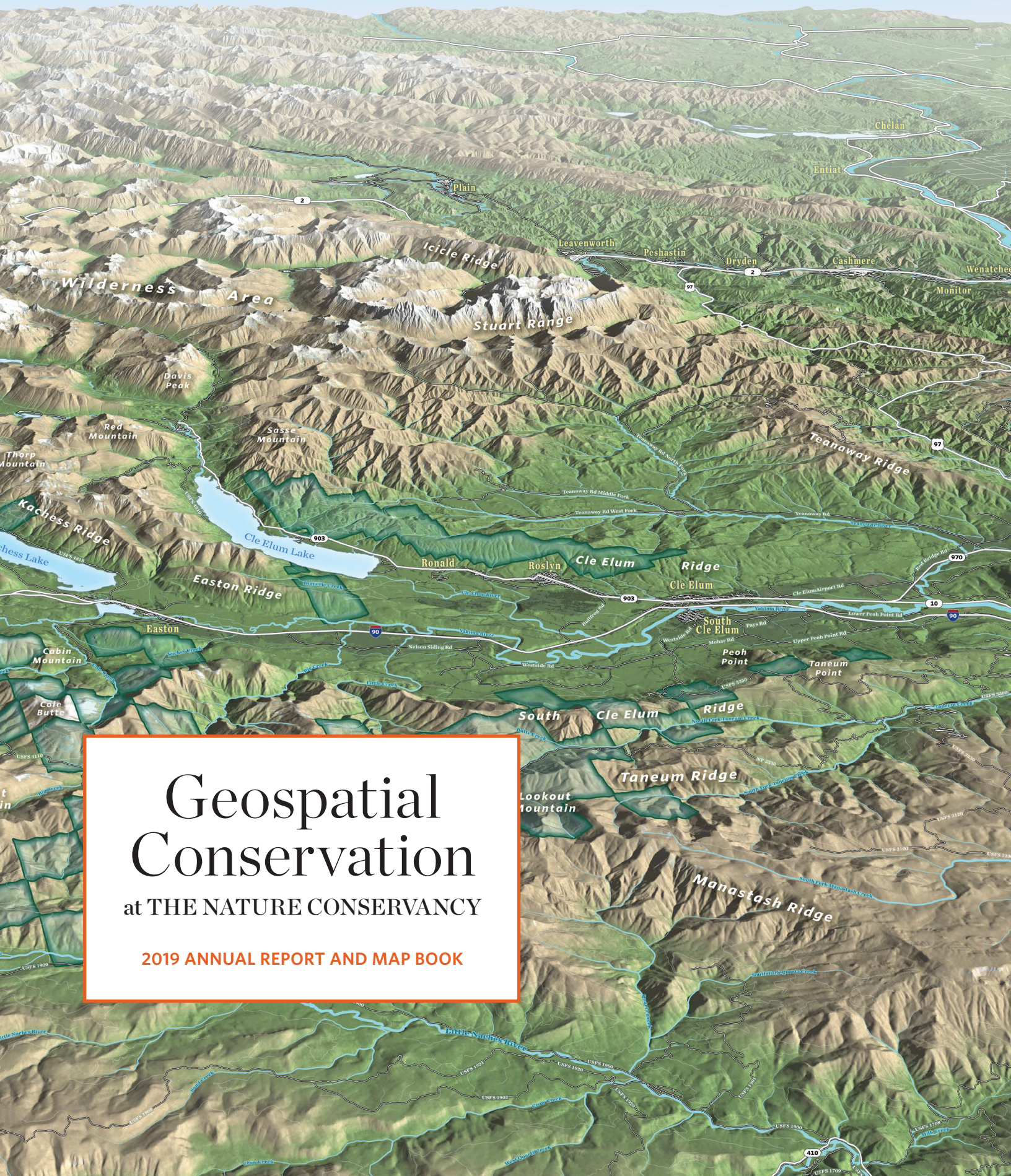
The Nature Conservancy



Geospatial Conservation

at THE NATURE CONSERVANCY

2019 ANNUAL REPORT AND MAP BOOK

Legends

Habitat of Orangutan
- Bornean Orangutan Habitat
- Wehea-Kelay Ecosystem Essential Area

Administrative Boundary
- City/Regency Boundary
- Provincial Boundary
- National Boundary

Inland Waters
- Rivers
- Lakes

Capitals
- Capital of Province
- Capital of Regencies

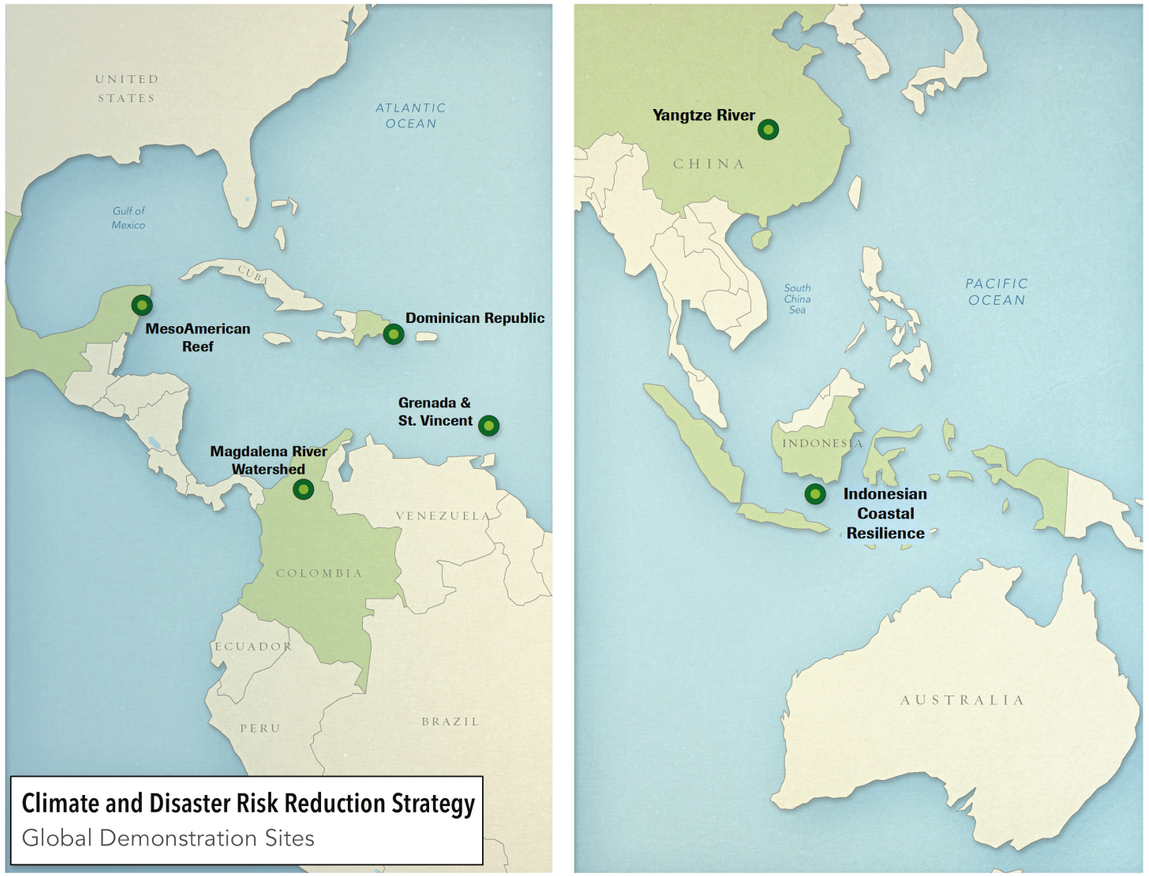
Content

FEATURED MAPS

This map (left) and others throughout the report were provided by Conservancy staff working around the world. Together they demonstrate the breadth and diversity of the organization's work.

The map on the left shows 2.87 million hectares of Bornean orangutan (Pongo pygmaeus) habitat with 2,900 individuals in East Kalimantan Province, Indonesia. Since 2016, The Nature Conservancy, working alongside the community, private sector, Provincial Government and the Ministry of Environment and Forestry, initiated the Forum of the Essential Ecosystem Area in Wahea-Kelay Landscape to manage 532,143 hectares (red boundary). With the majority of this area orangutan habitat, nine land managers have joined in the protection of 1,200 individual orangutans in Wehea-Kelay. This Essential Ecosystem Area is now a model for other multi-stakeholder efforts across East Kalimantan. Photo by Purnomo, Indonesia program. Cartography by Ghufran Zulqisthi, Indonesia program.

Ferdaña, Z., and Patton, J. (Eds.) 2019. *Geospatial Conservation at The Nature Conservancy: 2019 Annual Report and Map Book,* Arlington, VA: The Nature Conservancy.



The Nature Conservancy's disaster risk reduction strategy focuses on using natural infrastructure to sustain and build resilience in coastal and freshwater environments. Since 2007, the Conservancy has applied the power of natural solutions to address climate change in Latin America and Asia, among other locations. Cartography by Dan Majka, North America Science program.

© Aaron Huey

Conservation Maps

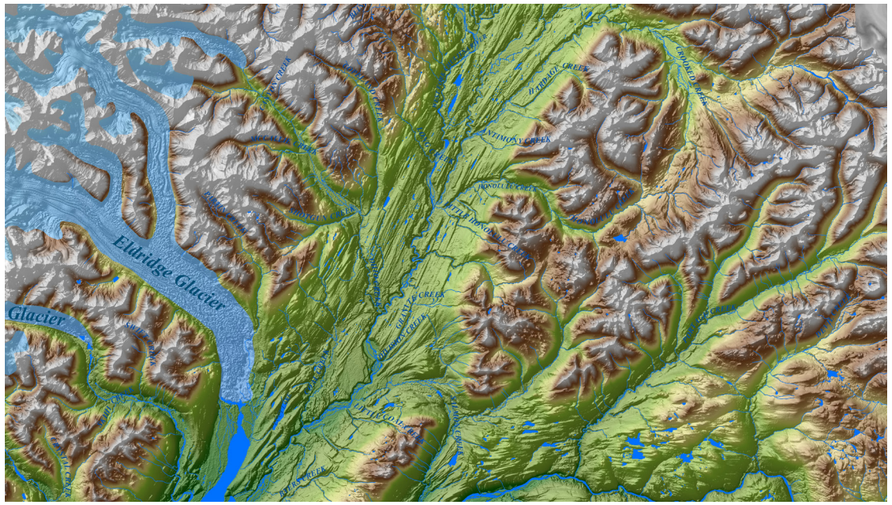
One of the most impactful experiences of my childhood was an annual two-week trip in nature led by a phenomenal teacher named Mrs. Black. On one of those trips, we camped on an uninhabited island in the San Juan Islands in Washington State with graduate students who taught us about marine biology and topographical mapping. I remember the excitement of exploring uncharted territory and carefully documenting features across the island—natural areas, cultural sites, physical details and their relationship to the marine environment. I still have a copy of the map.

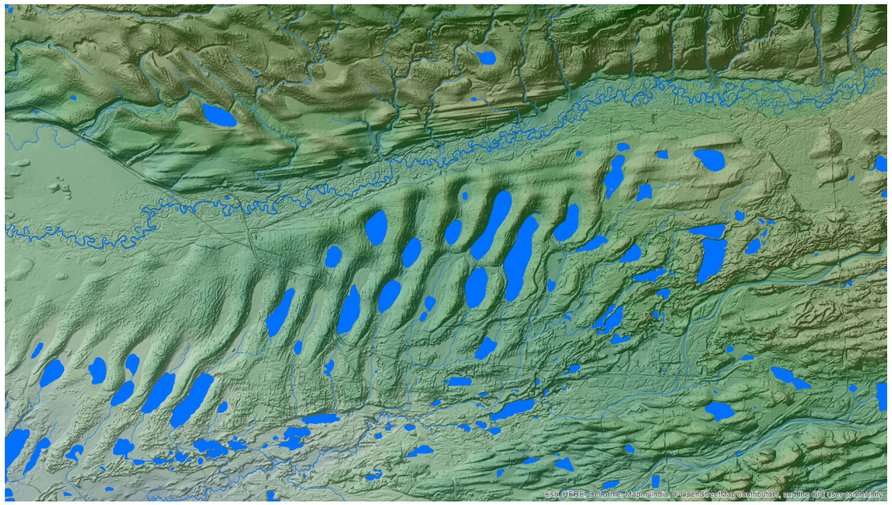
Now, as interim CEO of The Nature Conservancy, I have the privilege of working with a team that includes more than 750 GIS professionals who do this kind of work every day. Geospatial technology has come a long way since my childhood mapping days, but the sense of wonder I experienced working alongside those scientists remains the same.

Maps have always guided TNC's work, from parcel maps for real estate transactions, to global maps that inform our conservation priorities. Increasingly, our maps now help others integrate the value of nature into decision making, from businesses to city planners to federal government agencies. As U.S. Secretary of the Interior, I saw this firsthand when the Bureau of Land Management used TNC's science to inform its blueprint for balancing conservation with responsible renewable energy development across 22 million acres of California desert.

This first report characterizing the Conservancy's geospatial work affirms what we all know—that science matters. The examples that follow underscore the importance of developing and sharing spatial data to better understand the Earth's systems and how we can protect them. Further leveraging this expertise will play a critical role in our ability to achieve our vision of a future where nature and people thrive.

Sally Jewell
Chief Executive Officer





Encompassing over 25,000 square miles, the Matanuska-Susitna (Mat-Su) basin is rich in freshwater habitat upon which healthy wild salmon populations depend. A holistic, science-based understanding of the freshwater environment salmon require is crucial, including mapping and identifying the characteristics of the streams and lakes they use throughout their life cycle. In 2013, The Nature Conservancy initiated a hydrographic mapping and analysis program in the Mat-Su basin to map all lakes, rivers and streams and create the first 1:24,000 scale update to the USGS National Hydrographic Dataset (NHD). Through this work more than 27,000 miles of previously unmapped streams were discovered, for a total of 52,718 miles of streams and over 20,000 lakes added to NHD. This has helped address issues of water quality, development and zoning requirements as well as conservation planning and habitat studies. Cartography by Jim DePasquale, Alaska field office.

Geospatial Conservation at The Nature Conservancy

The mission of The Nature Conservancy (TNC) is to conserve the lands and waters on which all life depends. Operating in 74 countries with more than 600 scientists, we are tackling the most pressing threats to nature and people in freshwater, ocean and coast, and terrestrial environments. Thanks to the support of more than 1 million members, the Conservancy has built a significant record of success since our founding in 1951, having conserved over 120 million acres of land and more than 122 million acres of ocean with improved management. Geospatial technology—the combination of Geographic Information Systems (GIS), remote sensing and machine learning—has been an integral and critical decision support platform in support of these efforts.

GIS and remote sensing have informed TNC's conservation science approaches for decades. At least one in every three Conservancy staff uses maps, whether to monitor preserves, negotiate land and water transactions, or develop global ecosystem services analyses. Now, with the launch of this *Geospatial Conservation at TNC 2019 Annual Report and Map Book,* we are at a pivotal and exciting time. The GIS community has established a Leadership Council, formed working groups in key areas such as cartography and increased our central capacity in Information Technology (IT) to support geospatial activity across the Conservancy.

"Following decades of collaboration between Esri and The Nature Conservancy, I am excited to see this inaugural geospatial annual report. TNC is a global leader in applying GIS to inform conservation management plans and actions to address complex environmental challenges powered by the best available data, scientifically grounded spatial analysis and advanced visualization tools. This series of reports will inform readers about the trends and profound conservation impacts which have been realized by leveraging geospatial technology," says Jack Dangermond, Founder and President of the Environmental Systems Research Institute (Esri).

This report is designed to (a) provide a baseline of the Conservancy's 2019 geospatial work, (b) present "use cases" that illustrate ways that technology supports conservation and (c) examine emerging opportunities where TNC can best leverage geospatial technology to protect, conserve and restore ecosystems around the globe. The first section describes TNC's multi-faceted geospatial workforce, both where the organization is currently focused and also where we are headed. The second is a selection of maps and stories that illustrate our global conservation planning and action, and the third lays out an emerging plan to advance geospatial technology in the service of the Conservancy's mission to protect nature and preserve life.

Kind regards,

Zach Ferdaña
Geospatial Information Officer

Leon van Gurp
Senior Director, Application Management & Analytics

© Susan Miller

HONORING TY

This report is dedicated to Tyrone Guthrie, Spatial Data Systems Analyst with the Geospatial Systems Team in IT. Ty passed away on Sunday, April 21, 2019 after a long battle with synovial sarcoma.

Ty started at TNC in 2002 as a Spatial Analyst with the Colorado field office. From there he used his data wrangling, analysis, programming and GIS skills for conservation planning efforts with the Rocky Mountain divisional unit, assembling core geospatial datasets at our headquarters in Arlington, Virginia, and most recently with IT building and tending to the care and feeding of on-premise server and cloud infrastructure supporting GIS across the Conservancy.

Ty was a master woodworking craftsman, avid sailor, hiker, cyclist and swimmer. He was a noted limerick writer, painter, photographer, musician, voracious reader of police blotters and proud Canadian. Most importantly, Ty was a beloved husband, brother, son and uncle. For those lucky enough to stumble into his orbit at TNC, he was a loyal friend and colleague—ready to join adventures over the river and through the woods, and sometimes battling against rodents of unusual size. He never turned down invitations to hike up mountains, drive across the country, bike through rainforests or savor many a B-grade movie. He left his mark on our lives with his generosity, wit and kindness.

We will miss Ty tremendously. May this report reflect his excellent contributions to the geospatial world and conservation.

State of the Conservancy Map

At this consequential time, people are facing unprecedented environmental and social challenges. When developing practical solutions to complex problems, the Conservancy increasingly turns to existing and emerging technologies. Conservation practitioners have long relied on geospatial science, GIS and remote sensing to identify, prioritize, plan and meet goals. Recent advances in Artificial Intelligence (AI), Machine Learning (ML) and Big Data on cloud-based infrastructure have added even more options for effective action.

The Nature Conservancy is experiencing a geospatial renaissance. While not a comprehensive digest, content for our first *Geospatial Conservation at TNC 2019 Annual Report and Map Book* includes the findings of a global survey delivered to nearly 1,500 staff, results from a series of listening sessions in every region where we work and input from a newly-formed GIS Leadership Council.

The Geospatial Systems Team (GST) in the Conservancy's IT department is responsible for maintaining and improving internal and cloud-based geospatial servers, and collaborating in geospatial science with specific field programs and partners. This means supporting 20 internal geospatial servers as well as Amazon Web Service and Microsoft Azure cloud accounts, amounting to more than 90 terabytes of data that guide our conservation work. Servers are located in 15 TNC domestic offices and three in Latin America. These geospatial systems include four major capabilities: (1) ArcGIS Enterprise, Collector, and Web GIS; (2) Virtual Desktop Infrastructure (ArcGIS Desktop, Pro, R, ENVI, ERDAS); (3) High Performance Windows File Systems with SSD; and (4) Enterprise Geodatabase. The central IT team includes Geospatial Systems Architect Jeff Zurakowski, Geospatial Application Engineer Jan Slaats, Geospatial Data Scientist Francesco Tonini, Geospatial Systems Specialist Craig Cheeseman, and Geospatial Information Officer Zach Ferdaña.

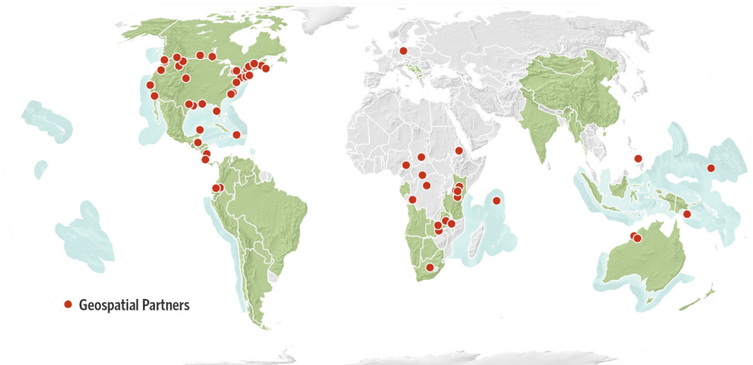
The purpose of the GIS Leadership Council is to assess the current state of geospatial work at TNC and design a strategic, community-driven collective vision. The formation of the Council is a game-changer. With membership representation spread across geographies and scales, and with emphasis on diversity, equity and inclusion, we are boosting communications and bringing capacity where needed. The Council aspires to be a voice of leadership on geospatial at TNC, centralizing our expertise to manage and amplify common themes, challenges and needs that arise within this community of practice.

Mapping for conservation planning and action touches down in the countries and ocean Exclusive Economic Zones illustrated on this map, shown here as "geospatial reach." This also includes GIS training and capacity building. Maps are central to TNC's mission in understanding our conservation strategies and in engaging audiences through the stories they reveal. This report highlights fourteen "use cases" that explicitly link geospatial technology to conservation. Cartography by Chris Bruce, Virginia field office.

The goals of the Council are to (a) represent the needs of the geospatial community, (b) leverage locally developed solutions at an enterprise scale, (c) participate in working groups and strategic initiatives on key topics and (d) support GST objectives to strengthen service delivery to our practitioners. Fiscal year 2020 (July 2019 – June 2020) members include:

- ***Leandro Baumgarten,*** Science Manager (Latin America)
- ***Fiona Becker,*** GIS Manager (Central U.S.)
- ***Tim Boucher,*** Spatial Scientist (Global Science)
- ***Melissa Clark,*** Spatial Ecologist (Eastern U.S.)
- ***Valerie Pietsch McNulty,*** Spatial Ecologist (Caribbean)
- ***Matt Merrifield,*** Chief Technology Officer California (Western U.S.)
- ***Nate Peterson,*** GIS and Conservation Information Manager (Pacific Division)
- ***Kei Sochi,*** Spatial Scientist (Conservation Strategies)
- ***Anne Trainor,*** Energy Strategy Director (Africa)

Each Council member serves one year. At the term's end, representatives will recommend another from their region or program.



This map also depicts the Conservancy's geospatial reach. The dots here indicate where the Conservancy supports other partner conservation non-profits by extending our GIS software license agreement with Esri to advance their missions. Through the establishment of a cartography working group of geospatial and marketing staff, these maps illustrate emerging standards and best practices in developing a cartographic vision for the organization. Cartography by Chris Bruce, Virginia field office.

Why an Annual Survey?

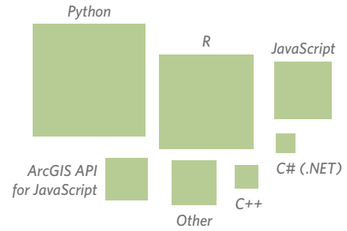
The Geospatial Systems Team (GST) conducted a survey to assess the status and needs of the geospatial community and understand how we define ourselves. Respondents were asked how they create spatial data, about potential training or staffing needs, their interest in specific areas and their priorities for the GST. With the survey as a baseline, we will be able to track trends over time and design and implement enterprise geospatial plans that support practitioners and lift geospatial work to a higher level of excellence. Please note: like all surveys, results are only as accurate as the responses and therefore do not necessarily reflect the status of the entire geospatial community.

GIS SUPPORT

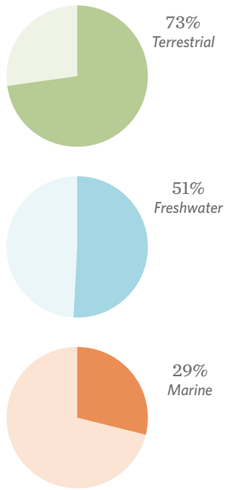
This survey question tried to get at what parts of the organization gained from leveraging geospatial technology for conservation. Not surprisingly, conservation projects featured most highly with 78% of the total GIS support. Science (59%) and Stewardship (43%) were also leading beneficiaries of GIS. TNC's Global Diversity, Equity and Inclusion (GDEI) team also reported using GIS data to further equity, human rights and gender issues.

GEOSPATIAL SCIENCE (Programming Languages)

Although programming does not seem to be a widespread skill among survey respondents (only 25% answered this question), Python and R were selected as the most common programming languages used by our GIS community. This trend matches what is currently seen in the GIS field outside of TNC.



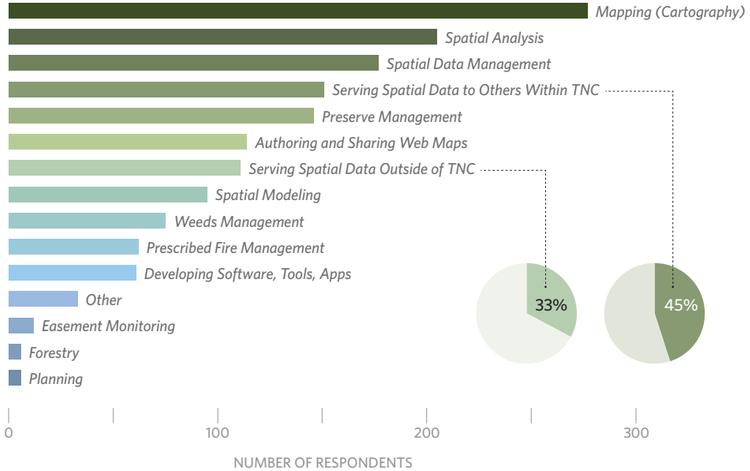
GIS USE BY HABITAT TYPE



About 70% of the respondents use GIS for terrestrial work at TNC. However, several respondents selected multiple habitat types in their answer, proving the multi-faceted nature of GIS work across different departments at TNC.

GIS USAGE TYPES

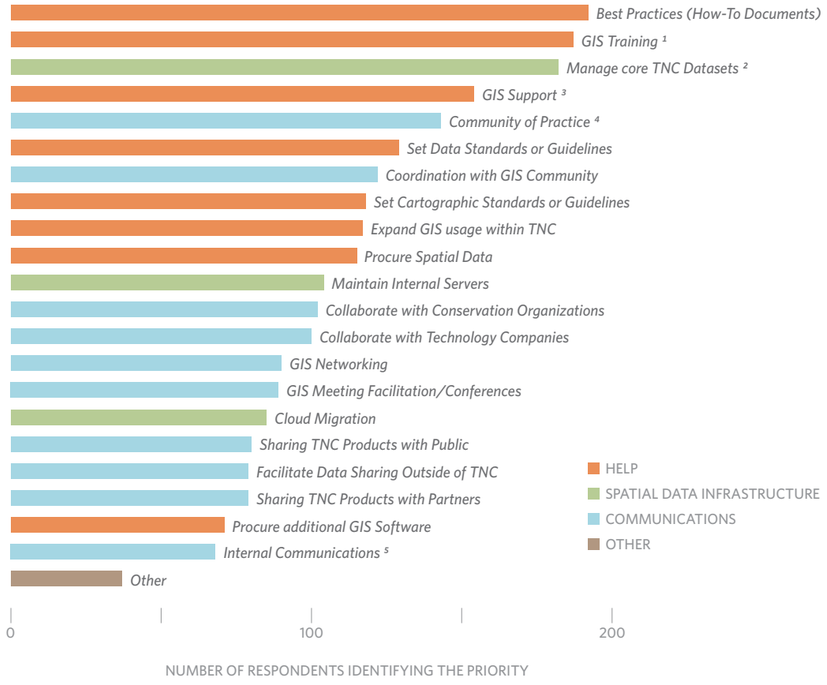
The vast majority of respondents (~83%) use GIS for mapping and cartography purposes. After all, maps are the most intuitive way to communicate relevant information across TNC (~45%) and to stakeholders outside TNC (~33%) while keeping track of field operations related to TNC preserve management (~43%). Given the large use of GIS for spatial analysis tasks (~60%) and data management (~53%), we can speculate that almost ⅔ of our GIS community are intermediate to advanced users.



PRIORITIES OF THE GIS COMMUNITY FOR CENTRAL GIS SUPPORT

In the survey, we asked participants to rank their top 10 priorities for the Geospatial Systems Team in the upcoming FY20. Of 301 respondents, 60% ranked their top three priorities to be the development of TNC-wide best practices (e.g. in the form of how-to documents), GIS training offerings, and the organization, management and centralization of core TNC datasets. About 50% also ranked GIS support and communication among GIS users within their top five priorities. This drives home a clear message that comes from our field programs: **they need support** to effectively develop capacity at the local level while having a team like ours as a point of reference for **centralizing** and **enabling access** to hundreds of GIS maps, apps, and layers that TNC has developed over time.

[1] e.g. Esri courses; [2] Organize, manage and centralize; [3] e.g. Help Desk; [4] e.g. GIS user working groups; [5] e.g. Intranet site CONNECT



Defining TNC's Geospatial Community

Our survey reached out to the Conservancy's geospatial community, which included the following:

1,452 STAFF
invited to participate in the global survey

364 RESPONDENTS
with **89%** completing the entire survey

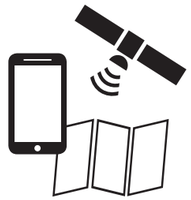
238 *members*
on the GIS community list serve

500 *user accounts* ON OUR **20** *internal servers*

753
My Esri users

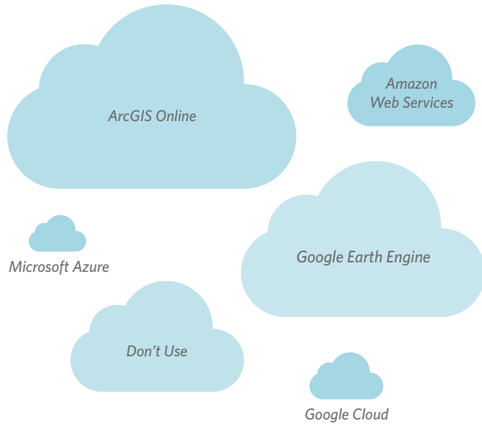
900 *active members*
on ArcGIS Online

By extension, TNC also supports
52 partner organizations
who are part of Esri's Authorized Entity Program, which offers GIS software licenses and training opportunities.



HOW TNC GENERATES SPATIAL DATA

Spatial data is generated in a number of ways such as GPS and mobile devices used by field crews, digitization of features of interest from satellite imagery and old paper maps, and output of spatial analysis tasks.

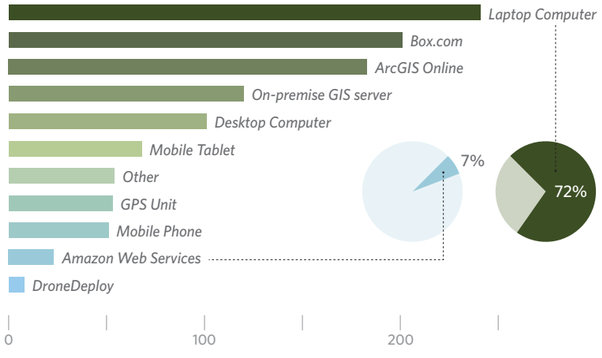


USING A CLOUD PLATFORM

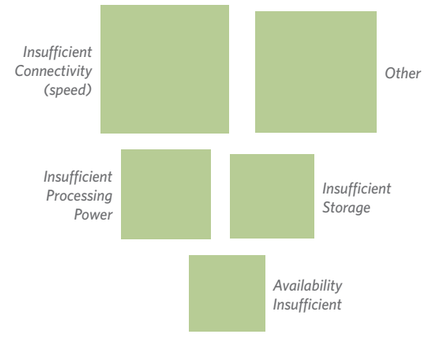
This survey question targeted *usage* and not *storage*. About 43% percent of respondents use ArcGIS Online to perform spatial analysis, publish web maps and store spatial data. One in four relies on Google Earth Engine to run spatial analysis, leveraging freely available satellite imagery. While ~10% currently use Amazon Web Services (AWS), we plan to expand its use with enterprise geospatial architecture in the coming year. We also plan to increase our use of Microsoft's Azure for performing specific geoprocessing, AI and machine learning tasks.

STORING SPATIAL DATA

More than 70% of respondents indicated a laptop computer as their most widely used way to store spatial data, along with Box (~60%). Given the low cost of cloud storage (e.g. AWS S3, Azure Blob storage), this is an area where TNC needs to push upon to quickly modernize and enhance its enterprise GIS architecture.



SERVER ADEQUACY

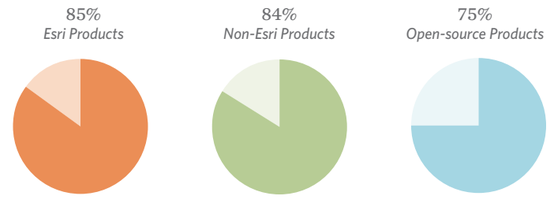


Over 30% of respondents who are currently relying on physical server infrastructure are not satisfied with the connectivity (speed) offered by this solution. One more reason to push for an incremental adoption of cloud server infrastructure to all TNC field programs who need to rely on fast and efficient ways to run their GIS work.

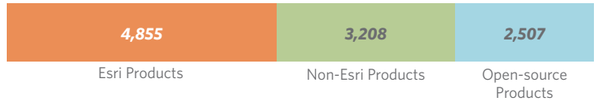
SOFTWARE USE
(Esri vs. Non-Esri product use and Open-source)

Geospatial software usage by Conservancy staff is heavily reliant on Esri products. From mobile, to desktop, to enterprise (server), the Esri product suite is used at all levels of the organization. Many additional software tools are brought to bear on our work, including non-Esri software and open-source software. Combining of all these software tools enables TNC's geospatial staff to achieve our Conservation mission.

Use Within the GIS Community



Individual Indications of Use



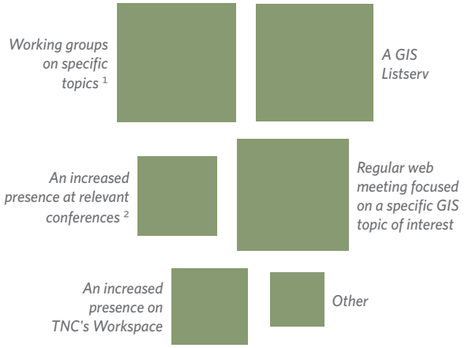
Number of Products Used [1]

Most-used Products

1. ***Google Earth/Google Maps*** is the most widely used product suite according to survey results. ***301*** respondents indicated use.
2. ***ArcGIS Desktop*** is the second most used product across all categories and the most used Esri product. ***297*** respondents indicated use.
3. ***Spatial Analyst*** and ***QGIS*** tied as the third most widely used products within the GIS community. ***268*** respondents indicated use of each of these products.

[1] Survey response 'Other' (offered as an option for each category) is not included in this data.

INCREASING GIS COMMUNITY

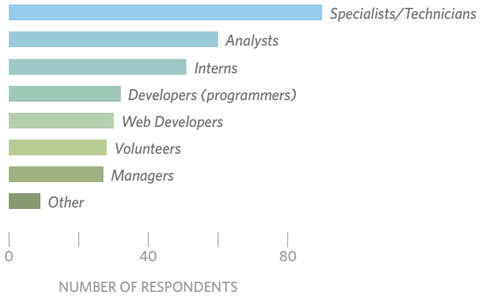


About two in three respondents selected working groups and GIS newsletters as the best way to increase our communications across the GIS community at TNC. Our user community wants to be kept up-to-date on geospatial trends in conservation and participate in discussions over specific areas of work (e.g. cartography, drones, AI) where shared knowledge is beneficial.

[1] Web publishing, cartography, etc.; [2] Esri User Conference, SCGIS (Society for Conservation GIS) Conference

ADDITIONAL GIS STAFFING NEEDS

GIS specialists and technicians are the most needed and sought out workforce across our GIS community at TNC (~76%), followed by GIS analysts (~50%) and GIS interns (~43%). This indicates a large need for additional GIS staff that can perform basic mapping and field collection tasks.



Women in Geospatial Technology

Our large GIS community represents different geographies and scales. Combined with TNC's emphasis on diversity, equity and inclusion, a strong potential to increase conservation support and impact is evident. Geospatial technology is helping TNC move the needle for women in science, technology, engineering and math (STEM) careers. Drawing from the survey, here are some important stats:

Of the 1,452 employees invited to participate in the survey,

630 **were women**

That's **43%**

Of the 364 employees who responded to the survey,

168 **were women**

That's **46%**

In 2017, TNC reported that women comprised *13% of management* and *26% of non-management* tech positions across the operations, technology and information systems and executive job families. Knowing this, women in GIS positions are taking steps to build a strong network of project managers, data administrators, GIS analysts and conservation coordinators.

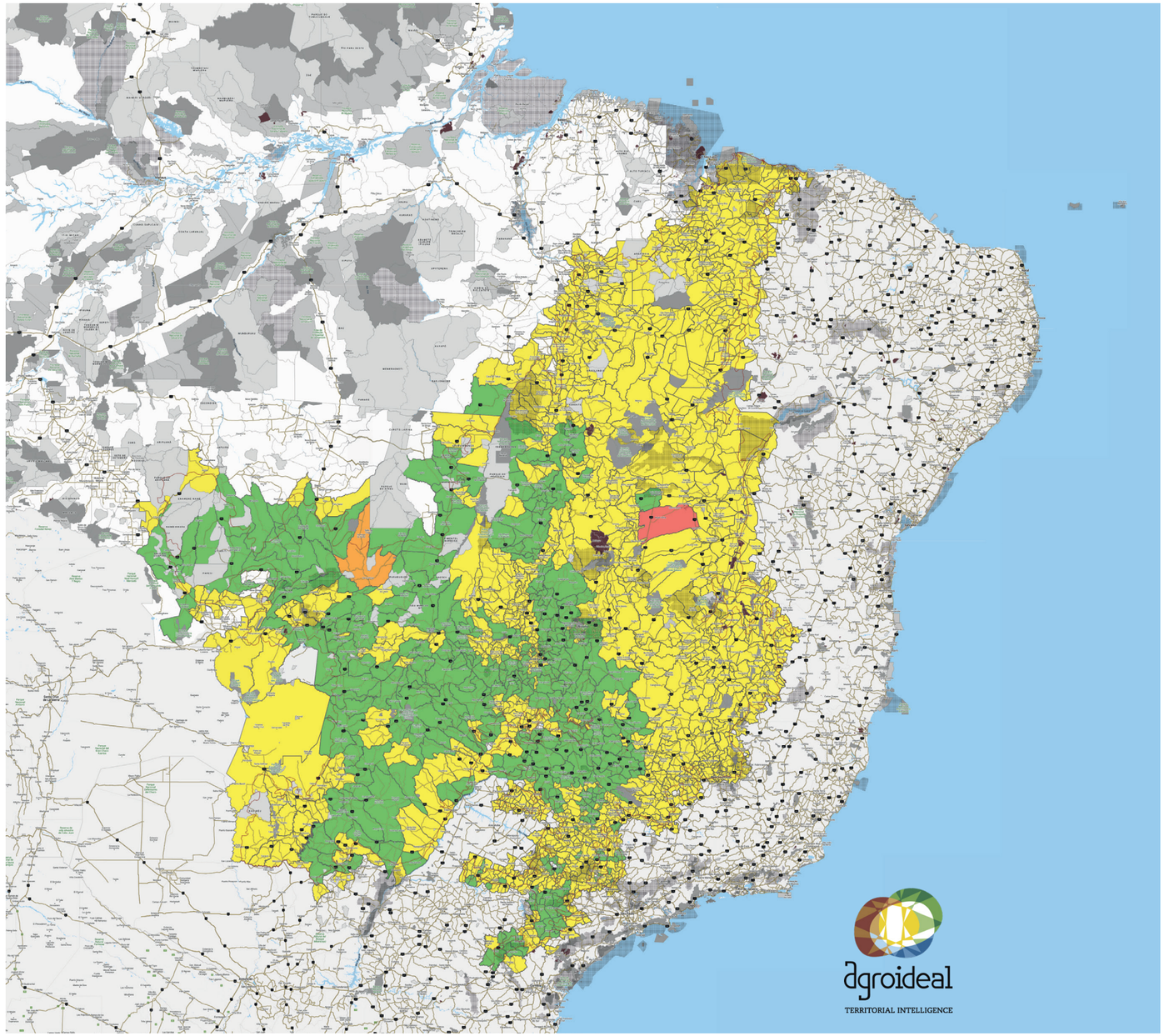
Soy farmer Fernando Pallaro lives in Santarém, in the state of Pará, Brazil. The Conservancy works with local communities in key municipalities to control deforestation and promote responsible production of soy and beef among farmers and ranchers. © Palani Mohan/Cargill Inc.

Geospatial Conservation Applications

There are hundreds of applications where maps play a central role in fulfilling the Conservancy's mission. While not a comprehensive representation of science programs and projects, these fourteen "use cases" illustrate how geospatial technology is used to provide decision support and leverage meaningful action. The GIS Leadership Council and the Geospatial Systems Team selected these examples. In the future, as the Council gains new membership and this report evolves, we will expand the array of use cases and maps to more fully highlight TNC's global work.

OUR PRIORITIES

- Tackle Climate Change
- Protect Land & Water
- Provide Food & Water Sustainably
- Build Healthy Cities



The red and orange municipalities represent regions that are prone to lose natural vegetation, are not in compliance with the Brazilian environmental registry and designed to allow farms to declare conservation for these private lands (over 3.9 million hectares). The yellow municipalities represent low environmental risk for soy future expansion but offer low economic opportunity (over 167 million hectares). Finally, the green municipalities are the most attractive for future sustainable soy expansion, having large stocks of soy suitable pasturelands in proximity to consolidated crops, high attainable soy yield and high historical yield according to census data (over 91 million hectares). Cartography by Erik Lopes and Osvaldo Jose Pereira, Brazil Science program.

REGION: **BRAZIL AND ARGENTINA**

Agroideal

A territorial intelligence system supporting social and environmental commitments

Agroideal is a free, online territorial-intelligence tool that was conceived collectively through the participation of 18 institutions. Developed to support decision-making on purchases and investments in the soy and beef sectors, it offers a combination of economic, social and environmental information for Amazonia and Cerrado biomes in Brazil and the Argentine Chaco, regions with highest rates of conversion of natural areas in Latin America. The system aligns with The Nature Conservancy's goals by enabling companies to act as purveyors of efficient territorial planning and better use of resources, which in turn contributes to landscape-sustainable production. Agroideal innovates by bringing unprecedented and strategic geographic information to these sectors, produced in partnership with renowned governmental research institutions in Brazil and Argentina.

Agroideal is particularly useful in places where agriculture is rapidly expanding in an unsustainable manner, and over natural areas like the MAPITOBA region in Central Brazil. (MAPITOBA is the combination of the initials of the four states that have most of the large remnants of Cerrado.) Targets include regions with the potential to guarantee soy crops of sufficient enough volume to meet official estimates through 2030 and avoid the prospect of converting new areas. In a business-as-usual scenario, 2.14 million hectares would be converted to soy; on the other hand, without cutting a single tree, 1.67 million hectares of pastures (non-native and composed of exotic grasses) can be available for soy crops.

Analysis points to Tocantins state as having the greatest potential for expansion over pastures suitable for soy. On the other hand, some municipalities—

Partners: ProYungas, WWF, Embrapa, Agrosatélite, Bunge, LDC, Cargill, Amaggi, COFCO, Agroicone, Earth Innovation, IDH, ABIOVE, Rabobank, CIARA-CEC, INTA, GeoAgris, FVS, CONICET

Website: agroideal.org

Contacts: Flávia Pinto (flavia.pinto@tnc.org); Leandro Baumgarten (lbaumgarten@tnc.org)

Software: Agroideal

Data Sources: LAPIG, IBAMA, EMBRAPA, SICAR, CPT, Agrosatelite, TNC, MapBiomas, PRODES, ProYungas, among others

Cattle on a Santa Vitoria Farm in São Félix Do Xingu in the Brazilian Amazon. The Conservancy is helping landowners reduce deforestation through practices like rotational grazing and replanting native vegetation. © Kevin Arnold

Formosa do Rio Preto (BA), Correntina (BA), Balsas (MA) and São Desidério (BA), among others—are prone to lose natural vegetation, especially priority areas for conservation. Using Agroideal spatial models, land managers are able to prioritize areas for intervention and identify areas where innovative financial incentives to prevent conversion might succeed.

REGION: **EASTERN CARIBBEAN**

Mapping Ocean Wealth in the Caribbean

Innovative, data-driven approaches to manage ocean assets

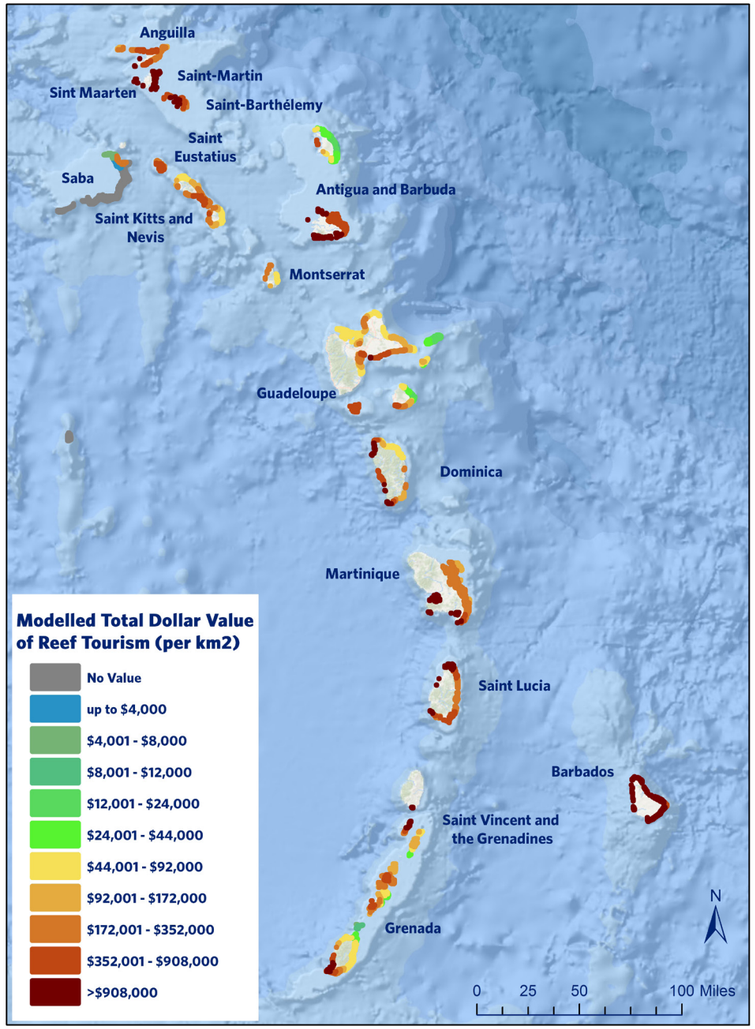
Top photo: Dean's Blue Hole, in the Bahamas, is the world's second deepest ocean blue hole. A global tourist attraction, it plays host to global free-diving competitions. The Conservancy is working to establish Marine Protected Areas around this location. © Jessica Wiseman

Bottom photo: Stunning coral reef of Grenada. The value of coral reefs for tourism in "Spice Isle" is estimated at over 22.6 million dollars (USD) per year. © Marjo Aho

Mapping Ocean Wealth (MOW) is a global initiative to map coastal and ocean ecosystem services—the benefits that nature provides to people. Coral reefs provide various ecosystem services such as recreation and tourism. Activities including SCUBA diving and snorkeling occur at coral reef habitat sites, but can also extend beyond the immediate footprint, for example, in calm waters and white sand beaches near coral reefs. To map benefits provided by coral reefs in the Eastern Caribbean, the MOW team used global data provided by the tourism industry as well as geotagged photos from Flickr to derive a spatial model of on-reef and reef-adjacent tourism values and visitation. The model results are displayed in an interactive mapping tool that illustrates global and jurisdiction-level recreational tourism values and visitation. Sustainable reef management is in part influenced by how tourism impacts the local economy; the mapping app allows users to explore the tourism value in specific places to support sustainability goals. In 2017, the World Travel and Tourism Council announced Mapping Ocean Wealth and the Recreation & Tourism mapping app as winner of the Tourism for Tomorrow Innovation Award.

Currently, the MOW team is adapting this model and its approach at the scale of the Eastern Caribbean in support of the Caribbean Regional Oceanscape Project, an initiative to improve ocean management. The team will refine existing coral reef tourism and fisheries models while developing novel methodologies to characterize recreational fishing, wildlife viewing and other nature-dependent tourism in participating countries (Dominica, Grenada, St. Kitts and Nevis, St. Lucia, and St. Vincent and the Grenadines). This work will incorporate a combination of Artificial Intelligence (AI) and machine learning techniques for enhanced examination of crowd-sourced data such as TripAdvisor reviews. The machine learning process begins by identifying a subset of text or images that represent the target data (e.g. photos taken underwater or reviews containing the phrase "healthy coral reefs"). Machine learning tools for text analytics and computer vision for images then uses this set of training data to identify a larger set of inputs. This is an interactive process that requires data scientists to assess preliminary results, indicating which of the model results best fit the desired criteria while having the AI tools learn patterns in the results that increase accuracy. In this way, machine learning techniques are helping the Conservancy fill critical data gaps relating tourism to conservation. "The more data we collect about coral reefs, the more insight we gain into the full value of protecting these vital natural ecosystems," says Dr. Lucas Joppa, chief environmental officer at Microsoft. "Using AI and machine learning, Azure Cognitive Services is helping to accelerate the process of classifying thousands of coral reef images throughout the Caribbean. This detailed visual data helps accurately inform a tourism-based economic valuation model that's designed to help bring conservation needs and eco-tourism opportunities into balance."

The resulting data models support these countries in ongoing and future marine spatial planning through the mapping of ecosystem service values, particularly relating to fisheries and nature-based tourism.



Fine-scale mapping of coral reef tourism varies across the Eastern Caribbean, helping environmental planners and managers prioritize areas for protection or conservation initiatives. Country-level statistics derived from the map quantify the importance of coral reef habitats to the island's tourism economy, which further emphasizes the need for effective management and conservation of these resources. Cartography by Kate Longley-Wood, Global Oceans program.

Partners: Microsoft, TripAdvisor, University of California at Santa Cruz, Florida International University, Critigen

Website: *Oceanwealth.org*

Contact: Kate Longley-Wood (*kathryn.longley-wood@tnc.org*)

Software: ArcMap v.10.3 and higher, ModelBuilder

Data Sources: World Travel and Tourism Council, DiveBoard, Global Accommodation Reference Database, UN World Tourism Organization, Flickr, TripAdvisor, Esri Basemaps, Microsoft

REGION: **MYANMAR**

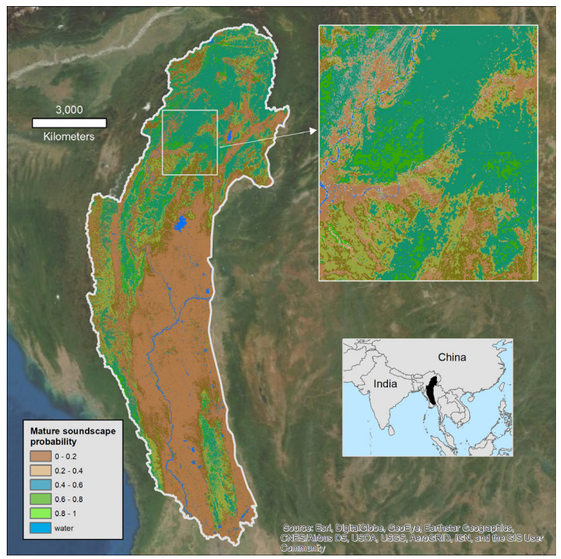
The Science of Sound

Acoustic soundscapes of mature teak forests in the Central Region of Myanmar

Across conservation science and management sectors, there has been an ever-increasing interest in ways to leverage bioacoustic soundscape data. Bioacoustics is a specialized field that focuses on recordings of ecosystems, collected by specialized recording equipment. The idea of a soundscape is to represent the entirety of the recording as a measure, or proxy, of biodiversity, whereas traditional bioacoustics focuses solely on individual species identification. Because of the numerous advantages in remote monitoring of ecological systems, The Nature Conservancy (TNC) is investing in the application of soundscape approaches. A leading question is how acoustic recordings can be translated into geospatial data. Given that mapped spatial data has become a critical component in understanding ecological process and guiding management decision making, TNC's global science group decided to tackle this question.

The group partnered with the Myanmar Forest Department, Forest Research Institute to collect hundreds of bioacoustic recording across the central-northern teak forest of Myanmar. Data were collected across a gradient of disturbed to mature forest conditions. A TNC biometrician developed novel Artificial Intelligence approaches to analyze the acoustic data and produce a model that represented characteristics of the ecological soundscape across measured forest conditions. This model was then used to find relationships with spatial data representing (1) current and temporal trends in above ground biomass using Copernicus Leaf Area Index 7 year-biweekly timeseries, (2) high accuracy forest/non-forest from TanDEM-X, in deriving characteristics of forest pattern and structure (e.g. fragmentation) and (3) geomorphometric characteristics from ASTER digital elevation model. This allowed the group to produce a probabilistic spatial estimate (map) of mature forest soundscapes based on landscape condition and pattern; that is, the likelihood of sounds associated with mature forest conditions. "Analysis at this scale requires big data storage, massive on-demand geoprocessing capability, and ready access to content from a variety of remote sensing sources. We are excited to partner with The Nature Conservancy to provide the right cloud solution for conservation success," says Mark Korver, Geospatial Lead at Amazon Web Services.

By using this map, local forest managers were able to focus conservation efforts on areas based not only on mapped mature forest, but also on areas with the highest associated biodiversity values. The analysis leveraged SWIFT data recorders, QUT acoustic processing workbench, R statistical software and Esri ArcGIS.



Partners: Myanmar Forest Department, Forest Research Institute

Websites: *nature.org/myanmarforests* and *blog.nature.org/science/tag/acoustics*

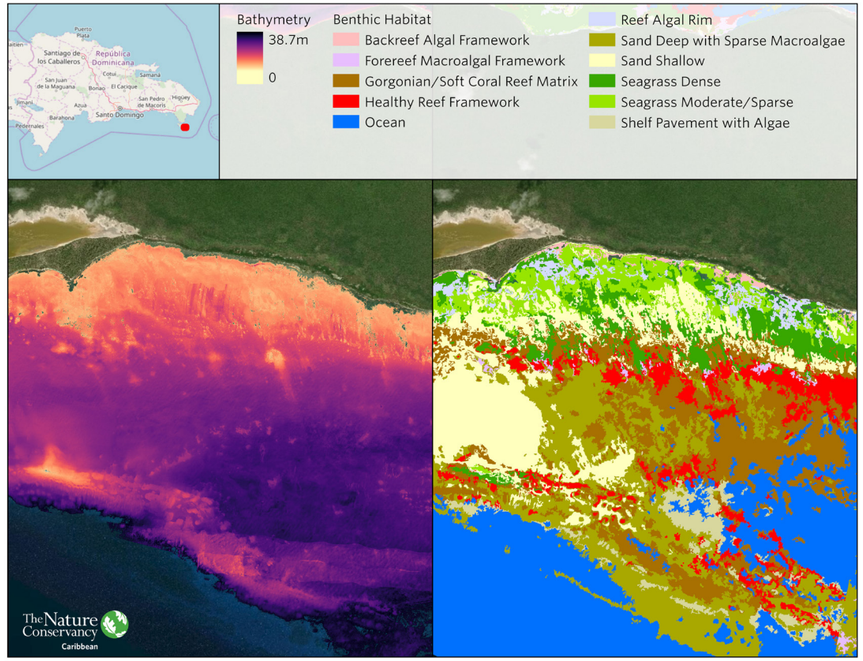
Contacts: Jeffrey S. Evans (*jeffery_evans@tnc.org*); Timothy Boucher (*tboucher@tnc.org*); Tint Thaung (*tint.thaung@tnc.org*)

Software: QUT Acoustics workbench; Acoustic Recorders (Cornell): R Statistical Software, Esri ArcGIS

Data Sources: Digital Elevation Model from ASTER GDEM, 7 day composites (2013-2018) of Leaf Area Index from Copernicus Global Land Services, and global forest cover derived from interferometric Synthetic Aperture Radar (SAR) data TanDEM-X

Photo: Forest Department Rangers secure a bioacoustics device to a tree for monitoring sound in Myanmar's tropical forest. © Tim Boucher

Map: Soundscape probabilities for mature forest in Chindwin and western Irrawaddy river basins, Myanmar. Cartography by Jeffrey Evans, Conservation Lands Science program & University of Wyoming, and Tim Boucher, Global Science program.



Side-by-side comparison of bathymetry data derived from ASU's Global Airborne Observatory and preliminary benthic habitat classifications from Planet Dove Satellite imagery in the Dominican Republic. Cartography by Valerie Pietsch McNulty, Caribbean division.

REGION: **CARIBBEAN BASIN**

Mapping Coral

Using drones, underwater cameras, and satellite imagery to map the Caribbean's corals

The Nature Conservancy and partners are developing a first-of-its-kind, high-resolution benthic habitat map across the wider Caribbean region. Arizona State University (ASU) collected hyperspectral imagery to create bathymetry, 3D habitat complexity, and live coral maps across marine parks located in the Dominican Republic and U.S. Virgin Islands. The daily repeat cycle of Planet's 100+ Dove satellite constellation offers the ability to create unparalleled cloud-free mosaics at a high spatial resolution (3.7m). Conservancy scientists used aerial drones, water surface drones, and underwater video cameras to collect field data to validate the detailed baseline maps.

"Tapping into a global network of satellites that supply daily images provides an unprecedented ability to map and monitor coral reefs at a scale we've never seen before. In collaboration with TNC, we can use these technologies to provide high-resolution 3D habitat and live coral cover maps to greatly advance conservation efforts," noted Greg Asner, director of the ASU Center for Global Discovery and Conservation Science.

Partners: Center for Global Discovery and Conservation Science (GDCS) at Arizona State University (ASU), Planet

Website: *caribbeanscienceatlas.tnc.org*

Contacts: Dr. Joseph Pollock (*joseph.pollock@tnc.org*); Dr. Steve Schill (*sschill@tnc.org*); Valerie Pietsch McNulty (*valerie.mcnulty@tnc.org*)

Software: ENVI, ArcGIS Pro, ArcGIS Online, StoryMaps, Survey123, eCognition

Data Sources: Planet Dove satellites, ASU's Global Airborne Observatory, aerial and surface drones, underwater video cameras

Working closely with the technical staff at Planet, TNC and ASU assembled a Caribbean-wide mosaic that radiometrically blends thousands of cloud-free Dove satellite scenes. Products derived from this mosaic include a new ocean atmospheric correction algorithm, an adaptive depth retrieval algorithm, and a water column attenuation algorithm for better estimating bottom reflectance. TNC has developed an extensive classification ruleset that uses the Dove-derived bathymetry and surface/bottom reflectance to produce an automatic eleven class benthic habitat classification. A pre-August 2017 mosaic is also being compiled and classified to assess the ability of the satellites to evaluate ecological damage to areas impacted by Hurricanes Irma and Maria in 2017.

This project is being conducted in collaboration with the Allen Coral Atlas, an effort led by Vulcan, Inc., to monitor the world's coral reefs. These maps are directly supporting projects in coral conservation and restoration, ecosystem services modeling, ecosystem-based adaptation, and marine spatial planning in several countries including the Dominican Republic's 8,000 km Southeast Marine Sanctuary.

Ataya tract and Cumberland Mountains from Cumberland Gap National Historic Park in Tennessee. This is part of the plant and animal "escape route" of species shifting their ranges to cooler climates. © Byron Jorjorian

REGION: **EASTERN UNITED STATES, CUMBERLAND FOREST**

Resilient and Connected Landscapes

A blueprint for conservation in a changing climate

In this first-of-its-kind study, the Conservancy identified a conservation portfolio that represents physical habitats of the eastern United States and aligned them into a network of climate-resilient sites, confirmed biodiversity locations and species movement areas (zones and corridors). The results provide a "blueprint for conservation" that aims to sustain the region's natural diversity by allowing species to adapt to climate impacts and thrive. The results have been used by the U.S. Fish and Wildlife Service in their landscape conservation designs, by states in their Wildlife Action Plans, and by more than 75 land trusts in their conservation and acquisition planning.

The Resilient and Connected Landscapes blueprint can be adapted to identify local land protection challenges and opportunities. For example, in 2019 the 253,000-acre Cumberland Forest Project, one of the largest-ever conservation projects in the Eastern U.S., protected a critical portion of the network that Conservancy scientists believe can provide an important "escape route" as plant and animal species shift their ranges to cooler climates. The data also support smart land-use planning. In North Carolina, the Conservancy has created "Principles of Low Impact Solar Siting and Design" to inform and potentially guide solar energy developers, operators and other stakeholders to site, construct and operate solar facilities in ways that minimize impacts to natural ecosystems and biodiversity, particularly with regard to siting in a resilient area or siting in such a way that climate corridors become fragmented.

Creating the Resilient and Connected Landscapes is a data-intensive modeling effort at a 30-meter resolution across the U.S. Project staff compiled existing data on biodiversity and protected areas, and developed geospatial models of microclimates, local connectedness, regional climate flow and sea level rise models.

Esri software has been integral to data gathering, analysis, modeling and publishing. In addition, models were built using a Resistant Kernel Algorithm (R) and Circuitscape (Python, Julia). The resulting maps and component data can be explored on a mapping tool and the data downloaded from the website.

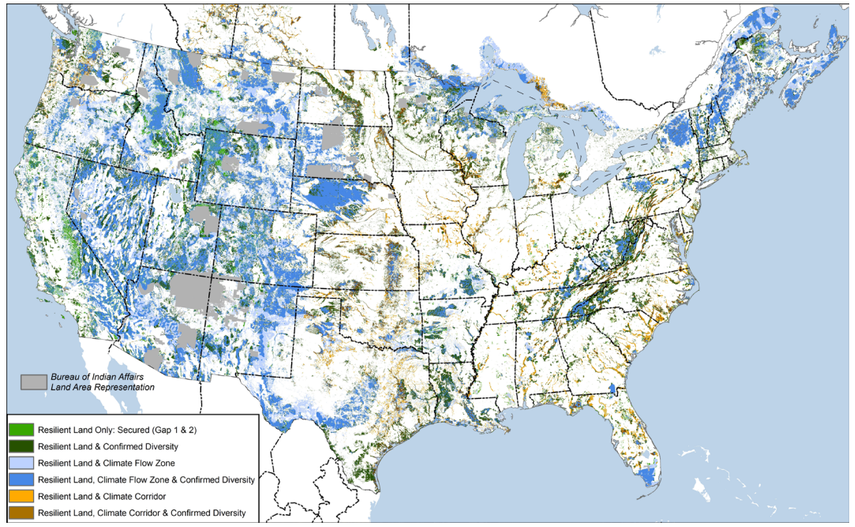
Partners: Duke Foundation, Donnelly Foundation, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration

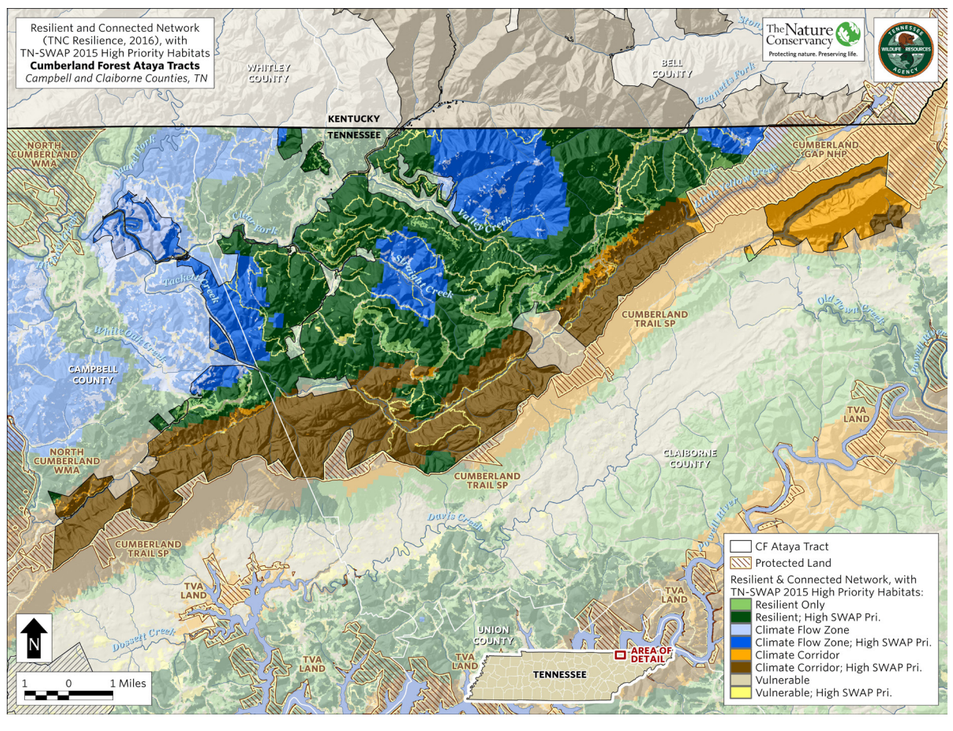
Websites: *nature.org/TNCResilience* and *maps.tnc.org/resilientland*

Contacts: Melissa Clark (*melissa_clark@tnc.org*) or *eScience@tnc.org*

Software: Esri ArcMap, ArcGIS Spatial Analyst Toolbox, Python, Model Builder, ArcGIS Server, and ArcGIS Online

Data Sources: TNC portfolio data, State Wildlife Action Plans, Digital Elevation Models, National Hydrography Data, National Wetlands Inventory, TNC Lands, PAD-US, Eastern Conservation Science Secured Lands, National Land Cover Dataset, Tiger Roads Data, National Land Cover Dataset, Digital Elevation Models, NOAA





Map above: In this first-of-its-kind study, TNC identified a conservation portfolio that represents physical habitats of the United States while aligning them into a network of climate-resilient sites, confirmed biodiversity locations and species movement areas (zones and corridors). Cartography by Melissa Clark, Eastern Conservation Science program.

Left map: The Ataya project, a 100,000 acre property part of the Cumberland Forest Project in Kentucky and Tennessee, is identified by the Resilient and Connected Networks as a critical linkage between the North Cumberland Wildlife Management Area in Tennessee, the Cumberland Gap National Historic Park and Kentucky Ridge State Forest in Kentucky. Cartography by Joey Wisby, Tennessee field office.

REGION: **CENTRAL JAVA (SEMARANG), INDONESIA**

Resilient Coastal Cities

Building an ecological and social resilience toolkit

The Resilient Coastal Cities project (RCC) reflects a unique partnership between The Nature Conservancy and the American Red Cross's Red Crescent Global Disaster Preparedness Center (GDPC), blending the Conservancy's experience with science-based ecosystem conservation and restoration with the GDPC's experience in community mobilization, raising awareness and education.

RCC identifies and enhances community resilience in Southeast Asia by building on existing approaches to community assessment, problem-solving, and preparedness outreach. Within the Conservancy's Coastal Resilience program, this work combines machine learning with geospatial analyses to capture near real-time flood reports in Semarang, Indonesia. Using Twitter, FloodTags built a Bahasa-trained machine learning algorithm to identify and capture flood-related messages in the city and surrounding area. To account for potential differences in the location of the flood compared to the location of the person Tweeting about it, location names mentioned in the body text are geo-parsed using a Geonames database rather than relying on the GPS coordinates. These flood reports are validated and served through FloodTag's dashboard and mapped to city administrative units (kecamatan) provided by the city of Semarang. These flood reports by kecamatan are then analyzed against demographic data and Open Street Map including the number of people and critical infrastructure that are potentially impacted by the flooding.

A mobile-friendly web application used by stakeholders examines flooding in the most vulnerable areas of the city with mangrove restoration in order to reduce risk. The science of ecosystem-based climate adaptation is growing rapidly. The web map highlights where potential adaptation actions, mangrove restoration and open space reclamation or preservation, overlap with areas that are reporting flooding. This innovative decision support tool enables planners to consider these natural solutions that can help communities become more resilient to future flood events.

This project illustrates the relationship between social and ecological resilience within the humanitarian cycle of preparedness, response, and recovery. As development increases and people continue to move to the coasts, new and improved strategies are crucial to mitigate risk and promote the health of the environment.

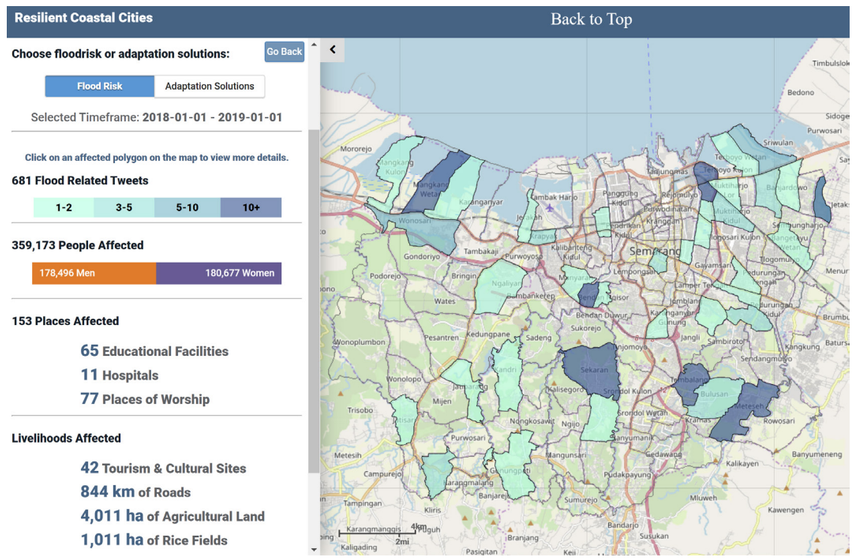
Partners: Global Disaster Preparedness Center (American Red Cross), Indonesia Red Cross Society, FloodTags, Wetlands International, Esri

Websites: *coastalresilience.org/project/indonesia* and *preparecenter.org/rcc*

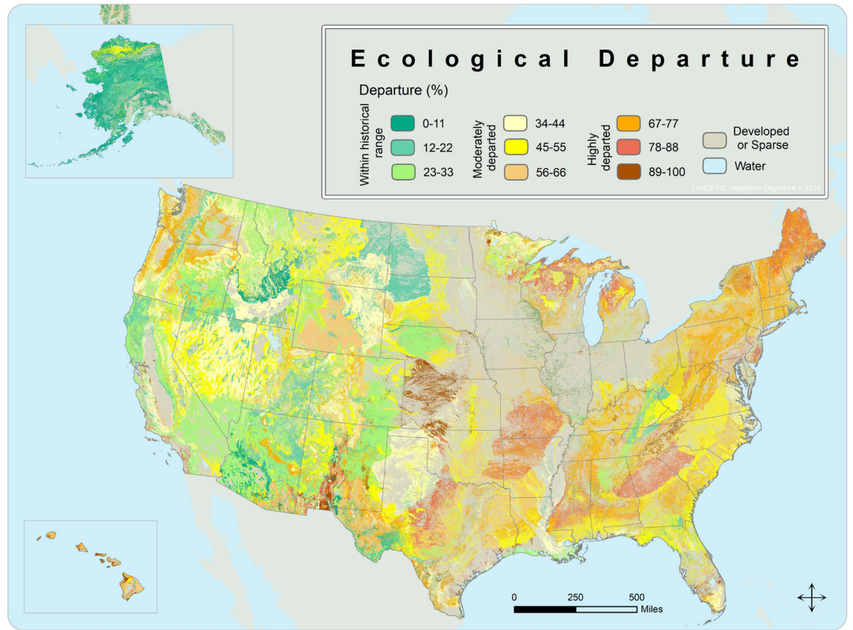
Contact: Laura Flessner (*laura.flessner@tnc.org*)

Software: ArcGIS API for Javascript 3.25 and 4.0, ArcGIS Pro 2.1.0, ArcGIS Desktop 10.6.1

Data Sources: Twitter, City of Semarang, Indonesia Central Bureau of Statistics 2014 Village Potential Statistics (PODES), Indonesian Ministry of Geospatial Agriculture



The Resilient Coastal Cities decision support tool enables planners in Semarang to improve city resilience to flooding by assessing potential impacts from single flood events while highlighting areas that show trends of repetitive flooding over time. This helps prioritize both short-term disaster response and longer-term nature-based adaptation and actions. Web map by Matt Silveira, North America Science program, and Laura Flessner, Global Oceans program.



This map of ecological departure in Eastern Washington shows how vegetation on the landscape today compares to historical conditions. Understanding current vegetation conditions is a key step in developing whole system forest conservation goals. This national map was modified using locally calibrated LANDFIRE data for the Eastern Washington Forests Whole Systems analysis. Cartography by Kori Blankenship, North America Science program.

REGION: **UNITED STATES AND ISLAND TERRITORIES, EASTERN WASHINGTON**

All-Lands Data: LANDFIRE

Supporting the conservation community through rich, comprehensive, ecologically-based information

Information is the foundation of every effective plan and conservation decision. The Nature Conservancy is a major partner in the LANDFIRE Program along with the USDA Forest Service and U.S. Department of the Interior. For more than 15 years, the Conservancy's team has worked with others to provide regionally and nationally relevant data sets that support natural resource management and wildland fire user communities. The product suite covers all lands and major vegetation types, regardless of ownership or life-form, and includes more than 20, 30-meter spatial resolution data layers (Arc GRIDS or GeoTIFF) and 800+ quantitative ecosystem models. All products are ready to use and free for download from LANDFIRE's website, or can be accessed via REST or WCS map services. The information includes both current and historical time periods, current structure and composition, succession and disturbance rates and more. Versions representing conditions in 2001, 2008, 2010, 2012, and 2014 are available for all areas; a 2016 version is in progress. The spatial extent, temporal periodicity and thematic depth of the data suite have supported hundreds of local, regional and national applications from bees and bears and birds to longleaf and lodgepole pine to carbon accounting and climate change. A sample of these applications can be explored on TNC's web map.

Partners: U.S. Department of the Interior Office of Wildland Fire, U.S. Department of Agriculture Forest Service Fire and Aviation Management

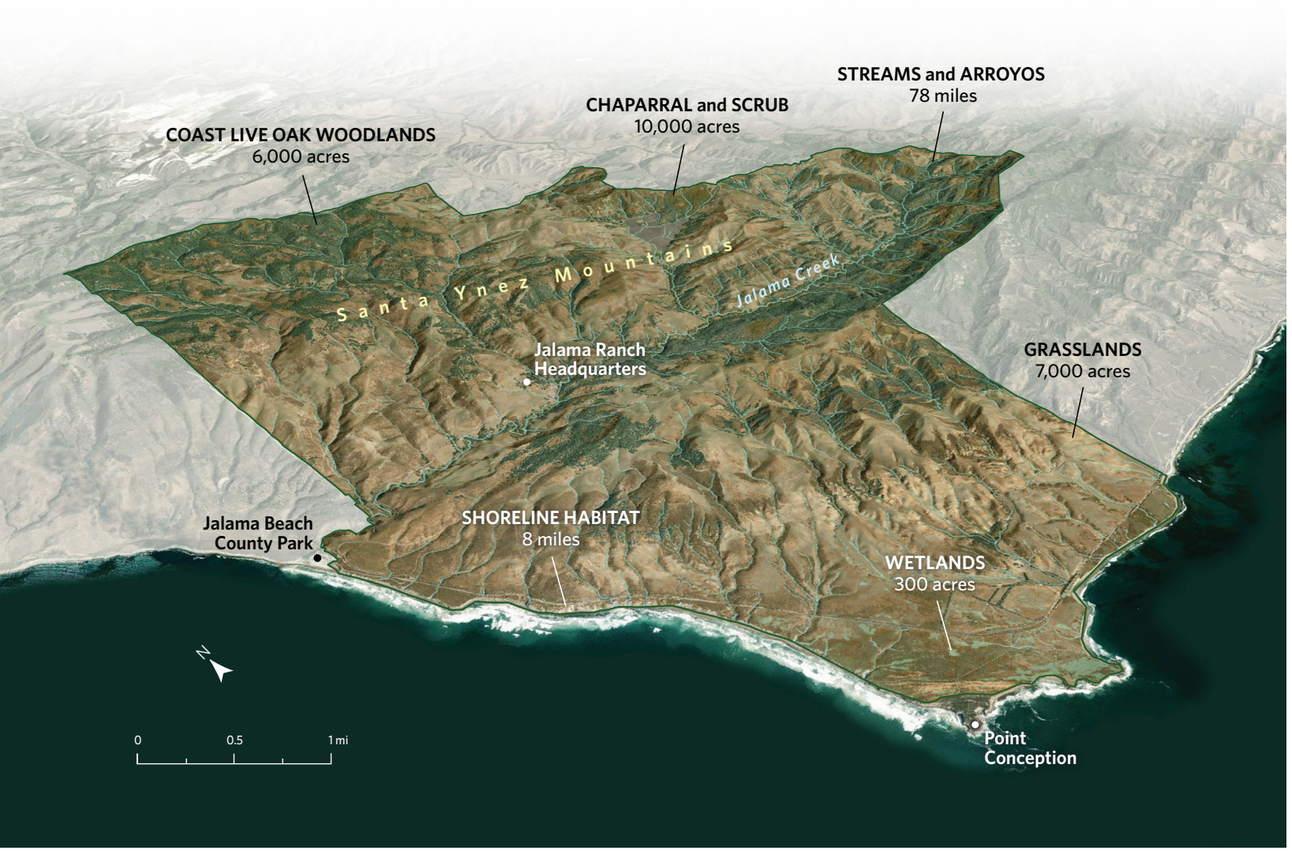
Websites: *landfire.gov*, *maps.tnc.org/landfire*, *bit.ly/31X3bfH*

Contact: Jim Smith (*jim_smith@tnc.org*)

Software: ArcGIS

Data Source: LANDFIRE Vegetation Departure version 2014

The Conservancy's team works with TNC chapters and landscapes upon request. For example, LANDFIRE data sets were key components of the Eastern Washington Forests Whole Systems analysis, the first of several region-wide analyses supported in part by LANDFIRE data that explore vegetation conditions, fire regime departure and restoration needs. The project team at TNC measured the current ecological condition of forests across eastern Washington as the necessary first step towards developing whole system forest conservation goals. Building from a foundation of LANDFIRE models and data, the team performed a spatial analysis of Eastern Washington forests based on historic and current forest structure and composition, as well as ownership and management designation data. They compared the departure of current forest vegetation from historic conditions in the current landscape, ownership and management context. Ultimately, they were able to evaluate how well the ecosystem-scale processes that regulate these forests were functioning, and spatially illustrate the ecological context for setting whole systems goals and for developing conservation and restoration strategies.



Map above: The use, deployment, and coordination of geospatial tools across the series of habitats on the 24,364-acre preserve is crucial to help project managers and scientists make timely decisions about conservation actions (see more of TNC's land holdings in the U.S. at lands.tnc.org). Cartography by Megan Webb, California field office.

REGION: **SOUTHERN CALIFORNIA**

Jack and Laura Dangermond Preserve

A conservation laboratory in a last remaining stronghold of coastal California wilderness

The Jack and Laura Dangermond Preserve protects eight miles of last-of-its-kind wild coastline and more than 24,000 acres of oak woodland, chaparral and grassland habitats in Southern California. The preserve, located at Point Conception, Southern California's "elbow" where the coast bends northward to San Francisco (called "the last perfect place" by the *Los Angeles Times*) presents significant opportunities for geospatial innovation, among which is the restoration of oak woodlands.

Coast live oaks are among California's most iconic trees, unique in their ability to thrive in the dynamic, diverse environment. Drought resistant, adapted to fire, and evergreen with a dense, hemispherical crown and complex architecture of branches, they are a keystone species of coastal woodlands and the dominant feature on more than 6,000 acres of the preserve's land. However, despite its wide distribution and because of its unique habitat characteristics, areas of the coastal oak woodland need serious attention.

Partners: Esri, Padre Associates Inc.

Website: nature.org/crownofthecoast

Contact: Kelly Easterday (kelly.easterday@tnc.org)

Software: ArcGIS Pro, Adobe Illustrator, Photoshop, ArcGIS Online, Collector, Survey 123, Operations Dashboard

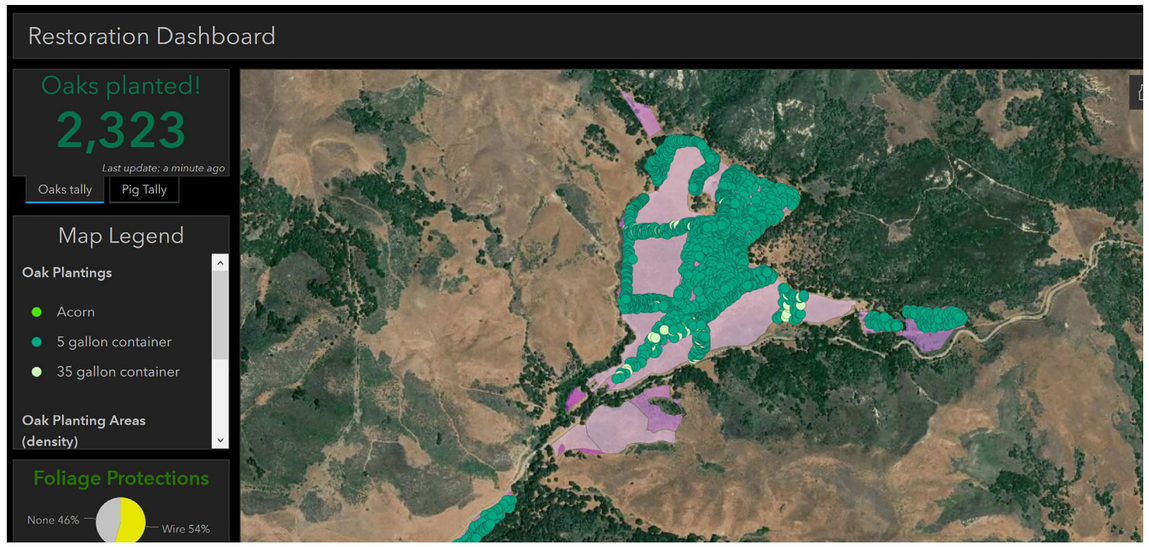
Data Sources: Esri basemaps, Field data collected by Padre Associates Inc.

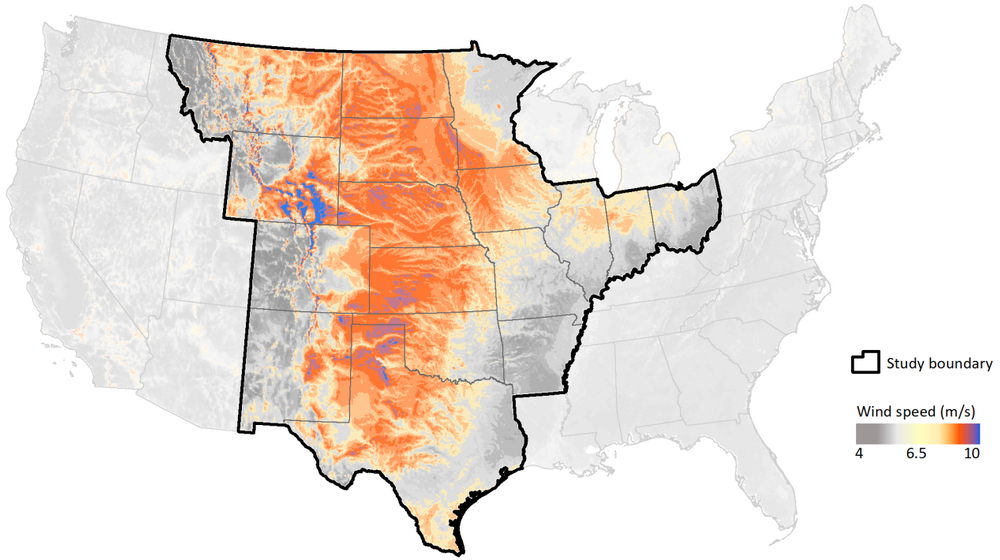
The large-scale restoration project is driven by orders from the California Coastal Commission that were transferred to The Nature Conservancy when it purchased the property in 2017. Using coast live oak acorns and seedlings collected from the preserve, restoration managers are beginning the project by re-planting 200 acres. To monitor the project's health and progress, the Conservancy enlisted the interconnected suite of ArcGIS Apps for the field including Collector, Survey 123 and Operations Dashboards, coordinated and hosted through ArcGIS Online. When used in conjunction, these applications enable project teams to capture critical spatial information on the location, health and condition of each tree planted. The ongoing work is conducted by a spatially distributed team of project managers and scientists who access real-time information that supports timely decision-making. Further, the map and report structure allow for the generation of complete annual monitoring reports that are required by the Coastal Commission.

The trees will be monitored for five years; metrics on each individual will be collected annually and updated live in the operations dashboard. This project, one of many taking place on the preserve, relies on quick, reliable data capture and delivery in order to ensure that the preserve remains the last perfect place in California.

Photo: Larry Serpa, aquatic ecologist for California's Stewardship program, surveys a stand of coastal live oak woodlands with Jack and Laura Dangermond Preserve Director Michael Bell. © Bill Marr/TNC

Map below: Restoration Dashboard is an operations viewpoint of key information from the teams in the field showing over 2,323 individual trees planted. The dashboard was built using the Esri platform by Katie Andrews, California field office.





REGION: **GREAT PLAINS/ MIDWEST U.S.**

Site Wind Right

Accelerating a clean, low-impact energy future

Site Wind Right (SWR) is The Nature Conservancy's approach to promoting smart, renewable wind energy in the right places, that is, where wind development is unlikely to encounter significant wildlife-related conflict, project delays and cost overruns. It represents a collaborative effort involving more than 50 scientists and GIS professionals from across the organization who built upon published studies of wind and wildlife interactions.

The interactive online map incorporates more than 100 data sets on wind resources, wildlife habitat, current land use and infrastructure to help inform siting decisions across 17 states in the Central U.S. The region encompasses nearly 80 percent of the country's current and planned onshore wind capacity. The map was created to identify appropriate areas for wind development, and is an important source of information for screening early in the project siting process. It can also be used to support application of the U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines, specifically Tier 1 and Tier 2 evaluations.

Combining the SWR map with other land suitability factors suggests that over 1,000 gigawatts of wind energy may be developed exclusively in areas of low conservation impact. The results of this analysis indicate that it is possible to accelerate a clean, low-impact energy future, one that supports energy, climate and conservation goals.

Partners: Local, state, and federal wildlife agencies, and other conservation professionals

Website: *nature.org/sitewindright*

Contacts: Chris Hise (*chise@tnc.org*); Nathan Cummins (*ncummins@tnc.org*)

Software: ArcMap (10.1-10.6), ArcGIS Pro (2.2), ModelBuilder, ArcGIS Online

Data Sources: U.S. Fish and Wildlife Service, U.S. Geological Survey, The Nature Conservancy, State DNR and Heritage programs, and other data. For details, see methods paper, Appendix A (*nature.org/sitewindright*)

Map: The map above shows the "wind belt," an area of high wind resource in the central United States. Modified from NREL and AWS Truepower maps of average annual wind speed at 80-meter height (*energy.gov/eere/wind/windexchange*). Cartography by Chris Hise, Oklahoma field office.

Photo: Wind turbines in the southern Flint Hills region of Kansas. © Jim Richardson

REGION: **QUIROZ WATERSHED, PIURA STATE, PERÚ**

The Piura Water Fund

An investment portfolio to reduce sediment export

Partners: Fondo Regional del Agua FORASAN – Piura; Asociación para la Investigación y Desarrollo Integral – AIDER; International Climate Initiative of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety – IKI-BMU

Website: *fondosdeagua.org/en*

Contacts: For Piura Water Fund project: Alfredo Salinas (*asalinas@tnc.org*), Aldo Cardenas (*aldo_cardenas@tnc.org*). For RIOS and InVEST SDR modeling: Alfredo Salinas, Jorge Leon Sarmiento (*jleon@tnc.org*). For RBIS data management platform: Jorge Leon Sarmiento

Software: RIOS, InVEST Sediments Delivery Ratio Model, RBIS Data Management Platform

Data Sources: All data sources used for this exercise are properly described and stored at the dedicated RBIS platform for Water Funds in Peru. River Basin Information System (RBIS) information.

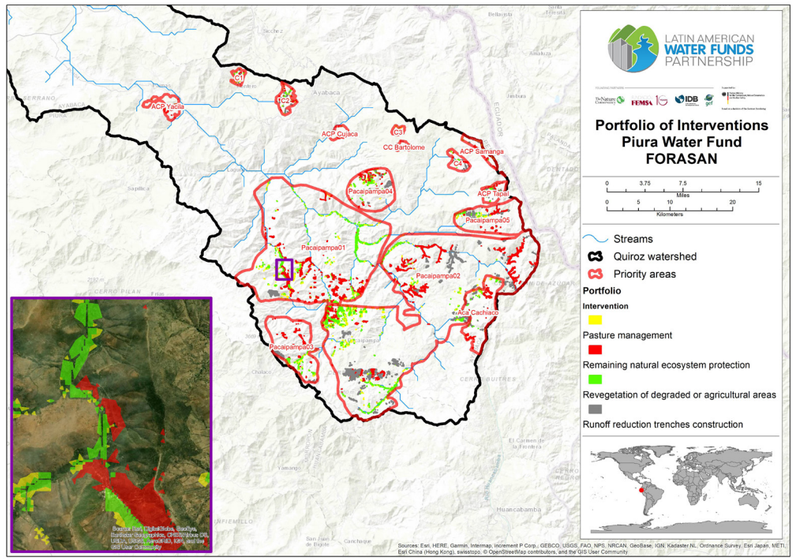
Within the framework of the Latin American Water Fund Partnership, The Nature Conservancy has been promoting the implementation of green infrastructure projects through "Water Funds," organizations that design and enhance financial and governance mechanisms to develop natural solutions to water security. In Peru, the Conservancy has supported the creation of three Water Funds in the supplying watersheds of the Lima, Cusco and Piura cities. In Piura, the Fondo Regional del Agua FORASAN was chosen as a design study for a green infrastructure investment portfolio.

A Water Fund portfolio of investments is a geographically explicit product that presents a combination of priority areas for activities that can potentially yield significant ecosystem services. Fifteen protected areas in the Quiroz River watershed were considered ideal candidates. The Water Fund team was asked to formulate optimal portfolios for interventions assuming an investment of $8 million, and to identify which of the protected areas would most likely offer the greatest return on investment.

Four potential activities were evaluated: natural remaining vegetation protection, restoration of natural ecosystems from current agricultural land covers, implementation of lower environmental impact cattle ranching practices in non-natural pastures and trenches for runoff water control and infiltration in agricultural land covers.

Two objectives that directed the study included the reduction of total suspended solids in water as a function of sheet erosion reduction and overflow sediments retention by riparian vegetation; and the reduction of surface runoff to increase infiltration, as function of above soil vegetation rain interception before soil saturation. The analysis generated portfolio maps detailing the activities and extent that they could be implemented in each of the areas given the allocated budget, and a cost-benefit comparison in terms of suspended sediments reduction per dollar invested.

The initial investment proposal details potential activities in each place, including cost, exact location and expected ecosystem services. Based on this analysis, TNC has determined that the four priority areas (Pacaipampa 2, Aca Cachiaco, Pacaipampa 5 and Criterios 4 or "C4") have a higher than average return on investment than the whole watershed average in terms of sediment reduction per USD invested in nature based solutions. This work provides clear guidance to Water Fund priority investment opportunities.



Priority areas ("Areas priorizadas," red outline) and geographic explicit portfolios showing the ideal places for the implementation of activities evaluated by the project team: Pasture management (yellow), remaining natural ecosystem protection (red), revegetation of degraded or agricultural areas (green), and runoff reduction trenches construction (grey). Cartography by Jorge Leon, Latin America division.

Photos (clockwise from top left): Jellyfish Lake in the Rock Islands of Palau. The Conservancy helped establish the Palau Conservation Society, a local environmental organization dedicated to protecting Palau's natural heritage. © Ian Shive; Many hands make for light work. Over four days, community members in Palau traced each 15-foot contour line to reach the highest point in the country at 580 feet. © Nate Peterson; The President of Palau, Thomas Remengesau Jr., overlooks the completed P3DM for Melekeok State. © Nate Peterson

REGION: **PAPUA NEW GUINEA, SOLOMON ISLANDS, PALAU AND THE FEDERATED STATES OF MICRONESIA**

Participatory 3D Modelling in the Pacific

Community engagement in Palau

The Pacific Division of The Nature Conservancy stretches across a vast swath of the western Pacific Ocean and includes the countries of Papua New Guinea, Solomon Islands, Palau, and the Federated States of Micronesia. The rural communities of these nations are virtually cut off from modern technology and communication channels. Therefore, the Conservancy uses a participatory approach to mapping, which strengthens community engagement and interest in better planning.

Participatory 3D Modelling (P3DM) is an innovative mapping method that brings GIS technologies to the remote communities in the Pacific. The process begins with a map of contour lines that are traced onto foam or cardboard sheets. Each contour interval is then cut and stacked together to create a 3D model of the geography. Once the blank model is completed, the community uses paint, push pins and strings to populate the map with vegetation types, coral reefs, roads, villages and locally important resource areas. This method engages the youth in building a local scale model of their area as well as the adults by populating the map with local knowledge.

Partners: Ngardok Nature Reserve, Government of Palau, German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

Website: *panorama.solutions*, search "3D mapping"

Contact: Nate Peterson (*npeterson@tnc.org*)

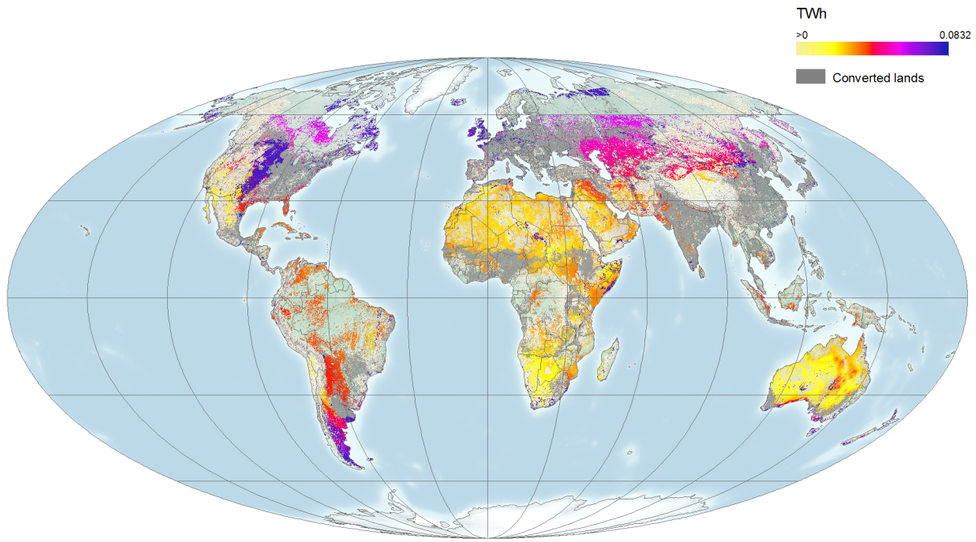
Software: ArcGIS Desktop 10.6

Data Source: 10 m Digital Elevation Model (DEM) from USGS

The Nature Conservancy has completed more than a dozen P3DMs across the Pacific. Given the growing impacts of climate change (i.e. sea level rise), the model developed in the island nation of Palau was especially interesting. To complete a P3DM of Melekeok state in Palau, TNC worked in collaboration with the Ngardok Nature Reserve Management, the state of Melekeok and Palau national government, with project support from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

ArcGIS Desktop provides the foundation for P3DM with its suite of cartographic tools. First, the Spatial Analyst extension is used to generate contours appropriate for the map scale (1:2,500 for Palau model). Then the cartographic tools, specifically Maplex, ensures clear and easy-to-read contour lines.

Sea level rise and shoreline integrity are key concerns for the local communities. Having the completed P3DM housed in the community center provides leaders and concerned citizens with an informative venue to plan for the future as conditions change. The 3D scale model of the community's homeland helps people see the big picture and plan accordingly.



REGION: **GLOBAL**

A Blueprint for Clean Energy

Siting renewable energy development

Fossil fuel use is a major driver of climate change, but transforming the energy landscape toward cleaner resources also poses environmental challenges. Clean energy infrastructure requires more space than fossil fuel-based development, converting natural lands that keep carbon stores locked in vegetation and impacting biodiversity areas (see Kiesecker et. al 2019, Frontiers in Environmental Science). However, Paris Climate Agreement energy goals can be met 17 times over without disrupting natural lands (see Baruch-Mordo et. al 2019, Environmental Research Letters).

To that end, The Nature Conservancy's research has been integrated into a tool designed to help policymakers identify lands that have been converted for human use that could be ideal for new energy installations.

First, maps of nighttime lights, roads and croplands were used to identify converted lands. Next, development suitability was estimated on converted lands for utility-scale wind, concentrated solar power photovoltaics (PV) and rooftop PV based on biophysical constraints including wind speed or the amount of solar radiation received per unit area, slope, elevation, and minimum land requirements. Sector-specific technical potential was then calculated by multiplying areas suitable by capacity factor maps, power density, and a factor of 8760 (hours/years). We created a final maximal renewable energy map by selecting the maximum TWh for each location across wind and solar sectors.

Terrestrial wind and solar technical potential on converted lands were summarized for each country and augmented with hydropower technical potential from converted freshwater systems defined as those with existing dams. Hydropower energy production potential was estimated from retrofitting old hydropower dams with more efficient equipment or from repurposing nonhydroelectric dams by adding power generating turbines. Results were summarized for each country to calculate whether their 2015 Paris Climate Agreement renewable energy goals can be met by developing renewables on converted lands and altered waterways.

This study illustrates a pathway toward a clean energy economy, including for the top 10 emitters in the world. The web tool can help decision-makers understand where technical potential for energy production can be realized while reducing impacts on natural lands.

Partners: World Wildlife Fund, Conservation International, Woods Hole Research Center

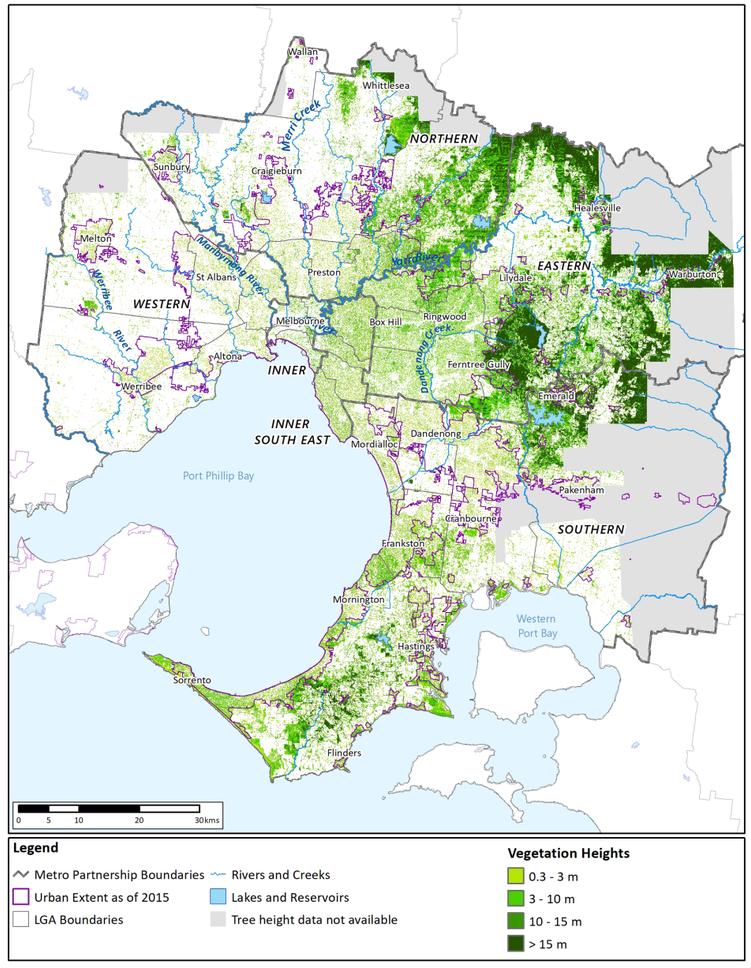
Website: *paris2practice.org*, Request access from contacts

Contacts: Dr. Sharon Baruch-Mordo (*sbaruch-mordo@tnc.org*); Dr. Joseph Kiesecker (*jkiesecker@tnc.org*)

Software: R Statistical Software and Esri ArcGIS Pro

Data Sources: European Space Agency 2017 Climate Change Initiative Land Cover (v1.6.1), National Oceanic Atmospheric Administration 2017 v4 DMSP-OLS Nighttime Lights Time Series, Unified Crop Layer (v2.3), Global Roads Open Access Data Set (gROADS) v1 (CIESIN), GRanD global dams database, Global terrain slope data from The Harmonized World Soil Database, Global Human Settlement data (2016).

Map of converted terrestrial lands overlaid by map of the maximal wind and solar technical potential. Cartography by Sharon Baruch-Mordo & Kei Sochi, Global Strategies – Science program.



Partners: Resilient Melbourne, Digital Globe, Trimble

Website: *natureaustralia.org.au/melbournegreenprint*

Contacts: Martin Hartigan (*martin.hartigan@melbourne.vic.gov.au*); James Fitzsimons (*jfitzsimons@tnc.org*); Nate Peterson (*npeterson@tnc.org*)

Software: ArcGIS Desktop 10.6, eCognition Essentials

Data Sources: Victorian Government LiDAR datasets, Digital Terrain Model and Digital Surface Model, both with 1 m resolutions, as well as a 2 m resolution Digital Globe 8-Band satellite imagery dataset. These data sets assisted the mapping of vegetation distribution across approximately 10,000 square km of metropolitan Melbourne (2,471,054 acres; 3,861 square miles) comprising five vegetation heights.

The map shows which regions have an abundance of trees and shrubs and those which have little. Cartography by Nate Peterson, Asia Pacific division.

REGION: **MELBOURNE, AUSTRALIA**

Living Melbourne

Mapping metropolitan urban forests

The Nature Conservancy's Australia program collaborated with Resilient Melbourne to develop a new metropolitan-wide urban forest strategy called *Living Melbourne: our metropolitan urban forest.* The strategy is the cumulative result of over two years of collaboration to develop the evidence base and actions required to connect, extend and enhance urban greening across the metropolitan area. *Living Melbourne* is a first for Australia in its scale, has been formally endorsed by 41 government and community organizations and has received unprecedented support for its vision, goals and actions.

A critical part of the strategy has been mapping the "urban forest" of native and exotic trees, shrubs and grasslands across both public and private lands in order to understand how vegetation cover relates to six commonly identified drivers of tree and vegetation cover: (1) mean annual rainfall—indicates moisture availability, (2) bioregion—indicates soil and local climate conditions, (3) density of people—indicates urban intensity, (4) SEIFA Index of Relative Social Disadvantage—indicates access to employment, education, and other services, (5) percent of rental dwellings—indicates ownership and resident investment and (6) percentage cover of surface water—indicates terrestrial area available for vegetation.

Vegetation maps were correlated against socio-economic and satellite-derived urban heat island data to identify heat health risks.

Using the urban forest canopy cover in combination with data layers for various bird species and other important animals enables the modelling of different levels of connectivity and landscape permeability for different species groups. By combining habitat models based on species records and known habitat preferences with the urban forest canopy map, habitat corridors can be identified for improvement.

REGION: **LAKE TANGANYIKA, AFRICA**

Conserving Africa's Great Lakes

Visualizing the complexities of people and landscapes

The African Great Lakes region has one of the highest concentrations of great lakes on earth. Their basins present numerous development opportunities in a region where many people live in severe poverty and depend almost exclusively on natural resources for their livelihoods. Effective development of the lakes and their basins coupled with coordinated conservation planning has the potential to spur sustainable growth for other parts of the continent. In May 2017, The Nature Conservancy, alongside numerous international and regional organizers and partners, sponsored the African Great Lakes Conference: Conservation and Development in a Changing Climate in Entebbe, Uganda, to increase coordination, strengthen capacity, inform policy with science and promote basin-scale ecosystem management in the region. During the conference, a Story Map, the African Great Lakes Atlas, was created, focusing on seven of Africa's Great Lakes (Albert, Edward, Kivu, Malawi/Nyasa/Niassa, Tanganyika, Victoria, Turkana).

The Atlas highlights key biophysical and socioeconomic characteristics and is intended to stimulate discussions around lake development and conservation of the lakes and their basins, especially in the face of increasing variability and climate change. The interactive map is organized by topic area (climate, agriculture, human dimensions and land cover); visual representations, icons, and data points make grasping complex concepts more easily done. By drawing attention to the interconnected relationships among people and their environment, the map invites users to visualize biophysical aspects of the environment (i.e. climate variability or soil types) alongside socioeconomic realities (i.e. women's rights and children's health), and offers an opportunity to consider the critical importance of holistic approaches to conservation and the benefits those approaches may provide to nature and people.

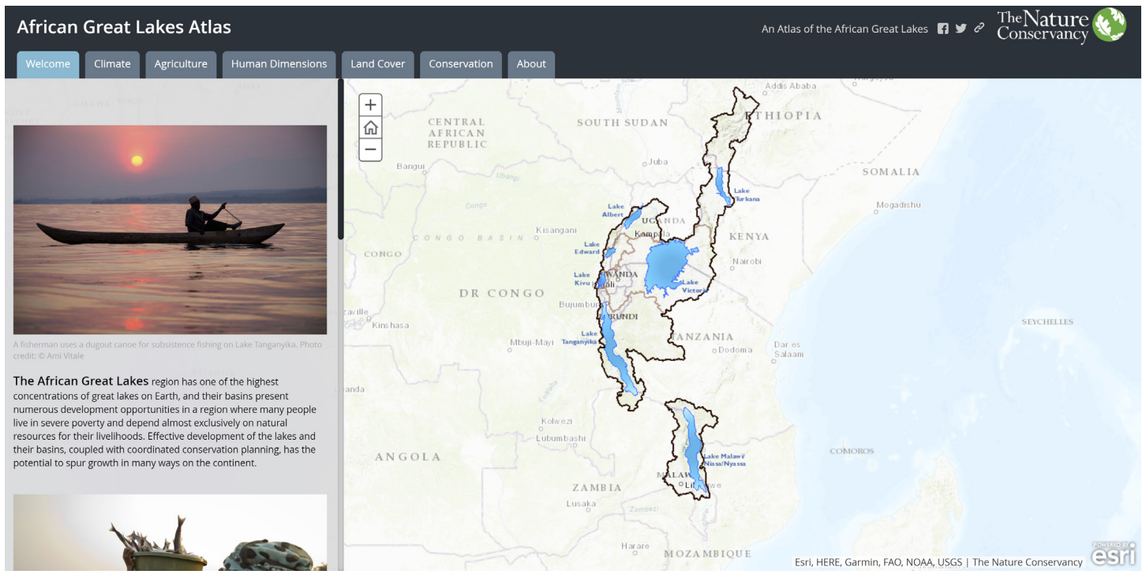
Partners: National Fisheries Resources Research Institute, Uganda; Lake Tanganyika Authority; University of Nairobi

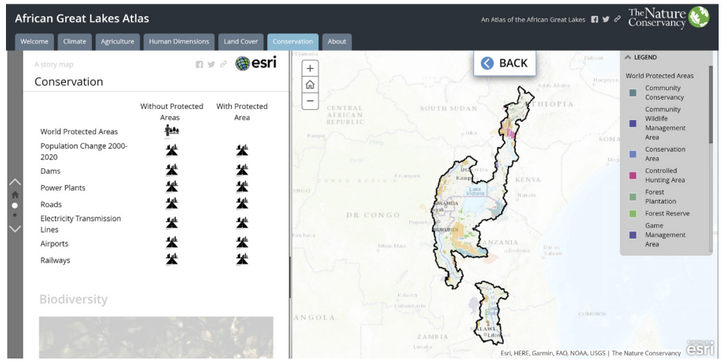
Website: *maps.tnc.org/AfricanGreatLakes*

Contact: Tracy Baker (*tracy.baker@tnc.org*)

Software: ArcMap 10.3.1, ArcGIS Online, and ArcGIS StoryMaps

Data Sources: WorldClim, International Food Policy Research Institute HarvestChoice, Center for International Earth Science Information Network, USAID Demographic and Health Surveys, Key Biodiversity Areas, Famine Early Warning Systems Network, Anthromes, GlobCover, Tree Loss, World Protected Areas, Ecoregions





Maps: The African Great Lakes Atlas provides information to facilitate discussions around conservation and management of land and water resources across the region's primary lake basins as a mechanism to support the protection and enhancement of critical ecosystem services relied upon by people. Web map by Erik Martin, Maine field office, and Tracy Baker, Africa program.

Photo: Agriculture Officer Clement Mabula, teaches sustainable agriculture methods to farmers in the village of Mgambo, Tanzania. Nearby Lake Tanganyika provides 40% of all protein for lakeshore villages. © Ami Vitale

For instance, human population density in the region has risen over the years and is among the highest in the world. The Atlas demonstrates that the lakes provide valuable ecosystem services through domestic, urban, industrial, and agricultural water provision; waste disposal and hydropower generation; and modulation of local and global climate.

Investment opportunities in agriculture, hydropower generation, urban and industrial development, recreation, mining, oil exploitation, and tourism are on the rise, increasing the need for sustainable development plans. And, because the lakes are shared by more than one country, with actions that are implemented at a national level, the Atlas helps users visualize priority areas in the context of development, see where potential conservation-development conflicts exist and identify ecosystem services and high-value biodiversity areas.

An Emerging Geospatial Enterprise

This map highlights some of Maine's coastal land conservation work. The full map shows all fee, easement, transfer, and assist projects the chapter has completed in its history. Acreage figures in the infographic reflect work accomplished across the entire state, not within the map extent. Cartography by Nicole LaBarge, Maine field office.

The Nature Conservancy has a nearly 70-year history of land stewardship. Through monitoring and ground-truthing projects, compiling spatial data and leveraging emerging technologies, the Conservancy continues to increase its impact. In the coming year, the GST will advance these approaches and develop a geospatial enterprise plan around three key objectives: (1) creating a TNC preserves and priority areas database management system, (2) completing a geospatial cloud migration and transformation and (3) engaging tech partners in geospatial innovation including AI/ML.

TNC PRESERVE AND PRIORITY AREA MANAGEMENT

The Conservancy's preserves and priority sites management activities typically focus on local applications that offer vital information for land stewardship activities, adaptive habitat management, community engagement and volunteer efforts. In order to ramp up local activities, managing and assembling data at state-wide, ecoregion, national and global scales, the Conservancy is investing in accessible technologies that can support accepted standards, systematic data collection, centralized storage and reporting technology.

The Conservancy performs field work in more than 1,400 preserves in the U.S. alone. Monitoring these lands is a big task, necessitating the tracking of conditions through automated technology. Using camera traps that record wildlife occurrences and the Internet of Things (IoT) to remotely monitor devices that sense real-time parameters (i.e. air quality, temperature, streamflow, wildlife poaching, other ecological conditions), practitioners mine rich data sources to manage and predict future conditions. Landscape change detection observed by remotely sensing satellites can be analyzed relative to data from a network of on-the-ground sensors. Ultimately, a deeper understanding of the natural world is possible when geospatial data at various scales are integrated.

The Conservancy has a long track record of successful social and ecological-based data management. Along with those from Esri, National Geographic and others, TNC's data will further integrate with advanced monitoring efforts in the U.S. and Africa within secured conservation areas and, increasingly, in other places around the world. Efforts are underway to standardize data gathered from the Conservancy's preserves in order to compile information across geographies and increase their applicability. A modular design will enrich these data with, for example, compliance information related to the Americans with Disabilities Act. Rather than storing databases on local or regional computer servers, they will be migrated to a new geospatial cloud architecture, thereby facilitating access, improving security, ensuring adequate compute resources and enabling dashboard visualizations. By advancing scientific understanding of conservation lands, the Conservancy can share information with partners and deepen our collective intelligence.

GEOSPATIAL CLOUD TRANSFORMATION

The Conservancy has used geospatial-based cloud technology for more than a decade. Building on experience, GST aims to develop an enterprise geospatial solution: transferring the majority of TNC's geospatial data holdings to the cloud. The goal is to design and implement efficient cloud-based decision support systems for our critical spatial data, the majority of which is currently hosted on-premise. For this transformation, we are designing a three-phased approach: (1) migrating select data to the cloud, (2) consolidating current ArcGIS Server capabilities and (3) supporting modeling and advanced geoprocessing efforts in conservation science.

At this time, the Conservancy's spatial data storage footprint is more than 90 Terabytes spread over 20 on-premise servers hosted from TNC field offices. In the first phase of this approach, GST and the field offices will migrate data to the cloud to increase access to and scaling of systems to accommodate spatial data storage needs while reducing data redundancy. This will foster better collaboration, data sharing and decision support between offices and with partners. The initial enterprise cloud transformation will provide virtual desktop infrastructure (VDI) and centralized file-based data storage. The VDI offers customized GIS desktops with the tools, applications and software required by the Conservancy's GIS users, while VDI configurations are managed centrally by IT. With VDI in the cloud, the organization can leverage elastic capabilities to increase compute capacity and storage in near real-time, supporting dynamic workloads as requirements change. As part of this transformation, consolidating data in specific cloud data centers will reduce duplication, increase access and minimize the burden of moving large amounts of GIS information.

A second phase is to simplify TNC's geospatial architecture and data that includes consolidating present ArcGIS Server capabilities supporting map, feature, image and geoprocessing services. Collector for ArcGIS has been widely adopted by Conservancy property, conservation easement and invasive species monitoring with 46 field offices requesting a setup on an on-premise server. In addition, 26 offices are using a customized Conservancy product, Collector Companion, for enhanced reporting on monitoring efforts. Centralizing these data on one ArcGIS Enterprise site will facilitate data roll-up and streamline workflows for better database management and decision making. This, along with increased support to conservation field programs who manage custom web mapping applications—for example, Freshwater Network and Coastal Resilience—enhances TNC's data holdings with more intuitive and better access to information.

The third phase of geospatial cloud migration includes data transformation as well as modeling and advanced geoprocessing support. Through collaboration with Esri, Microsoft, Amazon, and others, the objective is to enhance geospatial-based conservation planning approaches with remote sensing and machine learning methods. Combining the expertise of conservation scientists and geospatial planners with the skills of our corporate partners, a

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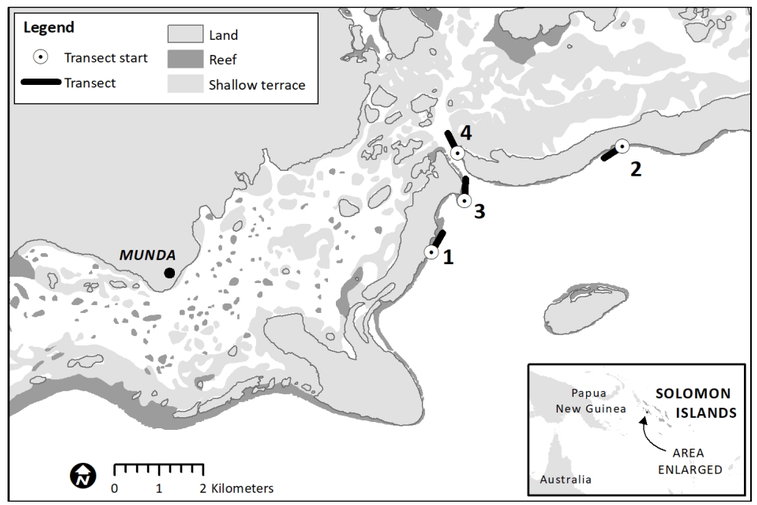

Location of four long term underwater monitoring sites in Roviana Lagoon, Western Province, Solomon Islands. Monitoring revealed that populations of bumphead parrotfish and humphead wrasse had drastically declined from 1980's levels and now meet the IUCN Red List thresholds for Critically Endangered species. Cartography by Nate Peterson, Asia Pacific division.

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robust cloud-based enterprise solution enables comprehensive exploration of emerging technologies in the AI and Big Data space. This three-phased approach will lead to more efficient and effective activities on the ground. In some cases, field programs may choose to have a local storage solution while still accessing cloud-based "authoritative" Conservancy data. Specific privacy and data security laws in specific countries will also be considered under an emerging geospatial enterprise plan.

GEOSPATIAL INNOVATION WITH PARTNERS

Rapid progress in the AI field, in several instances surpassing human accuracy for tasks involving computer vision, natural language processing and machine translation, have prompted inventive approaches to data management. A new field at the intersection of AI and GIS, known as geospatial AI or geoAI, is creating opportunities that were not considered feasible until recently, including leveraging the vast amount of data streaming from mobile devices, social media, vehicle sensors and cameras, and imaging sensors on drones, airplanes and satellites.

There is a shared interest and perceived value in cloud-based AI and machine learning solutions to address planning and sustainability issues; to that end, the Conservancy has established partnerships with Microsoft, Amazon, and Esri to explore and pilot capabilities of cloud-based geospatial data. In 2017, Microsoft and Esri formed an innovative collaboration to combine geospatial technology and AI as part of Microsoft's AI for Earth program to translate projects on the Azure cloud into analytics and communications messages. Similarly, the Conservancy has started a productive engagement with Amazon Web Services around their Open Data Initiative, supporting cloud-based modeling efforts that better measure our conservation impact through landscape condition assessments.

Given the Conservancy's bold vision for a more sustainable path to 2050, it is crucial to continue exploring collaborations with key partners who apply AI, machine learning and Big Data to achieve meaningful conservation outcomes. Geospatial-based planning approaches and local-to-global impacts can be realized when we create a well-defined pipeline of geoAI projects and position TNC to examine where technology is best deployed, advise on appropriate tools and engage with partners.

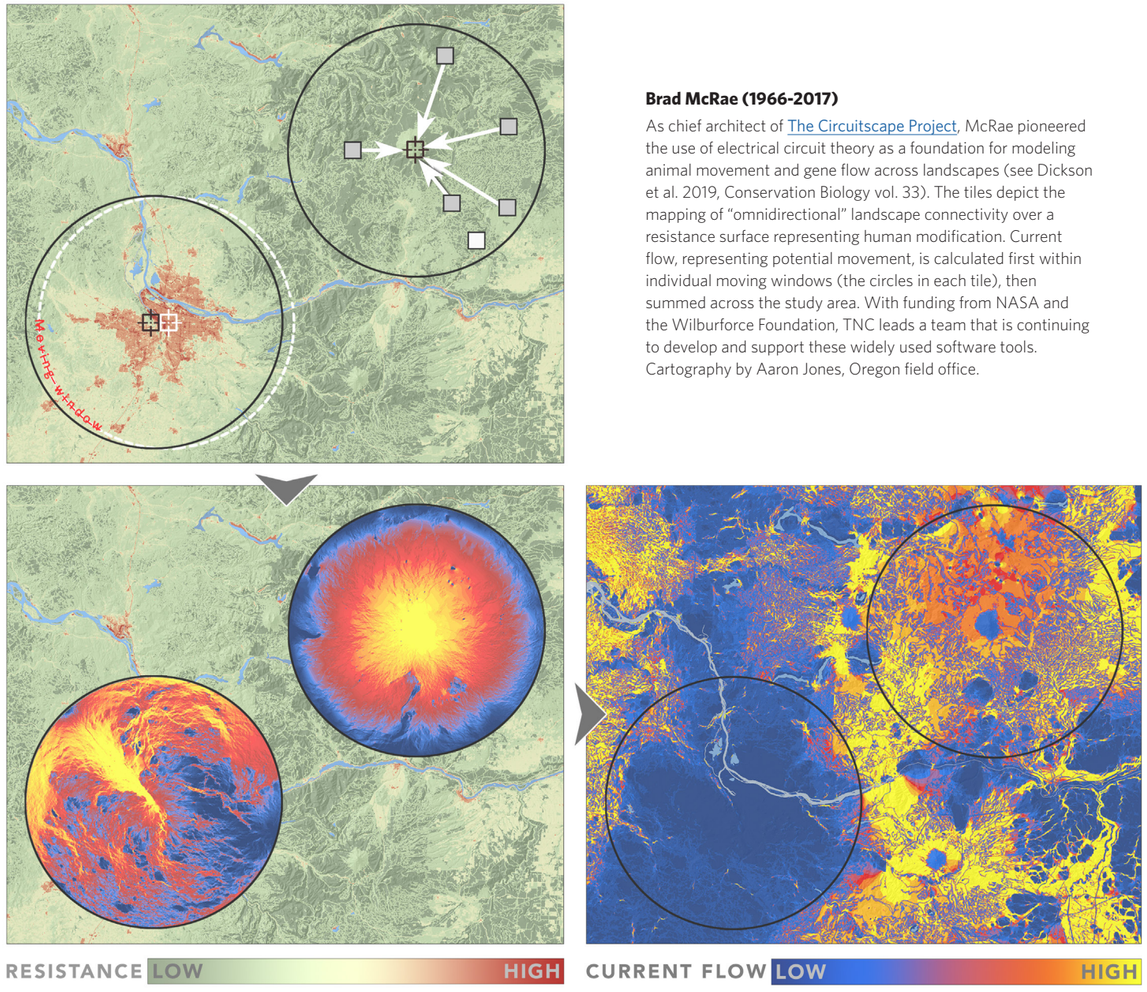
What's Next

Earlier in this report, we mentioned "a geospatial renaissance," noting that one in three staff is either a geospatial professional or frequent map user. As a digital companion to this *Geospatial at TNC Annual Report and Map Book*, we are updating and expanding on TNC Maps in a new Geospatial Conservation Atlas. This year our community has organized into groups and initiatives and established a GIS Leadership Council to guide the work. Through this emerging work, we are already noticing that geospatial systems and communications programs are beginning to reach broader audiences both within and beyond the Conservancy.

Working groups internal to TNC, with invited partners as reviewers, will tackle specific topics and design projects, develop best practices and contribute to the enterprise geospatial plan. One group is currently looking at cartography, with the aim of establishing consistency between the GIS community and marketing and communications. Other emerging focus areas include remote sensing, drone mapping, database management and web applications.

A strategic geospatial initiative is intended to be a focused effort across the global GIS community. This can include efforts to support or enhance TNC-wide programs or activities, for instance, creating a geospatial conservation atlas and data center, web map applications and other cartography products. As an example, we are exploring the addition of preserve and ecosystem data to Open Street Map (OSM) and designing a workforce event across the organization to contribute to it. Through this effort we plan to demonstrate how adding natural resource data to OSM is good for conservation.

As the renaissance progresses, the Conservancy will harness the power of geospatial technology to protect the lands and water upon which all life depends. This is the first of what will be many annual reports that convey the breadth and diversity of preservation, conservation and restoration work told through the power, influence and vitality of mapping.



Brad McRae (1966-2017)

As chief architect of The Circuitscape Project, McRae pioneered the use of electrical circuit theory as a foundation for modeling animal movement and gene flow across landscapes (see Dickson et al. 2019, Conservation Biology vol. 33). The tiles depict the mapping of "omnidirectional" landscape connectivity over a resistance surface representing human modification. Current flow, representing potential movement, is calculated first within individual moving windows (the circles in each tile), then summed across the study area. With funding from NASA and the Wilburforce Foundation, TNC leads a team that is continuing to develop and support these widely used software tools. Cartography by Aaron Jones, Oregon field office.

ACKNOWLEDGEMENTS

First and foremost, the entire geospatial community at TNC serves a critical function in supporting conservation decisions throughout the organization. For this they deserve a hearty round of applause. Within this community, there are a few individuals to acknowledge. Thanks goes to Jeannie Patton in the LANDFIRE group for her insights and magnificent co-editing skills on this report. The GIS Leadership Council deserves ample credit for navigating the content strategy behind the report and authoring or co-authoring most of the use cases. Appreciation is extended to IT leadership for supporting the growth of the Geospatial Systems Team, in particular Larry Bond, interim CIO. Thanks also goes to Jordan Van Gorder for his Power BI wizardry. Last but not least, thanks to TNC's Marketing team for taking on this project, leading the layout and design, compiling photos and championing an emerging collaboration with the GIS community. This includes Krista Schmidt, Kirsten Neus, Monica Chan, Melissa Dale, Jay Sullivan, Christopher Johnson and Ethan Kearns.

The Nature Conservancy

Cover: The Nature Conservancy's Central Cascades Forest connects large wilderness areas to the north and south, knitting together a fragmented landscape into connected conservation corridors. The Conservancy is working with forest owners to identify tracts that reflect the local community's values while supporting forest health, fire resilience, economic vitality, recreational opportunities and conservation. This 9x7 foot map is on display in the Cle Elum, Washington field office as a tool to engage and inspire the local community. Cartography by Erica Simek Sloniker, Washington field office.

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