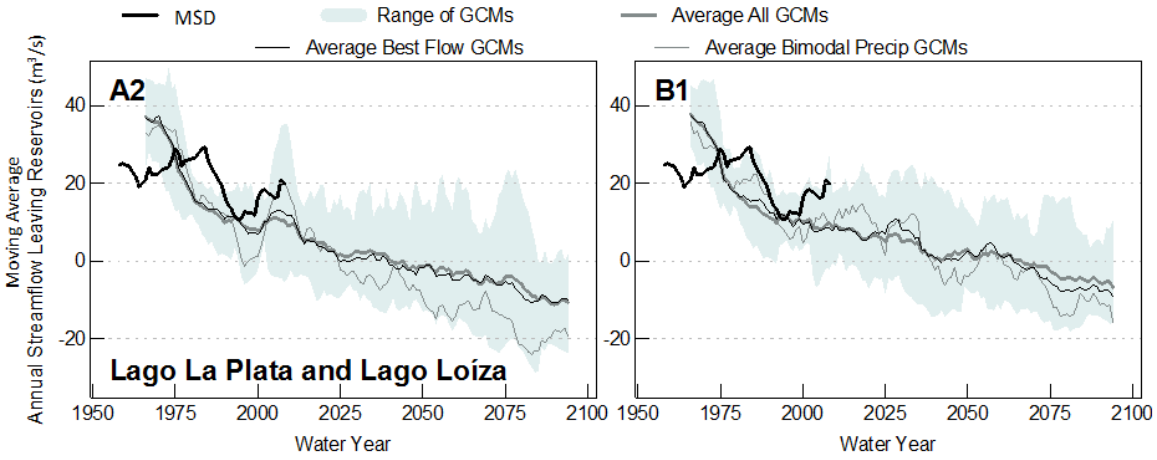
Propagation of uncertainty from statistically downscaled climate models to hydrologic models

Many tropical islands have limited water resources with historically increasing demand, all potentially affected by a changing climate. The effects of climate change on island hydrology are difficult to model due to steep local precipitation gradients and sparse data. This work uses ten projected climate models under two greenhouse gas emission scenarios to evaluate the uncertainty propagated in projecting the effects of climate change on water resources in a tropical island system. The assessment is conducted using a previously configured hydrologic model for Puerto Rico. Projected climate data and their modelled hydrologic variables versus historical measurements and their modelled hydrologic variables are found to have empirical distribution functions that are statistically different with less than 1 year of daily data aggregation. Thus, only annual averages of the projected hydrologic variables are employed as completely bias-corrected model outputs. The magnitude of the projected total flow decreases in the four regions covering Puerto Rico, but with a large range of uncertainty depending on the projected climate. The multi-model mean projected total flow decreases by 50–90% of historical amounts from the 1960s to the 2090s for the high emissions greenhouse gas scenarios and by 40–80% for the low emissions scenarios. At the two most important reservoirs for San Juan, Lago La Plata and Lago Loíza, projected streamflow is shown to decrease substantially below projected withdrawals by 2099.

Collaborating Institutions: U.S. Geological Survey, Southeast Climate Science Center; North Carolina Cooperative Fish and Wildlife Research Unit

Related Publication: Van Beusekom, A.E. and Collazo, J.A. 2015. Climate change and water resources in a tropical island system: propagation of uncertainty from statistically downscaled climate models to hydrologic models." International Journal of Climatology (early online). http://onlinelibrary.wiley.com/doi/10.1002/joc.4560/full

Institute Contact: Ashley Van Beusekom, ashleyvanbeusekom@fs.fed.us



Ten-year moving averages of annual streamflow leaving Lago La Plata and Lago Loíza from simulated streamflow with estimated withdrawals subtracted using MSD, range of GCMs, and multi-model GCM ensembles.

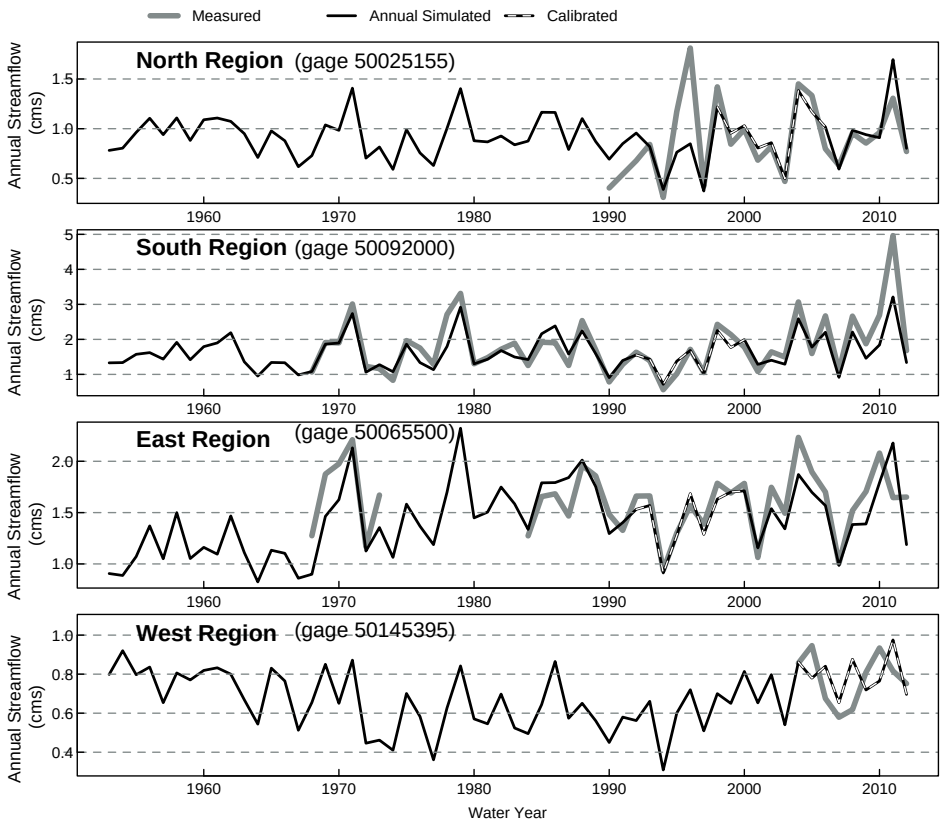
Modeling surface runoff in Puerto Rico with dynamic land cover

This study quantitatively explores whether land cover changes have a substantive effect on simulated streamflow within the tropical island setting of Puerto Rico. The Precipitation Runoff Modeling System (PRMS) was used to compare streamflow simulations based on five static parameterizations of land cover with those based on dynamically varying parameters derived from four land cover scenes for the period 1953-2012. The PRMS simulations based on static land cover illustrated consistent differences in simulated streamflow across the island. It was determined that the scale of the analysis makes a difference: large regions with localized areas that have undergone dramatic land cover change may show negligible difference in total streamflow, but streamflow simulations using dynamic land cover parameters for a highly altered subwatershed clearly demonstrate the effects of changing land cover on simulated streamflow. Incorporating dynamic parameterization in these highly altered watersheds can reduce the predictive uncertainty in simulations of streamflow using PRMS. Hydrologic models that do not consider the projected changes in land cover may be inadequate for water resource management planning for future conditions.

Collaborating Institutions: North Carolina State University, U.S. Geological Survey

Related Publication: Van Beusekom, A.E., Hay, L.E., Viger, R.J., Gould, W.A., Collazo, J.A., and Henareh Khalyani, A. 2014. The Effects of Changing Land Cover on Streamflow Simulation in Puerto Rico. Journal of the American Water Resources Association 50(6):1575-1593. doi: 10.1111/jawr.12227

Institute Contacts: William Gould, wgould@fs.fed.us; Ashley Van Beusekom, ashleyvanbeusekom@fs.fed.us



Annual Measured and Simulated Streamflow during the Calibration and Evaluation Periods at the "Best" Gages in the North, South, East, and West Regions of Puerto Rico.

Tropical Responses to Altered Climate Experiment (TRACE)

Tropical forests are expected to experience a significant and permanent increase in temperature over the next 20 years. Given the importance of these ecosystems to biodiversity as well as the cycling of water and carbon on a global scale, studying their potential to adapt to a new climate regime is critical to our ability to effectively manage these ecosystems and to accurately predict feedbacks to future climate. In response to a recognized need to understand tropical forest responses to increased temperature, Forest Service researchers and partners have established the first field warming experiment to be conducted in a tropical forested ecosystem in the Luquillo Experimental Forest of northeastern Puerto Rico. The Tropical Responses to Altered Climate Experiment (TRACE) will warm small patches of forest by 4 °C relative to control plots, using a hexagonal array of Infra-Red heaters established 2m above the understory vegetation. A multitude of responses to warming will be assessed ranging from the effects on the microbial community composition and function to the acclimation potential of photosynthesis of understory plants. Construction of the infrastructure began Fall 2013 and was completed in May 2015. In anticipation of the start of this unprecedented experiment, TRACE has been featured in several local and international news outlets such as Al Jazeera America, ClimateWire, and El Nuevo Día. Pretreatment data collection is currently underway and the experiment is set to begin Spring 2016. More information about this project is available at www.forestwarming.org.

Tropical Responses to Altered Climate (TRACE) Research Plot.

Collaborating Institutions: Michigan Technological University; U.S. Geological Survey; U.S. Department of Energy, Terrestrial Division

Related Publication: Cavaleri, M.A., Reed, S.C., Smith, K.W., Wood, T.E. 2015. Urgent need for warming experiments in tropical forests. Global Change Biology 21 (6): 2111-2121. http://www.treesearch.fs.fed.us/pubs/49346

Assessing leaf-level effects of increased temperature on tropical forest canopy trees

Temperatures are expected to increase substantially in tropical forested ecosystems in the coming decades. Tropical trees are among the world's most important carbon sinks, yet evidence suggests they may already be near a high temperature threshold, which could potentially reduce their ability to take up carbon from the atmosphere. At the same time, whether or not tropical plants will acclimate to anticipated changes is not well understood. Forest Service scientists and partners will address this question with *in situ* warming of individual canopy leaves accessible from a canopy access tower in the Luquillo Experimental Forest. The canopy access tower was installed in November 2015 and has been officially certified as safe to climb. The tower will be instrumented with a weather station to monitor the local climate. At the same time, engineers at Michigan Technological University have developed a novel, state of the art system for warming canopy leaves. Canopy research is set to begin Summer 2016.

Collaborating Institution: Michigan Technological University

Related Publication: Cavaleri, M.A., Reed, S.C., Smith, K.W., Wood, T.E. 2015. Urgent need for warming experiments in tropical forests. Global Change Biology 21 (6): 2111-2121. http://www.treesearch.fs.fed.us/pubs/49346

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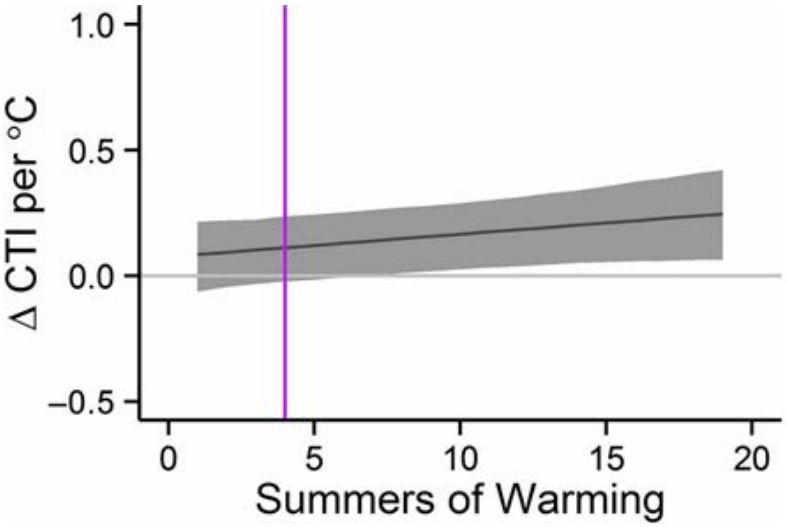
◂ The Luquillo Experimental Forest canopy access tower, installed November, 2015.

Experiment, monitoring, and gradient methods used to infer climate change effects on plant communities yield consistent patterns

We assessed the consistency of three approaches in estimating warming effects on plant community composition: manipulative warming experiments, repeat sampling under ambient temperature change (monitoring), and space-for-time substitution. The three approaches showed agreement in the direction of change (an increase in the relative abundance of species with a warmer thermal niche), but differed in the magnitude of change estimated. Experimental and monitoring approaches were similar in magnitude, whereas space-for-time comparisons indicated a much stronger response. These results suggest that all three approaches are valid, but experimental warming and long-term monitoring are best suited for forecasting effects over the coming decades.



Thermophilization of plant communities in response to multiple years of experimental warming scaled to a 1 °C increase in temperature. Thermophilization is a pattern of species turnover wherein more cold-adapted species decline in relative abundance and more warm-adapted species increase. The purple reference line shows effect size after four summers of warming. (8 regions, 12 studies, 320 plots).

Collaborating Institutions: National Ecological Observatory Network, University of Colorado, University of British Columbia, Grand Valley State University, Faroese Museum of Natural History, Memorial University, Norwegian Institute for Nature Research, University of Iceland, University Centre in Svalbard, U.S. Fish and Wildlife Service, Université du Québec à Trois-Rivières, Icelandic Institute of Natural History, University of Gothenburg, University of Edinburgh, Edinburgh, Florida International University, Swiss Federal Institute for Snow and Avalanche Research, University of Texas at El Paso, and HOMER Energy.

Related Publication: Elmendorf, S.C., Henry, G.H.R., Hollisterd, R.D., Fosaa, A.M., Gould, W.A., Hermanutz, L., Hofgaard, A., Jonsdottir, I.I., Jorgenson, J.C., Levesque, E., Magnusson, B., Molau, U., Myers-Smith, I.H., Oberbauer, S.F., Rixen, C., Tweedie, C.E., Walkers, M. 2015. Experiment, monitoring, and gradient methods used to infer climate change effects on plant communities yield consistent patterns. PNAS. 112(2): 448-452. www.pnas.org/cgi/doi/10.1073/pnas.1410088112

Institute Contact: William Gould, wgould@fs.fed.us

Assessing vulnerabilities to climate change in tropical agriculture and forestry

This is the first major output of the USDA Caribbean Climate Hub. It is a review of vulnerabilities and adaptation practices in sectors involved in forest management, livestock, grassland and grazing management, and crops such as coffee, fruit trees, plantains, bananas, vegetables and root crops. Historically, people have depended on these products for subsistence and export as valuable cash crops. Currently, Puerto Rico and the U.S. Virgin Islands import the vast majority of their agricultural products and local production is well below its full potential. The study highlights vulnerabilities to climate change and increasing climate variability in the region's forestry and agricultural sectors:

- Food security is reliant on local productivity – however, climate change and extreme weather events in other regions also impact global markets and maritime shipping which can affect U.S. Caribbean food security and agriculture production;
- Climate change and weather variability are likely to make prices more volatile, which influence landowner decisions and farming success;
- The arrival and proliferation of new and existing pests may adversely affect humans, livestock, wildlife and crops;
- Sea level rise and salt water intrusion are affecting coastal populations, aquifers, and prime agricultural lands;
- Conflicting demands on a limited land base highlight the need for multi-sector adaptation planning;
- Unemployment and poverty levels are among the highest in the United States;
- Producers may lack access to expertise, information, research, financing or equipment for adaption; and
- High production costs, labor issues, and competition from external producers present barriers to expansion of local production.

Collaborating Institutions: The USDA Tropical Agricultural Research Station (TARS), The USDA Natural Resource Conservation Service (NRCS) Caribbean Area, the Farm Service Agency (FSA) and Rural Development (RD) in Puerto Rico and the U.S. Virgin Islands, and the USDA Office of the Chief Economist (OCE).

Related Publication: Gould, W.A., Fain, S.J., Pares, I.K., McGinley, K., Perry, A. and Steele, R.F. 2015. Caribbean Regional Climate Sub Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies, United States Department of Agriculture, 67 pp.

Institute Contact: William Gould, wgould@fs.fed.us

Research site in Laguna, the southern most site of ditricution of *Laguncularia racemosa* in the Brazilian Atlantic coast.

Element uptake in mangroves

Long-standing cooperative work continued with researchers in Venezuela on the mangroves of the Maracaibo basin. They finished the analysis of uptake and resorption of minerals by mangrove species with contrasting mechanisms of salt regulation, *Laguncularia racemosa* and *Rhizophora mangle*. The salt excluder (*R. mangle*) was more efficient at restricting Na and S uptake, resorbing P, and accumulating Fe than the salt secreter (*L. racemosa*).

Collaborating Institution: Universidad del Zulia, Maracaibo, Venezuela

Related Publication: Medina, E., Fernandez, W., & Barboza, F. (2015). Element uptake, accumulation, and resorption in leaves of mangrove species with different mechanisms of salt regulation. Web Ecology, 15 (1): 3.

Contact: Ernesto Medina, medinage@gmail.com

Mangrove photosynthesis and soil-plant relationships

A study in Brazil investigated the soil-plant nutrient relations and photosynthesis of mangrove species near their southern most sites in that country (26-28ºS). At each site, δ13C values of *Avicennia schaueriana* were consistently higher than those for the other species, indicating that these species are subjected to contrasting water stress conditions. Leaf concentrations of C were lower, whilst those of N were always higher in *A. schaueriana*, indicating accumulation of salts and non-protein N-compounds in leaves. Lower photosynthetic rates and carboxylation efficiency of *R. mangle* may constitute constraining factors preventing this species from establishing at higher latitudes. Sites sampled were comparatively fertile, because sediment transport through fresh water run-off is predominant in humid coasts, and therefore plants were not limited by nutrient supply, nor particularly stressed by soil salinity. The results were presented in the XI Latinamerican Botanical congress in Bahia, Brazil (October 2014).

Collaborating Institutions: Universidad Stadual de Rio de Janeiro, Brazil; University of Puerto Rico-Río Piedras

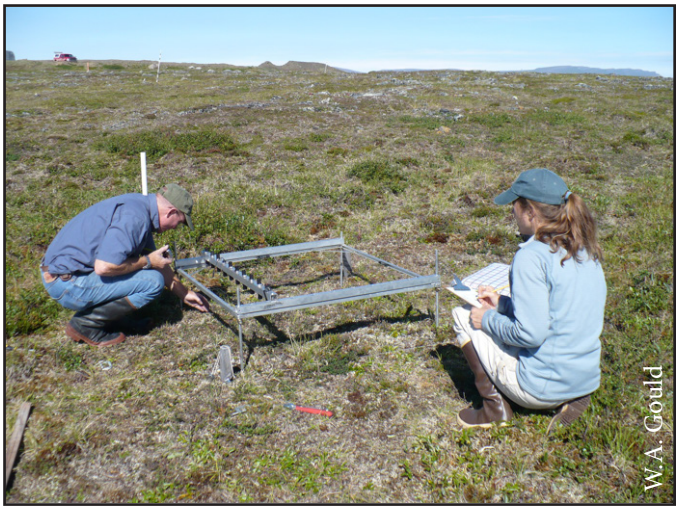
Contact: Ernesto Medina, medinage@gmail.com

Related Publications: Soares, M.L.G., Tognella, M.P.P., Cuevas, E., and Medina, E. 2015. Photosynthetic capacity and intrinsic water-use efficiency of *Rhizophora* mangle at its southernmost western Atlantic range. Photosynthetica 53 (3): 464-470.

Tognella De Rosa, M., Soares, M., Cuevas, E. and Medina, E. 2016. Heterogeneity of elemental composition and natural abundance of stables isotopes of C and N in soils and leaves of mangroves at their southernmost West Atlantic range. Brazilian Journal of Biology 76 (4).

Field team at Palhosa, Brazil.

Terrestrial ecosystems at Toolik Lake, Alaska

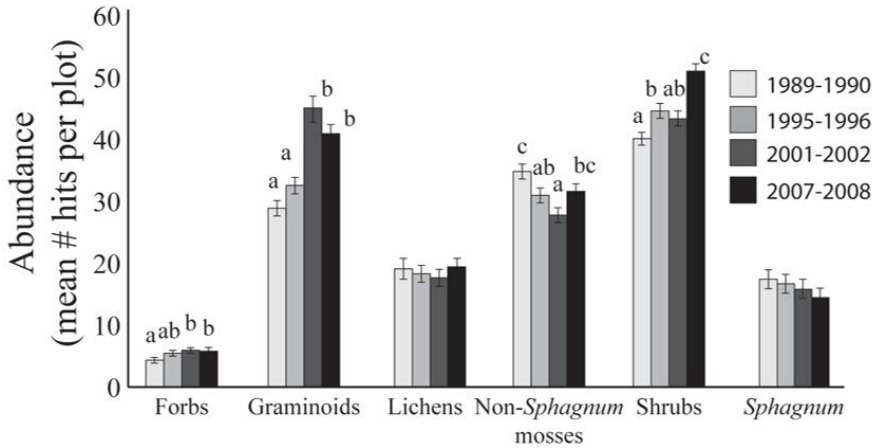


This is a chapter in a synthesis book based on research at the Toolik Lake Long Term Ecological Research Site. The chapter focuses on the overall structure and function of different components of the landscape near Toolik Lake, Alaska. It describes and compares key physical, chemical, and biological controls over the distribution and function of these ecosystems. It discusses timescales and trajectories of system-level change in response to changes in the controls. It considers how current and anticipated changes in climate affect the dynamics of soils and soil biota in arctic tundra ecosystems. It also predicts how the expected changes in global and arctic climates may alter the landscape and terrestrial ecosystems near Toolik Lake, and suggests priorities for future research. Our contribution is based on long term monitoring of vegetation plots at the Toolik LTER site, which show trends towards increasing cover and dominance of the grasses and woody shrubs versus the mosses and lichens.

Collaborating Institutions: Woods Hole Marine Biological Laboratory, University of Alaska, University of Texas, University of Minnesota, University of Michigan, University of Florida, Colorado State University, University of California.

Related Publication: Shaver, G.R., Laundre, J.A., Bret-Harte, M.S., Chapin, F.S. III, Mercado-Díaz, J.A., Giblin, A.E., Gough, L., Gould, W.A., Hobbie, S.E., Kling, G.W., Mack, M.C., Moore, J.C., Nadelhoffer, K.J., Rastetter, E.B., Joshua, P. Schimel, J.P. 2014. Terrestrial ecosystems at Toolik Lake, Alaska. In Hobbie, J.E. and Kling, G.W. (eds.). A changing arctic: ecological consequences for tundra, streams, and lakes. Oxford Univ. Press, Oxford, New York. 90 pp.

Institute Contact: William Gould, wgould@fs.fed.us



Change in the mean number of total hits per plot of different vegetation growth forms located at the Imnavait Creek and Toolik grids from 1989-1990 to 2007-2008 (Letters above the bars indicate significant differences. Error bars represent standard errors).

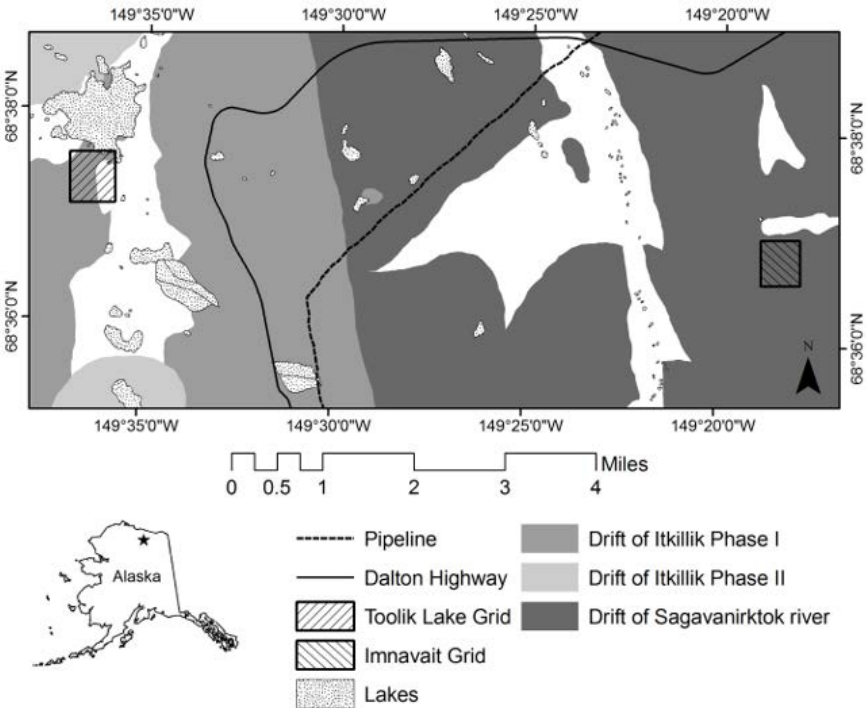
Soil nutrients, landscape age, and Sphagno-Eriophoretum vaginati *plant communities in Arctic moist-acidic Tundra landscapes*

In this work we assessed how organic and mineral soils from Toolik and Imnavait grids, two long-term research sites in northern Alaska, vary in terms of a number of different physical and chemical parameters, including total C, N, and S. These two sites differ in landscape age and glacial history by over 100,000 years, but currently have similar vegetation composition. Our analysis was narrowed to soils in *Sphagno-Eriophoretum vaginati* plant communities. We found that most of the parameters evaluated were not significantly different between these sites, except for total Ca, which was significantly higher in organic soils from Imnavait (older) vs. Toolik (younger), and total Na, which was significantly higher in mineral horizons from Toolik compared to Imnavait. Moreover, the abundance of non-*Sphagnum* mosses was positively correlated with total Ca in organic soils; whereas the abundance of forbs, non-*Sphagnum* mosses and bryophytes was negatively correlated with total Na in mineral soils. We suggest that differences in the concentration of these two elements are most likely tied to landscape age differences between these sites. However, observed dissimilarity in terms of total Ca in organic soils and total Na in mineral soils was concordant with correlation patterns observed between these elements and the abovementioned growth forms. Therefore, it is possible that existing differences in vegetation composition between these sites are also influencing the concentration of these elements in soils, particularly that of Ca since non-*Sphagnum* mosses are dominant above organic soils in these sites and are therefore expected to significantly affect biogeochemical processes of this horizon.

Related Publication:

Mercado-Díaz, J.A., Gould, W.A., González, G. 2014. Soil nutrients, landscape age, and *Sphagno-Eriophoretum vaginati* plant communities in Arctic moist-acidic Tundra landscapes. Open Journal of Soil Science 4:375-387.

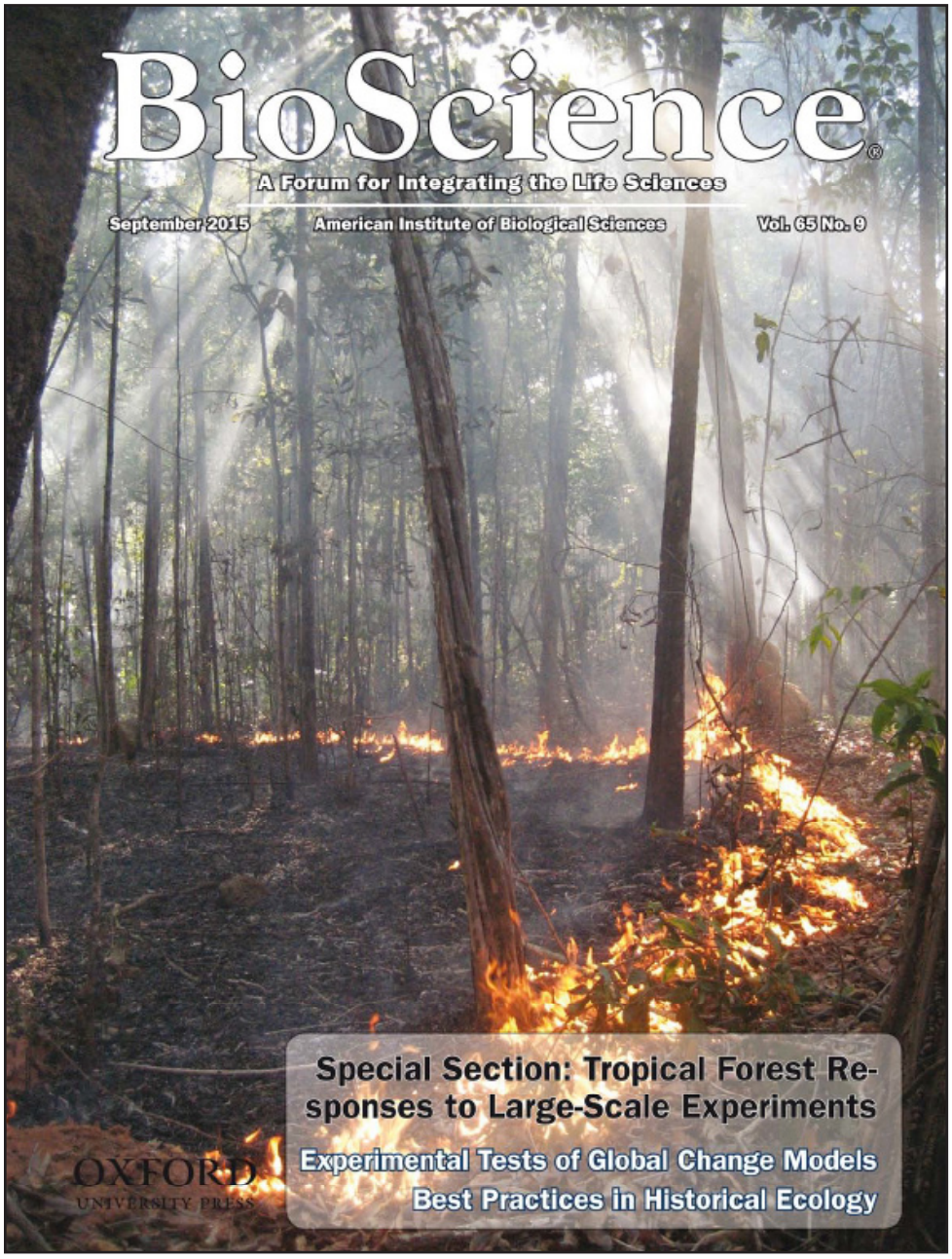
Institute Contacts: William Gould, wgould@fs.fed.us; Grizelle González, ggonzalez@fs.fed.us



Landscape ages and the location of the Toolik Lake and Imnavait Creek 1km^2 grids in the Upper Kuparuk River region in Northern Alaska.

Tropical forest responses to large-scale experiments

Six synthesis articles covering recent large-scale field experiments that have been highly influential in tropical ecology and that further our understanding of how these forests will respond to global environmental change were published in *Bioscience*. Two of the articles focus on how human-induced habitat loss or hunting has altered tropical forests. The remaining four articles address global climate change effects on tropical forests-specifically, hurricanes, drought, fire, and temperature changes. This special section of hot-topic synthesis articles will provide a long-lasting source of understanding of tropical forests, as well as provide motivation and direction for establishing future research needs in these threatened ecosystems.



Collaborating Institution: USDA, National Wildlife Research Center

Related Publication: Shiels, A.B. and González, G. Tropical Forest Responses to Large-Scale Experiments. 2015. Volume 65 (9): 839-840. doi: 10.1093/biosci/biv126. http://bioscience.oxfordjournals.org/content/65/9/839.short

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Tropical forest responses to large-scale experimental hurricane effects

A Special Issue of Forest Ecology and Management on Tropical Forest Responses to Large-scale Experimental Hurricane Effects was published, containing 13 manuscripts summarizing the findings of a 10-year, on-going manipulative experiment (the Canopy Trimming Experiment, CTE), that simulates two key aspects of hurricane effects in a wet tropical forest. Although previous studies of tropical and subtropical forests have documented changes resulting from hurricanes, it is not clear which of the two simultaneously occurring direct effects of hurricanes—canopy openness or debris deposition—most influence responses. In the Luquillo Experimental Forest (LEF), a multi-disciplinary team of scientists used experimental manipulations, representing a replicated factorial design, to determine the independent and interactive effects of canopy openness and debris deposition on forest structural and functional characteristics. Although simulated hurricane effects triggered complex dynamics, increased canopy openness accounted for the majority of the documented shifts in forest biota and biotic processes, the large inputs of canopy debris and interactive effects of canopy openness and debris also produced important forest changes. Canopy openness increased pioneer plant recruitment and species richness, and decreased litterfall and decomposition; several animal groups were reduced in abundance or diversity. Debris deposition significantly increased tree basal area and microbial diversity on leaf litter, but these increases were relatively small and ephemeral. Arguably, hurricanes are the most important natural disturbance affecting the LEF, and most variables measured in the CTE showed evidence of resistance or resilience. By identifying the causal factors affecting secondary successional trajectories of diverse taxa, biogeochemical attributes, microclimatic characteristics, and measures of ecosystem processes following hurricane disturbance, we better understand tropical forest dynamics resulting from past hurricanes and are better able to predict mechanisms of forest changes related to future hurricanes.

Collaborating Institution: USDA, National Wildlife Research Center, University of California, Berkeley, University of Utah

Related Publication: Forest Ecology and Management (Volume 332, Pages 1-136, 15 November 2014), edited by Aaron B. Shiels and Grizelle González.

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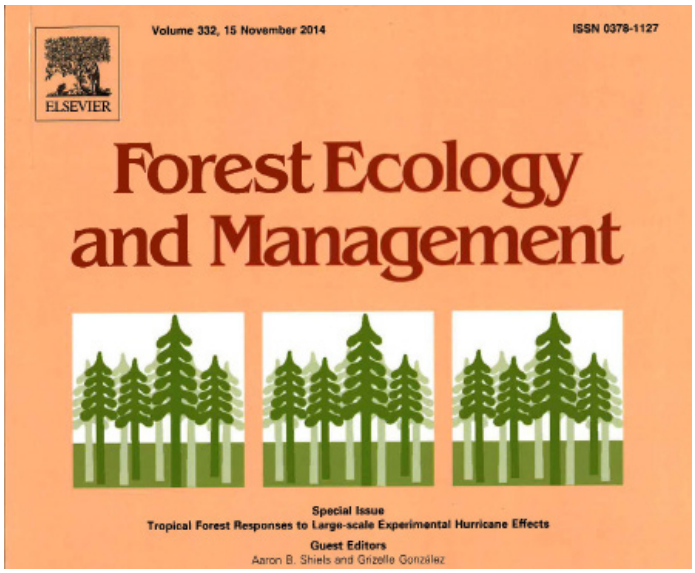


Post-hurricane canopy openings influence ecosystem processes in a tropical rainforest

Intense hurricanes disturb many tropical forests, but the key processes driving post-hurricane forest changes are not fully understood. In Puerto Rico, our Institute scientists collaborated with researchers from the Luquillo Long-Term Ecological Research Program to simulate hurricane effects in the Luquillo Experimental Forest, and determine the mechanisms of forest change associated with canopy openness (via loss of branches) and organic matter (debris) addition. By studying in isolation the individual effects of storms, we were able to observe how changes in microclimate cascaded down through the food web. An important conclusion from this research is that short-term responses of biota and ecosystem processes to cyclonic storms appear to be largely driven by canopy opening and the subsequent shifts in light and moisture, with added debris playing a relatively smaller role through the supplement of carbon and nutrients. This research highlights the dynamic nature of tropical forest ecosystems, and helps inform predictions of how plant, animal, and fungal species might respond to anticipated increases in the frequency of major hurricanes.

Arborist removing tree branches for the Canopy Trimming Experiment.

Collaborating Institutions: USDA Forest Service Center for Forest Mycology Research, Forest Products Laboratory; USDA National Wildlife Research Center; University of Puerto Rico-Río Piedras

Related Publications: Shiels A., González G., Lodge, D.J., Willig, M.R., and Zimmerman, J.K. 2015. Cascading effects of canopy opening and debris deposition from a large-scale hurricane experiment in a tropical rainforest. Bioscience 65 (9): 871-881. doi:10.1093/biosci/biv111

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

Recently trimmed trees in the Canopy Trimming Experiment.

S. Stankavich

Soil carbon and other biogeochemical properties in the Canopy Trimming Experiment

A soil profile in the Luquillo Experimental Forest.

In order to determine the long term effects of canopy trimming and debris deposition on soil carbon and nutrients, and identify the depth to which these disturbances can be detected, we measured soil carbon and other biogeochemical properties in depth profiles of the Canopy Trimming Experiment. Results showed a strong depth dependence of soil moisture and pH, with higher water content and acidity in the topsoil (> 40 cm), where biological activity is concentrated. After a decade of recovery, we measured significantly higher soil carbon and nitrogen content within the top 20 cm. Soil phosphorus—mainly bicarbonate-extractable organic phosphorus—also responded positively to debris deposition, with significantly higher values in the top 30 cm. Concentrations of reactive iron (Fe) species, including citrate-ascorbate and HCl extractable Fe, showed marked decreases with depth, and no apparent treatment effects. Finally, preliminary results from soil carbon fractionation suggest that debris deposition increased the free light fraction in the top 10 cm over 10 years.

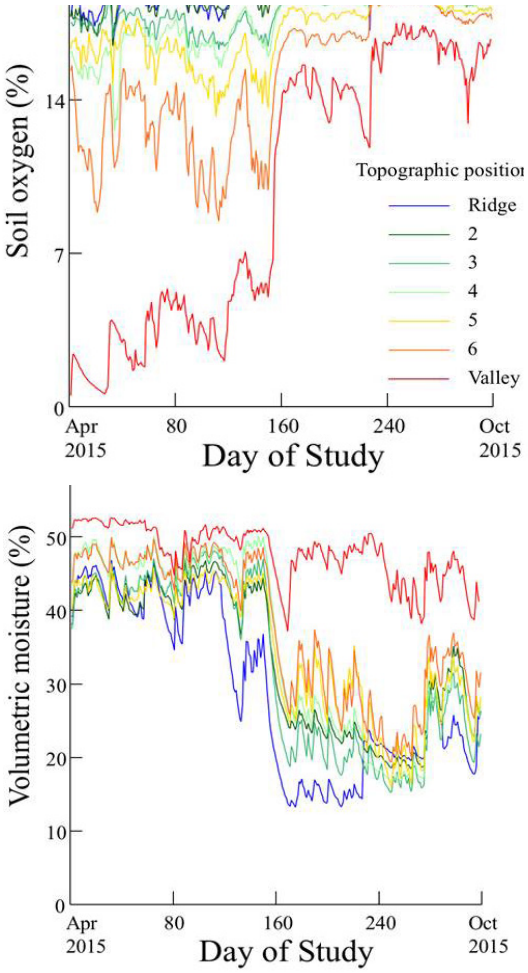
Considering all four treatments, debris deposition without canopy trimming caused the largest changes in soil carbon and nutrients over the 10 year period, with disturbance effects being detectable down to ~30 cm depth (for soil organic phosphorus). Interestingly, the effects of debris deposition combined with canopy trimming (i.e., hurricane simulation), did not lead to large changes in soil carbon and nutrients, highlighting the longer-term resistance and resilience of soil biogeochemistry to hurricane-associated disturbances in this wet tropical forest. Large pulses of organic matter deposited during hurricanes appear to subsidize the forest floor but are coupled with rapid and efficient decomposition leading to no detectable changes in C and P stocks over time.

Collaborating Institution: University of California, Berkeley

Related Publication: Silver, W. L., S. J. Hall, and G. González. 2014. Differential effects of canopy trimming and litter deposition on litterfall and nutrient dynamics in a wet subtropical forest. Forest Ecology and Management 332: 47-55.

Contact: Whendee Silver, wsilver@berkeley.edu

Soil properties across a replicated catena in a subtropical wet forest



The objective of this study is to determine the spatial and temporal dynamics and drivers of soil oxygen (O_2) availability and redox-sensitive biogeochemical processes using easily measured and modeled parameters. The study is designed to capture the biogeochemical response to extreme climate events, such as the drought that occurred in the Luquillo Experiment Forest in 2015. We are using automated soil O_2 sensors coupled with measurements of soil chemical and physical properties, climate, and greenhouse gas concentrations and fluxes. These results will be used to derive quantitative relationships linking climate and soil physical properties to redox-sensitive biogeochemical processes in tropical forests, and better model C and nutrient cycling and greenhouse gas fluxes in Earth system models, such as the Community Land Model (CLM) module of the Community Earth System Model (CESM). Preliminary results showed that average soil O_2 concentrations, volumetric soil water content, pH, and greenhouse gas emissions such as CO_2 and CH_4 all vary, often non-linearly, with topographic position along the catena from ridge to valley. In response to the drought conditions, there was a striking lag in the response of both soil moisture and O_2 in these soils. This suggests a high degree of resilience to short-term drying, and a threshold-type behavior with more severe drought. Drought increased soil aeration, which resulted in rapid iron oxidation and a dramatic decline in pH in lower topographic zones, which can feed back on nutrient cycling and net primary productivity in humid tropical forests. In summary, drought resulted in dramatic changes in redox-sensitive biogeochemistry with potential cascading effects. Current research is exploring more detailed drought effects using controlled experiments.

Collaborating Institution: University of California, Berkeley

Related Publication: Liptzin, D. and W. L. Silver. 2015. Spatial patterns in oxygen and redox sensitive biogeochemistry in tropical forest soils. Ecosphere 6(11):211. http://dx.doi.org/10.1890/ES14-00309.1

Contact: Whendee Silver, wsilver@berkeley.edu

T. Heartsill-Scalley

Assessment of a stream reach that combines open channelization with built-up, impermeable (gray) riparian areas and canopy forming vegetation (green) riparian with permeable surfaces.

Watershed Analysis

Characterization of a tropical, urban stream network in a sub-watershed of the Río Piedras

In many instances urban streams are flowing along roads, parks and through cities while being invisible and highly modified to many people. One such case is the Quebrada Doña Ana, within the Río Piedras Watershed (RPWS) system, a major component of the San Juan Bay Estuary hydrological system. The headwaters of the Doña Ana are highly modified and channelized, which is representative of most urban streams in the RPWS. To understand current stream conditions and associated hydrological dynamics within the urban landscape, a first step is to develop a site-specific hydrological network layer. We generated a stream network using historic and current hydrological data from federal and state agencies, and geo-referenced field data to describe stream structural and physical characteristics. The Doña Ana stream network had 81.4% of its stream length modified, including both channelized stream sections that were open and those that were buried. Buried stream sections are those that flow underground and whose water flow is not visible from the surface. Most of the Doña Ana stream reaches are currently pluvial drainages as evidenced by historical aerial photographs. Only 18.6% of the stream segments were classified as unmodified. Riparian land cover in most of the Doña Ana watershed was impermeable/gray cover, with less than half classified as green infrastructure, including both open and closed canopy areas. The next phase of this project will further quantify historical changes to the stream network and riparian cover in light of current soil classifications.

Collaborating Institutions: San Juan Bay Estuary Program; Fundación Puertorriqueña de Conservación

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

Analysis of the channelization of the Río Piedras

The United States Army Corps of Engineers (COE) designed a Flood Control Project (FCP) for the Río Piedras Watershed in 1978, in response to flooding in the San Juan Metropolitan Area that was causing significant losses in property and urban infrastructure. The COE developed a plan to construct concrete channels, improve natural channels, construct retaining basins upstream, replace bridges, mitigate loss of mangrove area, and provide for improved recreation in the watershed, to protect the watershed against the 100-year flood event. In 1984, the COE estimated about 6 years of construction at a cost of $253.5 million with a positive benefit to cost ratio of 2.6. By 1991, the FCP was modified, eliminating still basins and adding high velocity channels upstream to maximize water discharge during intense rainfall events, with increased cost total of $303.5 million and proposed construction time of 11 years. Several alternative flood control measures were discarded during the planning process due to high cost. After completion, the Flood Control Project has a life expectancy of 50 years, and will allow residual flooding to occur in places to a depth of 2 meters, causing estimated damages of 1.2 million dollars to infrastructure in the watershed. Today, thirty years after the original survey report was published, FCP expenditures have reached about a billion dollars and flood control construction is in progress at the lower tidal reaches of the river without any indication as to when the Project will move upstream.

We analyzed a series of reports, documents, data, and arguments prepared by the COE regarding the channelization of the Río Piedras in order to 1) summarize the contents of those supporting materials; 2) evaluate the accuracy of predictions and assumptions used to justify the channelization; and 3) to make a case for the need to reassess the flooding problems in the San Juan Metropolitan Area, in the context of the evolving social and ecological conditions in the city. We uncovered many assumptions that the COE had to make during the planning of the Flood Control Project, but which turned out not to be correct over the long-term. The invalidation of these assumptions raises questions about the hydrological and economic feasibility as well as the effectiveness of the proposed Flood Control Project. Our intent was not to propose specific solutions to the problem of flood control in the city, but rather to emphasize the need for a total reassessment of flooding and flood control in the Río Piedras Watershed. Until the current course of channelization is thoroughly reviewed, other viable alternatives cannot be debated and vetted for their efficacy.

Collaborating Institution: University of Puerto Rico, Río Piedras

Related Publication: Lugo, A.E., Nytch, C.J., and Ramsey, M. 2013. An analysis of US Army Corps of Engineers documents supporting the channelization of the Río Piedras, Acta Científica 27(1-3): 4-72.

Institute Contact: Ariel E. Lugo, alugo@fs.fed.us

Flood control channel at the lower reaches of the Río Piedras Watershed.

U.S. Army Corps of Engineers

Inventory and Monitoring

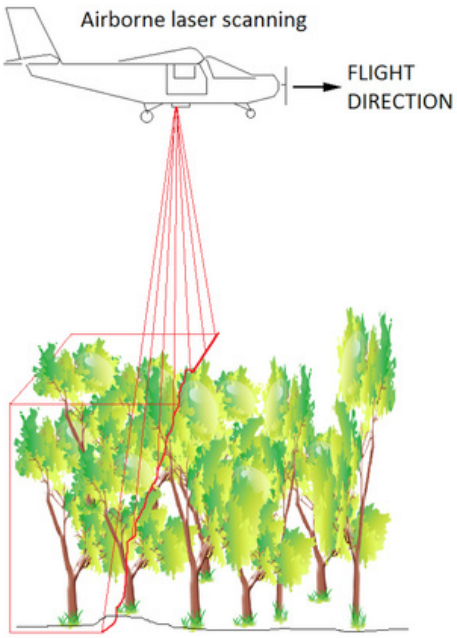
When data are too good: redefining tropical forest gaps using airborne laser scanning data

In the early 1980s, gap formation and regeneration in gaps were thought to hold the key to understanding tropical forest diversity resulting from "intermediate disturbance." Gaps were exciting places to study rapidly changing biogeochemical processes and an accessible location for doing plant physiological studies. Everyone was studying gaps but not everyone agreed on how to define a gap. Brokaw (1982) presented a practical definition that seemed to solve the problem. "A gap is a hole in the forest extending through all levels down to an average height of two m[eters] above the ground." This definition has been debated, but it has been fantastically successful. Brokaw did his work walking around on the forest floor.

Looking at forests from an aircraft carrying a laser scanner gives a three dimensional picture of forest structure. The shorthand name for the method is LiDAR, standing for light detection and ranging. LiDAR provides stunning details of forest structure, but it makes gap detection more complicated. When we applied Brokaw's definition to LiDAR data we found that forest turnover times were unreasonably long – thousands of years (Hunter et al. 2015). How could that be? It turns out that the data were too good, and reflections off fine-scale forest material in gaps turned them into non-gaps by the Brokaw definition. The field observer ignores many of the vegetative features that appear in gaps above two meters (stray vines, fallen canopies, tall saplings), while the LiDAR detects them reliably.

In order to understand gaps with LiDAR technology, we had to redefine them with a method that ignores the haphazardly placed objects. Through an optimization process based upon forest growth statistics, we found that for two forests in the Amazon, the height cut off for gaps ought to be 10 meters and the minimum area a minimum of 10 meters squared, to make gap detection biologically reasonable. Now that we know how to detect gaps using LiDAR, we are studying a wide range of intact and managed Amazon forests (over 16,000 ha in our archives) to understand gap creation rates and forest dynamics.

Institute Contact: Michael Keller, mkeller.co2@gmail.com



wiki.awf.forst.uni-goettingen.de

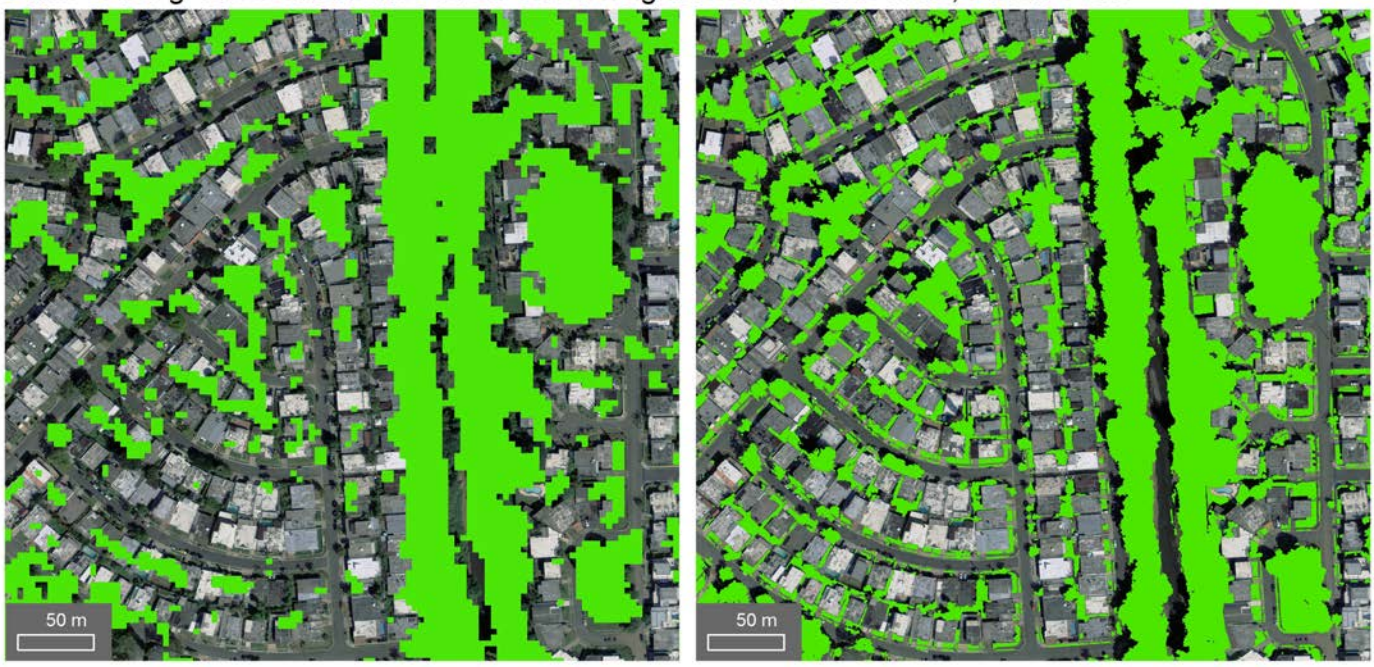
Quantifying green areas in San Juan using high-resolution imagery

The value of green infrastructure for management and provision of ecosystem services in cities is gaining importance in urban planning and ecological research. Detailed information about urban vegetation is crucial to efforts to manage green infrastructure, and high-resolution imagery can provide detailed observations of urban areas. However, most knowledge and remote sensing applications on green infrastructure in cities comes from temperate zones. This can be a problem in places like the tropics, where urban areas are expanding rapidly, and with little or no information to support sustainable growth efforts. Our study used high-resolution (0.3 m) imagery to quantify the vegetation of the city of San Juan and surrounding municipalities. We found that 61% of San Juan is green, and that some neighborhoods are greener than previously thought. In addition, spatial pattern analysis allowed us to classify urban vegetation into residential vs. non-residential vegetation, which is important for urban planning. Further, our study showed that very small pixels (< 1-2 m) are ideally needed for quantifying and mapping urban vegetation in places such as San Juan. Overall, our study highlights the value of high-resolution data for assessing vegetation in tropical cities, and provides novel geospatial on urban vegetation to support city planning and scientific research

Collaborating Institutions: University of Wisconsin, Madison

Contacts: Sebastián Martinuzzi, sebamartinuzzi@gmail.com; Tischa Muñoz-Erickson, tamunozerickson@fs.fed.us

Detail of the green infrastructure at La Sierra neighborhood in San Juan, Puerto Rico.



Year 2002 - processed at 4 meters spatial resolution using pixel to pixel image classification techniques.

Year 2010 - processed at 0.3 meters spatial resolution using Object Oriented Image Analysis.

Synthesis on characterizing tropical forests with multispectral imagery

Tropical forests have far more species diversity than temperate or boreal forests, and their role in Earth's atmospheric greenhouse gas budgets is large. Multispectral satellite imagery, i.e., remotely sensed imagery with discrete bands ranging from visible to shortwave infrared wavelengths, is the timeliest and most widely available imagery for inventories of greenhouse gas sinks and sources related to tropical forests. Such inventories are conducted for the United Nations program, REDD+, which will compensate developing countries for Reducing greenhouse gas Emissions to the atmosphere from Deforestation or Degradation, and for sustainably managing forests and their carbon stocks. Together with collaborators we summarized how multispectral imagery can help characterize tropical forest attributes related to forest carbon emissions, including forest type, age, structure, and disturbance type or intensity, and the storage, degradation and accumulation of carbon in tree biomass. They also reviewed how this imagery can reveal feedbacks between tropical forest degradation and climate and how to cloud-screen and gap-fill imagery. They review how the spectral information inherent to multiyear image time series has high sensitivity to the age, height or biomass of forests and how the spectral and textural information in multispectral imagery of high spatial resolution can be used to estimate tropical forest biomass.

Collaborating Institutions: Remote Sensing Centre, Brisbane, Australia; Agricultural Research for Development, Montpellier, France; Amazon Institute of People and the Environment, Belém, Brazil; Carnegie Institution for Science, Stanford, California; US Geological Survey, Flagstaff, Arizona.

Related Publication: Helmer, E., Goodwin, N.R., Gond, V., Souza Jr, C.M., and Asner, G.P. 2015. Characterizing tropical forests with multispectral imagery. Chapter 14. In: Prasad S. Thenkabail, ed. Land Resources: Monitoring, Modeling and Mapping. Remote Sensing Handbook vol. 2. Boca Raton, FL: CRC Press, Taylor & Francis Group. p. 367-396. http://www.treesearch.fs.fed.us/pubs/49987

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

Example of tropical forest landscape in Amazonia as seen in Landsat imagery.

Resource Management and Governance

Conserving mangroves in the context of the Anthropocene

As human activities have expanded across the global landscape and changed the conditions that affect the functioning of the biota, many have come to describe a new geologic epoch being referred to as the Anthropocene. As conditions change, ecosystems are affected in new and unforeseen ways. For mangroves, this means coping with sea level rise, atmospheric warming, changes in atmospheric gas composition, changes in the frequency and intensity of atmospheric events and in hydrological conditions, and loss of cover as a result of urbanization, agriculture, and other land use changes. Building on more than 40 years of mangrove research, we collaborated with Venezuelan investigators to consider mangrove ecophysiology and tree functioning, mangrove responses to global change, and policies and institutions that affect mangroves at local to global scales, to provide a better understanding of the issues and opportunities for mangrove conservation in the 21st century. Findings suggest that mangrove composition is changing with the movement of mangrove species across continental barriers as a result of human activity, and that these trends will lead to novel mangrove forests and in some cases expand the range of mangroves worldwide. Preserving mangroves in the Anthropocene will not be achieved by isolating mangroves from people, but rather by regulating interactions between mangroves and humans through effective management based on sound science that goes beyond the traditional scope of ecological analyses to include the social forces converging on mangroves. Increased collaboration between governments, non-governmental organizations, and communities that depend on mangroves for their livelihood will be critical for the conservation of mangroves in the Anthropocene.

Collaborating Institution: Instituto Venezolano de Investigaciones Científicas, Caracas, Venezuela

Related Publication: Lugo, A.E., Medina, E., and McGinley, K. 2014. Issues and challenges of mangrove conservation in the Anthropocene - Desafios de la conservación del mangle en el Antropoceno. Madera y Bosques vol. 20, num. especial : 11-38.

Institute Contacts: Ariel E. Lugo, alugo@fs.fed.us; Kathleen McGinley, kmcginley@fs.fed.us


Mangrove reforestation in Puerto Rico. G. Bauer

Examining policies, laws, institutions, and instruments governing forest conservation and sustainable management

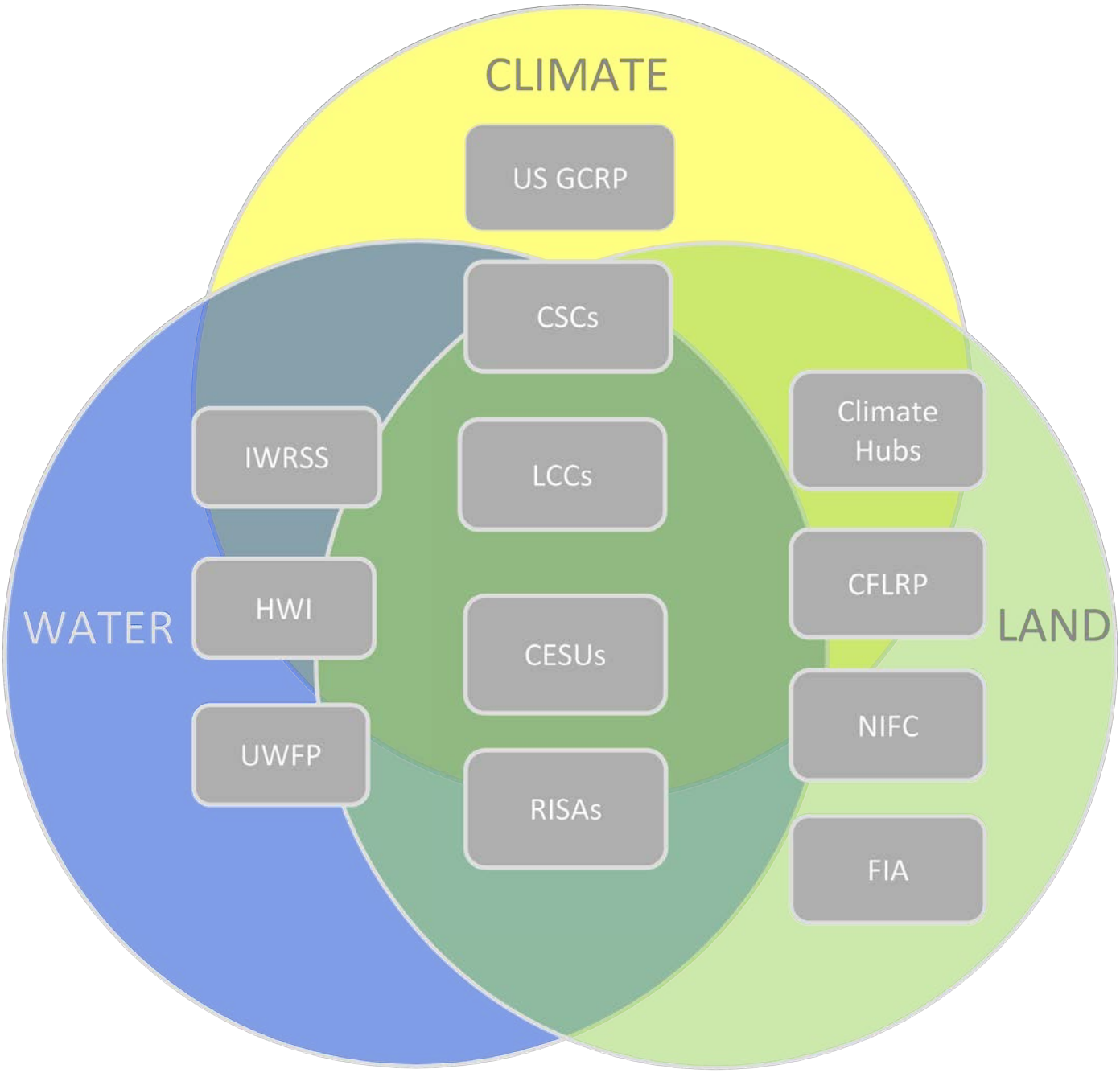
As part of our collaborative work on forest governance, we analyzed forest policies, laws, institutions, and instruments governing forest conservation and management in the United States, as part of a broader national process to measure, monitor, and report on forest sustainability using the Montreal Process Criteria and Indicators for the Conservation and Sustainable Management of Forests. Specifically, we examined: (1) land tenure, (2) legislation, (3) law enforcement, (4) taxation and incentives, (5) cross-sectoral coordination, (6) partnerships, (7) public participation and conflict resolution, (8) institutions and personnel, (9) research, and (10) monitoring and reporting as they relate to forests and their sustainability. We report on public laws that govern public lands, which comprise about one-third of the nation's forests. These laws dictate management and public involvement through a broad range of detailed processes and prescriptions. Federal and state laws also protect wildlife and endangered species on all public and private lands, and range in their rigor of voluntary to requisite practices for protecting water quality, air quality, and other public goods. Federal and state laws also provide for technical and financial assistance, research, education, and planning on private forest lands, but do not require or prescribe specific actions or standards.

Many newer market based mechanisms, including forest certification, wetland banks, payments for environmental services, and conservation easements are used ever more frequently to implement sustainable forest management (SFM) across the country. And, there is increasing development of cross-sectoral policies and programs that link related policy networks, purposes, and desired outcomes at all levels. Critical partnerships affecting forests are evolving around cross-boundary issues, such as climate change, land use, and water conservation. Yet, barriers persist in addressing issues that cross ecological, social, political, legal, and other boundaries. Also, forestry faces ongoing challenges from other land uses, particularly in places where incentives for SFM are low and pressures for development and/or agriculture are high.

Related Publications: McGinley, K., Cubbage, F.W., 2015. Criterion 7: Legal, Institutional, and Economic Framework. In: USDA Forest Service, In Press, National Report on Sustainable Forests – 2015. USDA Forest Service, Washington, DC.

McGinley, K., Cubbage, F.W., 2015. Policy, Laws, Organizations, and Other Governance Arrangements Influencing Forests in the US: A Baseline Assessment. In: Congress Proceedings, XIV World Forestry Congress, Durban, South Africa, 7-11 September 2015.

Institute Contact: Kathleen McGinley, kmcginley@fs.fed.us

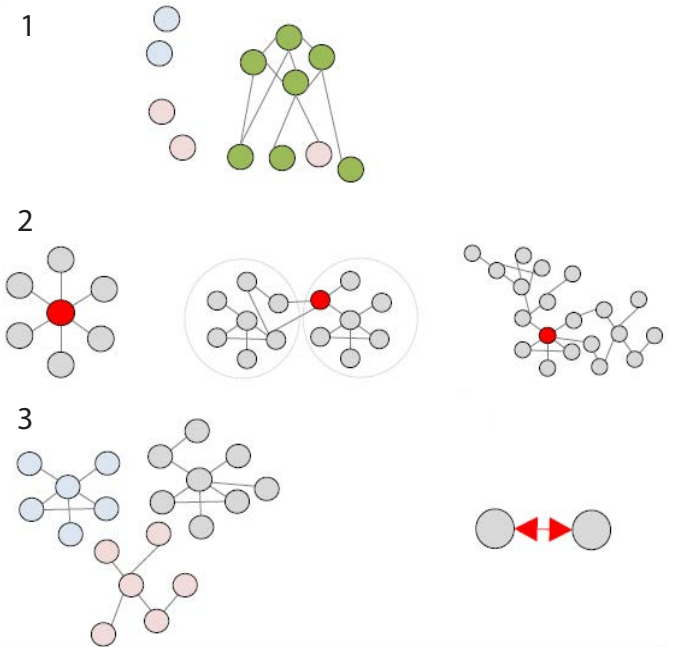


CESUs - NPS Cooperative Ecosystems Studies Units
CFLRP - Collaborative Forest Land Restoration Progam
Climate Hubs - USDA Regional Hubs for Risk Adaptation and Mitigation of Climate Change
CSCs - USFWS Climate Science Centers
FIA - USFS Forest Inventory and Analysis
HWI - EPA Healthy Watersheds Initiative
IWRSS - Integrated Water Resources Sciences and Services Consortium
LCCs - USFWS Landscape Conservation Cooperatives
NIFC - National Interagency Fire Center
RISAs - NOAA Regional Integrated Sciences and Assessments
US GCRP - US Global Change Research Program
UWFP - Urban Waters Federal Partnership

Select key cross-boundary partnerships and programs promoted by the US federal government that directly support sustainable forests. Source: McGinley and Cubbage, In Press.

Understanding knowledge-action networks for sustainability

In this study we explore how social networks influence efforts to link knowledge and action for sustainability. Social networks are patterned social relations that link actors together through various connections, such as friendships, communication, information, and in this case, knowledge. New institutional arrangements are emerging that recognize the complex, and sometimes networked, interactions between knowledge and decision-making for environmental sustainability. We refer to these arrangements as knowledge-action networks. In the area of urban sustainability, for instance, cities and national entities are investing in efforts that facilitate knowledge production, dissemination, and use across multiple sectors by creating boundary organizations to manage water and other resources, long-term collaborative social-ecological research sites (e.g., urban Long-Term Ecological Research sites), and most recently, sustainability research networks by the National Science Foundation. We conducted a review of the literature on social networks, governance, and knowledge production and found three key challenges to understanding knowledge-action networks: 1) defining boundaries; 2) characterizing power distributions; and, 3) identifying obstacles to knowledge sharing and connectivity. These knowledge network properties may express themselves in different network structures of knowledge flow. We propose that concepts and tools from social network theory are useful to understand barriers and opportunities associated with how information and knowledge flow among the multiple actors and organizations involved in knowledge production and use for decision-making and action.



Conceptual illustration of the networked interactions between ways of knowing and information exchange among actors involved in sustainability decision-making and governance. Circles represent different governance actors and the lines between them represent exchanges of information and knowledge among them. Examining opportunities for translating knowledge to action requires investigating these challenges (1) establishing network boundaries that capture actors with relevant and diverse ways of knowing, (2) identifying whether a single way of knowing occupies a position of privilege and power over information, and (3) identifying the probability that information sharing among multiple ways of knowing will encourage (or detract from) the effectiveness and efficiency of the knowledge network (Muñoz-Erickson and Cutts, 2015).

Collaborating Institution: University of Illinois at Urbana-Champaign

Related Publication: Muñoz-Erickson, T.A. and B.B. Cutts. 2015. Structural dimensions of knowledge-action networks for sustainability. Current Opinion in Environmental Sustainability 18: 56-64.

Institute Contact: Tischa Muñoz-Erickson, tamunozerickson@fs.fed.us

Scientists and municipal planners collaborate in exploring green alternatives to flood control in the city

City planners of the Municipality of San Juan are exploring more sustainable approaches to manage the high incidence of flood events in the city without having to rely on hard structural solutions (e.g., river channelization) that may put communities and ecological values at risk. In 2013, the Municipality received funding from the Department of Natural Resources and the Environment to develop a capacity building program for exploring green alternatives to flood control in San Juan. Municipal planners reached out to Institute scientists and other collaborators under its San Juan Urban Long-Term Research Area (ULTRA) network to provide assistance in the design of workshops that explore and deliberate different approaches to using green areas alternatives as a flood control measure. Four different workshops have been held so far that included nine presentations from scientists and professionals from backgrounds in climate change, hydrology, green infrastructure, landscape architecture, and program development. In addition to specific cases in Puerto Rico, two cases, one from the Kissimmee River in Florida and the Jordan River in Salt Lake City, were also presented. More details on the workshops and presenters can be found on the projects website (http://www.lacuencadelriopiedras.com). A key outcome of this effort is the formation of a civic alliance to bring together the various participants and stakeholders that these workshops convened. Institute and San Juan ULTRA scientists will continue to support and work with the Municipality and the alliance to explore sustainable pathways towards flood resilience for the city.

Collaborating Institution: Municipality of San Juan; University of Puerto Rico, Medical Sciences; University of Puerto Rico, Río Piedras

Institute Contact: Tischa Muñoz-Erickson, tamunozerickson@fs.fed.us

Participants at a workshop hosted by the Municipality of San Juan at the Museo de Vida Silvestre.

M. Santiago

Butterfly project on the green roof at the Institute's spatial analysis laboratory.

Wildlife Ecology and Biodiversity Conservation

Through the Institute's Wildlife and International Cooperation programs' collaborative scientific investigations, technological advice and outreach to local governments, universities, NGOs, and indigenous communities, long-term research and the conservation and management of remaining tropical submontane (cloud) forest is promoted in Nicaragua's Northern Highlands Ecoregion, along with dry forest and wetlands ecosystems in southern Nicaragua's Paso del Istmo Biological Corridor. What follows are some key findings from several ongoing projects.

Complex landscape matrices in tropical America as biodiversity strongholds

Forest management to promote biodiversity and ecological restoration in the Neotropics is complex, especially in montane agroforestry landscapes currently experiencing increasing pressure from the effects of regional climate change. Often bioindicator taxa are used to summarize the effects of disturbance, describe observed changes and help raise awareness of the biological consequences, and to assist in identifying conservation targets and to guide adaptive and ameliorative measures. We used birds, nymphalid butterflies and land snails as bioindicators of habitat degradation and to track the effects of climate change in five montane agroforestry management systems: cloud forest, riparian, early serial regeneration, pasture and grasslands, and shade coffee, one of the premiere cash crops in the region. Our studies were conducted in agroforestry lands at three locations in the Jinotega Province, two within the Datanlí-El Diablo Natural Reserve at the Juan Roberto Zarruk Biological Station, Finca Santa Maura, within the Cerro Datanlí-El Diablo Natural Reserve, the Cerro EL Gobiado, and a disjunct cloud forest within the El Jaguar Private Wildlife Reserve. Of the 6,679 detections of 215 bird species, five forest-dependent species (Golden-crowned Warbler, Black-faced Antthrush, White-breasted Wood-Wren, and Ochre-bellied Flycatcher) showed predictable population decreases as forest cover diminished. Of the 49 butterfly species collected (227 individuals), only one species, *Satyrotaygetis gigas*, showed population declines with ecosystem disturbance. Although none of the 42 species of molluscs (590 individuals) showed declines with habitat deterioration, three species were restricted to forest (*Euglandina obtuse*, *Helicina oweniana*, *Helix trigonostoma*). These bioindicators will help fill gaps in assessment issues of agroforestry ecosystems, natural and private reserves, and areas of payment for environmental services, all of which are related to the preservation and sustainability of the region's natural resources.

Institute Contact: Wayne Arendt, warendt@fs.fed.us

Long-term biomonitoring documents the importance of agroscapes in measuring biodiversity at local and landscape levels

Nicaragua biodiversity monitoring and training.

Our biodiversity and climate change research was carried out along the Pacific Slope Ecoregion within the Paso del Istmo Biological Corridor (PIBC) in southeastern Nicaragua, and at the Juan Roberto Zarruk Biological Station, Finca Santa Maura, within the Cerro Datanlí-El Diablo Natural Reserve in Nicaragua's Northern Highlands Ecoregion. Of the 168 species of birds detected in the PIBC, the significant correlation between habitat type and forest-interior birds, as well as other bioindicator species of forest health and sustainability, underlined the importance of the preservation and management of mature forest remnants with ample understory, younger wooded tracts and brushy areas under regeneration to preserve and promote biodiversity among similar agroscapes within the Paso del Istmo. Of the 123 species of birds and 29 species of nymphalid butterflies detected among five habitat types in the Northern Highlands, i.e., secondary and riparian forest, forest fallow, coffee plantation, and pastureland with scattered trees, coffee plantations had the highest avian species richness, whereas forest fallows harbored the most species of nymphalid butterflies. Among the most common species observed (within both taxa), many were forest-dependent, further demonstrating that anthropic landscapes are vital in maintaining a rich biodiversity. Within the interior of the coffee plantations, which are interspersed within a complex matrix of remnant forest, we found forest-interior and bioindicator species of birds and butterflies. This supports the argument that agroecological practices and resultant agroscapes, concomitant with the preservation of forest remnants, have a positive effect at the local landscape level and are an integral piece of the major ecosystem mosaic generally used to measure biodiversity at local and landscape levels.

Related Publications: Herrera-Rosales, H.M., Tórrez, M., Arendt, W.J. 2014. Registros del Cuco Hormiguero (Neomorphus geoffroyi) en la Reserva de Biósfera de Bosawas, Nicaragua. Zeledonia 18: 55–61; www.treesearch.fs.fed.us/pubs/48942

Maes, J.M., Tórrez, M.A., Covlin, V., and Van den Berghe, E. 2014. *Memphis philumena* (Lepidoptera: Nymphalidae), nuevo para la fauna de Nicaragua. Revista Nicaragüense de Entomología, 7 pp.

Institute Contact: Wayne Arendt, warendt@fs.fed.us

Pilot assessment of mercury exposure in selected biota from the lowlands of Nicaragua

Lacustrine and wetlands populations of vertebrates inhabiting the Neotropics, including humans, piscivorous and insectivorous birds, as well as ground-foraging invertivores such as basilisk and *Ameiva* lizards, exhibited elevated levels of methylmercury (MeHg) in blood, hair, or feathers (as high as 0.72 ppm) as a result of methylation, biomagnification upwards through the food chain, and bioaccumulation as residuals in their tissues and circulatory systems. Feather MeHg concentrations exceeded >3.0 ppm in several species of Nearctic-Neotropical migratory birds sampled. Birds from a riverine wetland near agricultural cultivations east of Cárdenas (río Tirurí) on Lake Nicaragua had the highest MeHg concentrations of all the invertivores sampled at all sites. The two sites with lowest MeHg concentrations were the Pacific coast sites (a riverine wetland and mangrove forest). Whereas the low levels of the MeHg contaminant in the Pacific coast wetlands are encouraging from both environmental and health risk standpoints, the elevated levels of MeHg found in the human population, piscivorous and ground-foraging birds and reptiles inhabiting the wetlands bordering Lake Nicaragua is particularly troublesome, owing to the increased threat to human health and development as well as the heightened probability of affecting local and regional biodiversity resulting from poor reproductive performance of resident and migratory birds. Additional research is planned and the authors are working closely with the Nicaraguan Government's Department of Natural Resources in drawing up plans to assess and reduce the accumulation of MeHg in the environment.

Related Publication: Lane, O., Arendt, W.J., Tórrez, M., and Cruz Gámez Castellón, J. 2013. Pilot assessment of mercury exposure in selected biota from the lowlands of Nicaragua. Mesoamericana 17: 19–28.

Institute Contact: Wayne Arendt, warendt@fs.fed.us

Sampling for mercury poisoning.

Long-term research on the dry forest avian community in the Guánica Biosphere Reserve

Declared in 1919 under the administrative authority of Puerto Rico's Insular Forest Service, the Guánica Commonwealth Forest (also known as Guánica State Forest, or Bosque Estatal de Guánica) is located in southwestern Puerto Rico about 160 km (100 miles) and a 2-hour drive from San Juan. The Guánica Commonwealth Forest was renamed the Guánica Biosphere Reserve in 1981 when it was designated as part of UNESCO's (United Nations Educational, Scientific, and Cultural Organization) program on Man and the Biosphere (MAB). The Reserve covers 4400 ha along an elevational gradient of 0 to 228 m (752 feet) above sea level, comprising diverse coastal habitats, including deciduous and semi-evergreen forests, wetlands, several mangrove cays, and 21 km (13 miles) of undeveloped coastline and marine estuaries. We began conducting research and monitoring in the Guánica dry forest in 1973. To date, 185 species of birds, the reserve's dominant vertebrate taxon, have been recorded: 97 permanent residents or summer breeders and visitors, and an almost equal number (88) of "wintering" or passage migrants and transients. Of Puerto Rico's 17 species of endemic birds, all but 2, the Puerto Rican Parrot and Elfin-woods Warbler, occur within the confines of the Reserve. This guide will serve as a baseline for tracking forest bird population fluctuations concomitant with global warming and the ever-changing climate.

Related Publications: Lane, O., Arendt, W.J., Arendt, W.J., Faaborg, J., Canals, M., and Bauer, J. 2015. Bird checklist, Guánica Biosphere Reserve, Puerto Rico. Research Note SRS-23. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 23 p.

Institute Contact: Wayne Arendt, warendt@fs.fed.us

W. Arendt

Training Nicaraguan university students.

Plant functional attributes used to inform conservation planning and management for endangered bird habitat

As part of our collaborative research on the habitat characteristics of the endangered migrant Kirtland's Warbler (Aves; *Setophaga kirtlandii*) on its wintering grounds in The Bahamas, we published our studies of two fruiting plant species important to the warbler (Fleming et al. 2015). The shrubs black torch (*Erithalis fruticosa,* L.) and wild sage (*Lantana involucrata*, L.) are especially important in the diet of the warbler during the dry season at the end of the winter. These two shrubs occur in recently disturbed sites. We sought to determine, based on functional characteristics of the plants, whether a particular type of disturbance in The Bahamas favors their presence. We used data from our field experiments (i.e., seed broadcasting and shrub cutting) to determine mechanisms and conditions favoring establishment and persistence ("vital attributes") of the two shrubs and categorized them into the plant functional types as previously defined in the literature. We then compared hypothesized distributions of these plant functional types among different anthropogenic disturbance regimes to observed distributions of the two shrubs to identify disturbance regimes most likely to produce the warbler's habitat. Among the anthropogenic disturbances examined, areas of large-scale land clearing combined with subsequent goat grazing most often supported the shrubs, which were rare in burned areas.

Juvenile male Kirtland's Warbler in The Bahamas (top), black torch (lower right), and wild sage (lower left).

Both shrub species were functionally categorized as widely dispersed, but largely shade intolerant species capable of establishing or regenerating after disturbance via both seeds and vegetative mechanisms. Utilizing a plant functional type framework to predict species occurrence among different disturbances regimes and evaluating those predictions with field data provides a strong theoretical basis for conservation strategies. Understanding which regimes of disturbance favor a habitat of concern can aid the prioritization of areas for protection or the design of habitat management protocols for the warbler and other species.

Institute Contact: Joseph Wunderle, jwunderlejrfs.fed.us

Avian conservation planning priorities for Puerto Rico and the U.S. Virgin Islands

Institute scientists involved in the Caribbean Landscape Conservation Cooperative collaborated with research and management partners to produce a report that highlights conservation planning priorities for birds throughout Puerto Rico and the U.S. Virgin Islands. The report synthesizes dozens of previous research, planning, and management efforts spanning multiple taxonomic groups and spatial scales to provide an up-to-date summary of the regional avifauana, anthropogenic and non-anthropogenic threats, as well as opportunities and strategies for protecting individual species, community groups, and habitat throughout the study area. An important goal was to showcase important breeding and migratory birds, their conservation status, and habitat needs. While this document is not itself a comprehensive plan, the conclusions within are aimed at guiding island-wide and regional avian conservation planning and management actions that will help maintain or increase populations over the next 20-25 years. Specific population objectives for 144 species were determined using the Partners in Flight prioritization process. Analysis of species distribution and stewardship management data from the Gap Analysis Project were integrated with existing literature to identify priority areas and establish quantitative habitat targets. Recommended actions include protecting rare and critical habitats, building upon protected areas to create convergent habitat linkages among jurisdictions and across public and private lands, and increasing monitoring of population trends of vulnerable species and responses to interspecies interactions, habitat loss, and climate change effects. These actions can be supported via a suite of strategies including expanding private lands and public engagement/monitoring programs, developing multi-level governance partnerships to integrate bird conservation with natural resource management and land use planning programs, fostering of increased coordination among various conservation-oriented entities, and improving outreach communication of science-based information to help in the conservation of avian species and habitats.

Collaborating Institutions: University of Puerto Rico-Río Piedras, U.S. Fish and Wildlife Service, and the Atlantic Coast Joint Venture.

Related Publication: Nytch, C. J., Hunter, W. C., Núñez-García, F., Fury, C., Quiñones, M., & Collazo, J. (February, 2015). Avian conservation planning priorities for Puerto Rico and the U.S. Virgin Islands (BCR 69). http://acjv.org/documents/PRUSVI_plan.pdf

Institute Contact: William Gould, wgould@fs.fed.us

G. Gonzalez

International Cooperation

Program Manager: Gerald Bauer, gbauer@fs.fed.us

International Cooperation conducts research and provides technical assistance and technology transfer throughout Central America and the Caribbean. Our primary focus areas for the past two years have been the Dominican Republic and Nicaragua. Additionally, we have cooperated with partners in more than 20 countries around the globe.

Global Activities

- International Cooperation participated in the U.S. Forest Service-USAID Disaster Assistance Support Program (DASP). This involved completing training to qualify in disaster response management, planning, operations, preparedness and prevention.

International Cooperation staff: Yaneris M. Soto Muñiz, Communications Intern; Mara C. Santana, Communications/Social Marketing Intern; Yanira L. Cortés, Support Service Specialist; Gerald Bauer, Program Manager.

Regional Activities

Several International Cooperation activities were carried out at the regional level, including the following:

Scientific Paper Presentations

- Integrando la investigación y educación ambiental para conservar las especies emblemáticas (Amazona auropalliata), Paso del Istmo, Nicaragua. Julio Martónez Velásquez, Martín Lezama López, y Kimberly Williams.
- Aves de Paso del Istmo, Rivas, Nicaragua, con énfasis en especies indicadores dependientes de bosque. Marlon Sotelo Reyes, Marvin Tórrez Gutiérrez, y Wayne Arendt.
- Evaluación de talleres ecológicos y aprovechamiento de plantas en entoros urbanos, Valle Central de Costa Rica. Katherine Ulate Gómez, Alberto Rico U. y Sofia Peñaranda Oses.

Poster Presentations

- La Red de Monitoreo Terra: Entender la Contaminacíon de Mercuro en Ecosistemas Terrestres. David C. Evers, David G. Buck, Oksana Lane, Wayne Arendt, et. al.
- Mercurio en Aves Residentes y Migratorios Neotropicales en Nicaragua, Selección de las Especies Indicadores. Oksana Lane, Wayne Arendt, y Marvin Tórrez.

Workshops and Working Groups

- Participated in and gave technical presentations at regional USAID climate change meetings and workshops.

Conservation education in Nicaragua. M. Dolkas

- Participated in Partners in Flight and Rocky Mountain Bird Observatory international working group on bird conservation to evaluate status of all birds in Central America. The Institute provided information based on 20 years of research in Nicaragua.
- Participated in Partners in Flight Western Working Group seminar sessions.
- Provided assistance to the Mesoamerican Society for Biology and Conservation.

Nicaragua Activities

International Cooperation continued with our long-term research, technical assistance and technology transfer to Nicaragua, with focus on the Paso del Istmus Biological Corridor with our NGO partner Paso Pacífico (www.pasopacifico).

Nicaraguan Junior Ranger parrot telemetry.

Research Support

For highlights of the Nicaragua research activities supported by IC, see the Wildlife Ecology section of this report and projects related to biodiversity monitoring and the effects of climate change.

Technology Transfer and Technical Assistance

More than 2,000 persons participated in IC technology transfer and technical assistance activities.

Highlights include the following:

- Sponsored technical seminar on bird conservation and conservation education.
- Organized technical seminar and guide training for the first Nicaragua Bird Festival
- Conducted workshops and conservation education activities and long-term monitoring on mammals (bats and monkeys), birds, and reptiles (sea turtles). Trained more than 50 local youth on monitoring techniques.
- Trained 250 Hispanic "Junior Rangers" from underserved, small communities in conservation techniques.
- Provided 150 pairs of binoculars to local youth.
- Presented conservation programs on local TV and radio stations, with more than 100,000 viewing.
- In coordination with the National Tourism Chamber of Commerce and the communities of Pearl Lagoon, completed the book "Pearls from the Lagoon, short stories & recipes."
- Institute partner NGO Paso Pacífico developed a variety of curriculum around bat, jaguar, and bird education for over 200 K-12 children in four communities in the Paso del Istmo. Students participated in workshops to learn wildlife identification and monitoring techniques and take field trips to observe wildlife in their habitat, learning the importance of these animals to the ecosystem and to respect them in their native environments.

Watershed mapping in Nicaragua.

M. Dolkas

Dominican Republic Activities

Nicaraguan community wildlife education.

International Cooperation provided leadership, mentorship and research, technical assistance and technology transfer to Dominican Republic partners in biodiversity conservation and sustainable tourism activities in local, underserved and disadvantaged, Hispanic communities, and tourism clusters in coordination with the Dominican Consortium for Tourism Development. We completed the Sustainable Tourism and Biodiversity Conservation project and started a new project, "Conservation and Sustainable Management of Urban Watersheds as Mechanisms for Adaptation to Climate Change."

Our primary focus was to assist Dominican Republic tourism clusters with biodiversity conservation and sustainable tourism development through on-the-ground technical assistance and training programs that included:

- Conducting biological assessments for project activities;
- Providing technical training for communities to develop ecotourism activities;
- Providing promotion and marketing assistance;
- Providing information to support environmental education; and
- Providing technical support to the Ministry of Environment in support of protected area management.

Activities Accomplished

- In coordination with local partners, completed and inaugurated the first accessible trail in the Dominican Republic. This trail is located in the National Botanical Garden. It was inaugurated by the U.S. Ambassador and USAID Director.
- Assisted the U.S. Embassy Speaker Program by hosting Terestella Gonzalez-Denton, former President of the Puerto Rico Tourism Board, to give presentations in Dominican Republic universities and local communities on community tourism development. A total of about 150 persons participated in these events.
- In coordination with the Technological University of Santo Domingo, gave the invited presentation "Social-ecological systems change, vulnerability, and the future of a tropical city" at the "Conferencia Científica Internacional, Sostenibilidad y Cambio Climático, SYCC14."
- Presented programs on sustainable tourism development in Dominican Republic on local TV and radio stations, with more than 50,000 individuals viewing these presentations.

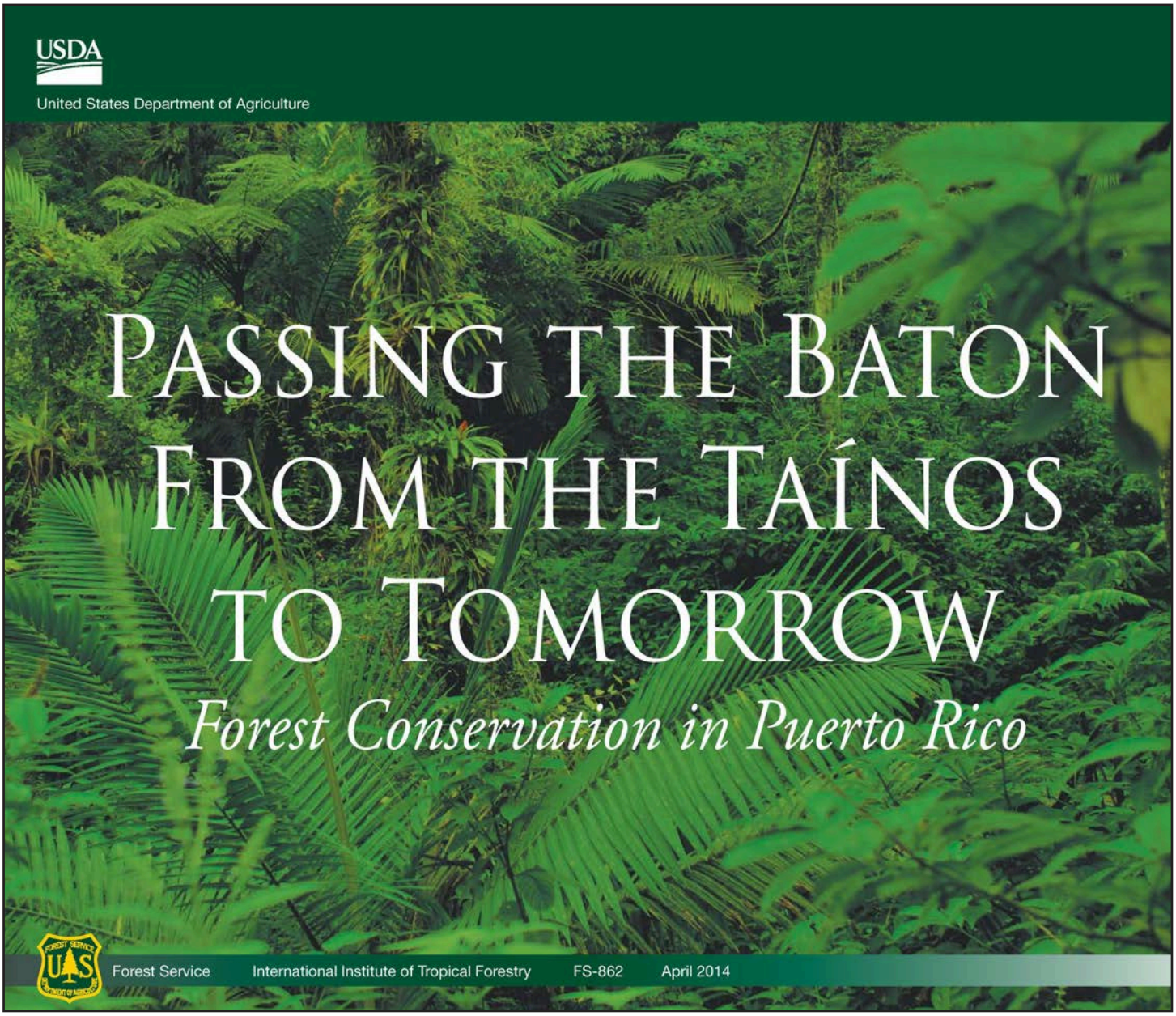
Training a local research technician in the Dominican Republic.

B. Nina

Puerto Rico Activities

International Cooperation accomplishments in Puerto Rico include:

- Completed the book "Passing the Baton," in honor of the Institute's 75th anniversary celebration. A public event was held with more than 100 persons present to inaugurate the book.
- In cooperation with the University of Puerto Rico, received a research grant under the Partnerships for Enhanced Engagement in Research (PEER) Program, for "Exploring Sustainable Solutions Aiming at Redressing Environmental Disasters in Haiti."



Nicaraguan Junior Ranger certification.

M. Sotelo

State and Private Forestry

Acting Program Manager: Magaly Figueroa, mafigueroa@fs.fed.us

State and Private Forestry provides professional, technical, and financial assistance to state agencies, universities, and non-profit organizations within Puerto Rico and the U.S. Virgin Islands (St. Thomas, St. Croix, and St. John). Through targeted 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, forest health, urban and community forestry, cooperative fire protection, 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 natural area restoration), 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.

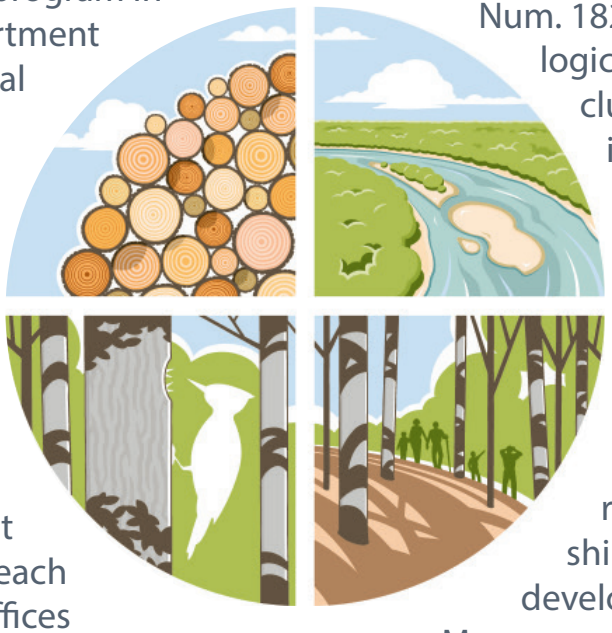
State and Private Forestry staff: Jorge Morales, Technical Information Specialist; Gisel Reyes, Technical Information Specialist; Kevin Carlin, Forest Entomologist; Aixa Mojica, Program Support Assistant; Magaly Figueroa, Acting Program Manager and Natural Resources Specialist; absent: Evelyn Pagán, Library Technician.

Tree harvesting workshop.

M. Figueroa

Forest Stewardship Program

The Forest Stewardship Program continued providing technical assistance to private landowners in Puerto Rico and the U.S. Virgin Islands for the development of management plans that promote sustainable management of forest resources. The program also provides educational opportunities related to diverse conservation initiatives and practices. Partner institutions for this program include the Puerto Rico Department of Natural and Environmental Resources Forest Service Bureau, and the U.S. Virgin Islands Department of Agriculture for the implementation of the program.



The DNER Stewardship Program in Puerto Rico focused on developing at least two management plans by each one of the seven regional offices and concentrating efforts in the Important Forest Resource Areas identified for Puerto Rico. The agency also contracted Cafiesencia, a nonprofit group, for the development of management plans in the Maricao Joint Priority Landscape. Moreover, the DNER partnered with the Tropical Agricultural Research and Higher Education Institute in Costa Rica (CATIE) to offer the course Diversified Management of Tropical Forests, a five-day training to strengthen the technical expertise on management of private forests. The course included agroforestry, forest products, non-timber forest products, certifications, and forestry and community management models. The same group participated in a workshop hosted by the Institute on the use of the Stewardship Mapping and Accomplishment Reporting Tool (SMART), an internet tool developed by the Forest Service for the creation of Forest Stewardship Management Plans. In 2014, the Commonwealth of Puerto Rico passed the Puerto Rico Model Forest Act under the Commonwealth Law Num. 182. It recognizes the ecological value of the lands included within, by declaring it a new priority area for planning, conservation, and for the inclusion of new non-industrial private forest lands.

In the U.S. Virgin Islands, the Department of Agriculture Forest Stewardship Program continued developing Forest Stewardship Management Plans for private landowners, successfully using SMART. Those plans are evaluated and approved by the Forest Stewardship Coordinating Committee. Previously, the plans were prepared by a private contractor hired by the U.S. Virgin Islands Department of Agriculture. In December, 2015, the department hired a new Forest Stewardship Coordinator, Louis Hilgemann, who will also serve as the Forest Legacy Coordinator.

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Forest Stewardship Program Accomplishments in Puerto Rico and the U.S. Virgin Islands

Performance Measures	Puerto Rico		U.S. Virgin Islands	
	2014	2015	2014	2015
Non-Industrial Private Forests in Important Forest Resource Areas (acres)	1,182,964	1,182,964	44,508	44,508
New Forest Stewardship Management Plans (number of plans)	9	21	2	3
Acres for New Forest Stewardship Program Management Plans	1,274	1,779	88	258
Acres in Important Forest Resource Areas	1,274	1,779	75	258
Acres Covered by Current Forest Stewardship Plans	1,976	2,573	240	1,267
Acres in Important Forest Resource Areas Covered by Current Forest Stewardship Plans	1,274	1,779	188	394
Landowners Assisted	15	26	33	18
Landowners Educated	15	1,689	34	18
Acres Covered by Practice or Other Forest Management Plans	--	859	--	0
Acres in Important Forest Resource Areas Covered by Practice or Other Forest Management Plans	--	859	--	0

Blue mahoe (*Taliparitielatum*) hardwood products

Shade grown coffee farmers as bird custodians

Cafiesencia, a community based nonprofit group, received a grant from the Forest Service to develop a project proposed to educate and build capacity among farmers and communities and promote conversion to and maintenance of shade grown coffee farms. The initiative is called Cafeicanto, which provides social, environmental, and economic opportunities to communities and private landowners through the implementation of agroforestry practices in the Puerto Rico Coffee Zone. Nine important watersheds originate in this zone, which also includes the PR005 Maricao/Susua Important Bird Area (IBA), which provides habitat to important neo-tropical migratory birds. The project area was divided in four modules: Maricao Module which includes Las Indieras and Montoso wards, and San Germán municipality upper wards; Yauco/Sabana Grande Module, which includes Rancheras, Frailes, and Collores wards in Yauco, and Tabonuco and Susúa wards in Sabana Grande; Río Prieto/Castañer Module, and Las Marías Module. Cafeicanto educated and trained coffee farmers and communities in agroforestry practices emphasizing shade grown coffee techniques and promoting the conversion of sun coffee to shade. Cafeicanto also partnered with the Puerto Rico Ornithology Society and Birdlife International to train farmers in bird monitoring techniques, electronic reporting tools, and the identification of eco-agrotourism opportunities. By the end of the training those farms were incorporated in the Birdlife/IBA Efforts Network, each one received their certification, and a customized bird guide to identify the birds in the properties.

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Coffee beans.

Community Forest and Open Space Program

The Río Hondo community forest

The Puerto Rico Municipality of Mayagüez, in partnership with the community based nonprofit organization Proyecto Comunitario Agro Eco Turístico del Barrio Río Hondo, Inc., (Estampas), received funding from the Community Forest and Open Space Program to acquire 67.99 acres of land located in the Río Hondo Ward. The property is the only large block of continuous forest remaining in the area and is surrounded by sub-urban communities, rural subdivisions, and several housing projects. Estampas has been leasing the property for over nine years and wanted to have the opportunity to acquire the land but was having problems identifying funding sources to complete the match required by the program. They reached out to the Muncipality of Mayagüez Mayor José Guillermo Rodríguez, who has supported the group for many years, and who agreed to present the proposal to the Forest Service. Once the Municipality of Mayagüez signed the grant with the Forest Service, Estampas began the formal process that precedes the acquisition of the land and identified the entity that will assist in the preparation of the management plan. The University of Puerto Rico in Mayagüez, College of Agricultural Sciences, is collaborating with the Municipality and Estampas to develop the community forest management plan. University professors Germán Ramos, Ph.D. and Oscar Abelleira, Ph.D., are in charge of assisting the community to develop the management plan. The first meeting with the community was held on November 3, 2015. The meeting was dedicated to presenting the Community Forest and Open Space Program to the attendees, discussing basic forest management concepts, community empowerment, and activities that are compatible with the program specifications. Attendees also identified activities they want to have on the property, and the information which was collected by Drs. Ramos and Abelleira. Dr. Abelleira for inclusion in the management plan. A small portion of the property is used to house the Estampas' operational headquarters, which consist of a trailer used as an office and a conference room for meetings and community workshops. The group also established tree green houses that produce plant material and vegetables for sale for fundraising purposes. The rest of the property (90%) is forested and consists of post-abandonment secondary forest. The forest regenerated through natural processes after cessation of previous agricultural practices associated with sugar cane, coffee, and grazing. The forest is composed of trees of white acacia (*Albizia procera*), guaraguao (*Guarea trichiliodes*), fruit trees such as mango (*Mangifera indica*), guamá (*Inga laurina*), shrubs, and old coffee trees (*Coffea arabica*). The forested portion of the property is used for educational, cultural, and recreational activities by the community, academia, students from the Consuelo Pérez Elementary School in Río Hondo, AmeriCorps volunteers, and many others.

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Río Hondo community forest.

Urban and Community Forestry Program

The goal of the Urban and Community Forestry (UCF) Program is to promote the conservation of our urban trees and forests. Each year, community members and volunteers participate in the development of urban forest management plans, tree planting activities, workshops and educational talks, and activities with kids. The UCF Cost Share Program provides financial resources to community groups for the implementation of conservation and management initiatives and educational opportunities related to urban green spaces. In Puerto Rico the program is administered by the Department of Natural and Environmental Resources Forest Service Bureau, and in the U.S. Virgin Islands by the Department of Agriculture. Each agency has appointed an Urban and Community Forestry Coordinator that works with local urban and community forestry partners. The Urban and Community Forestry Council advises State Foresters to plan program implementation, develop public policy for the protection and conservation of urban forests, and administer the Cost Share Program.

Pruning training to municipal emergency management officials.

The Puerto Rico DNER Forest Service Bureau continued efforts promoting urban community forestry and making available financial assistance to the community groups in Puerto Rico. To encourage community participation, the DNER and the Puerto Rico UCF Council updated their Guide for the Preparation of Proposals for the Urban and Community Forestry Cost Share Program, and offered a series of workshops in different parts of the island to train those groups in the use of the guide and answer questions related to the UCF Program authorities.

To improve technical expertise in urban forestry, the DNER offered five workshops on "Green Infrastructure" to forest technicians, management officials, and other technical personnel from the Forest Service Bureau working on the Urban and Community Forestry Program.

In the U.S. Virgin Islands, the Department of Agriculture and the UCF Council have been very successful in the promotion of the program and encouraging the participation of community groups in the Cost Share Program. The Urban and Community Forestry Program funds were used to reforest and rehabilitate urban parks, plant native trees, install irrigation systems, and educate the public at the Ag-Fair in St. Croix and environmental fairs hosted in St. John and St. Thomas.

Caribbean Urban and Community Forestry Strategic Plan discussing session.

The U.S. Virgin Islands Department of Agriculture UCF council completed the final draft of the Urban Forestry Law. This document was presented to stakeholder audiences in both St. Croix and St. Thomas, and modifications were made as a result of those facilitated meetings. The final draft law was presented to Senator Myron Jackson for his support and is now making its way through the legislative committee. Senator Jackson hopes to present it to the full Senate for approval during 2016.

In March 2015, the Puerto Rico and U.S. Virgin Islands Urban and Community Forestry Councils completed the process of creating a new Caribbean UCF Strategic Plan. The process began in March 2014 when both UCF councils met for a week in Ponce, Puerto Rico. This final plan outlines the activities needed to comply with the joint Strategic Plans. This is the first time that the U.S. Virgin Islands and Puerto Rico Urban and Community Forestry Councils worked together towards several common goals, and it is hoped that in the future, these councils can participate in joint activities to achieve their common goals. As a result the UCF Councils agreed on the following:

Our Common Vision Statement:
Our education efforts and strategic actions ensure the enduring benefits and environmental services of urban forests in the Caribbean landscape, enhancing community well-being and mitigating the effects of climate change.

Our Common Mission Statement:
Promote the proper management and sustainability of urban forests to improve the wellbeing of the Caribbean communities through education efforts, technical assistance, and partnerships between the public and private sectors.

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Urban and Community Forestry Certificate Program

The Center for Sustainable Development Studies of the School of Environmental Affairs at the Metropolitan University partnered with the International Institute of Tropical Forestry Urban and Community Forestry Program to develop the first continuing education program leading to a university professional certificate in Urban and Community Forestry. The certificate includes courses that will provide the participants with basic theoretical and technical knowledge to work in the protection, establishment, and management of trees in urban areas, business development, and community participation agreements for the co-management of forests and urban parks. The program consists of seven core courses and 105 contact hours for a total of 132 contact hours to complete the professional certificate. The certificate provides topics for all students, from architects, horticulturists and landscape design professionals, senior university students, and community members. For more information on the Urban and Community Forestry Certificate Program please visit the website http://cedes-umet.suagm.edu/,

Complementing this educational initiative, the Center produced three urban forestry videos for teachers and students and are available free of cost on its website. To access the videos please visit the following address: http://cedes-umet.suagm.edu/videos.asp. The videos are: Green Infrastructure, Trees for Urban Areas, and Maintenance of Urban Trees. Each video has a fact sheet with activities for the students and can be downloaded from the site.

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Urban and Community Forestry Program accomplishments in Puerto Rico and the U.S. Virgin Islands

Urban and Community Forestry Program Accomplishments	Puerto Rico		U.S. Virgin Islands	
	2014	2015	2014	2015
Percentage of population living in communities **managing** programs to plant, protect, and maintain their urban and community trees and forests.	23.74%	23.24%	0.00%	0.00%
Percentage of population living in communities **eveloping** programs and/or activities to plant, protect, and maintain their urban and community trees and forests.	0.00%	0.22%	21.92%	10.94%
Number of people living in communities provided educational, technical, and/or financial **assistance**.	704,295	710,821	23,809	11,881
Number of people living in communities that are **developing** programs/activities for their urban and community trees and forests.	0	6,526	23,809	11,881
Number of people living in communities **managing** their urban and community trees and forests.	704,295	704,295	0	0
Number of communities with active urban and community tree and forest **management plans** developed from professionally-based resource assessments/inventories.	33	33	7	7
Number of communities that employ or retain through written agreement the services of **professional forestry** staff who have at least one of these credentials: (1) degree in forestry or related field; (2) ISA certified arborist or equivalent professional certification.	225	225	7	7
Number of communities that have adopted and can present documentation of local/statewide **ordinances or policies** that focus on planting, protecting, and maintaining their urban and community trees and forests.	261	263	0	0
Number of communities with local **advocacy/advisory organizations**, such as active tree boards, commissions, or non-profit organizations that are formalized or chartered to advise and/or advocate for the planting, protection, and maintenance of urban and community trees and forests.	27	27	3	7
Number of hours of **volunteer service** logged (an agency -wide consistent metholodogy to be developed to track volunteer hours).	58,047	156,864	976	6,698

Educational Outreach

Project Learning Tree

The Institute partnered with the Puerto Rican Department of Natural and Environmental Resources (DNER) to sponsor the Project Learning Tree (PLT) program for the first time in Puerto Rico. Project Learning Tree is an award-winning environmental education program that is supported by a network of over 500,000 trained educators across the globe. By training teachers, educators and community leaders to use the PLT curriculum, this program integrates environmental education and outdoor learning components into all subject areas of the classroom. Using the PLT materials, students are taught how to think, not what to think, about complex environmental issues. On July 23rd and 24th 2014, the Institute and the DNER offered a Project Learning Tree facilitator training in Spanish at the Botanical Garden Río Piedras. Senior Vice President of the PLT organization, Kathy McGlauflin, was joined by other bi-lingual educators previously trained in the PLT curriculum to offer this workshop (a "train the trainers" event). Educators and biologists from the DNER, U.S. Forest Service, U.S. Fish and Wildlife Service, and other local organizations were among the first group of trained facilitators to attend this event. After receiving this training, facilitators are qualified to hold workshops across the island in order to teach educators how to incorporate the materials into their classroom.

Studies show that when environmental education and outdoor learning components are integrated into school programs, students improve their mastery of science, math, language and spelling, while simultaneously exhibiting enhanced cooperation and conflict resolution skills and gaining in self-esteem. The Institute is proud to show its commitment to increasing environmental literacy through science-based education by sponsoring PLT for the very first time in the Caribbean!

For more information about the program and how to become a PLT educator in Puerto Rico, please visit the Project Learning Tree website: https://www.plt.org/.

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Project Learning Tree workshop with teachers and natural resources specialists.

Conservation and resource management education

Environmental Interpretation

In February, 2015, the National Association for Interpretation (NAI) Southeast Region chapter celebrated its Annual Workshop in Humacao, Puerto Rico. The activity was hosted by the Puerto Rico Department of Natural and Environmental Resources. The workshop offered training on interpretation skills for communities, environmental organizations, concessionaires and DNER staff. The workshop proceedings were published and NAI recognized Puerto Rico as one of the jurisdictions with the highest number of certified interpreters.

Green Contact Program

The Puerto Rico Legislature approved the Green Contact Program Act, Law No. 36 of March 2015. The Program will be administered by the Puerto Rico Department of Education and developed in coordination with the DNER. The program promoted the participation of students in workshops and visits to areas of ecological value in order promote their contact with nature. The Department of Education in collaboration with the DNER designed a Circular Letter to implement this Law. Local Commonwealth and federal agencies, NGO and private entities representatives were identified to create a Green Contact Network.

Guide for Safer Trees in the Landscape

A publication funded by the U.S. Virgin Islands Urban and Community Forestry Program, the University of the Virgin Islands, and the U.S. Forest Service's Renewable Resources Extension Act was printed and is available for distribution. The Guide for Safer Trees in the Landscape, a 43-page handbook provides information on how to recognize and manage hazardous tree conditions. The handbook is illustrated with photographs of tree conditions that can be seen along roadways throughout the U.S. Virgin Islands and includes symptoms of tree stress on the roots, trunks, and canopy, and other symptoms of unhealthy trees, such as cracks, advanced decay, and deadwood. It includes sections on the value of trees in the environment, basic tools for tree management, and how to hire an arborist. The handbook is intended to be used by U.S. Virgin Islands citizens in their evaluation of their own trees for possible hazardous conditions. For more information about this publication, please contact Marilyn Chakroff, U.S. Virgin Islands Urban and Community Forestry Program Coordinator at (340) 778-0997 or via email marilyn.chakroff@gmail.com.

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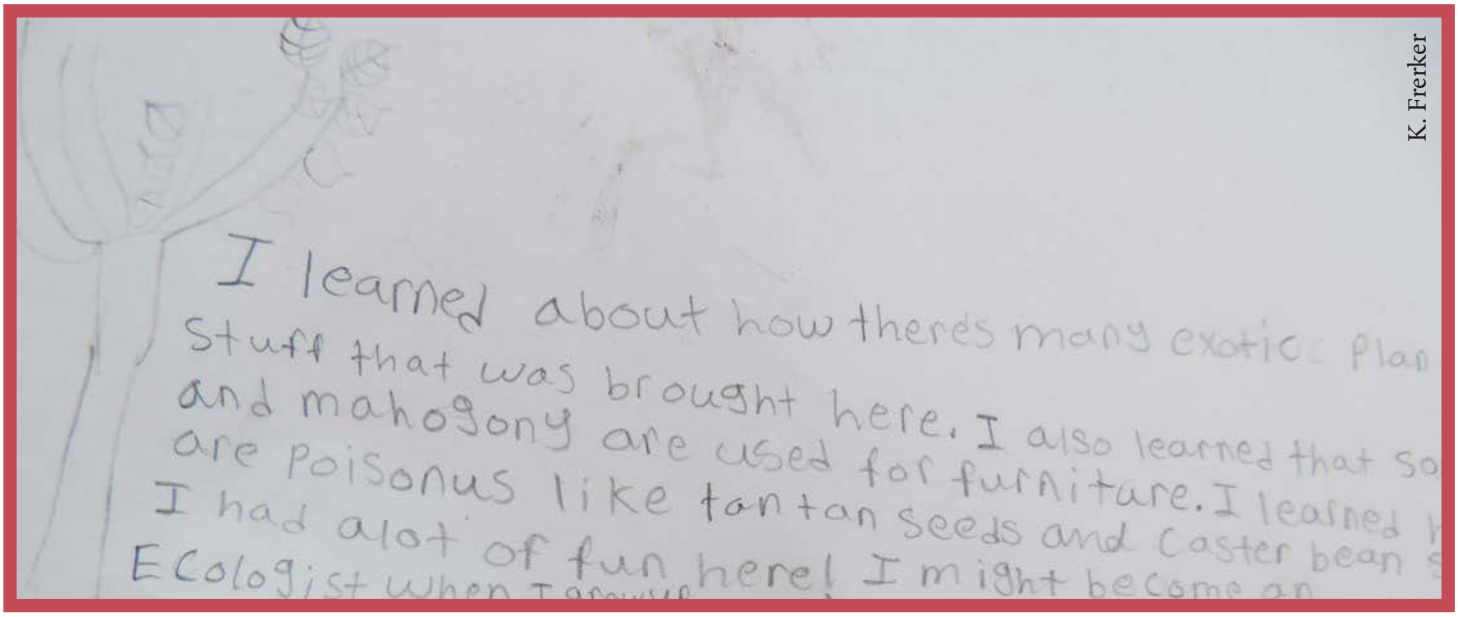

Student response to Forest Field Day actvities.

Forest Field Days at Estate Thomas

The Institute partnered with U.S. Virgin Islands non-profit, St. Croix Environmental Association to implement Forest Field Days, an environmental education program for fourth grade students that began in 2013. The Field Days, funded by the Forest Service's More Kids in the Woods program, took place at Estate Thomas Experimental Forest, a Forest Service property on St. Croix which was established in 1964. At each Field Day event, fourth graders from around the island rotated through a series of learning stations in the forest to participate in activities related to tree biology, plant identification, insect diversity, native and introduced species, watershed function and climate change. Each child also had the opportunity to hike through the forest with a guide who described the history of the Estate Thomas and the native and introduced trees that are found there. Partner agencies who presented at the events included the National Park Service, U.S. Virgin Islands Department of Planning and Natural Resources East End Marine Park, Univeristy of Virgin Islands Cooperative Extension Service, St. Croix Hiking Association, and several community volunteers.

At the end of the day, students gathered in the forest pavilion to create an 'accordion book' that demonstrated what they learned in the Forest. Each child chose one concept to illustrate and write about on their page. This proved to be a wonderful way to evaluate the effectiveness of each presentation and to improve future activities.

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Forest Field Days hike.

Cooperative Fire Program

The effect of El Niño in the Caribbean resulted in warmer temperatures and reduced rainfall across Puerto Rico and the U.S. Virgin Islands. The National Weather Service reported that 2015 was the third driest year on record (1899-2015), registering only 74 cm (29.12 in) of rainfall to the end of October, nearly 40 cm (16 in) below the normal year-to-date total. As a consequence, wildland fire incidence increased for both Puerto Rico and the U.S. Virgin Islands. The Puerto Rico Fire Department responded to 4,253 wildland fires affecting 5,713 ha (14,116.5 acres) of land. The U.S. Virgin Islands Fire Department responded to 258 wildland fires that affected 900 ha (2,224 acres) of land.

With Forest Service grant funds the Puerto Rico Fire Department was able to equip 100 percent of their structural fire trucks located on each Fire Station in Puerto Rico with personal protective equipment and wildfire equipment, making the response to wildland fires safer and more efficient. The department also acquired two bush cutters to be used for initial attack operations and fuel reduction under mitigation efforts. Twelve training sessions were conducted and 341 representatives from the Puerto Rico Fire Department, Department of Natural and Environmental Resources, Emergency Management Office, and community members participated. During those trainings the agency offered the courses Wildland Firefighter S-130, S-190, I-100, Mitigation Training for agriculture, S-131 Firefighter Type 1, S-200 Initial Attack Incident Commander Type 4, S-212 Wildland Fire Chainsaw, and S-231 Engine Boss.

M. Figueroa

Water pool for fire suppresion.

Wildland fire truck.

As part of the prevention efforts and to educate the public, the Puerto Rico Fire Department partnered with state, federal, municipal governments and local communities on the *Puerto Rico Frente al Fuego* campaign. The initiative included a comic book for kids, a music video, fire prevention songs, road signs in areas of high wildland fire incidence, and visits to schools and communities. The initiative included trainings to private landowners and communites on fuel reduction and mitigation techniques.

The U.S. Virgin Islands Fire Service is divided into two districts: the St. Thomas/St. John/Water Island district and the St. Croix district. There are seven fire stations in the St. Thomas/St. John/Water Island district and four in the St. Croix district. Forest Service grant funds were used to purchase firefighting equipment and supplies, wildland fire engines, specialized wildland fire training for firefighters, and educational supplies that were distributed to students during Prevention Week. The Prevention Unit of the Fire Service conducted education workshops, and performed fire extinguisher training and fire drills. During National Prevention Week, this Unit conducted a series of activities that reached over 30,000 students.

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Fire weather services increase public safety

Land and fire management agencies now have access to information on the potential for wildfires to start and environmental conditions that put life and property at risk. During the past few years, the National Weather Service (NWS) in San Juan has been working in close collaboration with the Institute and the U.S Fish and Wildlife Service Caribbean Region to collect and analyze climatological fire weather data for Puerto Rico and the U.S. Virgin Islands. This information is the backbone of criteria now used by the NWS to issue Fire Weather Watches, Red Flag Warnings and Fire Danger Statements in coordination with land and fire management agencies in Puerto Rico and the U.S. Virgin Islands.

An advisory is issued based upon conditions within a Fire Weather Zone, which is an area with similar fuel type, topography and climate. Red Flag Warnings are issued for the combination of fuels and weather conditions that support extreme fire danger and/or fire behavior and today are often broadcast by local television and radio stations. The National Weather Service may issue Fire Danger Statements for any zone, but within Puerto Rico it will issue Red Flag Warnings only within the Southern Coastal Plains and Mona Island, the Southern Hills, the West Coast, and Vieques, and in the U.S. Virgin Islands, Saint Croix. The fine fuels found in these areas gain and lose moisture more quickly than heavier fuels found in other areas of the region, and due to the drier climate and windiness typically burn more intensely than those in the wetter coastal and and mountainous areas. Islands in the Caribbean generally experience two peaks in fire activity during the course of a year, one in early March associated with the winter/spring dry season and a second one in early July associated with hot, dry air masses originating from the Sahara desert and the strengthening of the Caribbean low-level jet stream. Most fires are human-induced and may be intentional or accidental.

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Red Flag press conference.

Forest Legacy Program

The U.S. Virgin Islands Department of Agriculture completed the acquisition of two tracts of land located in St. Croix as part of the Forest Service's Forest Legacy Program. These two purchases are the third and fourth properties acquired for Forest Legacy in the U.S. Virgin Islands, making a total of 86 ha (213 acres) protected, and an investment of $2,118,000 from the Forest Legacy Program.

On November 27, 2013 the U.S. Virgin Island's Department of Agriculture closed on a 14 ha (35 acres) Forest Legacy property, Plot No. 3 Hamm's Bluff, in the northwest of St. Croix. The plot is adjacent to the government owned Hamm's Bluff property currently used by the Virgin Island's National Guard. The forests in northwest St. Croix once hid bands of maroons, people who escaped from the injustice of slavery. Hamm's Bluff is a steep cliff where some people jumped to their death rather than return to a harsh life as a slave. The tract was acquired for $279,000. Twenty five percent of that total was matched by $93,000 of value from a tract donated to the Trust for Virgin Islands Lands, Inc. through The Nature Conservancy.

Estate Northstar Legacy property.

On May 9, 2014 another tract was closed, a 41.3 ha (102.03 acres) Forest Legacy property, plots No 1, 1A, and 5 Estate Northstar in the north of St. Croix. The tract is a beautiful undisturbed forest that has been used by many hiking enthusiasts from the U.S. Virgin Islands and tourists, and is of cultural significance as it was also historically used as a home by maroons. The property was acquired for $970,000 and a twenty five percent match of $323,333 was provided by the value from the tract donated to the Trust for Virgin Islands Lands, Inc. through The Nature Conservancy.

The U.S. Virgin Islands Department of Agriculture hosted a community celebration on June 20, 2014 to announce the Forest Legacy Program acquisitions. The activity was attended by community members, government officials, partners, and community groups. The department continues promoting community participation and hosting facilitated sessions attended by community groups and stakeholders to identify what types of activities are adequate for the Forest Legacy properties and should be included in their land management plans.

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M. Figueroa

Marilyn Chakkroff, Virgin Islands Department of Agriculture Forest Legacy Coordinator, during Estate Northstar Forest Legacy Celebration.

Forest Health

Forest health monitoring program

Training and orientation to the scope and goals of forest health monitoring in eight Puerto Rico Commonwealth forests was completed. The Department of Natural and Environmental Resources forest health coordinator, a contracted biologist, as well as the University of Puerto Rico-Mayagüez (UPRM) project leader were trained in basic forest measurements, establishment and data recording of fixed monitoring plots, and vista point evaluation of forest conditions. A shared database for plot information and image collection was also created. A smartphone-compatible GPS application was used for data collection and retrieval to ArcGIS. Each person was mentored using the "train the trainer" model to support the goal of technology transfer to enable forest managers and field technicians to observe, collect and report changes in forest health conditions in accordance with the prescribed methodology. Forest managers were also briefed and given the opportunity for input as to the final application of this program in order to promote a cooperative work environment. To date, 24 fixed monitoring plots and 12 vista observation points are regularly monitored and reported. This information is shared with cooperators from UPRM and DRNA to support opportunities for research, management and development of the UPRM Entomology Museum and the future interactive website of forest entomology in Puerto Rico.

Additionally, three new occurrences of insects that affected forests and two potentially undescribed insect species were observed. A reforestation management recommendation has been developed regarding the use of certain tree species for roadside planting and defoliation.

Harrisia *cactus mealybug monitoring on Caja de Muertos*

A project to measure the level of infestation and rate of spread of the *Harrisia* cactus mealybug on the Caja de Muertos nature reserve was developed, in response to an urgent request from the Puerto Rico Department Natural and Environmental Resrouces. Personnel training in basic scientific methods was completed. A field survey form and data base was developed. Ten monitoring plots along the leading edge of the outbreak were established to measure the intensity and rate of spread of the mealybug. To date, data analysis suggests that the rate of spread is increasing exponentially. A management plan consistent with the restrictions of this nature reserve and the capabilities of the host agency were developed and submitted to a USDA Animal and Plant Health Inspection special team for consideration. The data plots have also provided research opportunities for international cooperators to further develop biologic control agents.

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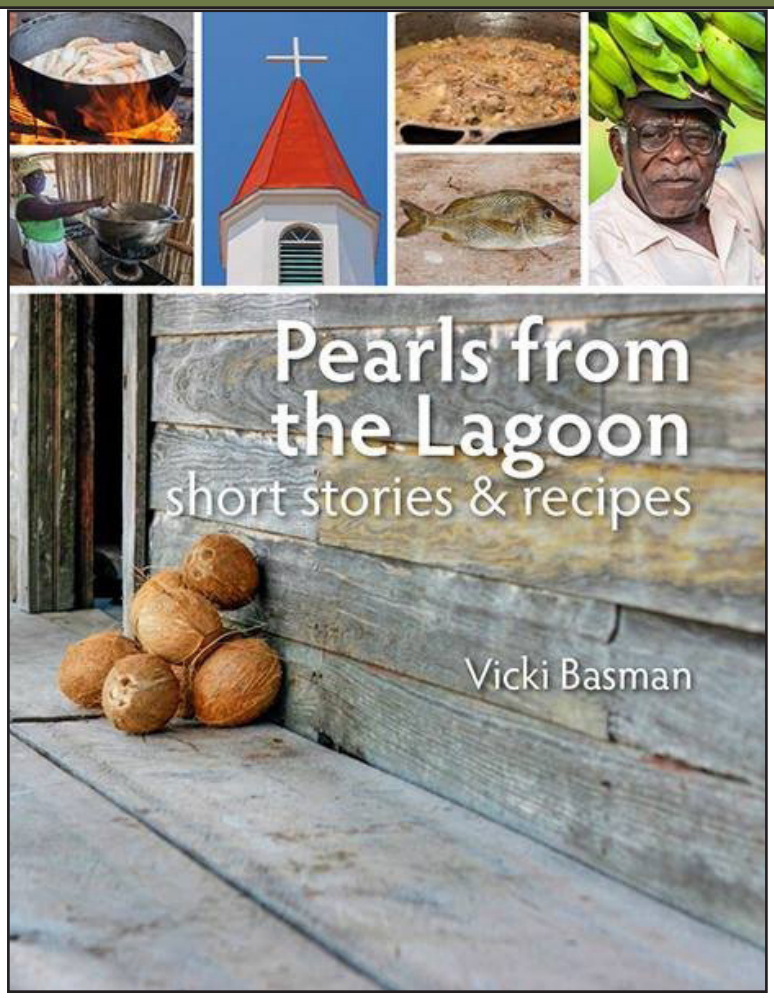
Cactus mealybug monitoring in Guánica State Forest.

Awards

- Dr. Michael Keller was elected as a Fellow for 2014 to the American Association for the Advancement of Science (AAAS), in the Section of Geology and Geography, honoring him for contributions to innovation, education, and scientific leadership.

- Dr. Joseph Wunderle, Jr. was the recipient of the Ralph W. Schreiber Conservation Award, given by the American Ornithologists' Union. This award honors extraordinary scientific contributions to the conservation, restoration, or preservation of birds and/or their habitats.

- Poetic Science, a collaborative exhibit developed by the Institute and the Museum of Contemporary Art of Puerto Rico, received the award of Best 2014 Collective Exhibition in Puerto Rico from the International Association of Art Critics.



- Jerry Bauer was honored with the first Thomas Belt Conservation Award" for his dedication and skill in communicating the value and beauty of nature in Central America.

- 2nd Place Book Category, "Pearls from the Lagoon, short stories & recipes," National Association for Interpretation 2014 Media Award.

- Award of Excellence, Photography: Paso del Istmo book, 21st Annual Communicator Awards.

- Award of Distinction, Book: Paso del Istmo book, 21st Annual Communicator Awards.

- Award of Distinction, Brochure: Colonial City Bird Guide, 21st Annual Communicator Awards.

Publications

2014

1. Andersen, R. A., S. E. Reutebuch, R. J. McGaughey, M. V. N. d'Oliveira, and M. Keller. 2014. Monitoring selective logging in western Amazonia with repeat lidar flights. Remote Sensing of Environment. http://dx.doi.org/10.1016/j.rse.2013.08.049

2. Boal, C. W., J. Wunderle, J.M., and W. J. Arendt. 2013. Autumn monitoring of resident avifauna on Guana Island, British Virgin Islands. Ornitologia Neotropical 24: 335-343.

3. Brandeis, T. J., F. J. Escobedo, C. L. Staudhammer, D. J. Nowak, and W. C. Zipperer. 2014. San Juan Bay Estuary Watershed Urban Forest Inventory. General Technical Report SRS-190. U.S. Department of Agriculture Forest Service, Southern Research Station, Asheville, NC.

4. Cantrell, Sharon A.; Molina, Marirosa; Lodge, D. Jean; Rivera-Figueroa, Francisco J.; Ortiz, Maria; Marchetti, Albany A.; Cyterski, Mike J.; Pérez-Jiménez, José R. 2014. Effects of a simulated hurricane disturbance on forest floor microbial communities. Forest Ecology and Management. 332: 22-31.

5. Cusack, D. F. and T. L. McCleery. 2014. Patterns in understory woody diversity and soil nitrogen across native- and non-native-urban tropical forests. Forest Ecology and Management 318: 34-43.

6. de Miranda, S. d. C., M. Bustamente, M. Palace, S. Hagen, M. Keller, and L. G. Ferreira. 2014. Regional variations in biomass distribution in Brazilian savanna woodland. Biotropica 46: 125-138.

7. Domínguez Miranda, J. P. 2013. Experiencias sobre la legalizacion y proteccion de areas naturales: el caso de El Salvador, C.A. Biosistemas and U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry, San Salvador, El Salvador and Rio Piedras, PR.

8. Driscoll, C. T., P. M. Groffman, J. M. Blair, A. E. Lugo, C. M. Laney, and D. P. C. Peters. 2013. Cross-site comparisons of precipitation and surface water chemistry. Chapter 6. Pages 46-50 in D. P. C. Peters, C. M. Laney, A. E. Lugo, S. L. Collins, C. T. Driscoll, P. M. Groffman, J. M. Grove, A. K. Knapp, T. K. Kratz, M. D. Ohman, R. B. Waide, and J. Yao, editors. Long-term trends in ecological systems: a basis for understanding responses to global change. USDA ARS Tech. Bull. No. 1931. USDA Agricultural Research Service, Las Cruces, NM.

9. Erickson, H. E., E. H. Helmer, T. J. Brandeis, and A. E. Lugo. 2014. Controls on fallen leaf chemistry and forest floor element masses in native and novel forests across a tropical island. Article 48. Ecosphere 5.

10. Espírito-Santo, F. D. B., M. Gloor, M. Keller, Y. Malhi, S. Saatchi, B. Nelson, R. C. Oliveira Junior, C. Pereira, J. Lloyd, S. Frolking, M. Palace, Y. E. Shimabukuro, V. Duarte, A. Monteagudo Mendoza, G. López-González, T. R. Baker, T. R. Feldpausch, R. J. W. Brienen, G. P. Asner, D. S. Boyd, and O. L. Phillips. 2014. Size and frequency of natural forest disturbances and the Amazon forest carbon balance. Nature Communications 5: 1-6.

11. Fleming, G. M., J. Wunderle, Joseph M., D. N. Ewert, and J. J. O'Brien. 2014. Estimating plant biomass in early-successional subtropical vegetation using a visual obstruction technique. Applied Vegetation Science 17: 356-366.

12. Fonseca da Silva, J. 2014. Species composition, diversity and structure of novel forests of *Castilla elastica* in Puerto Rico. Tropical Ecology 55: 231-244.

13. Free, C. M., R. M. Landis, J. Grogan, M. D. Schulze, M. Lentini, and O. Dunisch. 2014. Management implications of long-term tree growth and mortality rates: A modeling study of big-leaf mahogany (*Swietenia macrophylla*) in the Brazilian Amazon. Forest Ecology and Management 330: 46-54.

14. González, G., D. J. Lodge, B. A. Richardson, and M. J. Richardson. 2014. A canopy trimming experiment in Puerto Rico: The response of litter decomposition and nutrient release to canopy opening and debris deposition in a subtropical wet forest. Forest Ecology and Management 332: 32-46.

15. González, G., F. J. Rivera-Figueroa, W. Gould, S. A. Cantrell, and J. R. Pérez-Jiménez. 2014. Microorganisms in small patterned ground features and adjacent vegetated soils along topographic and climatic gradients in the High Arctic, Canada. Open Journal of Science 4: 47-55.

16. Henareh Khalyani, A., A. L. Mayer, and E. S. Norman. 2014. Water flows toward power: socioecological degradation of Lake Urmia, Iran. Society and Natural Resources 27: 759-767.

17. Hunter, M. O., M. Keller, D. Vitoria, and D. C. Morton. 2013. Tree height and tropical forest biomass estimation. Biogeosciences 10: 8385-8399.

18. Jennings, L. N., J. Douglas, E. Treasure, and G. González. 2014. Climate change effects in El Yunque National Forest, Puerto Rico, and the Caribbean Region. Gen. Tech. Rep. SRS-193. U.S. Department of Agriculture Forest Service, Southern Research Station, Asheville, NC.

19. Kennedy, R. F., S. Andrefouet, W. B. Cohen, C. Gómez, P. Griffiths, M. Hais, S. P. Healey, E. H. Helmer, P. Hostert, M. B. Lyons, G. W. Meigs, D. Pflugmacher, S. R. Phinn, S. L. Powell, P. Scarth, S. Sen, T. A. Schroeder, A. Schneider, R. Sonnenschein, J. E. Vogelmann, M. A. Wulder, and Z. Zhu. 2014. Bringing an ecological view of change to Landsat-based remote sensing. Frontiers in Ecology and Environment 12: 339-346.

20. Lane, O. P., W. J. Arendt, M. A. Torrez, and J. C. Gamez Castellon. 2013. Pilot assessment of mercury exposure in selected biota from the lowlands of Nicaragua [Evaluacion piloto de exposicion al mercurio en biota selecta de las tierras bajas de Nicaragua. Mesoamericana 17: 19-28.

21. Lodge, D. J., Cantrell, S. A., and G. González. 2014. Effects of canopy opening and debris deposition on fungal connectivity, phosphorus movement between litter cohorts and mass loss. Forest Ecology and Management. 332: 11-21.

22. López Machado, E., K. Soto Hidalgo, and T. Heartsill-Scalley. 2012. Composición y estructura de un bosque tropical urbano en el karso norteno de Puerto Rico. Acta Científica 26: 54-67.

23. Lugo, A. E., ed. 2012. Acta Científica 26: 166.

24. Lugo, A. E. 2012. Social silviculture: a new paradigm in the search for sustainable land conservation in the tropics? Bois et Forets des Tropiques 314: 3-5.

25. Lugo, A. E. 2013. Novel tropical forests: nature's response to global change. Tropical Conservation Science 6:325-337.

26. Lugo, A. E. 2014. Evolving conservation paradigms for the Anthropocene. Pages 47-59 in V. A. Sample and R. P. Bixler, editors. Forest conservation and management in the anthropocene: adaptation of science, policy and practices. Proceedings RMRS-P-71. U.S. Forest Service Rocky Mountain Station, Fort Collins, CO.

27. Lugo, A. E. 2014. Poetic science: aproximaciones artístico-científicas sobre El Yunque. Visión Doble 3.

28. Lugo, A. E. 2014. Tropical cities are diverse and deserve more social-ecological attention. Article 23. Ecology and Society 19.

29. Lugo, A. E., O. Abelleira Martínez, and J. Fonseca da Silva. 2012. Aboveground biomass, wood volume, nutrient stocks and leaf litter in novel forests compraed to native forests and tree plantations in Puerto Rico. Bois et Forets des Tropiques 314: 7-16.

30. Lugo, A. E. and M. Alayón. 2014. Understanding the vulnerability and sustainability of urban social-ecological systems in the tropics: perspectives from the city of San Juan. Special feature issue. Ecology and Society 19.

31. Lugo, A. E., C. M. Concepción, L. E. Santiago-Acevedo, T. A. Muñoz-Erickson, J. C. Verdejo Ortiz, R. Santiago-Bartolomei, J. Forero-Montana, C. J. Nytch, H. Manrique, and W. Colón-Cortés. 2012. In search of an adaptive social-ecological approach to understanding a tropical city. Acta Científica 26: 121-134.

32. Lugo, A. E., B. Eav, G. S. Foster, M. Rains, J. Reaves, and D. J. Stouder. 2014. Forest Service Experimental Forests and long-term data sets: stories of their meaning to station directors. Chapter 2. Pages 25-57 in D. C. Hayes, S. L. Stout, R. H. Crawford, and A. P. Hoover, editors. USDA Forest Service Experimental Forests and Ranges: Research for the Long Term. Springer, New York.

33. Lugo, A. E. and T. Heartsill Scalley. 2014. Research in the Luquillo Experimental Forest has advanced understanding of tropical forests and resolved management issues. Chapter 19. Pages 435-461 in D. C. Hayes, S. L. Stout, R. H. Crawford, and A. P. Hoover, editors. USDA Forest Service Experimental Forests and Ranges: Research for the Long Term. Springer, New York.

34. Lugo, A. E., E. H. Helmer, and O. Ramos González. 2013. The greening of the Caribbean: from the Tainos to the Anthropocene. Ninth Annual Public Lecture. Environmental Foundation of Jamaica in association with the Jamaica Protected Areas Trust / Forest Conservation Fund, Kingston, Jamaica.

35. Lugo, A. E. and T. A. Muñoz-Erickson. 2013. Sustainable cities: a model case study. International Innovation 116: 36-38.

36. McDowell, W. H., R. L. Brereton, F. N. Scatena, J. B. Shanley, N. V. Brokaw, and A. E. Lugo. 2013. Interactions between lithology and biology drive the long-term response of stream chemistry to major hurricanes in a tropical landscape. Biogeochemistry 116: 175-186.

37. Medina, E., E. Cuevas, A. E. Lugo, E. Terezo, J. Jiménez-Osornio, P. A. Macario-Mendoza, and P. Montañez. 2014. Conservative nutrient use by big-leaf mahogany (*Swietenia* macrophylla King) planted under contrasting environmental conditions. Revista Arvore 38: 479-488.

38. Medina, E., E. H. Helmer, E. Meléndez-Ackerman, and H. Marcano-Vega. 2014. Natural vegetation groups and canopy chemical markers in a dry subtropical forest on calcareous substrate: the vegetation of Mona Island, Puerto Rico. Caribbean Naturalist 13: 1-15.

39. Mercado-Diaz, J. A., W. A. Gould, G. González, and R. Lucking. 2013. Four new species of *Coenogonium* (Ascomycota: Ostropales) from vulnerable forest ecosystems in Puerto Rico. The Bryologist 116: 373-381.

40. Miller, J. S., G. A. Krupnick, H. Stevens, H. Porter-Morgan, B. Boom, P. Acevedo-Rodríguez, J. Ackerman, D. Kolterman, E. Santiago, C. Torres, and J. Vélez. 2013. Toward target 2 of the global strategy for plant conservation: an expert analysis of the Puerto Rican flora to validate new streamlined methods for assessing conservation status. Annals of the Missouri Botanical Garden 99: 199-205.Muñoz Erickson, T. A., A. E. Lugo, and B. Quintero. 2014. Emerging synthesis themes from the study of social-ecological systems of a tropical city. Article 23. Ecology and Society 19.

41. Muñoz-Erickson, T. A., A. E. Lugo, and B. Quintero. 2014. Emerging synthesis themes from the study of social-ecological systems of a tropical city. Article 23. Ecology and Society 19.

42. Muñoz-Erickson, T. A. 2014. Co-production of knowledge-action systems in urban sustainable governance: The KASA approach. Environmental Science and Policy 37: 182-191.

43. Muñoz-Erickson, T. A. 2014. Multiple pathways to sustainability in the city: the case of San Juan, Puerto Rico. Article 2. Ecology and Society 19.

44. Muñoz-Erickson, T. A., A. E. Lugo, E. Meléndez-Ackerman, L. E. Santiago-Acevedo, J. Seguinot-Barbosa, P. Méndez-Lázaro, M. Hall, B. Quintero, A. Ramírez, D. García-Montiel, R. G. Pontius Jr., O. M. Ramos-González, R. Santiago-Bartolomei, J. Verdejo-Ortíz, J. R. Ortíz-Zayas, C. M. Concepción, D. Cusack, J. Giusti, W. McDowell, M. L. Cruz-Torres, J. Vallejo, L. Cray, J. Zimmerman, V. Cuadrado-Landrau, and M. Figueroa. 2014. Knowledge to serve the city: insights from an emerging knowledge-action network to address vulnerability and sustainability in San Juan, Puerto Rico. . Cities and the Environment (CATE) 7: Art. 5.

45. Pérez, C., J. Frangi, J. F. Goya, A. Luy, and M. Arturi. 2013. Contenido de nutrientes en las raices finas y el mantillo de rodales de *Eucalyptus grandis* de diferente edad en la Mesopotomia Argentina [Fine roots and litter nutrient content of Eucalyptus grandis stands presenting different ages in Mesopotomia Argentina]. Bosque 34:303-310.

46. Peters, D. P. C., C. M. Laney, A. E. Lugo, S. L. Collins, C. T. Driscoll, P. M. Groffman, J. M. Grove, A. K. Knapp, T. K. Kratz, M. D. Ohman, R. B. Waide, and J. Yao. 2013. Long-term trends in ecological systems: a basis for understanding responses to global change. USDA ARS Tech. Bull. No. 1931. USDA Agricultural Research Service, Las Cruces, New Mexico.

47. Peters, D. P. C., C. M. Laney, A. E. Lugo, S. L. Collins, C. T. Driscoll, P. M. Groffman, J. M. Grove, A. K. Knapp, T. K. Kratz, M. D. Ohman, R. B. Waide, and J. Yao. 2013. Long-term trends in ecological systems: an introduction to cross-site comparisons and relevance to global change studies. Chapter 1. Pages 1-20 in D. P. C. Peters, C. M. Laney, A. E. Lugo, S. L. Collins, C. T. Driscoll, P. M. Groffman, J. M. Grove, A. K. Knapp, T. K. Kratz, M. D. Ohman, R. B. Waide, and J. Yao, editors. Long-term trends in ecological systems: a basis for understanding responses to global change. USDA ARS Tech. Bull. No. 1931. USDA Agricultural Research Service, Las Cruces, NM.

48. Peters, D. P. C., A. E. Lugo, I. Chapin, F.S, A. J. Tepley, and F. J. Swanson. 2013. Disturbance regimes and ecological responses across sites. Chapter 9. Pages 58-71 in D. P. C. Peters, C. M. Laney, A. E. Lugo, S. L. Collins, C. T. Driscoll, P. M. Groffman, J. M. Grove, A. K. Knapp, T. K. Kratz, M. D. Ohman, R. B. Waide, and J. Yao, editors. Long-term trends in ecological systems: a basis for understanding responses to global change. USDA Agricultural Research Service, Las Cruces, NM.

49. Pfeifer, M., V. Lefebvre, T. A. Gardner, V. Arroyo-Rodríguez, L. Baeten, C. Banks-Leite, et al. 2014. BIOFRAG - a new database for analyzing BIOdiversity responses to forest FRAGmentation. Ecology and Evolution 4: 1524-1537.

50. Quiñones, M., W. A. Gould, J. Castro-Prieto, and S. Martinuzzi. 2013. Spatial analysis of Puerto Rico's terrestrial protected areas [1:240 000]. IITF-RMAP-03. Research Map. U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry, Río Piedras, Puerto Rico.

51. Raich, J. W., D. A. Clark, L. Schwendenmann, and T. Wood. 2014. Aboveground tree growth varies with belowground carbon allocation in a tropical rainforest environment. PLOS One 9:e100275.

52. Ramírez, A., K. G. Rosas, A. E. Lugo, and O. M. Ramos-González. 2014. Spatio-temporal variation in stream water chemistry in a tropical urban watershed. Article 45. Ecology and Society 19.

53. Ramos-González, O. M. 2014. The green areas of San Juan, Puerto Rico. Ecology and Society 19: article 21.

54. Robinson, K., J. Bauer, and A. E. Lugo. 2014. Passing the baton from the Taínos to tomorrow: forest conservation in Puerto Rico. FS-862. U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico.

55. Shaver, G. R., J. F. Laundrie, M. S. Bret-Harte, I. Chapin , F. Stuart, J. A. Mercado-Díaz, A. E. Giblin, L. Gough, W. A. Gould, S. E. Hobbie, G. W. Kling, M. C. Mack, J. C. Moore, K. J. Nadelhoffer, E. B. Rastetter, and J. P. Schimel. 2014. Terrestrial ecosystems at Toolik Lake, Alaska. Pages 90-142 in S. E. Hobbie and G. W. Kling, editors. Alaska's changing Arctic: Ecological Consequences for Tundra, Streams and Lakes. Oxford University Press.

56. Torrez, M., W. J. Arendt, and M. Sotelo. 2013. Composicion de aves del Pacifico Sur de Nicaragua enfatizando las especies indicadoras dependientes de bosque [Community composition of Nicaragua's Pacific Slope forest birds, emphasizing forest quality-dependent species]. Mesoamericana 17: 39-48.

57. Treuhaft, R., F. Goncalves, J. R. dos Santos, M. Keller, M. Palace, S. N. Madsen, F. Sullivan, and P. M. L. A. Graca. 2015. Tropical-forest biomass estimation at X-Band from the spaceborne TanDEM-X interferometer. IEEE Geoscience and Remote Sensing Letters 12: 239-243.

58. Van Beusekom, A. E., L. E. Hay, R. J. Viger, W. A. Gould, J. A. Collazo, and A. Henareh Khalyani. 2014. The effects of changing land cover on streamflow simulation in Puerto Rico. Journal of the American Water Resources Association.

59. Van Haren, J., R. C. de Oliveira Jr., T. P. Beldini, P. B. de Camargo, M. Keller, and S. Saleska. 2013. Tree species effects on soil properties and greenhouse gas fluxes in East-central Amazonia: comparison between monoculture and diverse forest. Biotropica 45: 709-718.

60. Vose, James M.; Swank, Wayne T.; Adams, Mary Beth; Amatya, Devendra; Campbell, John; Johnson, Sherri; Swanson, Frederick J.; Kolka, Randy; Lugo, Ariel E.; Musselman, Robert; Rhoades, Charles. 2014. The role of experimental forests and ranges in the development of ecosystem science and biogeochemical cycling research. In: Hayes, D.C.; Stout, S.L.; Crawford, R.H.; Hoover, A.P., eds. USDA.

61. Weaver, P. L. 2013. Long-term changes in structure and composition following hurricanes in a primary lower montane rain forest in Puerto Rico. Bois et Forets des Tropiques 317: 7-21.

62. Wood, T. E., M. Detto, and W. L. Silver. 2013. Sensitivity of soil respiration to variability in soil moisture and temperature in a humid tropical forest. PLOS One 8: e80965.

63. Wunderle Jr., J.M., P. K. Lebow, J. D. White, D. Currie, and D. N. Ewert. 2014. Sex and age differences in site fidelity, food resource tracking, and body condition of wintering Kirtland's Warblers (Setophaga kirtlandii) in the Bahamas. Ornithological Monographs 80: 62.

2015

1. Arendt, W. J., J. Faaborg, M. Canals, and J. Bauer. 2015. Bird checklist, Guánica Biosphere Reserve, Puerto Rico. Research Note SRS-23. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 23 p. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48011

2. Beltran, W., and J. M. Wunderle, Jr. 2014. Temporal dynamics of arthropods on six tree species in dry woodlands on the Caribbean Island of Puerto Rico. Journal of Insect Science 14(199): 2014; doi: 10.1093/jisesa/ieu061. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47859

3. Cavaleri, M. A., S. C. Reed, K. W. Smith, and T. E. Wood. 2015. Urgent need for warming experiments in tropical forests. Global Change Biology 21(6): 2111-2121. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49346

4. Cutts, B. B., T. A. Muñoz-Erickson, and S. T. Shutters. 2015. Public Representation in Water Management—A Network Analysis of Organization and Public Perceptions in Phoenix, Arizona. Society & Natural Resources: 1-18. doi: 10.1080/08941920.2015.1020581. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49348

5. Elmendorf, S. C., G. H. R. Henry, R. D. Hollister, A. M. Fosaa, W. A. Gould, L. Hermanutz, A. Hofgaard, I. I. Jonsdottir, J. C. Jorgenson, E. Levesque, B. Magnusson, U. Molau, I. H. Myers-Smith, S. F. Oberbauer, C. Rixen, C. E. Tweedie, and M. Walkers. 2015. Experiment, monitoring, and gradient methods used to infer climate change effects on plant communities yield consistent patterns. PNAS 112(2): 448-452. www.pnas.org/cgi/doi/10.1073/pnas.1410088112. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48245

6. Fleming, G. M., J. M. Wunderle, Jr., D. N. Ewert, J. J. O'Brien, and E. H. Helmer. 2015. Functional attributes of two subtropical shrubs and implications for the distribution and management of endangered bird habitat. Journal of Plant Ecology. 8(6): 578–592. doi: 10.1093/jpe/rtu036. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48247

7. González, G. 2015. Ecología de las lombrices de tierra. Pages 201-206 in Joglar, R. L., Santos Flores, C. J., and J. L. Tórres Pérez, eds. Biodiversidad de Puerto Rico: Invertebrados. Serie de Historia Natural. San Juan, PR: Proyecto Coquí.Treesearch link: http://www.treesearch.fs.fed.us/pubs/48514

8. Gould, W. A. 2014. Plant community composition data: Bathurst Inlet and the Canadian Transect. Pages 40-43 in Walker, D.A., ed. Alaska Arctic Vegetation Archive (AVA) Workshop, Boulder, Colorado, USA, October 14-16, 2013. CAFF Proceedings Report 11. Akureyri, Iceland. ISBN: 978-9935-431-29-5.

9. Gould, W. A., S. J. Fain, I. K. Parés, K. McGinley, A. Perry, and R. F. Steele. 2015: Caribbean Regional Climate Sub Hub assessment of climate change vulnerability and adaptation and mitigation strategies. United States Department of Agriculture, 67 p.

10. Grogan, J. 2011. Mahogany, mogno (*Swietenia macrophylla* King). Pages 101-108 in: Shanley, P., Cymerys, M., Serra, M., and G. Medina, eds. Fruit Trees and Useful Plants in Amazonian Life. Rome: Food and Agriculture Organization of the United Nations, Center for International Forestry Research, People and Plants International.

11. Grogan, J., R. M. Landis, C. M. Free, M. D. Schulze, M. Lentini, and M. S. Ashton. 2014. Big-leaf mahogany *Swietenia macrophylla* population dynamics and implications for sustainable management. Journal of Applied Ecology 51(3): 664-674. doi: 10.1111/1365-2664.12210. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49204

12. Grogan, J., and M. D. Loveless. 2013. Flowering phenology and its implications for management of big-leaf mahogany *Swietenia macrophylla* in Brazilian Amazonia. American Journal of Botany 100: 2293-2305. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49205

13. Grogan, J., M. Peña-Claros, and S. Günter. 2011. Managing natural populations of big-leaf mahogany. Pages 227-235 in: Günter, S., B. Stimm, M. Weber, and R. Mosandl, eds. Silviculture in the Tropics. Springer Verlag, Berlin, Germany.

14. Heartsill-Scalley, T., and T. López-Marrero. 2014. Land cover composition, water resources and land management in the watersheds of the Luquillo Mountains, northeastern Puerto Rico. Caribbean Geography 19: 43-68. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49358

15. Herrera-Rosales, H. M., M. Tórrez, and W. J. Arendt. 2014. Registros del Cuco Hormiguero (*Neomorphus geoffroyi*) en la Reserva de Biósfera de Bosawas, Nicaragua. Zeledonia 18(2): 55-61. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48942

16. Hobbs, R. J., E. Higgs, C. M. Hall, P. Bridgewater, F. S. Chapin III, E. C. Ellis, J. J. Ewel, L. M. Hallet, J. Harris, K. B. Hulvey, S. T. Jackson, P. L. Kennedy, C. Kueffer, L. Lach, T. C. Lantz, A. E. Lugo, J. Mascaro, S. D. Murphy, C. R. Nelson, M. P. Perring, D. M. Richardson, T. R. Seastedt, R. Standish, B. M. Starzomski, K. N. Suding, P. M. Tognetti, L. Yakob, and L. Yung. 2014. Managing the whole landscape: historical, hybrid, and novel ecosystems. Frontiers in Ecology and Environment 12(10): 557–564. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47867

17. Hudson, L. N., T. Newbold, and S. Contu, et al. 2014. The PREDICTS database: a global database of how local terrestrial biodiversity responds to human impacts. Ecology and Evolution. 4(24): 4701-4735. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49359

18. Hunter, M. O., M. Keller, D. Morton, B. Cook, M. Lefsky, M. Ducey, S. Saleska, R. C. de Oliveira, and J. Schietti. 2015. Structural dynamics of tropical moist forest gaps. PLOS ONE 10(7): e0132144. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48678

19. Kelty, M., L. Cámara-Cabrales, and J. Grogan. 2011. Red oak in southern New England and big-leaf mahogany in the Yucatan Peninsula: can mixed-species forests be sustainably managed for single-species production? Journal of Sustainable Forestry 30: 637-653. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49361

20. Klawanski, P. D., B. Dalton, and A. B. Shiels. 2014. Coqui frog populations are negatively affected by canopy opening but not detritus deposition following an experimental hurricane in a tropical rainforest. Forest Ecology and Management 332: 118-123. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47906

21. Kraichak, E., S. Parnmen, R. Lücking, E. Rivas Plata, A. Aptroot, M. E. S. Caceres, D. Ertz, A. Mangold, J. A. Mercado Díaz, K. Papong, D. Van der Broeck, G. Weerakoon, and H. T. Lumbsch. 2014. Revisiting the phylogeny of Ocellularieae, the second largest tribe within Graphidaceae (lichenized Ascomycota: Ostropales). Phytotaxa 189(1): 52-81. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48113

22. Leitold, V., M. Keller, D. C. Morton, B. D. Cook, and Y. E. Shimabukuro. 2015. Airborne lidar-based estimates of tropical forest structure in complex terrain: opportunities and trade-offs for REDD+. Carbon Balance and Management 10:3 doi: 10.1186/s13021-015-0013-x. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48369

23. Lücking, R., M. K. Johnston, A. Aptroot, E. Kraichak, J. C. Lendemer, K. Boonpragob, M. E. S. Caceres, D. Ertz, L. Itati Ferraro, Z. F. Jia, K. Kalb, A. Mangold, L. Manoch, J. A. Mercado-Díaz, B. Moncada, P. Mongkolsuk, K. Butsatorn Papong, S. Parnmen, R. N. Pelaez, V. Poengsungnoen, E. Rivas Plata, W. Saipunkaew, H. J. M. Sipman, J. Sutjaritturakan, D. Van Den Broeck, M. von Konrat, G. Weerakoon, and H. T. Lumbsch. 2014. One hundred and seventy-five new species of Graphidaceae: closing the gap or a drop in the bucket? Phytotaxa 189(1): 7-38. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48109

24. Lugo, A. E. 2015. Forestry in the Anthropocene. Science. 349(6250): 771. doi: 10.1126/science.aad2208. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49362

25. Lugo, A. E. 2014. Frederick N. Scatena: A tropical geomorphologist [obituary]. Forest Ecology and Management 332: 134-135.

26. Lugo, A. E., and E. Medina. 2014. Mangrove forests. Pages 343-352 in Encyclopedia of Natural Resources-Land. Vol. 1. New York: Land. Taylor and Francis. doi: 10.1081/E-ENRL-120047500. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48513

27. Lugo, A. E., E. Medina, and K. McGinley. 2014. Issues and challenges of mangrove conservation in the Anthropocene - Desafios de la conservacion del mangle en el Antropoceno. Madera y Bosques vol. 20, num. especial: 11-38. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48115

28. Lumbsch, H. T., E. Kraichak, S. Parnmen, E. Rivas Plata, A. Aptroot, M. E. S. Caceres, D. Ertz, S. Cunha Feuerstein, J. A. Mercado Díaz, B. Staiger, D. Van den Broeck, and R. Lücking. 2014. New higher taxa in the lichen family Graphidaceae (lichenized Ascomycota: Ostropales) based on a three-gene skeleton phylogeny. Phytotaxa 189 (1): 39-51. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48111

29. Marcano Vega, H., T. J. Brandeis, and J. A. Turner. 2015. Los bosques de Puerto Rico, 2009. Resour. Bull. SRS–202. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 115 p. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47948

30. Martiarena, R. A., J. L. Frangi, A. Von Wallis, M. F. Arturi, H. E. Fassola, and R. A. Fernandez. 2014. Propiedades del suelo y sus relaciones con el IS en plantaciones de *Pinus taeda* L. en la Mesopotamia Argentina. AUGM Domus 6: 47-65. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47862

31. Martinuzzi, S., G. I. Gavier-Pizarro, A. E. Lugo, and V. C. Radeloff. 2015. Future land-use changes and the potential for novelty in ecosystems of the United States. Ecosystems 18: 1332–1342. doi: 10.1007/s10021-015-9901-x. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49363

32. McDowell, W. H., and D. Liptzin. 2014. Linking soils and streams: Response of soil solution chemistry to simulated hurricane disturbance mirrors stream chemistry following a severe hurricane. Forest Ecology and Management 332: 56-63. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48372

33. McGinley, K., and F. W. Cubbage. 2015. Policy, laws, organizations, and other governance arrangements influencing forests in the US: A baseline assessment. In: Congress Proceedings, XIV World Forestry Congress, Durban, South Africa, 7-11 September 2015. http://foris.fao.org/wfc2015/api/file/5549895415ae74130aee6c6c/contents/5690a0cc-83cd-4bea-a70c-4caa9e73b92c.pdf

34. McGinley, K., G. Robertson, K. Friday, and C. Carpenter. 2015. Measuring tropical forest sustainability on islands in the Pacific and Caribbean using the Montreal Process Criteria and Indicators Framework. In: Congress Proceedings, XIV World Forestry Congress, Durban, South Africa, 7-11 September 2015. http://foris.fao.org/wfc2015/api/file/553530ccc13f7d133fb630db/contents/d0b4dd0a-e849-437c-8d52-944aeb3ca16c.pdf

35. Medina, E., W. Fernandez, and F. Barboza. 2015. Element uptake, accumulation, and resorption in leaves of mangrove species with different mechanisms of salt regulation. Web Ecol 15: 3-13. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48370

36. Meir, P., T. E. Wood, D. R. Galbraith, P. M. Brando, A. C. I. Da Costa, L. Rowland, and L. V. Ferreira. 2015. Threshold responses to soil moisture deficit by trees and soil in tropical rain forests: insights from field experiments. Bioscience 65(9): 882-892. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49371

37. Mercado-Díaz, J. A., W. A. Gould, and G. González. 2014. Soil nutrients, landscape age, and *Sphagno-Eriophoretum vaginati* plant communities in Arctic moist-acidic Tundra landscapes. Open Journal of Soil Science 4: 375-387.Treesearch link: http://www.treesearch.fs.fed.us/pubs/47342

38. Mercado-Díaz, J. A., W. A. Gould, G. González, and R. Lücking. 2015. Lichens in Puerto Rico: an ecosystem approach. Gen. Tech. Rep. IITF-GTR-46. San Juan, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry. 76 p. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48249

39. Mercado-Díaz, J. A., R. Lücking, and S. Parnmen. 2014. Two new genera and twelve new species of Graphidaceae from Puerto Rico: a case for higher endemism of lichenized fungi in islands of the Caribbean? Phytotaxa 189(1): 186–203. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47978

40. Norghauer, J. M., C. M. Free, R. M. Landis, J. Grogan, J. R. Malcolm, and S. C. Thomas. 2015. Herbivores limit the population size of big-leaf mahogany trees in an Amazonian forest. Oikos. doi: 10.1111/oik.02324. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49372

41. Norghauer, J. M., and J. Grogan. 2012. The intriguing case of Steniscadia poliophaea (Noctuidae): potent moth enemy of young mahogany trees in Amazonian forests. Pages 39-74 in: Cauterruccio, L., (ed.). Moths: Types, Ecological Significance and Control Methods. Hauppage, NY: Nova Science Publishers. P. 39-74.

42. de Oliveira Junior, R. C., M. M. Keller, J. F. da Fonseca Ramos, T. P. Beldini, P. M. Crill, P. B. de Camargo, and J. van Haren. 2015. Chemical analysis of rainfall and throughfall in primary forest in the Tapajós National Forest, Belterra, Pará, Brazil. Ambiente & Água 10: 263-285. doi: 10.4136/ambi-agua.1552. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48375

43. Prather, C. 2014. Divergent responses of leaf herbivory to simulated hurricane effects in a rainforest understory. Forest Ecology and Management 332: 87-92. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48302

44. Saatchi, S., Mascaro, J., Xu, L., Keller, M., Yang, Y., Duffy, P., Espírito-Santo, F., Baccini, A., Chambers, J., and D. Schimel. 2014. Seeing the forest beyond the trees. Global Ecology and Biogeography. doi: 10.1111/geb.12256. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48394

45. Sanchez, M. J., Lopez, E., and A. E. Lugo. 2015. Chemical and physical analyses of selected plants and soils from Puerto Rico (1981-2000). Gen. Tech. Rep. IITF GTR-45. Rio Piedras, PR: U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry. 600 p. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48345

46. Schimel, D., and M. Keller. 2015. Big questions, big science: meeting the challenges of global ecology. Oecologia 177: 925–934. doi: 10.1007/s00442-015-3236-3. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48406

47. Schowalter, T. D., Willig, M. R., and S. J. Presley. 2014. Canopy arthropod responses to experimental canopy opening and debris deposition in a tropical rainforest subject to hurricanes. Forest Ecology and Management. 332:93-102. Treeseach link: http://www.treesearch.fs.fed.us/pubs/48451

48. Sharpe, J. M., and A. B. Shiels. 2014. Understory fern community structure, growth and spore production responses to a large-scale hurricane experiment in a Puerto Rico rainforest. Forest Ecology and Management. 332: 75-86. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48452

49. Shiels, A. B., and G. González. 2015. Tropical Forest Responses to Large-Scale Experiments. BioScience 65 (9): 839. doi:10.1093/biosci/biv126. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49356

50. Shiels, A., González, G., Lodge, D. J., Willig, M. R., and J. K. Zimmerman. 2015. Cascading effects of canopy opening and debris deposition from a large-scale hurricane experiment in a tropical rainforest. Bioscience 65 (9): 871-881. doi:10.1093/biosci/biv111. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49302

51. Shiels, A. B., González, G., and M. R. Willig. 2014. Responses to canopy loss and debris deposition in a tropical forest ecosystem: Synthesis from an experimental manipulation simulating effects of hurricane disturbance. Forest Ecology and Management 332: 124-133. doi: 10.1016/j.foreco.2014.08.005. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47466

52. Shiels, A. B., and G. González. 2014. Understanding the key mechanisms of tropical forest responses to canopy loss and biomass deposition from experimental hurricane effects. Forest Ecology and Management 332: 1-10. doi:10.1016/j.foreco.2014.04.024. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47467

53. Silver, W. L., Hall, S. J., and G. González. 2014. Differential effects of canopy trimming and litter deposition on litterfall and nutrient dynamics in a wet subtropical forest. Forest Ecology and Management 332: 47-55. doi: 10.1016/j.foreco.2014.05.018. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47465

54. Siry, J. P., McGinley, K., Cubbage, F.W., and P. Bettinger. 2015. Forest tenure and sustainable forest management. Open Journal of Forestry 5: 526-545. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49514

55. Slik, J. W. F., Arroyo-Rodríguez, V., Aiba, S. I. and others. 2015. An estimate of the number of tropical tree species. Proceedings of the National Academy of Sciences 112(24): 7472-7477. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48481

56. Soares, M. L. G., M. M. P. Tognella, E. Cuevas, and E. Medina. 2015. Photosynthetic capacity and intrinsic water-use efficiency of *Rhizophora mangle* at its southernmost western Atlantic range. Photsynthetica 53(3): 464-470. Treesearch link: http://www.treesearch.fs.fed.us/pubs/48303

57. Staudhammer, C. L., F. J. Escobedo, N. Holt, L. J. Young, T. J. Brandeis, and W. Zipperer. 2015. Predictors, spatial distribution, and occurrence of woody invasive plants in subtropical urban ecosystems. Journal of Environmental Management 155: 97-105.

58. Tesón, N., V. H. Conzonno, M. F. Arturi, and J. L. Frangi. 2014. Dissolved organic carbon in water fluxes of *Eucalyptus grandis* plantations in northeastern Entre Ríos Province, Argentina [Carbono orgánico disuelto en flujos hídricos de plantaciones de Eucalyptus grandis del noreste, provincia de Entre Ríos, Argentina]. Bosque 35(3): 279-288. doi: 10.4067/S0717-92002014000300003. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49017

59. Timilsina, N., F. J. Escobedo, C. L. Staudhammer, and T. Brandeis. 2014. Analyzing the causal factors of carbon stores in a subtropical urban forest. Ecological Complexity 20: 23-32. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47122

60. Torrez, M. A., W. J. Arendt, M. Sotelo, and S. J. Adolfo López. 2014. Indicadores taxonómicos de cambio de hábitat en los bosques nubosos de Nicaragua. Memoria, VIII Congreso Interdisciplinario de Investigación, 15-16 de mayo de 2014. Managua, Nicaragua: Universidad Centramericana, Direccion de Investigacion. Paginas 37-45.

61. Trejo-Torres, J. C., M. A. Caraballo-Ortíz, M. A. Vives-Heyliger, C. W. Torres-Santana, W. Cetzal-Ix, J. A. Mercado-Díaz, and T. A. Carlo. 2014. Rediscovery of *Eugenia fajardensis* (Myrtaceae), a rare tree from the Puerto Rican Bank. Phytotaxa 191(1): 154-164. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49015

62. Willig, M. R., C. P. Bloch, and S. J. Presley. 2014. Experimental decoupling of canopy opening and debris addition on tropical gastropod populations and communities. Forest Ecology and Management. 332 (2014): 103–117. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49016

63. Van Beusekom, A., G. González, and M. R. Rivera. 2015. Short-term precipitation and temperature trends along an elevation gradient in northeastern Puerto Rico. Earth Interactions 19: 1-33. Treesearch link: http://www.treesearch.fs.fed.us/pubs/47734

64. Zimmerman, J. K., J. A. Hogan, A. B. Shiels, J. E. Bithorn, S. Matta Carmona, and N. Brokaw. 2014. Seven-year responses of trees to experimental hurricane effects in a tropical rainforest, Puerto Rico. Forest Ecology and Management 332: 64-74. Treesearch link: http://www.treesearch.fs.fed.us/pubs/49018

Literature Cited

Brokaw, N. V. L. 1982. The definition of treefall gap and its effect on measures of forest dynamics. Biotropica 14, 158-160.

Hunter, M. O., M. Keller, D. C. Morton, B. Cook, M. Lefsky, M. Ducey, S. Saleska, R. C. de Oliveira Jr., and J. Schietti. 2015. Structural dynamics of tropical moist forest gaps. PLOS One 10(7), e0132144. doi: 10.1371/journal.pone.0132144