



FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

International Institute of Tropical Forestry

Accomplishment
Report 2021



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Editorial message

This edition of the Institute's Accomplishment Report for fiscal year FY 2021 is the first compiled since the passage of Hurricane Maria in 2017. As highlighted on this report, we have included two new sections, 1) Hurricane Recovery Projects, summarizing what we have learned about the effects of Hurricane Maria on forests in the U.S. Caribbean and their recovery, and 2) This Is Who We Are (TIWWA) piece showcasing our efforts in fostering our values as an Agency. 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!



Grizelle González
R&D Assistant Director, Research Ecologist



Dr. Grizelle González, R&D Assistant Director, Research Ecologist;
Jamarys Torres-Díaz, R&D Administrative Support Assistant; Edward
Quigley, Product Designer; Omar Gutiérrez del Arroyo, Science writer

Director's Message

I express my whole gratitude to all Institute employees, contractors, and collaborators for their exemplary performance and dedication during the last year and during a historic pandemic. All of you have accomplished the Institute's important mission with professionalism, despite the several challenges and continuous change.

As I reviewed this past year's accomplishments, I could not help but reflect that our employees are performing at a high level with their focus of caring for the land and serving the people. The IITF Team is performing above and beyond during a time when the world is experiencing a pandemic and the reorganization of the Institute is ongoing. All of this during a time when government resources, employees, and budget were limited. State and Private Forestry continues to reestablish partnerships and do local field work; International Cooperation continues to work with our partners on webinars all over the world; and our scientists have continued to do great research and push out publications.

This Accomplishment Report reflects how we, together, performed during stressful times, maintaining stability while making adjustments and courageously coming on top. We can look into the future with optimism toward the opportunities and challenges awaiting us. Working as Acting Director for the International Institute of Tropical Forestry will forever be a part of me. I have learned so much in the past 2 years while working at the Institute and with its employees. This is a wonderful place to work and be a part of.

I invite everyone to let the IITF know how we have done and to give us feedback on how to be more effective. All feedback will be used to better the Institute and give our customers what they want. 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. Thank you for your continued support and I look forward to an exciting future!



Gerry Jackson
Acting Director

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!





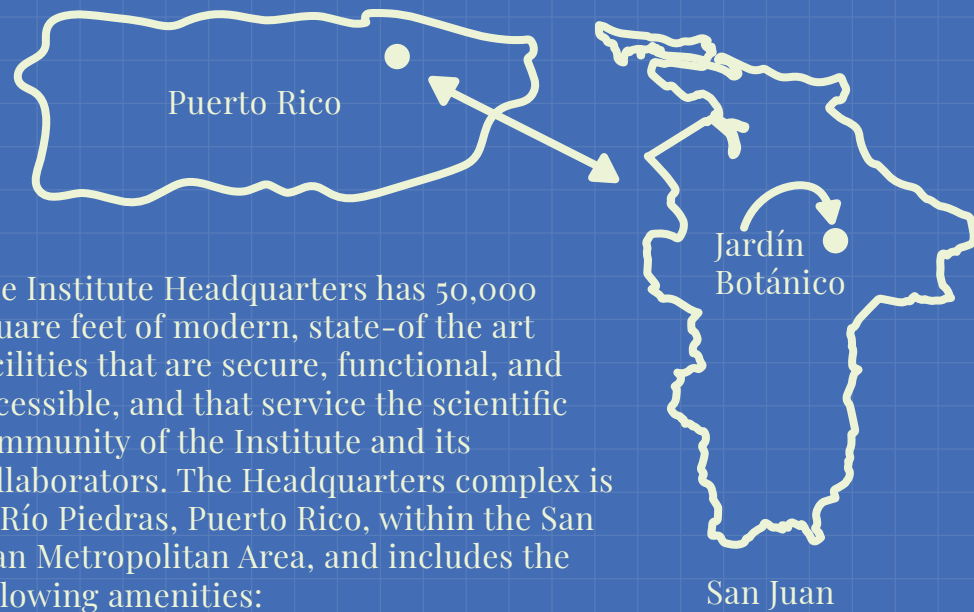
About the Institute

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.

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 employees or people 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.

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.

Institute Facilities



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 in Río Piedras, Puerto Rico, within the San Juan Metropolitan Area, 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 publications in English and Spanish on forestry, ecology, management, and utilization of tropical forests as well as other documents and materials related to tropical forests around the world.



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 conference 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.



Three back-up generators to ensure that electrical power is available for continuous operation during power black-outs, and a 3,400-gallon potable water tank that can provide drinking water during water shortages.

Institute Facilities

The Headquarters building



Institute Facilities

Forest Service National Library

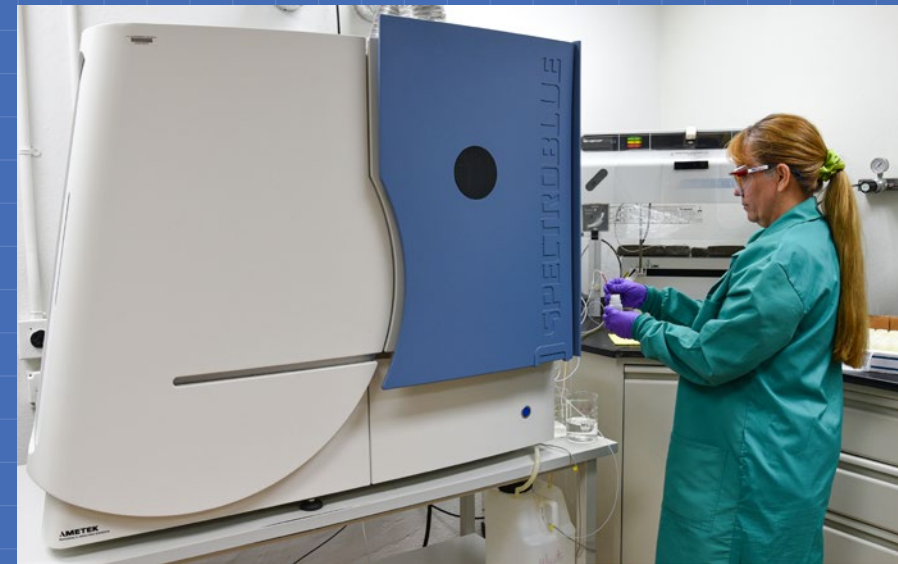


Spatial analysis laboratory



Institute Facilities

Chemistry laboratory



Sabana Field Research Station



The Sabana Field Research Station is situated adjacent to the Luquillo Experimental Forest (LEF, also known as El Yunque National Forest). It was originally established by the USDA 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 LEF, including the nearby Sabana River and Bisley Experimental Watersheds.

The station's 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, 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: <https://www.fs.usda.gov/detail/iitf/research/?cid=f-seprd486693>.

Operations Assistant: Miriam Salgado, PhD



Photos by: Gary Potts

Collaborators

Contractors:

Nora L. Álvarez-Berrios
Katlyn Betway
Johann Crespo Zapata
Aramis Garay Cruz
Normadie González
Iana F. Grullón-Penkova
Nicole A. Gutiérrez Ramos
Kris Harmon
Eva Holupchinski
Isabel Loza Rivera
Steve Maldonado Silvestrini
William F. Mejía García
Amelia Merced Alejandro
Monique Picón

Greening Youth Foundation Interns:

Lorena Cortés Torres
Andrés González Nieves
Christina de Jesús Villanueva
Alexander M. Lorenzo Ramos

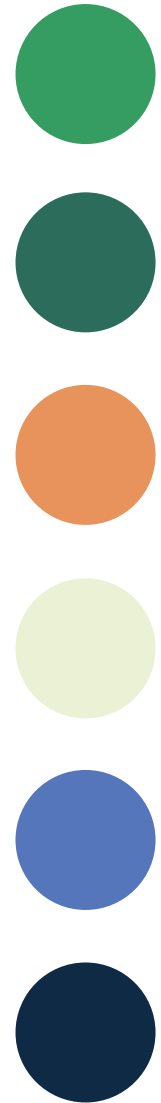
Volunteers:

Brissette M. Berrios Torres
Camila Colón Vega
Wanda Crespo Acevedo
Carmel Dill Cruz
Heather E. Erickson
Luis A. Esbrí Ruiz
Leinadis Fonseca Hernández
Stephanie González Ayala
Omar Gutiérrez del Arroyo
Elif Kardas
Edgardo Martínez
Ernesto Medina
Jordy Medina de León
Rebecca Montgomery
Ilán J. Nieves Gómez
Andrea Padilla
Janine Rice
Kermit Rivera
Luis Alexis Rodríguez-Cruz
Juan E. Santiago García
Nicole M. Soto Parrilla
Annais Talbot
Yamir Torres
German Vargas
Coralys Vicens López
Nelson Jr. Vientós Márquez
Joseph M. Wunderle Jr.
Sylvia Zavala

This is Who We Are

USDA Forest Service IITF Values

This is Who We Are - TIWWA



Safety

SAFETY in every way— physical, psychological, and social—for those who engage with and rely on our national forests and grasslands.



Conservation

As employees of the Forest Service, we believe in CONSERVATION. Protection when necessary. Preservation when appropriate. Restoration, when needed, and wise management for multiple use and enjoyment always.



Service

Our dedication to SERVICE describes not only our commitment to the American people but also our commitment to each other.

Diversity

We respect DIVERSITY in all things, including the people and communities we engage, and the cultures, perspectives, ideas, and experiences they embody and bring to the table.

Interdependence

Recognizing the INTERDEPENDENCE between us as colleagues—and between our agency and the people and communities we serve—means we know what we do always has an impact on others.



This Is Who We Are (TIWWA) is a guide designed to help us be values based, purpose driven, and relationship focused. This work is about WHO WE ARE and who we have ALWAYS been. It speaks to who we can be on our best days—drawing on our past, informed by our present, and remaining consistent with our historic mission. TIWWA outlines the Forest Service’s mission and purpose, forming the basis for creating an agency culture that is values based, purpose driven, and relationship focused. Three hundred Forest Service employees volunteered to be coordinators and ambassadors facilitating the conceptual framework for creating a safe, supportive, and inclusive culture.

At the International Institute of Tropical Forestry (IITF), Magaly Figueroa (State and Private Forestry Program Manager) is the TIWWA unit coordinator, Maya Quiñones (Natural Resources Specialist) and Shirley Prado (Executive Assistant) are ambassadors for the initiative. During the first phase, our IITF TIWWA team worked together to enhance relationship building and support strong communication. They also partnered with additional ambassadors from other regions to offer our coworkers engagement sessions in a modified schedule to encourage and facilitate participation from all Institute units and El Yunque National Forest (EYNF). Forest Service employees from Research and Development, State and Private Forestry, the IITF Library, Administration, International Cooperation and EYNF have attended the sessions. The Institute’s TIWWA team made the extra effort of offering most of the sessions in Spanish to better fit the needs of employees in Puerto Rico. This required translating the presentation and worksheets to fit local language and expressions. The Institute’s TIWWA team is the only unit in the US Forest Service offering engagement sessions in Spanish, honoring the Agency’s value of DIVERSITY. In total, they offered four sessions, including one full day in Spanish. At present, IITF employees have near-perfect levels of participation (98%), with a majority having completed their self-certification (86%).

Thanks to these notable efforts, the Institute’s TIWWA team was recognized in this year’s Chief’s Awards on the Forest Service Goal: Excel as a high-performance Agency and as part of the This Is Who We Are program.

This is Who We Are - Our Team



Gerry Jackson
Acting Director



Shirley A. Prado
Director's Office
Executive Assistant



Lía Sánchez
Director's Office
Office Automation Assistant



Rosa Ávila
Administration
Budget Officer



Eduardo Castro
Administration
Maintenance worker



Carolyn A. Pabón
Administration
Engineer



Janet Rivera
Administration
Grants Management Specialist

Omar Carrasquillo
Administration
Grants Management Specialist

Felix Torres Jr
Administration
Assistant Director
for Administration



Gerald "Jerry" Bauer
International Cooperation
Assistant Director,
Biological Scientist



Rebecca Cirretti
International Cooperation
Contractor



Yanira L. Cortés
International Cooperation
Administrative
Support Assistant



Mirel Volcán
International Cooperation
Contractor



Magaly Figueroa
State & Private Forestry
Assistant Director
Natural Resources Specialist



Kevin Carlin
S&PF
Forest Health
and Protection
Program Manager



Lorena Cortés
S&PF
Greening Youth
Foundation intern,
Forestry
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Aramis Garay
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Andrés González
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Greening Youth
Foundation intern



Christina de Jesús
S&PF
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Alexander Lorenzo
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Bryologist,
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Aixa Mojica
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Administrative
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Jorge Morales
Librarian



Evelyn Pagán
Library Technician



Maya Quiñones
Urban and Community
Forest Program and
Forest Stewardship
Program Manager,
Natural Resources Specialist



Sylvia Zavala
Volunteer Librarian



Grizelle González
R&D
Assistant Director,
Research Ecologist



Olga M. Ramos
R&D
GIS Laboratory
GIS Analyst



Carlos Rodríguez
R&D
Ecologist,
Land Manager,
Safety Manager



Miriam Salgado
R&D
Sabana Field
Research Station
Operations Assistant



Jamarys Torres
R&D
Administrative
Support Assistant

This is Who We Are - Our Team



Maysaá Ittayem
R&D
Chemistry Laboratory
Chemist



Edwin López
R&D
Chemistry Laboratory
Chemist



Joel S. Olivencia
R&D
Chemistry Laboratory
Electronics technician



María Marrero
R&D
Chemistry Laboratory
Chemist



Maribelís Santiago
R&D
Chemistry Laboratory
Chemist



Edgardo Valcárcel
R&D
Chemistry Laboratory
Biological Science Technician



Wayne Arendt
R&D
Research Wildlife
Biologist



William A. Gould
R&D
Research Ecologist
Director
Caribbean Climate Hub



Tamara Heartsill
R&D
Research Ecologist



Eileen H. Helmer
R&D
Research Ecologist



Michael Keller
R&D
Research Physical Scientist



Kathleen McGinley
R&D
Research Social Scientist



Tischa A. Muñoz
R&D
Research Social Scientist



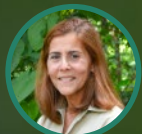
Tana E. Wood
R&D
TRACE PI
Research Ecologist



Ariel E. Lugo
R&D
Emeritus Scientist



Joseph M. Wunderle
R&D
Emeritus Scientist



María M. Rivera
R&D
Field Technician
General Biologist
Specialist



Carlos R. Estrada
R&D
Field Technician
Hidrology Technician



Humberto Robles
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Biological Science
Technician



Carlos M. Torrens
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Biological Science
Technician



Iván Vicens
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Forestry
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Iana F. Grullón
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Project Coordinator



Nicole A. Gutiérrez
R&D - TRACE
Plant Physiology Technician



M. Isabel Loza
R&D - TRACE
Project Manager



William F. Mejía
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Nora L. Álvarez
R&D
Caribbean Climate Hub
Fellow



Katlyn Betway
R&D
Caribbean Climate Hub
Contractor



Johann Crespo
R&D
Caribbean Climate Hub
Contractor



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Volunteer



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Contractor



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R&D
Caribbean Climate Hub
Contractor



Monique Picón
R&D
Caribbean Climate Hub
Contractor



Luis A. Rodríguez
R&D
Caribbean Climate Hub
Volunteer

Administration and Support

Employees by Unit

Research and Development	25
State and Private Forestry	5
International Cooperation	2

Administration 8 (+2 from Director's Office)

Workforce Statistics

Total IITF Permanent Employees	42
Average USDA service	21 years

Contractors/Interns/Volunteers 45

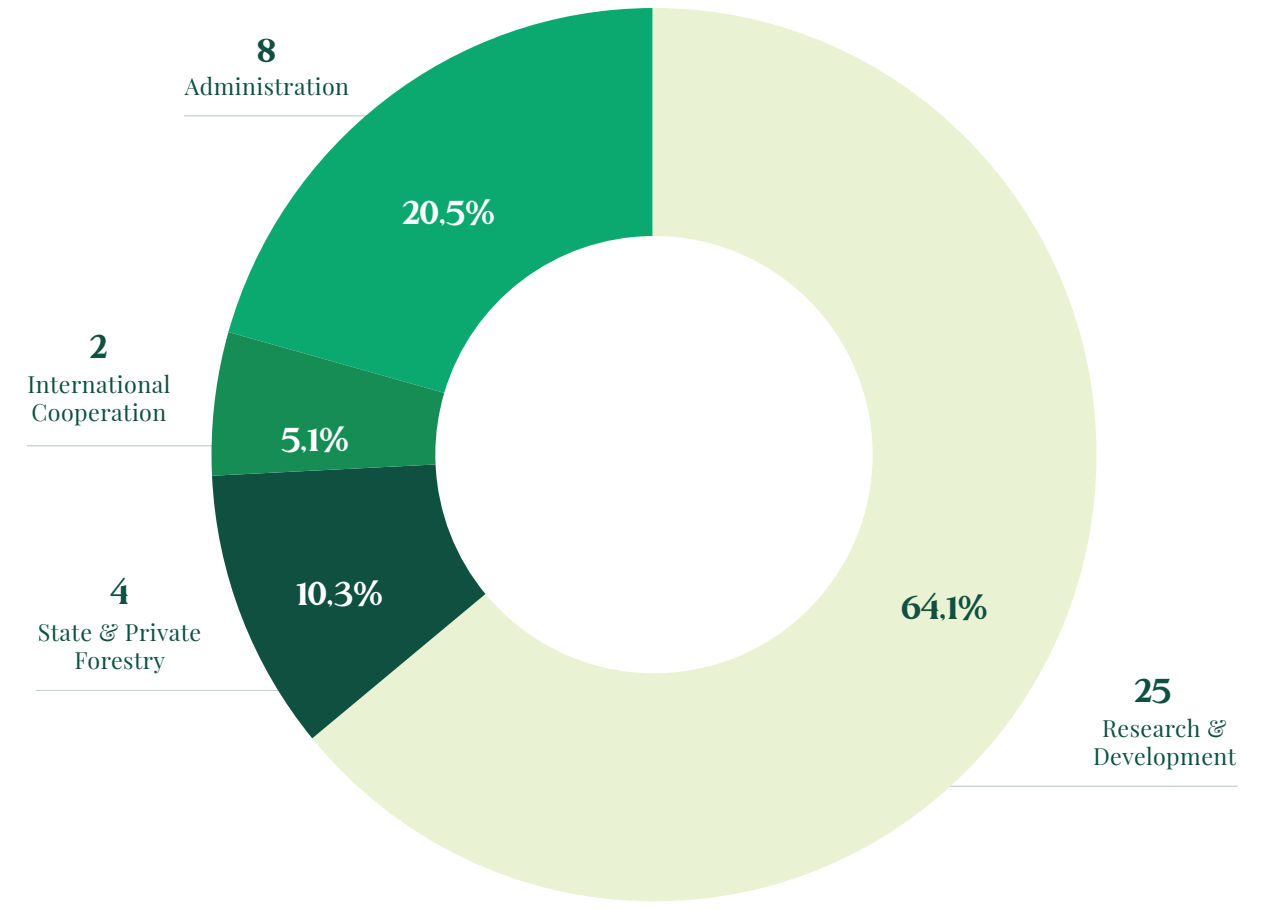
Occupation Type Breakdown

Professional	47%
Technical	28%
Administrative	25%

Educational Experience

Bachelor's degree	39%
Graduate degree (M.Sc. or Ph.D.)	30%

Distribution of IITF Employees by Unit



Administration and Support

Unit	Programmatic Funds	Salary	Total
Research and Development	\$ 601,915	\$ 2,620,919	\$ 3,222,834
International Cooperation	\$ 170,246	\$ 243,401	\$ 413,647
State and Private Forestry	\$ 2,313,385	\$ 383,596	\$ 2,696,981
Administration	\$ 487,620	\$ 1,252,488	\$ 1,740,108
Total	\$ 3,573,166	\$ 4,500,404	\$ 8,073,570

Incoming Funding

Research and Development	\$3.22 million
International Cooperation	\$0.41 million
State and Private Forestry	\$2.70 million
Administration	\$1.74 million
Programmatic Funds	\$3.57 million
Salary	\$4.50 million
Total IITF	\$8.07 million

Incoming Funding



Cooperators Who Received Funding from the Institute in FY21

Non-Governmental Organizations

Centro para la Conservación del Paisaje, Inc.
Distrito Caribe de Conservación de Suelos
Distrito de Conservación de Suelos y Aguas del Suroeste, Inc.
Greening Youth Foundation, Inc.
Para La Naturaleza, Inc.
Paso Pacifico
Protectores de Cuencas, Inc.
St. Croix Environmental Association
Ciudadanos del Karso, Inc.

Private Industry

GreenWood, Inc.
Janine Rice Consulting

Universities

Colorado State University
Humboldt University
North Carolina State University
Universidad Interamericana de Puerto Rico, Inc.
University of Minnesota
University of Puerto Rico - Río Piedras Campus
University of Puerto Rico - Agricultural Extension Service
University of Puerto Rico - Research Division
University of Wisconsin

State Government

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

Federal Agencies

Department of Health & Human Services (HHS),
Federal Occupational Health

Cooperators Who Provided Funds to the Institute in FY21

Universities

Arizona State University
Florida International University

Federal Agencies

Natural Resource Conservation Service (NRCS)
National Oceanic and Atmospheric Administration (NOAA)
Office of the Chief Economist (OCE), Climate Change Program Office
U.S. Department of Energy (DOE)
U.S. Geological Survey (USGS)



IITF - From Science to Action
Learning from Extreme Climate Events / Forest Responses to Hurricane Maria
By Omar Gutiérrez del Arroyo Santiago, PhD

Photo by: Gerald "Jerry" Bauer.



2017



2021

On September 20st, 2017, the forests of Puerto Rico faced their first major hurricane of the 21st century—Hurricane Maria—, which had profound effects on the social-ecological-technical systems (SETS) of Puerto Rico [Lugo, 2020]. This historic hurricane, and the wealth of scientific research that has been produced in the five years since, revealed the maturity of the International Institute of Tropical Forestry (the Institute) as the leading

institution of forest research and management in Puerto Rico and USVI. Scientists and technicians from the Institute and other institutions, along with collaborating land managers, documented the myriad effects of Hurricane Maria on SETS in Puerto Rico and the complex recovery process that is still ongoing, building on the knowledge about forest ecosystem dynamics accumulated throughout the deep history of the Institute [Zimmerman

et al., 2021]. The application of a wide range of methods that were available to our scientists for monitoring ecosystem responses to disturbance, including remote sensing techniques as well as plot-based observations, allowed for the development of a holistic perspective of the immediate and short-term effects of Hurricane Maria on the diverse forest ecosystems across Puerto Rico.



October 2010



October 2017



Photo by: Grizelle González

In order to better understand the causes of the large spatial variation of Hurricane Maria's effects, Institute scientists used satellite data to model the effects of hurricane forces on forests across the U.S. Caribbean [Van Beusekom et al., 2018]. These models consider independent variables such as kinetic energy and total rainfall, among other landscape characteristics, to explain the

observed spatial variation in greenness loss and landslide occurrence. Higher levels of greenness loss were observed for the Luquillo Experimental Forest (LEF; concomitant to El Yunque National Forest) compared to the entire region, in part due to the steep elevation gradient and rugged topography. Similarly, landslide occurrence—associated with high rainfall and soil clay content—

was more frequent in the LEF relative to the rest of the region. An assessment of forest susceptibility to hurricane effects based on these models revealed that both hurricane properties, such as intensity, and landscape characteristics, such as forest cover and fragmentation, were important for determining the future vulnerability of forests in the U.S. Caribbean to hurricane disturbance.



Photos by: Gerald "Jerry" Bauer.

A good example of the significant spatial variation of hurricane effects are the regional differences in hurricane-induced litterfall rates that were measured in the field by Institute scientists across four forests found in contrasting life zones [Liu et al., 2018]. While vegetation was severely defoliated after Hurricanes Irma and Maria at all sites, there was a gradient

of disturbance that was related to the exposure to the hurricane tracks, as well as the prevailing forest structure. Wet forests sustain higher levels of standing biomass, and thus produce more background litterfall than moist or dry forests. The magnitude of hurricane-induced pulses of litterfall were associated with these differences in forest structure, with higher

values in wet forests such as in the LEF and Río Abajo State Forest. Moreover, the significant effect of Hurricane Irma only on the forest in BEW just two weeks before Hurricane Maria highlighted the importance of considering the geographic position relative to the hurricane tracks for understanding the spatial variation observed across the landscape.

The effects of Hurricane Maria and subsequent forest recovery along an elevational gradient at the LEF were further explored using airborne LiDAR data acquired from 2016 to 2020 [Leitold et al., 2021]. This study was conducted in collaboration with NASA scientists and revealed widespread loss of canopy height across the study area. However, this reduction in forest canopy height was of variable magnitude across the

landscape, with larger statured forests in the lower elevations suffering more damage than shorter forests above 600 m. While the hurricane opened the canopy releasing light-limited understory vegetation, a combination of fast height growth and lateral crown expansion by surviving individuals and advanced regeneration were able to maintain a heterogeneous canopy with only a small fraction of forest gaps detected in

2018, only one-year post-hurricane. This LiDAR time series across the LEF elevation gradient also allowed for the determination of three change trajectories of canopy damage and recovery (loss-gain, loss-zero, zero-zero) that are related to the observed patterns of vertical redistribution and reveal the dynamics response of forest structure to the hurricane disturbance.



Photos by: Grizelle González

In the lowlands of the LEF at the Institute's Sabana Field Research Station, the Tropical Responses to Altered Climate Experiment (TRACE) also provided an invaluable research platform for studying the effects of Hurricane Maria, as well as its interaction with the forest warming treatment. Specifically, this experiment was able to capture the response of soil biogeochemistry to the hur-

ricane disturbance, which resulted in increases in soil carbon and nutrient concentrations [Reed et al., 2020]. The nutrient pulse caused by the hurricane debris also drove an increase in the phosphorus concentration of soil microbial biomass, demonstrating the significant effects of these disturbances on belowground processes. The post-hurricane soil nutrient pulse was of larger

magnitude in the warmed plots revealing a significant interaction between these two drivers of global change. Moreover, the abrupt changes caused by the hurricane resulted in a shift in the forest understory plant community composition, as well as a significant increase in the herbaceous cover due to increasing light penetration to the forest floor [Kennard et al., 2020].

As a result of the changes in forest structure caused by Hurricane Maria, some forest abiotic properties such as light availability and humidity were drastically affected [Van Beusekom et al., 2020]. The hurricane effects on canopy, understory, and soil microclimate were well-captured thanks to the ongoing satellite and field-based monitoring efforts as part of the Luquillo Long-Term Ecologi-

cal Research program's Canopy Trimming Experiment (CTE) in the LEF. In addition to providing the essential infrastructure for capturing the hurricane effects and recovery process, the long-term data derived from the CTE allowed for comparing previous treatment responses to the response of an actual hurricane. Looking into the future, these long-term ecosystem-scale experiments

provide an invaluable platform and source of information for improving our understanding of how tropical forest ecosystems will respond to more frequent disturbances.



Photos by: Grizelle González

The extensive research efforts conducted by Institute scientists and collaborators focused on understanding the effects of Hurricane Maria have been complemented by various collaborations with other USDA FS Research Stations and the University of Puerto Rico (UPR). For example, the preliminary results of the 2019 Forest Inventory Analysis (FIA)—conducted in collaboration with USFS Southern Research Station—have provided valuable plot-based

estimates of hurricane damage and mortality across the U.S. Caribbean. The 2019 FIA revealed that 31% of trees suffered the loss of their canopies, and that hurricane damage was more frequent for introduced (*S. campanulata*) compared to native species (*T. heterophylla*, *B. simaruba*). Across the island mortality rates averaged 10% (~144 million trees), showing a gradient of increasing mortality from dry to wet forests. In addition to these data, the FIA

provides a historical time series of estimates of forest cover, aboveground biomass, among other key forest variables. Another collaboration with scientists from the University of Puerto Rico using acoustic monitoring provided valuable insights into the response of bird and frog communities to Hurricane Maria across the LEF elevation gradient [Campos-Cerqueira and Aide, 2021].

Finally, the effects of Hurricane Maria on urban forests in three large municipalities of Puerto Rico were studied by scientists from the Department of Environmental Sciences at UPR Río Piedras. This post-hurricane assessment commissioned by the Institute found the vulnerability of urban green infrastructure was higher in San

Juan, where tree cover is relatively low, compared to the municipalities of Ponce and Mayagüez which have higher tree cover and had smaller losses of tree cover due to the hurricanes [Meléndez-Ackerman et al., 2018]. In all urban areas, associated with a loss of tree cover was a decreased capacity for the provision of key ecosystem

services such as pollution removal and carbon storage. The main recommendations of the report include the expansion of urban forest monitoring, as well as starting immediate efforts to increase urban canopy cover to replace the ecosystem services lost after the hurricanes of September 2017.



Photo by: Grizelle González

The historic event of Hurricane Maria in 2017 undoubtedly marked the Puerto Rican society and had major consequences for its forest ecosys-

tems. The Institute's unique position as a leader of scientific research on the island allowed for a wealth of knowledge to be developed based on the ex-

periences of many scientists that lived through and studied this extreme event. Some of the lessons learned from this event have been summarized in

a recent book authored by the Institute's past director (now Emeritus Scientist) that focuses on planning for resilience under extreme events. May the

lessons learned through these experiences and shared with the public in these publications by Institute scientists and collaborators continue improving

our fundamental relationship with the forests that sustain us.



References

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Research and Development



1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

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 a solid foundation 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.

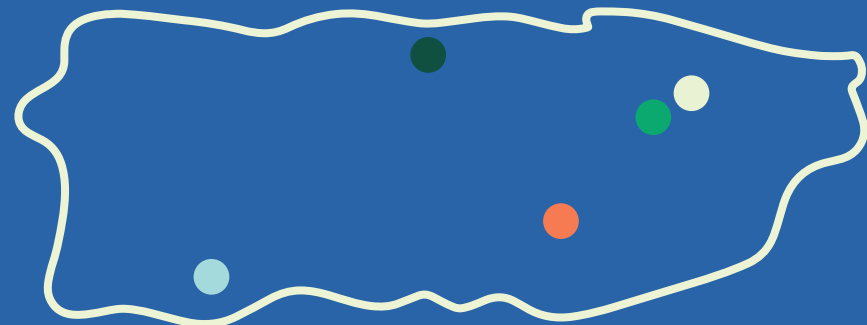
Grizelle González
R&D Project Leader,
Research Ecologist
grizelle.gonzalez@usda.gov

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

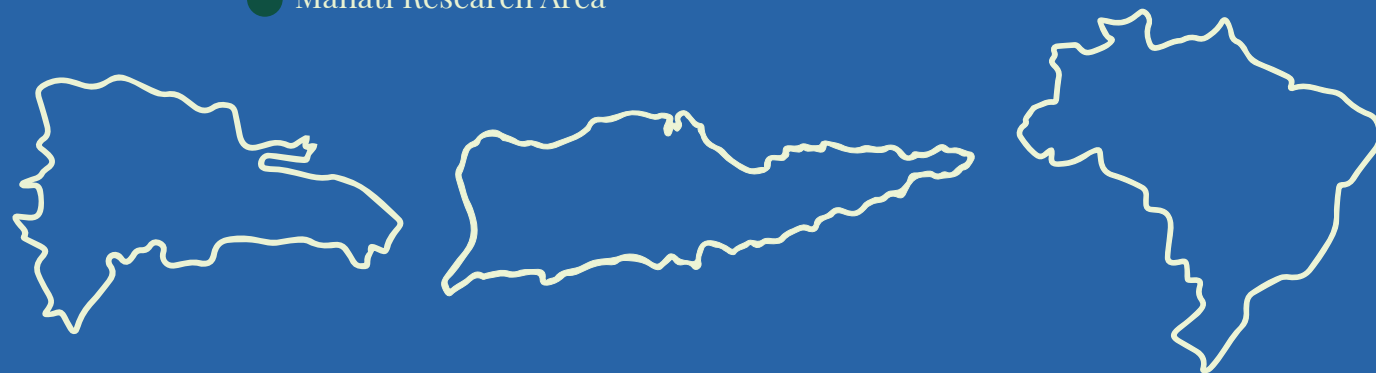
These include:

- 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 the LFDP
- El Verde Research Area
- Guánica Biosphere Reserve
- Guayama Research Area
- Manatí Research Area



Dominican Republic

Estate Thomas Experimental Forest, St. Croix, U.S. Virgin Islands

The Brazilian Amazon



Grizelle González

Assistant Director,
Research Ecologist
Soil ecology and biology, ecosystem ecology, tropical ecology, earth-worm ecology



Wayne J. Arendt

Research Wildlife Biologist
Urban birds, biodiversity, climate change, environmental contaminants, conservation and management of neotropical resident and migratory bird communities and invasive species



William A. Gould

Research Ecologist-
Director Caribbean Climate Hub
Conservation science, biodiversity, ecology, land cover mapping, modeling future scenarios for conservation planning, and field education and outreach



Tamara Heartsill-Scalley

Research Ecologist
Tropical forests, riparian vegetation, streams, wetlands, monitoring long-term responses of tropical forests to disturbances



Eileen Helmer

Research Ecologist
Tropical forest ecology, Caribbean vegetation, forest mapping, biodiversity, remote sensing, tropical montane ecosystems, climate change, forest dynamics, land-use and land-over change, drivers of ecosystem change



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



Kathleen McGinley

Research Social Scientist
Forest policy and governance; Adaptive, collaborative forest management; Community forestry; Forest certification; Tropical forest management; Criteria and Indicators of Sustainable Forest Management



Tischa A. Muñoz-Erickson

Research Social Scientist
Urban sustainability governance, collaborative natural resource governance, knowledge co-production, knowledge-action networks, civic environmental stewardship, foresight and anticipatory methods for climate adaptation and resilience, social-ecological-technological systems



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

Research Highlights

Puerto Rico Breeding Atlas

USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

International Institute of Tropical Forestry | General Technical Report IITF-53 | May 2021

The Puerto Rico Breeding Bird Atlas

Jessica Castro-Prieto, Joseph M. Wunderle, Jr., José Salguero-Farías,
Sandra Soto-Bayó, Johann D. Crespo-Zapata, William A. Gould



The International Institute of Tropical Forestry published a new atlas on breeding birds in Puerto Rico, the first effort of this nature in the Caribbean and Neotropics. The atlas provides information on the breeding season and geographic distribution of 130 species of breeding birds in Puerto Rico, its satellite islands and associated keys. It includes contributions from 344 volunteer observers from the Puerto Rican Ornithological Society who made more than 45,500 individual observations of terrestrial and aquatic birds in the period from 2004 to 2009.

The 325-page atlas contains four chapters describing the objectives and methodology of the study, the issues of changes to habitat and effects on bird life, the implications of climate change for breeding birds in Puerto Rico, and a postscript on the need to further study the impacts of 2017 Hurricanes Irma and María on the distribution and reproduction of birds.

The results of this voluntary effort provide a look at the distribution of 130 breeding bird species from 2004–2009, which can serve as the basis for future comparisons of bird responses to changes in land use and climate in Puerto Rico. These bird species are part of the richness and biodiversity of Puerto Rico. By improving our knowledge of their distribution and behavior, we help managers work to sustain breeding populations considering changing climate and threats to vulnerable habitats.

The description of each of the 130 bird species is detailed in 244 pages illustrated with photos, maps, tables, and graphs. Also included are 17 pages of bibliographic references, an appendix with the names of all the volunteers who worked in the effort, and another with the list of bird species in the atlas, including: 73 native residents, 26 exotic, 16 endemic, 13 subspecies endemic, and 2 native and migratory birds.

Some more well-known species included are the Yellow-shouldered Blackbird, the Puerto Rican Oriole, the Puerto Rican Spindalis, the Puerto Rican Tanager, the Northern Mockingbird, the House Sparrow, the Red-legged Thrush, the Gray Kingbird, the Puerto Rican Woodpecker, the Puerto Rican Tody, the Broad-winged Hawk, the Puerto Rican Owl, the Puerto Rican Emerald, the Cattle Egret, the Brown Pelican, the Willet, the Purple Gallinule, and four species of parrots, among others.

The idea for the study came from a meeting of the Society for the Conservation and Study of Caribbean Birds (now Birds Caribbean) in July 2003 on the island of Tobago. The breeding distributions summarized in the atlas facilitate comparisons with previously published distribution descriptions for each species and serve as a baseline for future studies of bird distributions and their responses to land use and climate change in Puerto Rico and the surrounding islands and keys.

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Related publication: Castro-Prieto, Jessica; Wunderle, Jr., Joseph M.; Salguero-Farías, Jose A.; Soto-Bayó, Sandra; Crespo-Zapata, Johann D.; Gould, William A. 2021. The Puerto Rico breeding bird atlas. Gen. Tech. Rep. IITF-53. Rio Piedras, PR: U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry. 311 p. <https://doi.org/10.2737/IITF-GTR-53>.



Image caption: The endemic Puerto Rican Tody or San Pedrito (*Todus mexicanus*) nests in small burrows they dig in exposed earthen banks, typically between February and March.

Photo by: Marconi Campos Cerqueira

Hurricane challenges in the agricultural sector through the eyes of public advisors in Puerto Rico and USVI



Image caption: USDA Climate Hub and Caribbean Climate Hub leaders view coffee trees damaged by Hurricane Maria on January 30, 2018. Coamo, Puerto Rico. Photo by: Eva Holupchinski

The 2017 hurricane season posed extraordinary challenges for the Caribbean. Puerto Rico and USVI were hit by hurricanes Irma on September 6 and María on September 20 causing unprecedented social, ecological, and economic effects. We analyzed the challenges caused by the hurricanes in the agriculture sector through a systematic assess-

ment of the experiences and perceptions of agricultural advisors in this region. Advisors perceived the effects on farmlands to be significant and devastating. The most prominent effects highlighted included power outages, communication issues, impassable roads and fallen trees. The implementation of critical practices for preparedness before the arrival

of the hurricanes was generally perceived as limited.

Additionally, the recovery stage was perceived to be impeded by a lack of materials, communication, transportation, planning, and agency coordination. Finally, the incorporation of long-term preparedness practices important to face future hurricanes was perceived to

be largely absent. The results indicate the need for more coordinated efforts in the integration and collection of data among emergency management and agricultural agencies to help expedite hurricane response and mitigation. Our study also reveals a gap in training and a need for educational resources on hurricane preparedness among agricultural advisors,

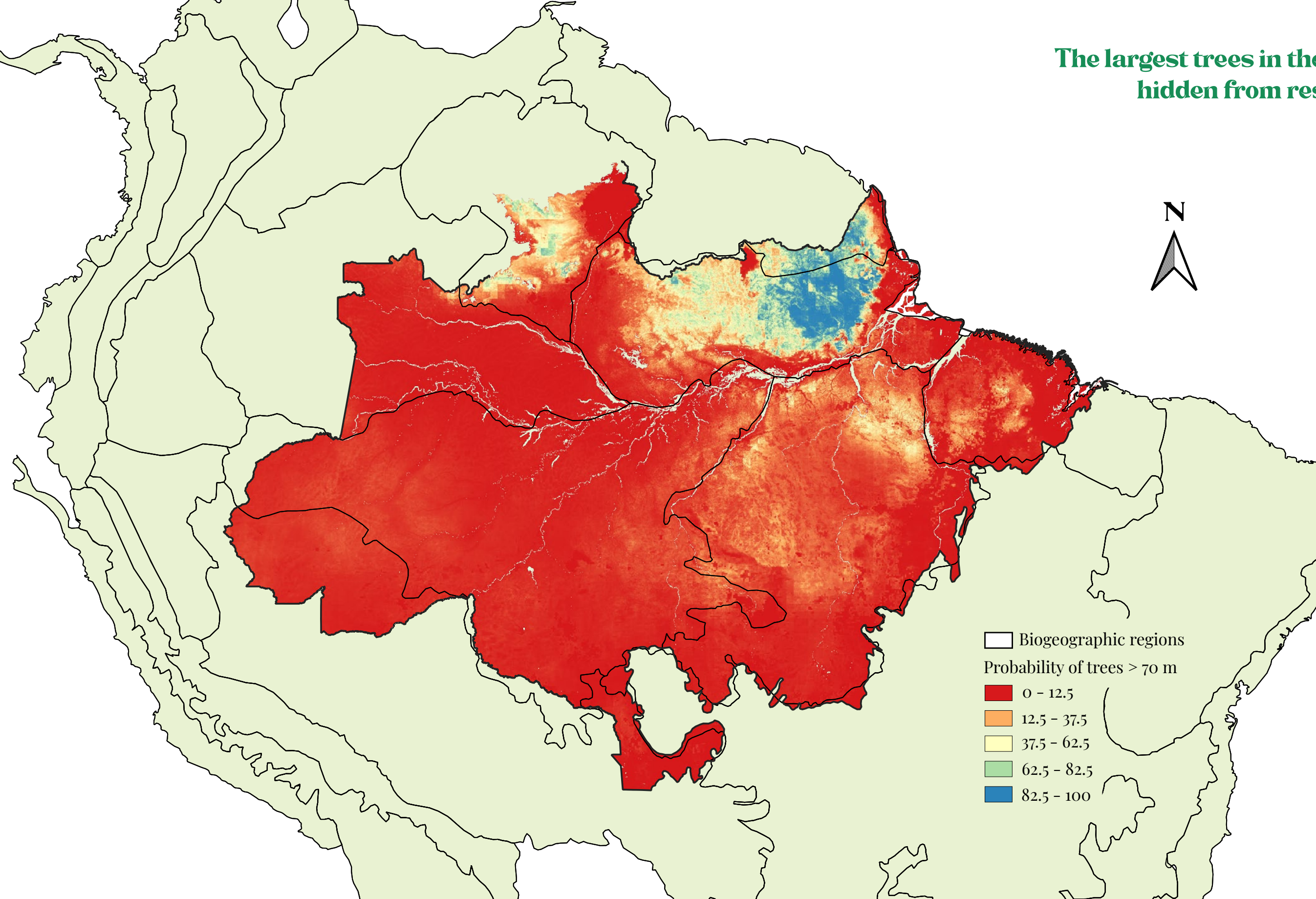
particularly concerning long-term strategies.

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Related publication: Álvarez-Berríos, Nora L.; Wiener, Sarah L.; McGinley, Kathleen A.; Lindsey, Angela B.; Gould, William A. 2021. Hurricane effects, mitigation, and

preparedness in the Caribbean: Perspectives on high importance-low prevalence practices from agricultural advisors. *Journal of Emergency Management*. 19-8:135-155. <https://doi.org/10.5055/jem.0585>

The largest trees in the Amazon have been hidden from researchers until now



The Amazon forest is the largest expanse of tropical forest on Earth. Unlike the tropical forests in Asia, it is not known for its towering trees – until now. Working with Brazilian colleagues we analyzed data from an airborne laser scanning survey of Amazon forests. The technology known as lidar measures the distance from the aircraft to the tops of the trees and the ground beneath the trees to allow us to estimate tree height. We found that a relatively unexplored region in the Northeastern Amazon harbored many tall trees and we asked why they were abundant there and rare or non-existent elsewhere in the Amazon. The answer seems to be wind. In regions with little wind, trees have the time to grow tall whereas in windier places they would be more likely to be knocked to the ground or broken in a storm before they became giants.

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Related publication: Gorgens, E.B., Nunes, M.H., Jackson, T., Coomes, D., Keller, M., et al. Resource availability and disturbance shape maximum tree height across the Amazon. *Glob Change Biol.* 2020; 27: 177– 189. <https://doi.org/10.1111/gcb.15423>

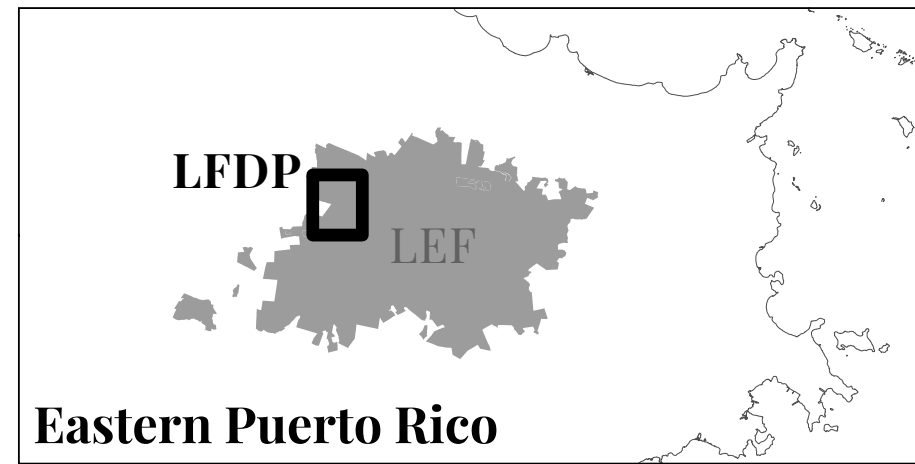
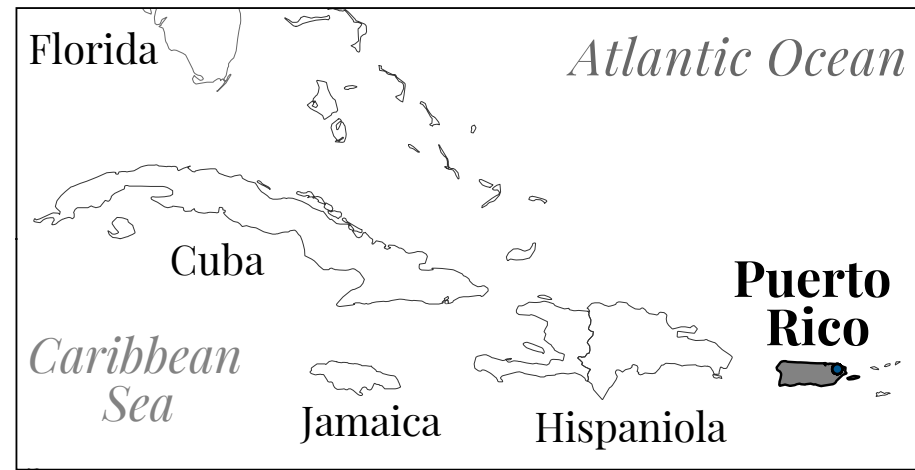
Map caption: The probability of giant tree occurrence based on environmental conditions estimated by a statistical model. In the regions colored blue, it is 87.5% likely to find at least one giant tree in an area of 375 ha (about 53 football fields or 1.4 square miles) Map credit: Eric Gorgens

Past land use distinctly alters riparian composition and leaf-fall along montane streams

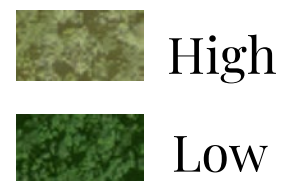
Although past land-use effects on composition and structure are described for many forest types, forested riparian areas are often overlooked. Tropical riparian areas contain unique and high number of species, also contributing to leaf-fall for aquatic fauna consumption. We asked: How does past land use alter composition in riparian versus upland areas? Which vegetation life forms characterize riparian zones? What is the composition and quantity of leaf litter in riparian zones compared to uplands? We sampled riparian and upland locations with high and low past land use in the Luquillo Experimental Forest, Puerto Rico. Riparian zones were characterized by greater presence of ferns and lianas, had higher species richness and greater leaf litter biomass than upland areas. Distinct leaf-litter species composition within riparian and upland areas may result from a combination of different land-use histories, various plant types, and environmental conditions. Although riparian areas are proportionally a small component of the forested landscape, they are significant contributors to ecosystem process, terrestrial and aquatic linkages, and plant community composition.

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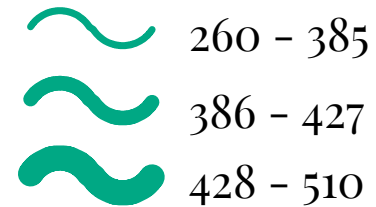
Related publication: Heartsill-Scalley, Tamara; Crowl, Todd A. 2021. Tropical forest understory riparian and upland composition, structure, and function in areas with different past land use. Applied Vegetation Science. <https://doi.org/10.1111/avsc.12603>



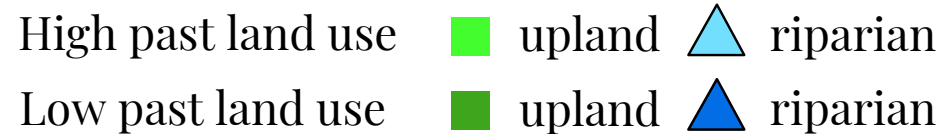
Past Land Use



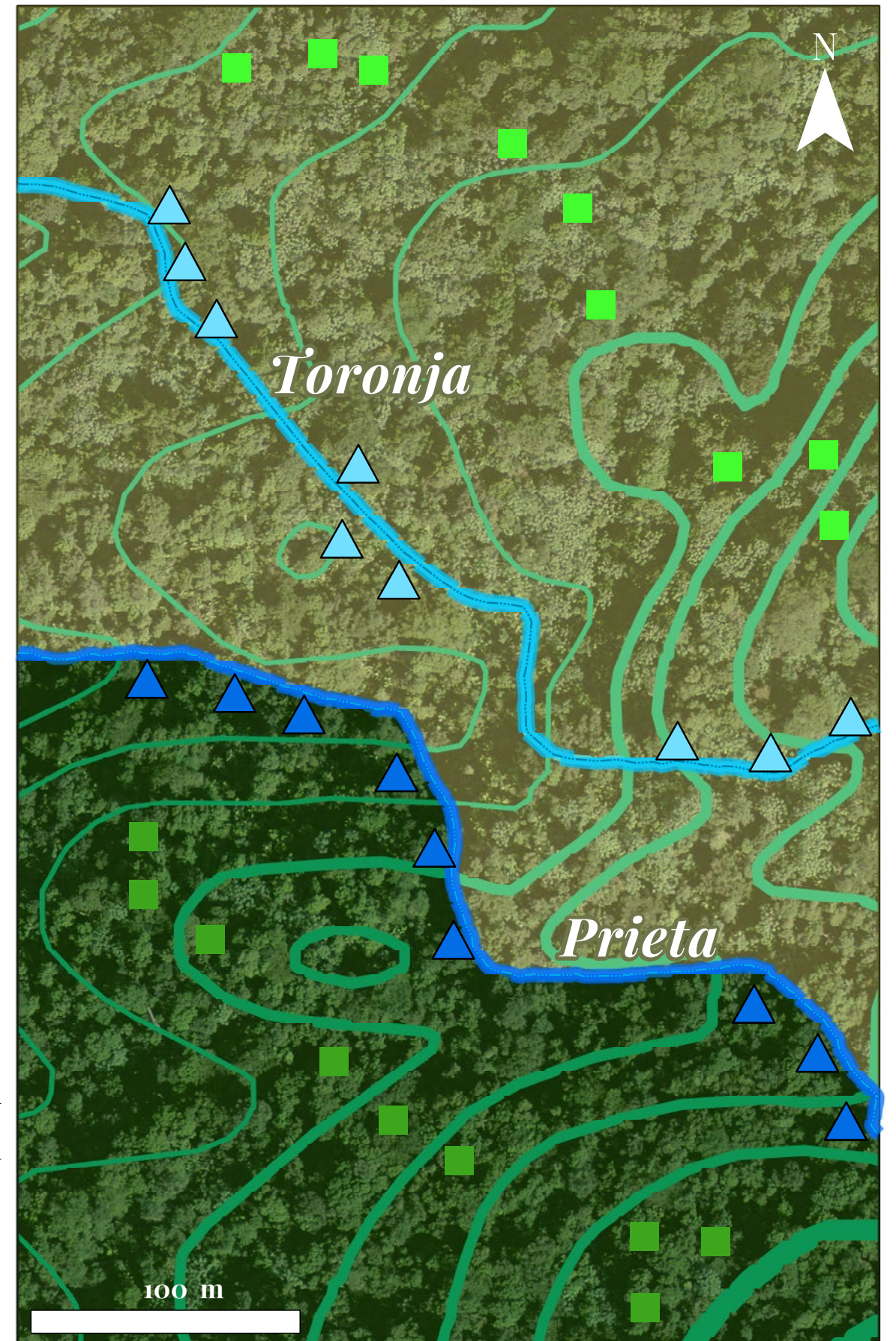
Elevation (m)



Plots



Stream



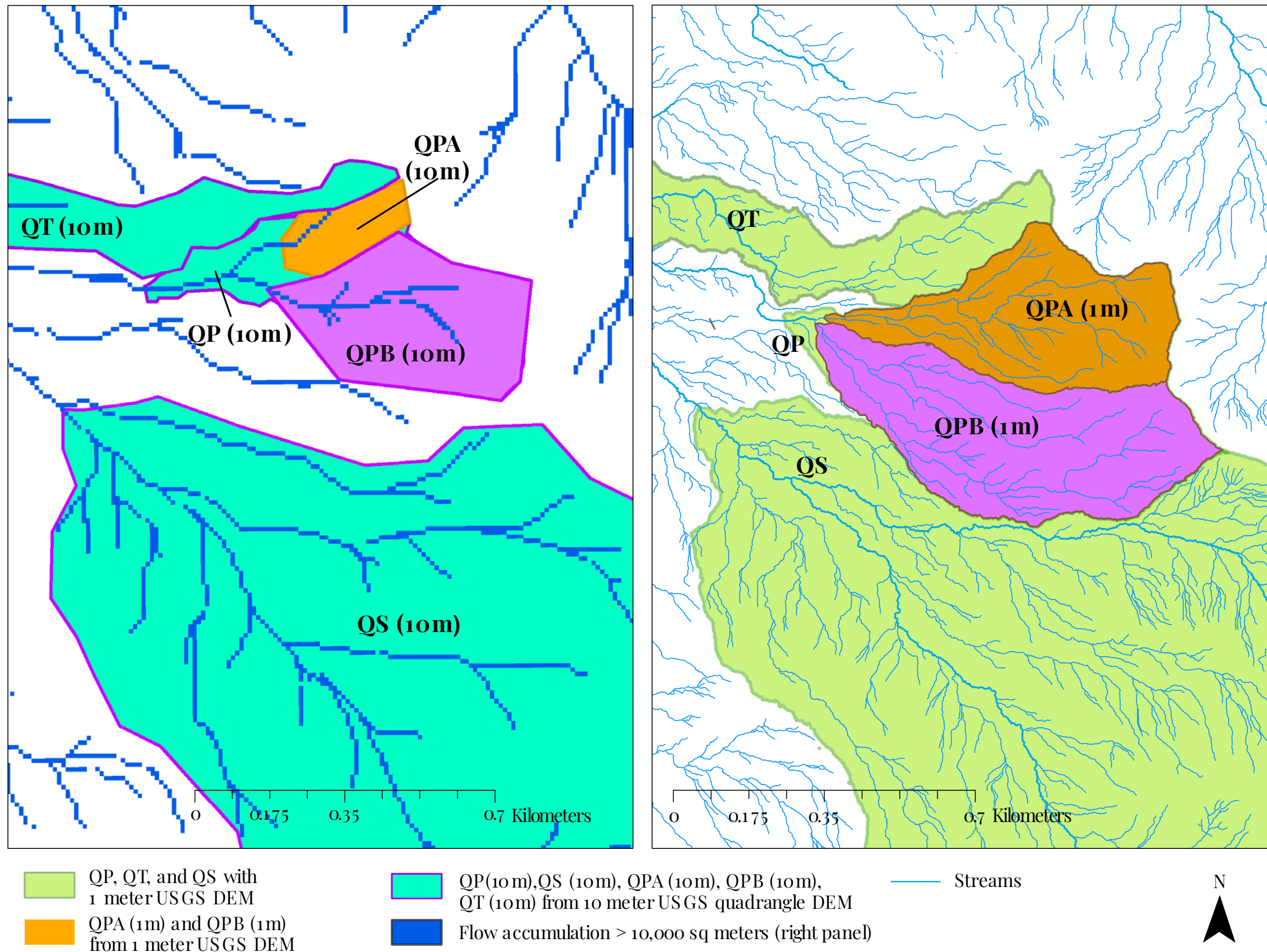
Map caption: Diagram of the Greater Antilles, highlighting Puerto Rico, and the Luquillo Experimental Forest (LEF) in the northeast, where the 16-ha Luquillo Forest Dynamics Plot (LFDP) is located. The diagram illustrates the relative locations of sampled upland (square) and riparian (triangle) vegetation areas, the streams Prieta and Toronja, and past land use. Map credit: Olga Ramos and Tamara Heartsill-Scalley

Accurately representing perennial and intermittent streams requires local knowledge

Streams and rivers of the Luquillo Experimental Forest, Puerto Rico, have been sites of extensive and continuous research on stream export of nutrients and organic matter, physicochemical constituents, and aquatic fauna populations. However, many of the streams and watersheds studied do not appear in standard scale (1:20,000) maps. A recent collaborative and multi-institutional effort was able to improve hydrological network information and identify knowledge gaps. The methods used to delimit and densify stream networks include the use of a new vertical datum (elevation model with local benchmarks) for Puerto Rico, elevation derived remote sensing technology (e.g., Light Detection and Ranging, LiDAR), and a combination of visual-manual and automated digitalization processes. The outcomes of this collaborative effort include improved watershed delineation and densification of hydrologic networks to reflect streams at the scale of on-going studies. The identification of unmapped roadways, culverts, and other features of the built environment that interrupt water flow and alter runoff pathways will improve flow accumulation models. This new hydrological data and the derived maps can contribute to enhance knowledge for watershed management, including attributes of riparian areas, aquatic fauna populations, flash-flood risk assessments, and on the effects of road and channel intersections, with broad practical applications.

Institute contact: Tamara Heartsill-Scalley, tamara.heartsill-scalley@usda.gov

Related publication: Leon, M. C., T. Heartsill-Scalley, I. Santiago, W. H. McDowell (2021). Watersheds and stream networks in the Luquillo Experimental Forest, Puerto Rico., HydroShare, <https://doi.org/10.4211/hs.1c8ffe88d6ec46bca853fd836bd2948e>



Map caption: Diagram of mapped streams in the El Verde Research Area, Luquillo Experimental Forest, Puerto Rico. Left panel contains stream networks derived from 10 square meter DEM from USGS quadrangle maps, right panel includes the newly delineated watersheds and their associated perennial and intermittent streams derived from 1 square meter USGS DEM. Watersheds derived from 10 m DEM are labeled as such (10 m). The long-term research watersheds and streams outlined in the figure are QS: Quebrada Sonadora; QP: Quebrada Prieta; QPA: Quebrada Prieta A; QPB: Quebrada Prieta B; and QT: Quebrada Toronja.

Map credit: Iván Santiago, Miguel León, William McDowell, and Tamara Heartsill-Scalley

Co-Producing Resilient, Sustainable, and Equitable Futures for San Juan, Puerto Rico. A Story Map

Recent record-breaking heat waves, devastating floods, and extended droughts have made it urgent to address the vulnerability of urban communities and ecosystems. Because of their concentration of people and infrastructure, cities are

particularly vulnerable to the impacts of a climate-changed future and extreme weather events. In collaboration with researchers and practitioners from a network of cities in the US and Latin America, the Urban Resilience to Extreme Events

Sustainability Research Network (urexsrn.net), a team of Forest Service scientists from the International Institute of Tropical Forestry (IITF) and their research collaborators developed participatory scenario-building workshops in San Juan, Puerto Rico,

between 2017 and 2018. The scenario workshop effort helped local stakeholders, practitioners, and civic leaders to explore together very long-term futures (to the year 2080) and chart pathways and actions to realize different plausible futures,

including a city adapted to Coastal, Urban, and Riverine flooding, a Connected Municipality, a city with Food and Energy Security, and a Just and Livable City. These visions were synthesized and visualized with an ArcGIS Story Map platform devel-

oped by a graduate student doing an internship at IITF with the support of a National Science Foundation INTERN Grant. The Story Map is available for wide distribution and, we hope, to seed inspiration and catalyze sustainability transitions.

Trasfondo de las visiones de San Juan

Revisión de los escenarios



Participantes del taller revisa el escenario de inundaciones urbanas.

El 23 de mayo de 2018 tuvimos un segundo taller con algunos participantes del primer taller para revisar sus visiones y estrategias teniendo en cuenta las lecciones aprendidas tras el paso del huracán María. El 1ero de febrero del 2019, reunimos por última vez a los participantes para refinar los escenarios. El equipo UREx SRN ha generado modelos del uso del suelo que representan los visiones de 2080 por cada escenario. Los participantes revisaron los modelos del uso del suelo e identificaron inconsistencias con su visiones. Los participantes refinaron cuándo y dónde se implementará sus estrategias propuestas para alinear mejor los modelos con sus visiones deseables. También, añadieron nuevas estrategias

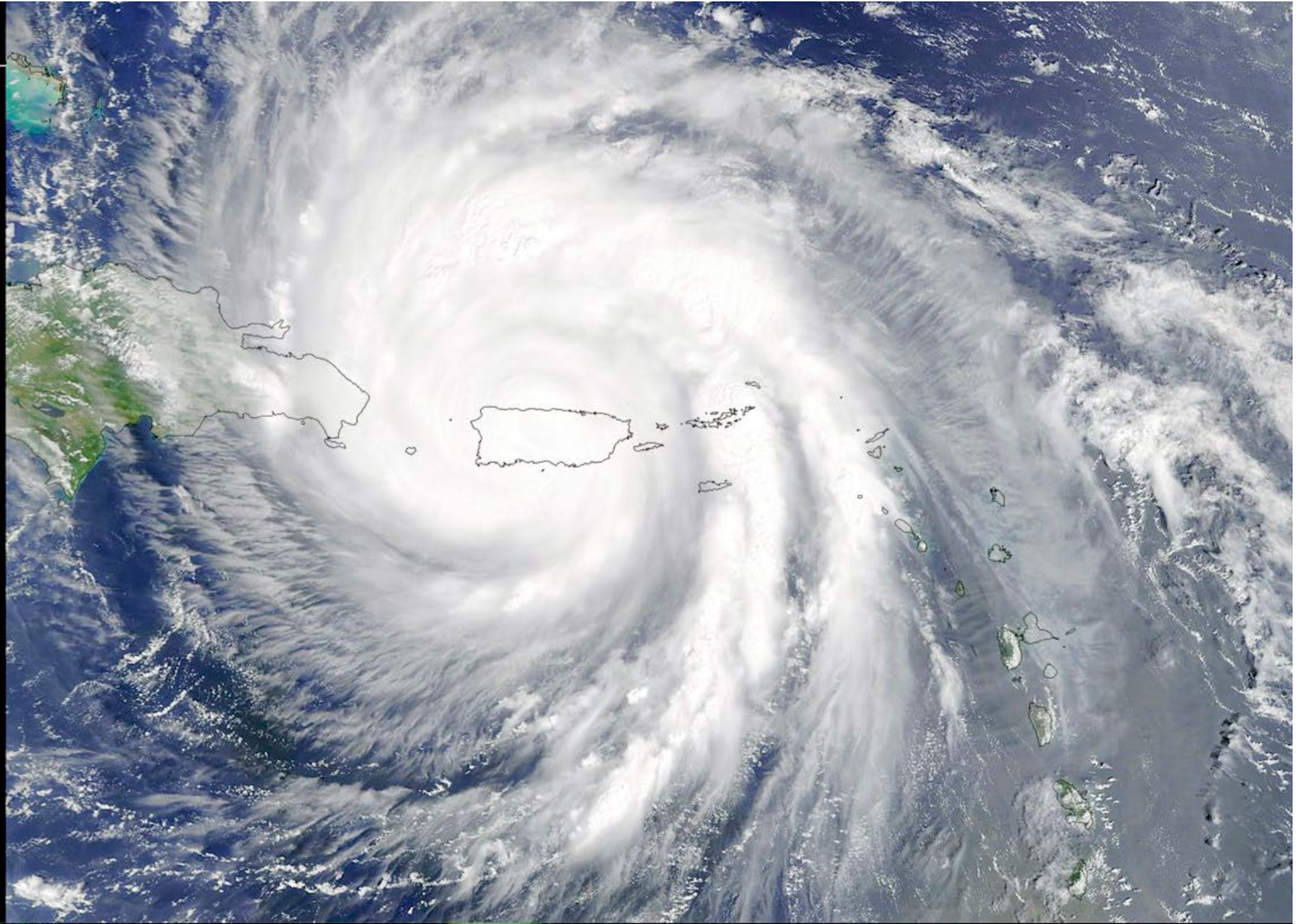


Image caption: Section of the Story Map, titled Visiones de Ciudad – San Juan 2080, showing scenario workshop participants identifying strategies to build resilience to coastal extreme events, such as Hurricane María, and proposing locations in the city where strategies are most needed to meet scenario goals. Image credit: Tischa A. Muñoz-Erickson

Resilient Urban Futures

Many cities across the world have taken a leading role in developing innovative plans and strategies to transition to more sustainable pathways. The simultaneous challenges of a changing climate and an increasing urban population, however, requires that planners, decision-makers, and practitioners be more ambitious about the solutions and changes they seek including radically transforming their cities. Through this open access book, a Forest Service scientist and her collaborators address the way in which urban and urbanizing regions profoundly impact and are impacted by climate change. The authors introduce a social-ecological-technological systems (SETS) perspective as a conceptual framework to understand how cities experience extreme weather events, adapt to climate change, and promote urban resilience from a systems perspective. The book includes twelve chapters that are co-authored by researchers from across many disciplines, including natural and social scientists, engineers, and designers, and that describe the methodological and participatory approaches to visioning and scenario-building across nine US and Latin American and Caribbean cities. The book also addresses how cities develop anticipatory and long-range planning capacities for more resilient futures, earnest collaboration across disciplines, and radical reconfigurations of the power regimes that have institutionalized the disenfranchisement of minority groups.

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Related publication: Muñoz-Erickson T.A. et al. (2021) Anticipatory Resilience Bringing Back the Future into Urban Planning and Knowledge Systems. In: Hamstead Z.A., Iwaniec D.M., McPhearson T., Berbés-Blázquez M., Cook E.M., Muñoz-Erickson T.A. (eds) Resilient Urban Futures. The Urban Book Series. Springer, Cham. https://doi.org/10.1007/978-3-030-63131-4_11



Photo caption: Practitioners and civic leaders from the Santurce neighborhood in the city of San Juan, Puerto Rico, participate in a workshop to explore and prioritize data visualization tools and platforms that may help connect and engage communities in coastal resilience planning. Photo by: Robert Hobbins.



Image caption: Flooded street in Florida during Hurricane Irma in 2017.

Framing Urban Resilience

Resilience is a popular concept in urban planning, yet we know little about how the concept is defined across different urban contexts and practitioners that engage in building resilience 'on the ground'. Because the way that resilience is framed has implications for the policies and solutions that are pursued (and who benefits from them), it is important to examine how transformative definitions of urban resilience are in practice. We used data from a survey of nine US and Latin American and Caribbean cities that are part of the Urban Resilience to Extreme Events Sustainability Research Network (UREx SRN), to explore how the concept is framed across multiple governance sectors, including governmental, non-governmental, business, research, and hybrid organizations. The results highlight that, in general across the nine cities, framings converge with definitions of resilience as the ability to resist, cope with, or bounce back to previous conditions, whereas sustainability, equity, and social-ecological-technological systems (SETS) perspectives are rarely associated with resilience. We argue that to support the radical changes cities need, resilience needs to be conceived in a more transformative, anticipatory, and equitable way, and acknowledge interconnected SETS.

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Related publications: Muñoz-Erickson, T.A., S. Meerow, R. Hobbins, E. Cook, D.M. Iwaniec, M. Berbés-Blázquez, N.B. Grimm, A. Barnett, et al. 2021. Beyond bouncing back? Comparing and contesting urban resilience frames in US and Latin American contexts. *Landscape and Urban Planning* 214: 104173. <https://doi.org/10.1016/j.landurbplan.2021.104173>

Yan, L. Framing resilience. *Nat. Clim. Chang.* 11, 719 (2021). <https://doi.org/10.1038/s41558-021-01149-9>

Disturbance and Resilience in the Luquillo Experimental Forest in Puerto Rico

The Luquillo Experimental Forest (LEF) has a long history of research on tropical forestry, ecology, and conservation, dating as far back as the early 19th century. Scientific surveys conducted by early explorers of Puerto Rico, followed by United States institutions, contributed early understanding of biogeography, species endemism, and tropical soil characteristics. Research in the second half of the 1900s established the LEF as an exemplar of forest management and restoration research in the tropics. Research conducted as part of a radiation experiment funded by the Atomic Energy Commission in the 1960s on forest metabolism established the field of ecosystem ecology in the tropics. Subsequent research has built on these early advances to develop new theories on ecosystem response to disturbance regimes and the role of the biota in ecosystem resilience. Recent and current research in the LEF has advanced understanding of resilience to hurricane disturbances, human land use, gamma irradiation, landslides, drought, and warming, showing that even following the most severe disturbances (e.g., landslides, agriculture) forests reestablish within 60 years. Work in the LEF has reversed the paradigm that tropical ecosystems are fragile, but instead exhibit remarkable resilience to many forms of disturbance present at multiple spatial and temporal scales. Current research is already advancing understanding of how climate change and attendant effects on the disturbance regime might affect the composition, structure, and function of tropical forest ecosystems.

Institute contacts: Grizelle González, grizelle.gonzalez@usda.gov, and Tana E. Wood, tana.e.wood@usda.gov

Related publication: Zimmerman, Jess K.; Wood, Tana E.; González, Grizelle; Ramirez, Alonso; Silver, Whendee L.; Uriarte, Maria; Willig, Michael R.; Waide, Robert B.; Lugo, Ariel E. 2021. Disturbance and resilience in the Luquillo Experimental Forest. *Biological Conservation*. 253(2): 108891-. <https://doi.org/10.1016/j.biocon.2020.108891>

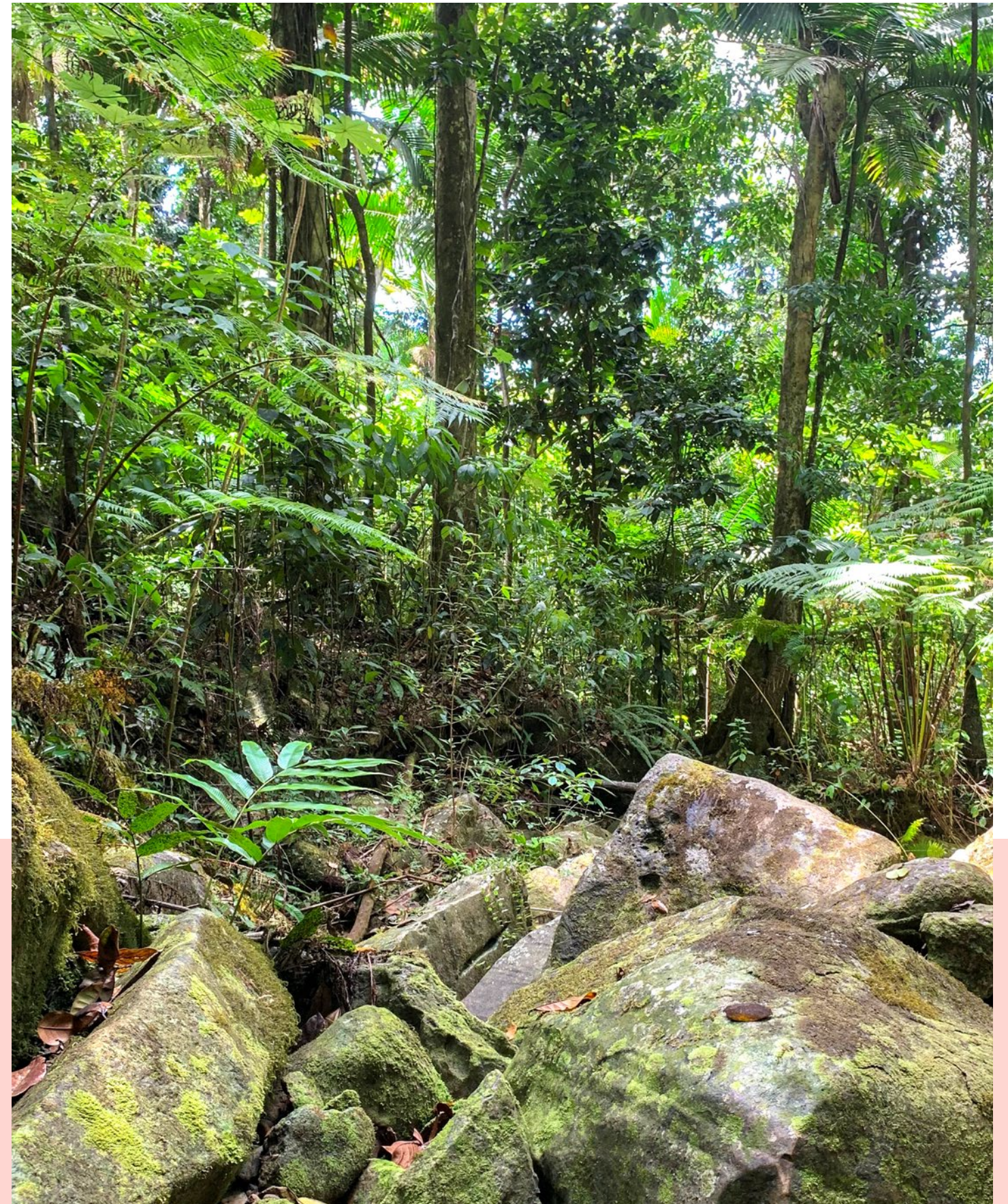


Image caption: The Luquillo Experimental Forest is one of the oldest forest reserves in the Western Hemisphere, and is also distinguished by one of the longest continuous research histories in the tropics.

Photo by: Grizelle González

Global data on earthworm abundance, biomass, diversity, and corresponding soil properties

Earthworms are an important soil taxon as ecosystem engineers, providing a variety of crucial ecosystem functions and services. Little is known about their diversity and distribution at large spatial scales, despite the

availability of considerable amounts of local-scale data. Earthworm diversity data, obtained from the primary literature or provided directly by authors, were collated with information on site locations, including coordi-

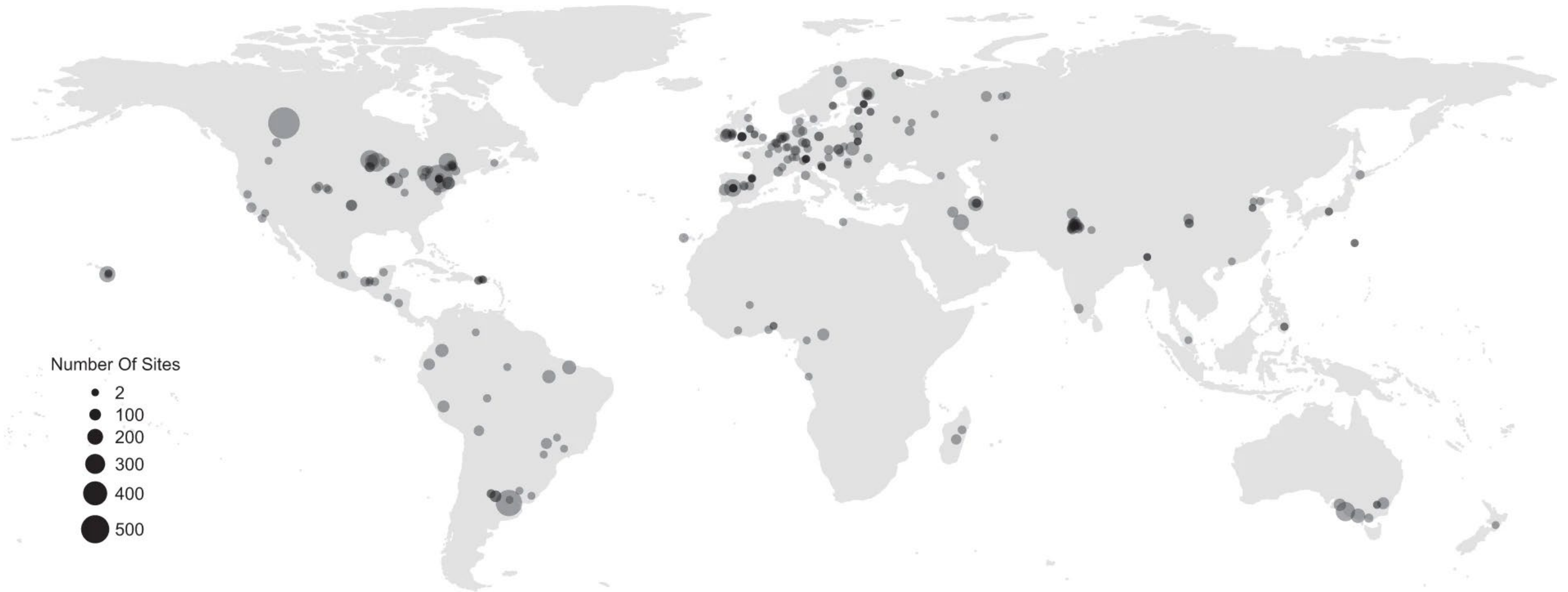
nates, habitat cover, and soil properties. Datasets were required, at a minimum, to include abundance or biomass of earthworms at a site. Where possible, site-level species lists were included, as well as the abundance and

biomass of individual species and ecological groups. This global dataset contains 10,840 sites, with 184 species, from 60 countries and all continents except Antarctica. The data were obtained from 182 published articles, pub-

lished between 1973 and 2017, and 17 unpublished datasets. Amalgamating data into a single global database will assist researchers in investigating and answering a wide variety of pressing questions, for example, jointly assessing

aboveground and below-ground biodiversity distributions and drivers of biodiversity change.

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Map caption: Locations of the 276 studies included in the database. Each circle represents the center of a study (a collection of sites where earthworms were sampled with a consistent method). The size of the circle indicates the number of sites within the study. Transparency is used only for aiding visualization. Map credit: Helen R.P. Phillips

Related publication: Phillips, Helen R. P.; Bach, Elizabeth M.; Bartz, Marie L. C.; Bennett, Joanne M.; Beugnon, Rémy; Briones, Maria J. I.; Brown, George G.; Ferlian, Olga; Gongalsky, Konstantin B.; Guerra, Carlos A.; König-Ries, Birgitta; Krebs, Julia J.; Orgiazzi, Alberto; Ramirez, Kelly S.; Russell, David J.; Schwarz, Benjamin; Wall, Diana H.; Brose, Ulrich; Decaëns, Thibaud; Lavelle, Patrick; Loreau, Michel; Mathieu, Jérôme; Mulder, Christian; van der Putten, Wim H.; Rillig, Matthias C.; Thakur, Madhav P.; de Vries, Franciska T.; Wardle, David A.; Ammer, Christian; Ammer, Sabine; Arai, Miwa; Ayuke, Fredrick O.; Baker, Geoff H.; Baretta, Dilmar; Barkusky, Dietmar; Beauséjour, Robin; Bedano, Jose C.; Birkhofer, Klaus; Blanchart, Eric; Blossey, Bernd; Bolger, Thomas; Bradley, Robert L.; Brossard, Michel; Burtis, James C.; Capowiez, Yvan; Cavagnaro, Timothy R.; Choi, Amy; Clause, Julia; Cluzeau, Daniel; Coors, Anja; Crotty, Felicity V.; Crumsey, Jasmine M.; Dávalos, Andrea; Cosín, Darío J. Díaz; Dobson, Annise M.; Domínguez, Anahí; Duhour, Andrés Esteban; van Eekeren, Nick; Emmerling, Christoph; Falco, Liliana B.; Fernández, Rosa; Fonte, Steven J.; Fragoso, Carlos; Franco, André L. C.; Fusilero, Abigail; Geraskina, Anna P.; Gholami, Shaieste; González, Grizelle; Gundale, Michael J.; López, Mónica Gutiérrez; Hackenberger, Branimir K.; Hackenberger, Davorka K.; Hernández, Luis M.; Hirth, Jeff R.; Hishi, Takuo; Holdsworth, Andrew R.; Holmstrup, Martin; Hopfensperger, Kristine N.; Lwanga, Esperanza Huerta; Huhta, Veikko; Hurisso, Tunsisa T.; Iannone, Basil V.; Iordache, Madalina; Irmeler, Ulrich; Ivask, Mari; Jesús, Juan B.; Johnson-Maynard, Jodi L.; Joschko, Monika; Kaneko, Nobuhiro; Kanianska, Radoslava; Keith, Aidan M.; Kernecker, Maria L.; Koné, Armand W.; Kooch, Yahya; Kukkonen, Sanna T.; Lalthanzara, H.; Lammel, Daniel R.; Lebedev, Iurii M.; Le Cadre, Edith; Lincoln, Noa K.; López-Hernández, Danilo; Loss, Scott R.; Marichal, Raphael; Matula, Radim; Minamiya, Yukio; Moos, Jan Hendrik; Moreno, Gerardo; Morón-Ríos, Alejandro; Motohiro, Hasegawa; Muys, Bart; Neiryneck, Johan; Norgrove, Lindsey; Novo, Marta; Nuutinen, Visa; Nuzzo, Victoria; Mujeeb Rahman, P.; Pansu, Johan; Paudel, Shishir; Pérès, Guénola; Pérez-Camacho, Lorenzo; Ponge, Jean-François; Prietzel, Jörg; Rapoport, Irina B.; Rashid, Muhammad Imtiaz; Rebollo, Salvador; Rodríguez, Miguel Á.; Roth, Alexander M.; Rousseau, Guillaume X.; Rozen, Anna; Sayad, Ehsan; van Schaik, Loes; Scharenbroch, Bryant; Schirrmann, Michael; Schmidt, Olaf; Schröder, Boris; Seeber, Julia; Shashkov, Maxim P.; Singh, Jaswinder; Smith, Sandy M.; Steinwandter, Michael; Szlavecz, Katalin; Talavera, José Antonio; Trigo, Dolores; Tsukamoto, Jiro; Uribe-López, Sheila; de Valença, Anne W.; Virto, Iñigo; Wackett, Adrian A.; Warren, Matthew W.; Webster, Emily R.; Wehr, Nathaniel H.; Whalen, Joann K.; Wironen, Michael B.; Wolters, Volkmar; Wu, Pengfei; Zenkova, Irina V.; Zhang, Weixin; Cameron, Erin K.; Eisenhauer, Nico. 2021. Global data on earthworm abundance, biomass, diversity and corresponding environmental properties. *Scientific Data*. 8(1): 135-. <https://doi.org/10.1038/s41597-021-00912-z>

Sampling methods for soil and litter fauna

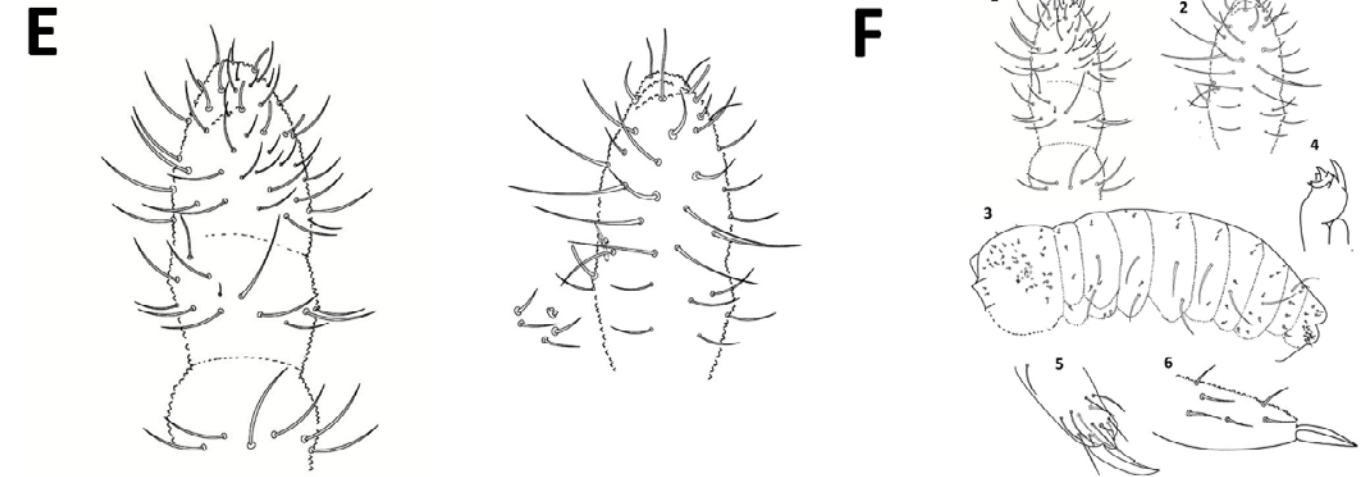
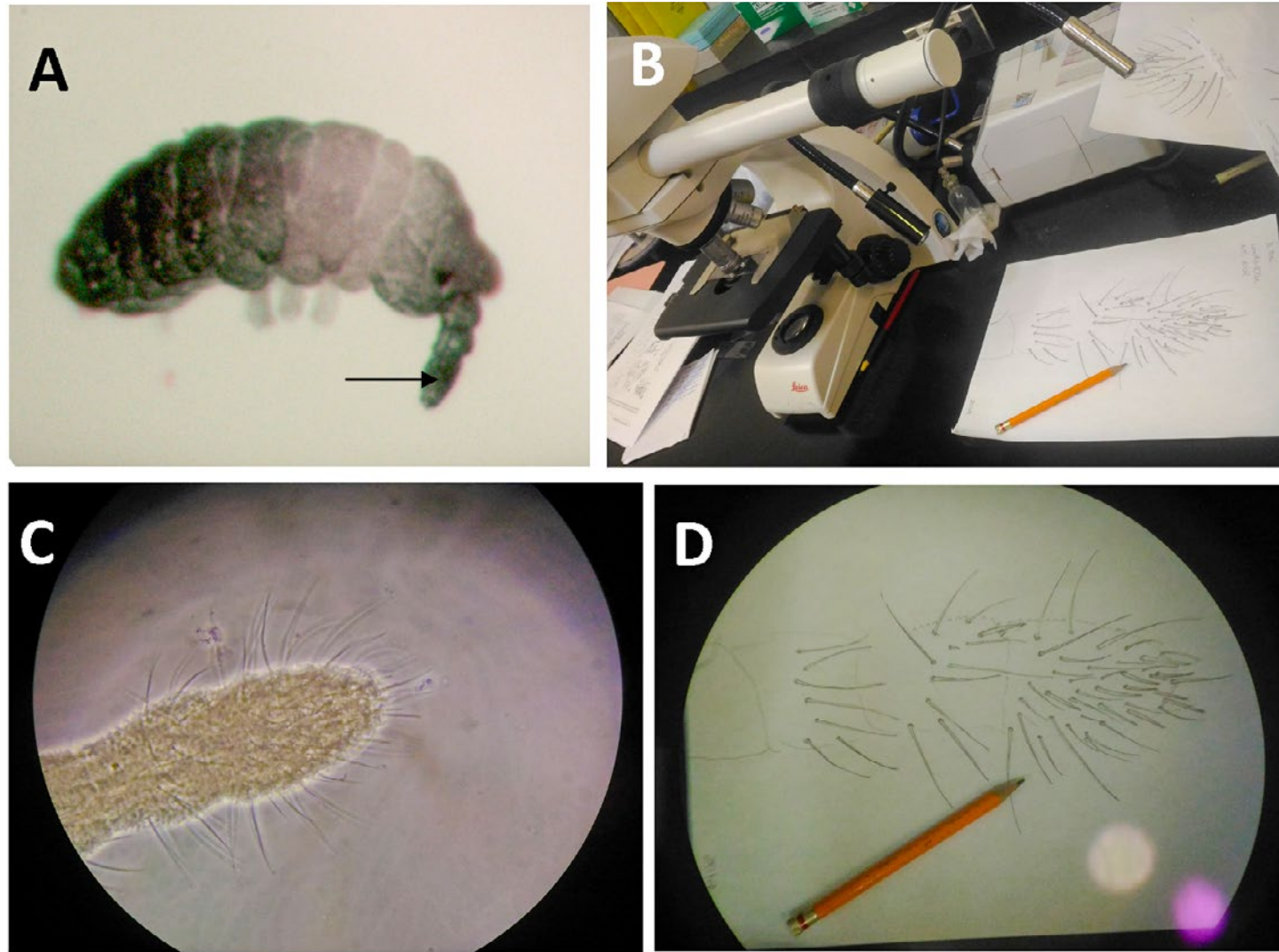


Image caption: Collembolans are not well known in the tropics; therefore, it is common to find new species. The first characteristic to note is the coloration pattern that must be seen under the dissecting microscope (Fig. A). For the specimens that cannot be identified using primary literature, it is necessary to look for revisions of the group and the original descriptions of the species and genera. Then one can determine if the specimens belong to a new species. The principal criteria used for this determination is morphological differentiation, in combination with differences in chaetotaxy. These characteristics must be seen under the microscope (Fig. B). For new species description it is necessary to draw all the morphological characteristics, made with the aid of a drawing tube (Figs. C-D). As the final step of description, all drawings are digitized (Figs. E-F), and with species descriptions, submitted for review as a new species in a specialized peer review journal. Image credit: Claudia M. Ospina-Sánchez.

The soil is an important resource for several ecosystem and biosphere processes. Yet, soil biology is challenged with the identification of many and diverse species and to understand the specific role organisms play, how they are organized, and how they respond to changing environmental conditions. Within this context, there is no universal tool or method that can be applied to a comprehensive study of all the soil and litter fauna that can be found across all soil types and environmental conditions around the globe. Thus, the type of sampling system used for any soil investigation must be carefully planned as an integral part of the study. In this chapter, we review numerous techniques and approaches to evaluate and quantify the influences of soil and litter fauna and provide methodological considerations for ecological studies of soil fauna with emphasis on the study of the decomposition process. The study of soil ecology and health remains a relevant field of research. We hope this review of methodologies for the study of soil and litter fauna will help elucidate the most appropriate technique to use based on resources at hand, organism of interest, and habitat characteristics.

Institute contact: Grizelle González, grizelle.gonzalez@usda.gov

Related publication: González, G; Barberena-Arias, M F.; Huang, W; Ospina-Sánchez, C M. 2021. Sampling Methods for Soil and Litter Fauna. In: Santos J.C., Fernandes G.W. (eds) Measuring Arthropod Biodiversity. Springer, Cham. https://doi.org/10.1007/978-3-030-53226-0_19

International Cooperation

IITF International Cooperation Team



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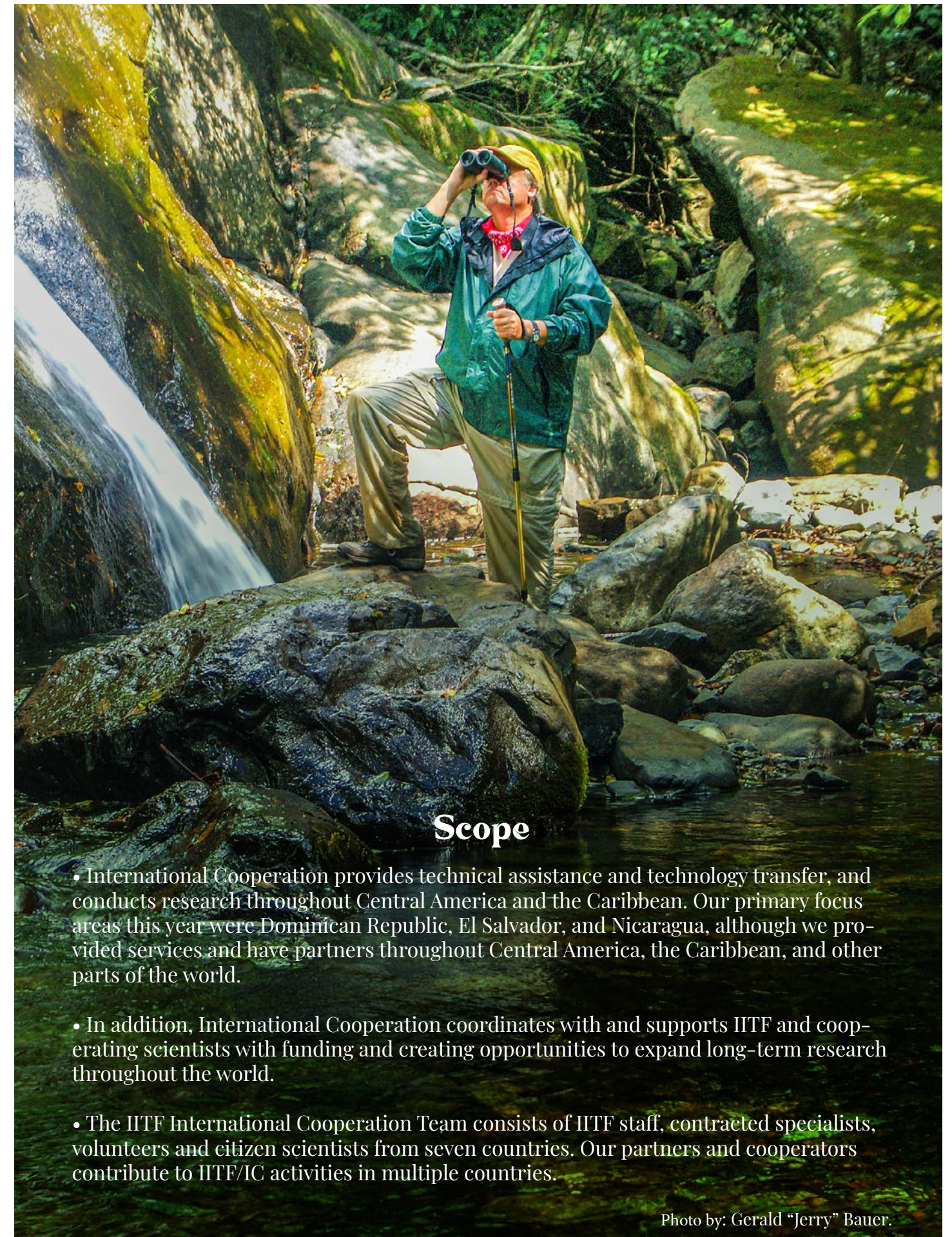
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Scope

- International Cooperation provides technical assistance and technology transfer, and conducts research throughout Central America and the Caribbean. Our primary focus areas this year were Dominican Republic, El Salvador, and Nicaragua, although we provided services and have partners throughout Central America, the Caribbean, and other parts of the world.
- In addition, International Cooperation coordinates with and supports IITF and cooperating scientists with funding and creating opportunities to expand long-term research throughout the world.
- The IITF International Cooperation Team consists of IITF staff, contracted specialists, volunteers and citizen scientists from seven countries. Our partners and cooperators contribute to IITF/IC activities in multiple countries.

Photo by: Gerald "Jerry" Bauer.

Global and Regional Activities

- International Cooperation Assistant Director is in a leadership role of IITF's chartered "International Urban Field Station" (IURFS), leading IITF scientists and international collaborators in long-term technical assistance, technology transfer and research in climate change adaptation, urban wildlife, conservation of urban green areas, conservation education, and biodiversity conservation activities.
- Provided technical assistance and guidance to U.S. Forest Service supported Forest Therapy Program, through the Association of Nature & Forest Therapy (<https://www.natureandforesttherapy.earth/>) and Conservation Conexions (<https://conservationconexions.com/>). We provided guidance to Forest Therapy guides in Guatemala, Nicaragua, Puerto Rico, and United States and assisted with development of guides in Central America.
- Provided technical assistance for a lecture "Forest Therapy: Developing Connections Among Ecosystem and Human Diversity with Forest and Community Health" presented by an IITF collaborator at the 2nd World Conference of Forests for Public Health held in South Korea on October 2021.
- Presented technical sessions on conservation, environmental communications, arts & science, forest therapy, and research at the 2021 "Arts Program at The Nature of Cities Festival". This was a global virtual 3-day conference whose core philosophy was to foster inclusivity and lower barriers to participation. The festival focused on facilitating transdisciplinary dialogue, small group workshops, arts engagement, and fostered a collaborative spirit around solutions for how to build cities that are better for nature and all people. IITF supported technical, capacity building and socio-ecological presentations from Dominican Republic, Nicaragua, Puerto Rico and United States.
- 200 persons trained from the Dominican Republic, Puerto Rico, U.S., Costa Rica, Colombia, Nicaragua, Guatemala, and El Salvador (universities, NGOs, private sector, governmental agencies) participated in the i-Tree webinar "Desarrollo y Uso de la Herramienta i-Tree para explorar el potencial de infraestructura verde urbana como estrategia para la resiliencia y adaptación al cambio climático en la ciudad de Santo Domingo".
- Provided technical assistance and guidance for participation in the biodiversity and conservation education global program Nature City Challenge (<https://citynaturechallenge.org/>), in 2 locations in Dominican Republic and 6 locations in Nicaragua. More than 15 collaborators with 75 volunteers participated in this program. Social media post reached an estimated 25,000 persons.
- Provided technical assistance and guidance to organize Global Big Day conservation education activities in Costa Rica, Dominican Republic, Nicaragua, Panamá, and Puerto Rico. More than 25 collaborators with 75 volunteers participated in this program. Social media post reached an estimated 50,000 persons.



Nicaragua Activities

International Cooperation continued with technical assistance and technology transfer and in supporting IITF and collaborating scientists with long-term biodiversity research, through our long-term partners Set Net Communications, Paso Pacífico and Biosistemas Network under the “Sustainable Tourism and Conservation in Critical Watersheds” project that began in 2005 in collaboration with USAID.

The activities carried out in 2021 were aligned to 6 thematic axes based on our mission and general objectives: 1) Environmental Education, 2) Citizen Science, 3) Gender and Entrepreneurship; 4) Knowledge Transfer, 5) Technology and Innovation and 6) Research.



Adelayde Rivas, Executive Director Set Net Communications instructing a participant from the Girls with Wings (“Niñas con Alas”) program on how to digitally capture Nicaragua’s rich biodiversity. Photo by: Gerald “Jerry” Bauer.

Highlights

- Technical assistance and guidance for development of “Concurso Premio a la Niñez Naturalista 2021” (Youth Nature Contest), a program to teach and support STEM activities to youth ages 8 to 16 years old. Five presentations were selected as outstanding in the category of Innovation and Activism. Participation of about 30 youth. In collaboration with 30 partners from NGOs and private sector.
- Technical assistance and guidance for development of “Niñas con Alas” (Girls with Wings), a program to teach conservation to young females, ages 8 to 16 years old. Participation of 20 youth. Conducted several workshops and field trips to protected areas and tree nurseries. In collaboration with 30 partners from NGOs and private sector.
- 20 civil organizations participated in conservation programs during the year.
- More than 500 high-quality photographs to document and promote conservation given to local partners on issues of reforestation, environmental education, citizen science, female scientist, and research.
- Developed 15 free online webinars promoting conservation, long-term research, female scientists, citizen science and similar issues.
- Developed alliances with 3 local universities to support conservation and environmental issues with students. University of Commercial Sciences, Ibero-American University of Science and Technology, Central American University (UCA).
- Developed 4 corporate videos with themes of environmental conservation, gender, and entrepreneurship.
- Provided technical assistance to 5 women entrepreneurs for product development.
- Developed more than 50 designs for promoting and marketing educational and training campaigns for environmental and sustainable development issues with multiple partners.
- Conducted bird monitoring programs in multiple locations and developed data bases submitted to eBird (<https://ebird.org>), sites included: NIGA Tisma, Granada, Chocoyero.
- 7th year of annual Christmas Bird Count in the Paso del Istmo wildlife corridor led by Paso Pacifico with 53 participants and 177 species recorded.
- Incorporation of 200 youth in Paso Pacifico’s environmental education program “Guardaparque Junior” with support from Marlon Sotelo on units relating to migratory birds, parrots, and forests.
- Developed social media post for local NGOs and local communities to promote Audubon’s Christmas Bird Count.
- Reached 100,000 persons on social media networks and activities. In collaboration with local and international partners from NGOs and private sector.
- More than 800 volunteers assisted with project activities.
- Provided conservation training to 300 persons (students, community members, local entrepreneurs).



Nicaraguan children celebrate International Migratory Bird Day 2021 as part of the Girls with Wings (“Niñas con Alas”) program at El Chocoyero Wildlife Reserve, Managua, Nicaragua. Photo by: Adelayde Rivas.



Junior Rangers helping collect data on bird diversity in Nicaragua. The Junior Ranger program was started by IITF partner Paso Pacifico and has trained more than 1,000 Nicaraguan youth with IITF technical support. Photo by: Gerald “Jerry” Bauer.



Photo by Gerald Bauer



Photo by: Gerald "Jerry" Bauer.

Dominican Republic Activities

International Cooperation provided leadership, mentorship for technical assistance, technology transfer, and long-term research to Dominican Republic partners and collaborators in biodiversity conservation, sustainable tourism development, conservation of urban green, blue, gray and brown spaces, and climate change adaptation activities in local, underserved and disadvantaged, Hispanic communities and major urban centers under the USAID funded project "Conservation and Sustainable Management of Urban Watersheds as Mechanisms for Adaptation to Climate Change." USAID continues to be a long-term partner in all of our Dominican Republic activities, as well as many local institutions and collaborators.

Highlights

- Provided technical assistance, guidance and mentorship to the long-term study "Santo Domingo ULTRA Climate Change Adaptation and 'green areas' avian research" Theme: "Modeling urban bird-habitat associations with i-Tree tools in Santo Domingo, Dominican Republic". USFS-IITF/USAID/Dominican Republic PAPA (No. AEG-T-00-07-00003-00 TASK #7).

- Technical assistance and guidance for capacity building workshop on biodiversity monitoring and nature guiding to less advantaged, underserved Hispanic communities in Samaná Peninsula, Dominican Republic. Eighteen persons were trained as nature guides and citizen scientists. Collaborators included Centro para la Conservación y Ecodesarrollo de la Bahía de Samaná

y su Entorno (CEBSE), Grupo Acción Ecológica, and local communities.

- Technical assistance and guidance for biodiversity monitoring capacity building to less advantaged, underserved Hispanic communities in coastal areas in Montecristi, Dominican Republic. Five persons were trained in biodiversity monitoring techniques, and biodiversity monitoring plots were established for insect and bird monitoring. This work was completed in cooperation with USAID/DR and Dartmouth College. Local collaborators included local NGOs Centro para la Conservación y Ecodesarrollo de la Bahía de Samaná y su Entorno (CEBSE), Grupo Acción Ecológica, AgroFrontera and local communities.

- IITF IC and Wildlife programs, along with Dartmouth

College and a local agrarian conservation NGO, AgroFrontera, are currently finalizing maps, methodologies and sampling protocols in anticipation of an upcoming collaborative biodiversity monitoring program. Conjointly with the biodiversity research, is the preparation of a multiple-agency management plan to mitigate invertebrate and vertebrate pest damage to row crops, mostly rice, in an effort to increase yield and regional production in the northeastern section of the country. Our research studies and management efforts are critical components of the Integrated Marine Ecosystem Management in Northern Hispaniola (IMEM) project scheduled to begin later this year.

- Provided technical assistance and guidance to local NGOs to conduct Audubon Christmas Bird counts in

three areas in Dominican Republic.

- Provided technical training for communities to develop ecotourism activities.

- Provided information to support environmental education in local schools and communities.

- Provided technical support to the Ministry of Environment in support of protected area management.

- Provided integrated urban bird research and i-Tree Eco results now being used by the Dominican government's Ministries of the Environment and Tourism and city planners to promote urban plant and animal conservation, environmental integrity and ecosystem function in the metropolitan area. Results have revealed the rich interchange of natural and

anthropogenic ecological services provided by urban trees and birds to urbanites and the city of Santo Domingo's reciprocity.

- IC began participation in the US Forest Service and The Nature of Cities "Urban Field Station Artist Residency: Collaborative Arts for the Urban Environment" program. The program's mission is to promote understanding of and engagement with urban ecology through art. This is the first participation in a foreign country.

- "The Dominican Republic Art Resident program "Connections, ecological and societal between United States, Canada, and Dominican Republic" brings together artists and scientists to collaborate on the development of a series of street art depicting the connections of the natural and built envi-

ronment. The art is based on IITF long-term research with IITF IC/R&D and NRS, in which IITF's Wayne Arendt is a PI. Collaborators include IITF IC/R&D, NRS, FS Urban Field Station Network, FS IP, DR Public Art Commission and DR Ministry of Environment, INTEC and local neighborhood organizations. We negotiated with local Santo Domingo businesses and the Santo Domingo Municipal Government to allow us to develop a mural on several walls in the city. Mural development in SD will begin in January 2022.

- Art Resident artist Kilia Llano painted the first mural in Miami, Florida in collaboration with The Wynwood Walls & Art District (<https://museum.thewynwoodwalls.com/main> ; www.thewynwoodwalls.com/ ; <https://www.instagram.com/awall-muralprojects>).



Field crew at bird banding station in the Bajo Yuna Mangrove National Park in the Samaná Bay, Dominican Republic. Dr. Wayne Arendt started this long-term bird research in the late 1970s, making it one of only a few long-term bird research studies in the Dominican Republic. Photo by: Gerald “Jerry” Bauer.

Wayne Arendt, IITF Research Wildlife Biologist, teaching local counterpart technicians Maria Paulino and Leonardo Cortés data collection techniques. This is part of an ULTRA (Urban Long-Term Research Area) bird study in Santo Domingo, Dominican Republic. Photo by: Gerald “Jerry” Bauer.



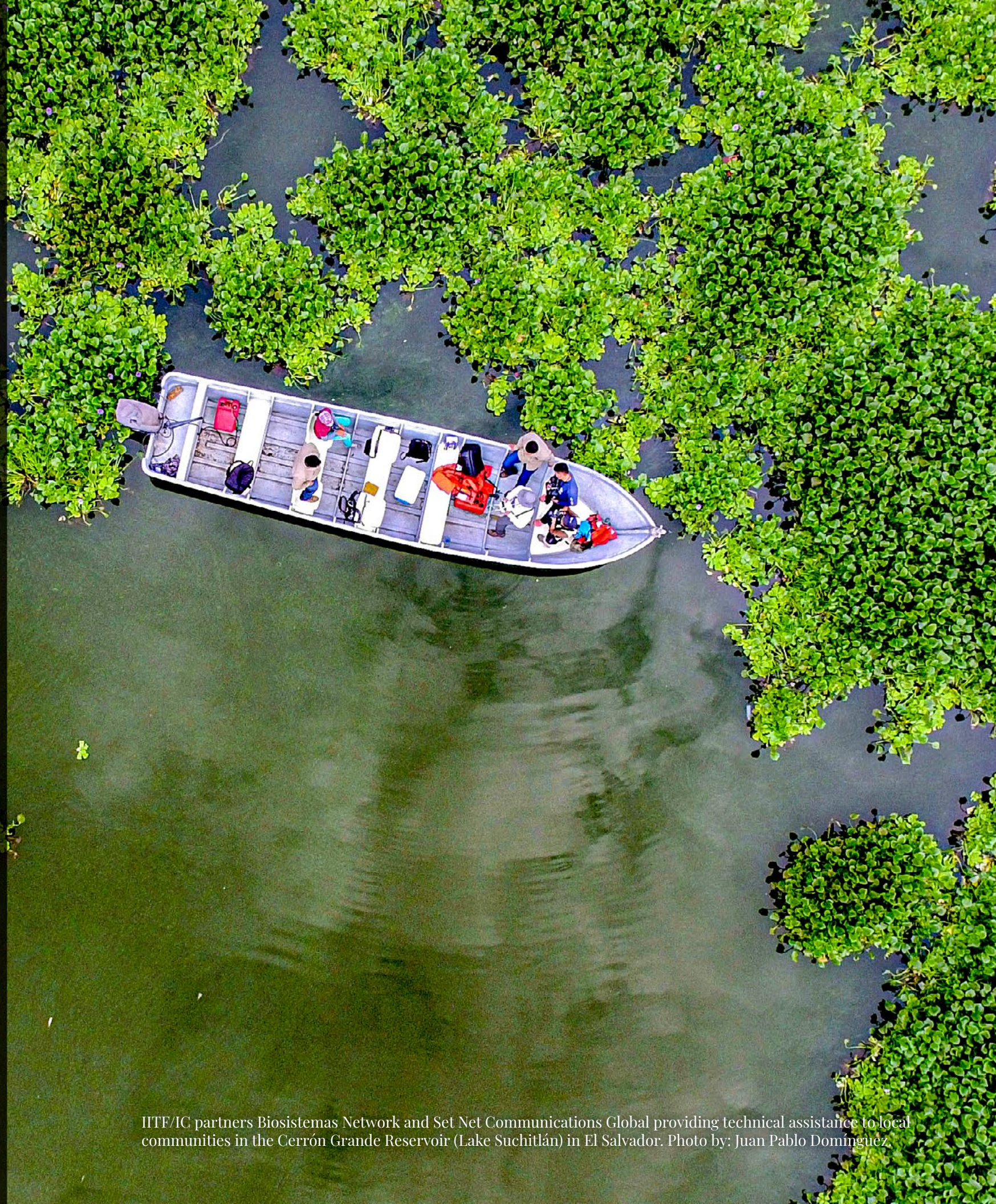
Wall mural “Conexión” painted by USFS Urban Field Station Art Resident Kilia Llano in Santo Domingo, Dominican Republic. This mural depicts the migratory Cape May Warbler as an international ambassador making connections from Canada and the U.S.A. to the Caribbean island of Hispaniola. Kilia is the first non-U.S. Resident Artist in this program. Photo by: Gerald “Jerry” Bauer.

El Salvador Activities

International Cooperation provided leadership, mentorship, technical assistance, technology transfer, and long-term research to El Salvador partners and collaborators in biodiversity conservation, protected area management, sustainable tourism development, and climate change adaptation activities in local, underserved and disadvantaged, Hispanic communities. IITF IC activities in El Salvador were directed by our long-term partners Paso Pacífico and Biosistemas Network.

Highlights

- Provided technical assistance and guidance for capacity building workshop “Introduction to Basic Research and Monitoring Techniques for Terrestrial Species” to less advantaged, underserved Hispanic communities in El Salvador. Fifteen community members were trained in biodiversity monitoring techniques and as citizen scientists. Collaborators included Centro para Biosistemas Network, Fundación Naturaleza, Territorios Vivos and local communities.
- Provided technical assistance and guidance for capacity building workshop “Research techniques and study design to monitor wildlife species, Morazán, El Salvador” (Técnicas de Investigación y Diseño de Estudios para el Monitoreo de Especies. Morazán, El Salvador”).
- Provided technical assistance for establishment of a community ranger program in the mountains bordering the Olomega Lagoon in El Salvador. Eight Community rangers are creating fire breaks and removing garbage at RAMSAR wetland and along the forest edge with support from Paso Pacífico. IITF is providing technical assistance to plan ranger training and also interpretative signage for the protection of forests.
- Mentored and provided technical assistance to U.S. State Department Fulbright Scholar and Penn State University PhD Candidate for research project in El Salvador, Central America.
- Study and protection of critically endangered yellow-naped Amazon parrots at the Tasa-jera wetlands with FUNZEL. Technical assistance for the design of a program to ensure participation of underserved and minority community members.
- Provided technical assistance and guidance for establishment of the biological station “La Cueva del Puma”, situated on the lower part of the río Sapo basin.
- Provided technical assistance and guidance for mammals monitoring program using camera-traps operated by youths of the local communities around the río Sapo basin.
- Provided technical assistance for the establishment of two long-term forest monitoring plots of 50 m x 50 m.
- Provided technical assistance for development of a forest fires prevention and combat campaign.



IITF/IC partners Biosistemas Network and Set Net Communications Global providing technical assistance to local communities in the Cerrón Grande Reservoir (Lake Suchitlán) in El Salvador. Photo by: Juan Pablo Domínguez.

Puerto Rico Activities

International Cooperation accomplishments in Puerto Rico include:

Technical assistance and guidance for development of Northeast Ecological Corridor Public Awareness Campaign. Collaborators included the Coalición Pro Corredor Ecologico del Noreste, Sierra Club PR, Department of Natural and Environmental Resources, and local communities.”

Technical assistance to El Yunque National Forest on development of conservation education at El Portal Visitor Center and forest signage.

Technical assistance and guidance to bryologist Amelia Merced (IITF contractor) for development of workshop, field guide and posters for bryophytes in El Yunque National Forest using the resources Bryophytes of El Yunque National Forest, Puerto Rico Field Guide, and other resources developed in a Forest Health project. In collaboration with IITF R&D and S&PF.

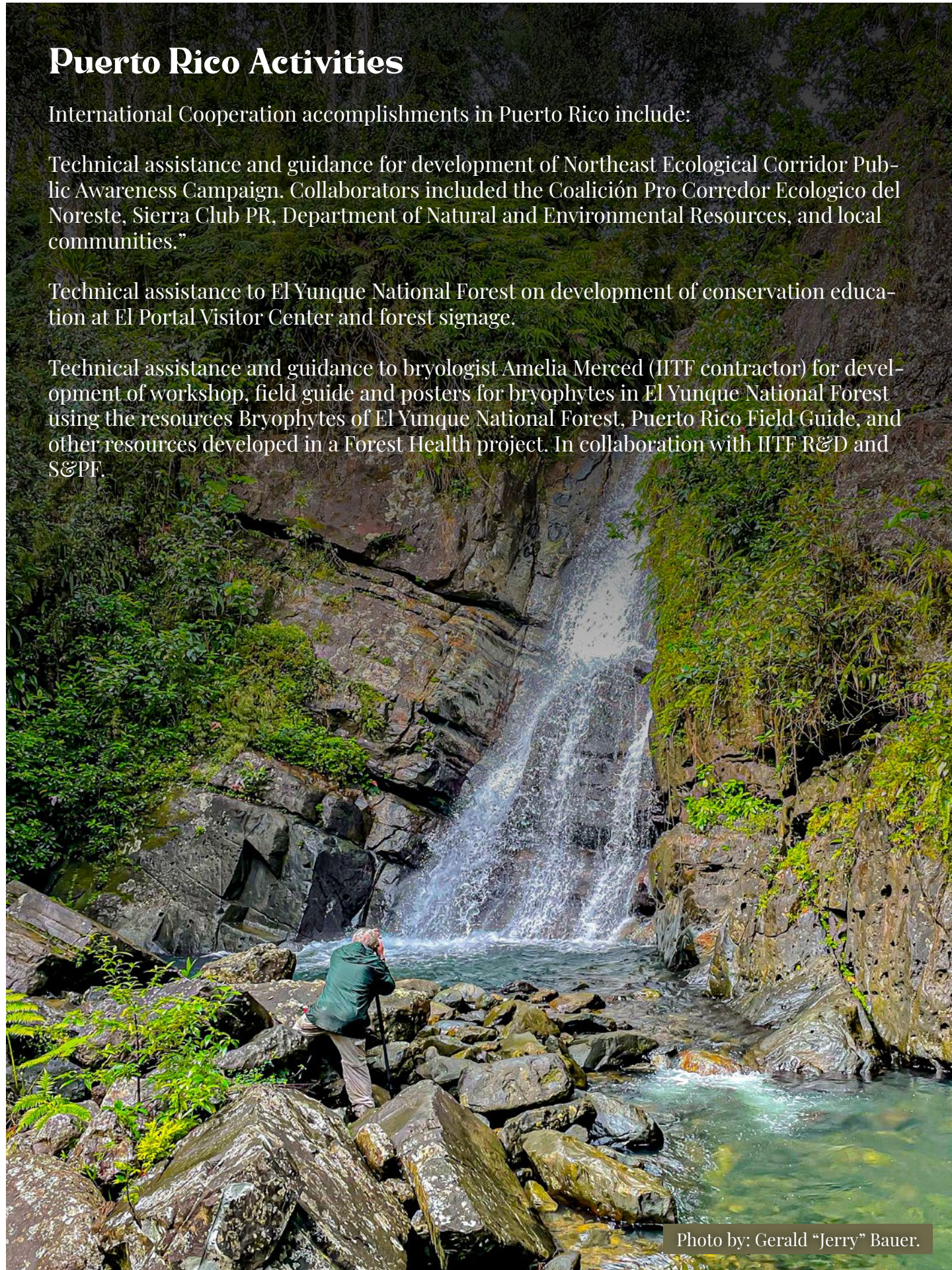


Photo by: Gerald “Jerry” Bauer.

Awards

Chief’s Honor Award for 2021. Awarded to Gerald Bauer for “Applying Knowledge Globally” for “Forty-five years building international conservation partnerships, preserving tropical biodiversity and promoting ecosystem and socio-economic services while mitigating the effects of global climate change in Latin America and the Caribbean. Only one award, recognizing Gerald’s contribution, was awarded by the Chief in 2021 to an individual.

Federal Recreation Lands “Share the Experience Employee Photo Contest”. Honorable Mention. Awarded to Gerald Bauer. Photo: Juan Diego Waterfall, Luquillo Experimental Forest/El Yunque National Forest.

JERRY BAUER
Biological Scientist
US Forest Service

2021 Chief's Award
for
Applying Knowledge Globally
Bauer, Gerald Patrick
(Jerry)

International Cooperation Team Leader
& Executive Board, International Urban
Field Station International Institute of
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INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

State and Private Forestry



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S&PF
Assistant Director,
Natural Resources
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Aramis Garay
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Training Specialist



Andrés González
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Christina de Jesús
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Evelyn Pagán
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Program Manager,
Natural Resources
Specialist



Sylvia Zavala
S&PF
Library
Volunteer

Goals

- Conservation of working forest landscapes encompasses the need to perpetuate the multiple values, uses and services provided by forests in Puerto Rico and US Virgin Islands. These benefits may be protected or increased by implementing better conservation practices and sustainable forest management. Two main objectives under this goal are: identify and conserve high priority forest ecosystems and landscapes in Puerto Rico currently under private control; to manage private forested land actively and sustainably.
- Protect forests from harm: recognition of threats affecting forested lands, and to identify ways to control or substantially reduce their harmful effects. Two main objectives under this goal are: identify, manage, and reduce threats to forested ecosystems health; reduce risks of wildfire impacts.
- Enhance public benefits associated with trees and forests to maximize ecosystem services: protect and enhance water quality and quantity; improve air quality and conserve energy; assist communities reducing forest health risks; maintain and enhance economic benefits and values of trees; protect, conserve, and enhance wildlife and fish habitat; connect people to trees and forests, and promote stewardship activities; manage forests to mitigate and adapt to global climate change.

Key Issues

- Fragmentation of forest ecosystems.
- Water resources and watershed conservation strategies.
- Information needs related to ecosystem services and other benefits from public and private forest land.
- Disturbances affecting forests (hurricanes, floods, droughts, fires, pests, etc.).
- Concerns over invasive species.
- Economic opportunities and alternative market development

Highlights



Forestry professionals from the Department of Natural and Environmental Resources visit Café Lareño shade Coffee Plantations where agroforestry practices as being implemented. Photo by: Magaly Figueroa.

Capacity Building and Technical Assistance to DNER- Forest Service Bureau personnel

Cafiesencia and the Institute's State and Private Forestry unit, partnering with the Department of Natural and Environmental Resources (DNER), developed and implemented a special

training curriculum for the DNER-Forest Service Bureau personnel on Best Tropical Forest Management Practices recommended for Puerto Rico. The purpose of the training was to share infor-

mation on forest recovery, watershed protection, wood production, and agroforestry practices. Cafiesencia—the NGO that is leading this effort—made presentations about the Forest Stewardship

Program (FSP) to prepare the State Forest Managers to work with neighboring private landowners interested in the program. The training included a description of the FSP, as well as details

about the benefits of the FSP Management Plan. The curriculum included information on the preparation of forest management plans, design and development of forest management objec-

tives and practices, technical assistance, and outreach techniques. Cafiesencia also developed an educational booklet with this information for future reference of the participants.

Congress of Land Custodians and Farmers

The Congress for Land Custodians and Farmers was offered via Zoom on March 27, April 10, and April 24, 2021. It promoted a dialogue among custodians, farmers, and communities throughout Puerto Rico who have expressed their desire and interest in expanding opportunities to develop and conserve land and farms while respecting and protecting important forest ecosystems. The Congress covered science -agroforestry

systems and community projects, sustainable forest management, and forest management for ecological and agroforestry production; economy- economic approach of forests and ecosystem services, sustainable forest planning, and payment programs for environmental services; and education- community aqueducts, network of women in forests, and eco-museology to support integrated and sustainable initiatives in the

governance of diverse landscapes. All presentations and information on conservation agencies programs and special initiatives are available at: <https://www.congresocustodiospr.org/>. The congress was attended by 503 participants representing 65 municipalities of Puerto Rico, 11 USA States, and 7 countries (Argentina, Costa Rica, Dominican Republic, Bolivia, England, Netherlands, and Austria).



Banner for the 2021 Congress for Land Custodians and Farmers titled "Towards recovery and resilience".

Photo by: Christina De Jesús

Cooperative Fire Protection

In Puerto Rico, wildland fire incidence is higher in the south of the island due to the drier climate. The accumulation of woody debris in fields after the hurricanes in 2017, which has the potential to become suitable for fueling forest fires, the Puerto Rico Fire Department (PRFD) has been implementing measures to prepare for wildland firefighting in the event of a possible drought scenario. In Puerto Rico, because of the higher availability of plant material that can act as fuel—including grasses, shrubs, trees, and dead leaves—wildland fires are more frequent from January to August, which keeps firefighters busy fighting fires with an average of 3,000 to 5,000 annual forest fires. In 2021, the PRFD responded to 4,012 wildland fires. With the assistance of the IITF State and Private Forestry unit and the National Weather Service, and other state and federal partners, the PRFD implements prevention, mitigation, and response programs to wildfires, establishing strategies including inter-agency efforts to work together in the planning process, response phase, resources coordination and fire monitoring. The PRFD Operation Center in Juncos facilitates a centralized approach to respond to wildland fires throughout the island and other specialized operations. The PRFD activates four wildland fire crews around Puerto Rico during the dry season, covering the south, west, north, and east of the island. The wildland fire crews implement fuel mitigation through controlled burning and firebreaks (strips or blocks of vegetation that have been cleared to slow or control a wildland fire) in abandoned and state lands, in addition to fighting wildland fires. The State Fire Assistance Program made possible the acquisition of specialized heavy equipment to manage wildland forests using multiple tools and techniques to control wildland fires and to protect the natural resources in Puerto Rico. The year 2022 is expected to have a very active fire season with many wildland fires likely to occur due to the availability of plant material.

The make-up of US Virgin Islands is unique in that the Territory consists of three major islands and a smaller inhabited island, each of which requires its own fire stations. The Virgin Islands Fire Service (VIFS) 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. All stations are open 24 hours a day, seven days a week. The agency has three main areas of operations: Emergency Operations (Suppression), Arson Investigation and Prevention (Prevention), and Administration. The VIFS provides service to over 108,000 year-round residents and an additional 10,000 to 15,000 seasonal vacationers. During Fiscal Year 2021, the wildland firefighters responded to 27 wildland fires that affected over 12 acres of land throughout the Territory. The USVI Fire Department acquired two portable floating pumps to increase its capability to provide water for wildland fire suppression in areas where no regular pumps are available. The Prevention Unit of the VIFS conducted yearlong fire education workshops, performed fire extinguisher training, and fire drills. This unit conducted a series of educational activities that reached 785 students. The goal of the Prevention Unit is to safeguard the community from fires and other related hazards through programs which will educate the public and enhance observance to fire regulations. The Administration Unit, through management of the available financial resources, provides the support for efficient operations of all units. USDA Forest Service grant funds were used to purchase firefighting gear, firefighting supplies, and educational supplies that were distributed to students during Fire Prevention Week.



Firefighters from the Puerto Rico Fire Department and volunteer firefighters from the Department of Natural and Environmental Resources during a fire line training in the forest. Photo by: Fish and Wildlife Service.

Department of Natural and Environmental Resources Volunteer Fire Crews

The Department of Natural and Environmental Resources (DNER) Wildland Fire Unit consists of highly trained personnel that assists on identifying, managing, and reducing threats to forest ecosystems in order to reduce wildland fire occurrence, especially at the DNER's Protected Natural Areas. Thanks to financial assistance from the IITF State and Private Forestry unit (SPF), DNER fire crews have the necessary equipment and personal safety supplies to continue assisting the PR Fire Department (PRFD) with wildfire prevention and suppression in the Protected Natural Areas. SPF funding is used to acquire uniforms, boots, personal safety supplies, suppression tools, and traveling equipment necessary for dispatching assignments. The DNER wildland firefighters are expected to join efforts with the non-profit organization Protectores de Cuencas (PDC) to continue reforestation and habitat restoration efforts in the Guánica State Forest. The DNER fire crews prepared fire lines along road PR-333 to protect the areas that had been reforested by PDC. These firebreaks prevent the spread of fire and facilitate suppression activities. During the 2021 fire season, four wildland fires were reported on the PR-333 in Guánica. The DNER fire crews assisted the PRFD as volunteer wildland firefighters. In October 2021, the DNER assisted local community leaders and the municipality of Guánica in a project called "Rescatemos el Puente de Hamaca". The DNER has an active participation in the Caribbean Multi-Agency Coordination Group (CMACG). In 2021, DNER firefighters were deployed to California, Oregon, and Washington to help fire suppression in those states, and as a training opportunity. Firefighters also participated in several workshops such as the RT 212 "Chainsaw Refresher" and RT 130 "Training for First Responder and CPR".



Fire Weather Committee and RAWS

This committee was reactivated during Fiscal Year 2021 to serve as a venue for state and federal agencies to discuss needs and opportunities on fire forecasts and issuing the Red Flag Warnings for Puerto Rico and US Virgin Islands. State and Private Forestry owns four operational Remote Automatic Weather Stations (RAWS), three located in Puerto Rico (Maricao, Guánica, and Salinas) and one in St Croix, US Virgin Islands. We acquired two new RAWS that will be installed in the Mayaguez area (Eugenio Maria de Hostos airport and the San Sebastián area). We planned to acquire and install a RAWS for the San Sebastian area due to increased wildland fire incidence in northwest Puerto Rico. These RAWS are strategically placed to cover high wildland fire incidence areas. State and Private Forestry emphasizes collaborations and establishing new partnerships, including with non-traditional partners. In December 2021, technicians from the Puerto Rico Seismic Network helped us by maintaining the RAWS in the Guánica State Forest. Thanks to our new partners, our station in Guánica is fully operational. This work was possible thanks to Victor Huerfano, PhD, Director of the Puerto Rico Seismic Network, Jose Cancel, Scientific Instrumentation Specialist and his team, Roberto Viqueira, Director of Protectores de Cuenca, and Darien Lopez, Forest Manager of the Guánica State Forest.

The NOAA-Weather Service in San Juan uses the weather data from these stations to monitor weather and for the daily preparation of fire weather forecasts, fire danger statements and ratings, and spot reports. You can access data from these and other RAWS in the area visiting <https://raws.dri.edu/prF.html>.





Forest Health training by UPR Extension Service to DNER Personnel in October 2021. Photo by: Magaly Figueroa.

Forest Health Protection

During Fiscal Year 2021, the Department of Natural and Environmental Resources (DNER) coordinated three workshops to train DNER state forest managers, partners, and the Puerto Rico Wildland fire crews. Two trainings were offered in person, taking all COVID-19 safety precautions. A third training was offered via Zoom. The first workshop

was given at the Cambalache Tree Nursery, in collaboration with the Forest Health Clinic of the Extension Service at the University of Puerto Rico in Mayagüez, and focused on Tree Pest Management, including the identification of common pests in Puerto Rico and how to install and monitor traps to collect pest samples. This training was offered to a

total of 31 state forest managers. Each forest manager was supplied with traps and attractants to install in their forests and assist on this effort. A second workshop was offered by the Forest Health Clinic and focused on the identification of pests and diseases. The workshop was offered to the Wildland fire fighters of the Puerto Rico Fire Department and

the DNER Volunteer Wildland fire fighters, with the participation of 34 attendees. Lastly, the Forest Health Clinic offered a virtual workshop titled “Monitoring and Management of Pests and Diseases in Protected Natural Areas” with the participation of 21 attendees including DNER forest managers and biologists, IITF staff, and program partners.

Field observations identified a beetle from the Cerambycidae family that is attacking the almácigo trees (*Bursera simaruba*) in the Guánica State Forest. The DNER is coordinating with the Forest Health Clinic for the identification of the beetle species, to monitor its effects, and to identify the location of infestation sites in the Guánica State Forest and

private forests in the area. The Guánica State Forest is a United Nations International Biosphere Reserve and is one of the most extensive tropical dry forests in the world with around 9,000 acres.

Forest Legacy

In 2021, the Puerto Rico Department of Natural Resources (DNER) completed the revision of the Assessment of Needs. The document had not been revised since its publication in 2000. This revision comes at a time when there is a pressing need for conservation in the face of the threats of climate change and extreme events. Forest Legacy Areas were reassessed considering the protection of coastal forests that are continually threatened for urban developments, the protection of karst forests that provide multiple

ecological and economic benefits, and the establishment of forested corridors. The analysis was performed by Estudios Técnicos in collaboration with the Wildlife, Wetland, and Forest Subcommittee, MC Environmental Specialists, and DNER staff. The analysis resulted in the expansion and connection of existing Forest Legacy Areas (FLAs). Sixteen changes to the original 8 Forest Legacy Areas were made, adding 373,961 acres to the original 857,248 acres of FLAs, expanding these areas to a total of 1,231,210 acres. DNER

is close to completing the fee acquisition of 8 forested tracts located in the south, north, and west boundaries of the Guánica State Forest under the Expanding the Guánica State Forest Project. These tracts will increase the area of protected forests and promote connectivity among critical habitats for federal endangered and threatened species. Tracts provide diverse wildlife and critical habitat for the endangered Puerto Rican Crested Toad and Puerto Rican Nightjar, as well as 16 other listed species. DNER has also advanced

efforts under the Protecting the Central Mountain Range Project. This project seeks to acquire in fee 712 forested acres within four properties in the Puerto Rico Central Mountain Range. In 2021, all land surveys were completed. Acquisition of these tracts ensures the conservation in perpetuity of buffer zones and biological corridors that connect two important life zones and expands habitat protection for two State Forests.

During 2021, US Virgin Islands appointed Daniel McK-

enzie as the Territorial Forest Legacy Program Coordinator. Mr. McKenzie and the Virgin Islands Department of Agriculture submitted the Inner Brass Island Forest Legacy Project to the FY2023 panel, as well as a grant application to the EPA Recreation Economy Program in collaboration with the Departments of Tourism, Sports, and Recreation, the Virgin Islands Trail Alliance, USVI Epscor, and supported by the Office of the Governor Albert Bryan and State Representative Stacey Plaskett. All recreational op-

portunities will be designed under Forest Legacy Program authorities and compatible uses. All Virgin Island Forest Legacy properties remained undisturbed with no build-out, construction, or violation of any kind. The Virgin Islands Department of Agriculture's Forest Legacy Program continues monitoring efforts of acquired properties and outreach efforts to identify important forest lands to opt and participate in future competitive processes.

Forest Stewardship

The Forest Stewardship Program provides technical assistance to private forest landowners in Puerto Rico and US Virgin Islands to implement sustainable forest management practices within their forest land. The Program runs through the Puerto Rico Department of Natural and Environmental Resources (DNER) in Puerto Rico and through the Virgin Islands Department of Agriculture (VIDA) in US Virgin Islands. In the year 2021, the Forest Stewardship Program at the Puerto Rico DNER, in collaboration with local nonprofit organizations (Cafiesencia, Centro para la Conservación del Paisaje, Distrito de Conservación del Caribe, and Protectores de Cuencas, Inc.), created and approved 68 new forest management plans covering 5,625 acres. In 2021, the Program in Puerto Rico had 124 active forest management plans, totaling 11,836 acres. These management plans included specific recommendations with the following forest practices that serve as the focal points of the program: 1) commitment of the owners in actions aimed at protecting and conserving the forest in the highest regions of priority watersheds to help maintain and improve water quality and quantity; 2) improvements in wildlife habitat through the planting of tree species that provide food and shelter; 3) control of wild-land fires in fire prone areas of the island's semi-arid ecoregion; and, 4) promote ecotourism and educational activities that allow landowners to obtain additional economic income. In US Virgin Islands, VIDA conducted a Tree Giveaway where over 150 trees were distributed to community members. The Forest Stewardship Program in US Virgin Islands has 234.5 acres in 16 active forest management plans with the Program.

The US Forest Service State and Private Forestry unit at IITF is dedicated to forming lasting collaborations with local partners to promote the sustainable use of private forest lands in the US Caribbean. Our unit created and leads an interagency working group within the Puerto Rico State Technical Committee to identify and discuss private forest landowner needs in Puerto Rico and explore interagency collaborations to assist with those needs. The working group was formed in October 2020 with recurrent monthly meetings that have incorporated an increasing number of partners from local and federal government agencies, nonprofit organizations, and members of the academia. The working group has facilitated cross-agency orientations to help increase knowledge and communication between organizations that work closely with private forest landowners in Puerto Rico. Our unit also works closely with our sister agency Natural Resources Conservation Service (NRCS) and in 2021 did a joint visit to the island of St. Croix to promote collaboration between our programs in US Virgin Islands.



Joint Chiefs Landscape Scale Restoration Projects

We continue our partnership with NRCS implementing the Joint Chiefs' Landscape Scale Restoration (LSR) Partnership initiative in the southwest Puerto Rico in collaboration with Southwest Soil and Water Conservation District, FWS, Department of Natural and Environmental Resources, Protectores de

Cuenca, and Para La Naturaleza. Project provides technical assistance and forest management planning, and incentives from NRCS for the implementation of conservation practices to landowners in the area to restore important habitats that house at risk species such as broad-winged hawk, sharp-winged

hawk, elfin-woods warbler, and improving habitat for the reintroduction of the Puerto Rican parrot. During this year we completed 22 Forest Stewardship Management Plans including 1,810 of important forest land. The project produced 40,000 trees for the implementation of forest management prac

tices including shade coffee restoration and distributed 12,002 trees to forest landowners participating in the initiative. Due to COVID-19 restrictions, educational and volunteer activities and wildland fire prevention trainings were postponed for Spring 2022. A new Joint Chiefs Landscape Scale Res-

toration Partnership Project was approved for Puerto Rico in the Eastern area and with activities within and close to El Yunque National Forest. The project is titled Landscape-scale Restoration Initiative to Increase Ecosystem Resilience in Eastern Puerto Rico through Effective Conservation Management

Practices and proposes to work collaboratively at a landscape-scale level to increase conservation actions on private lands to improve ecosystem function and health in the region while improving economic and ecological services for local communities.



Panoramic view from farm in Fajardo, Puerto Rico participating in the Forest Stewardship Program. Photo by: Maya Quiñones.

Landscape Scale Restoration

Protectores de Cuenca is a local NGO that has a co-management agreement with the Department of Natural and Environmental Resources to manage the Guánica State Forest. The Guánica State Forest is a United Nations International Biosphere Reserve. The Guánica State Forest is one of the most extensive tropical dry coastal forests in the world with 9,800 acres of land. The Landscape Scale Restoration project prevents wildland fires in fire prone landscapes in the Guánica State Forest. Project includes mitigation measures such as eradicating invasive grasses and planting 20,000 trees. Since September 2021, Protectores de Cuencas (PDC) initiated coordination with the Department of Natural and Environmental Resources and the Municipality of Guánica to begin the planning phase of the project. The NGO acquired the materials needed for growing the plant material that will be used in the reforestation efforts, including containers and germination trays. The NGO owns and manages its own nursery, so the preparation of all the germination soil mix is prepared in house. Protectores was able to initiate the reforestation efforts by planting 300 trees from six native species. This reforestation took place in an area that has been burned several times over the years and close to Puerto Rico Road #333. Each reforested area is treated to eradicate invasive grasses and protected with the installation of fire breaks. After planting, all trees are irrigated as this is a very dry area and to promote the survival of trees.



Monitoring the distribution, ecology, and conservation status of Sphagnum in Puerto Rico

This initiative is a special Forest Health Program project. Amelia Merced, PhD, an expert on bryophytes, in collaboration with the Herbarium of the University of Puerto Rico, found one of the species of Sphagnum moss (*Sphagnum perichaetiale*) native to the north coast, that was last seen 35 years ago, and before that in 1922. It was believed to have disappeared from Puerto Rico. Due to changes in coastal landscapes in the last 100 years, two of Puerto Rico's three Sphagnum species were thought to be extinct.

Sphagnum portoricense from El Yunque National Forest, will be included in the list of Critical Elements in the Natural Heritage Program of the PR Department of Natural and Environmental Resources. The initiative continues looking for other populations and other missing species. In addition, it seeks to develop descriptions of the habitat and ecological conditions that support Sphagnum species for proper management, thereby improving forest/ecosystem health and conservation in Puerto Rico.

Urban and Community Forestry

The US Caribbean Region Urban and Community Forestry Program provides education and assistance to communities to promote the conservation and effective management of urban trees in Puerto Rico and US Virgin Islands. The Program runs through the Puerto Rico Department of Natural and Environmental Resources (DNER) in Puerto Rico and

through the Virgin Islands Department of Agriculture (VIDA) in US Virgin Islands. In 2021, the program at the regional level supported special projects to develop geospatial data for the US Caribbean that are important for urban forestry planning and management, including the development of LiDAR derived canopy cover map and wildland urban interface

data for both Puerto Rico and US Virgin Islands.

Through our local government partners, the Urban and Community Forestry Program provides cost-share grants with 1:1 match through a competitive process to communities, organizations, local and municipal governments, and educational entities to promote the

conservation and planting of urban trees as well as educational activities to help communicate the benefits of urban trees. In US Virgin Islands, proposals are currently accepted all year round. In Puerto Rico, DNER is working on updating their proposal guide and a proposal window is planned for 2022.

The Urban and Community Forestry Program also awarded a grant to the University of Puerto Rico to work with the Garden and Community Forest of Capetillo, a local food forest within an underserved community in the heart of San Juan, Puerto Rico. This project will help document forest conditions through a new tree inventory and identify tree man-

agement practices that help increase forest resiliency in the face of climate change and hurricanes. The project will also engage neighbors and students in fruit tree plantings and workshops to showcase the food forest to nearby communities and the region as a whole.



Urban trees providing shade to pedestrians at Paseo La Princesa in Old San Juan, Puerto Rico. Photo by: Maya Quiñones.

Conservation Education in US Virgin Islands - Community Nature Exploration -

The Urban and Community Forestry Program awarded funds to the St. Croix Environmental Association for the conservation education project titled Community Nature Exploration. The purpose of this project is to build a program based on a nature booklet as learning a tool, offering in-person events such as hikes, nature walks, and snorkel tours for the community, in which all participants will learn how to use the Community Nature Exploration Booklet as a self-guided island-wide scavenger hunt in St. Croix, VI.



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