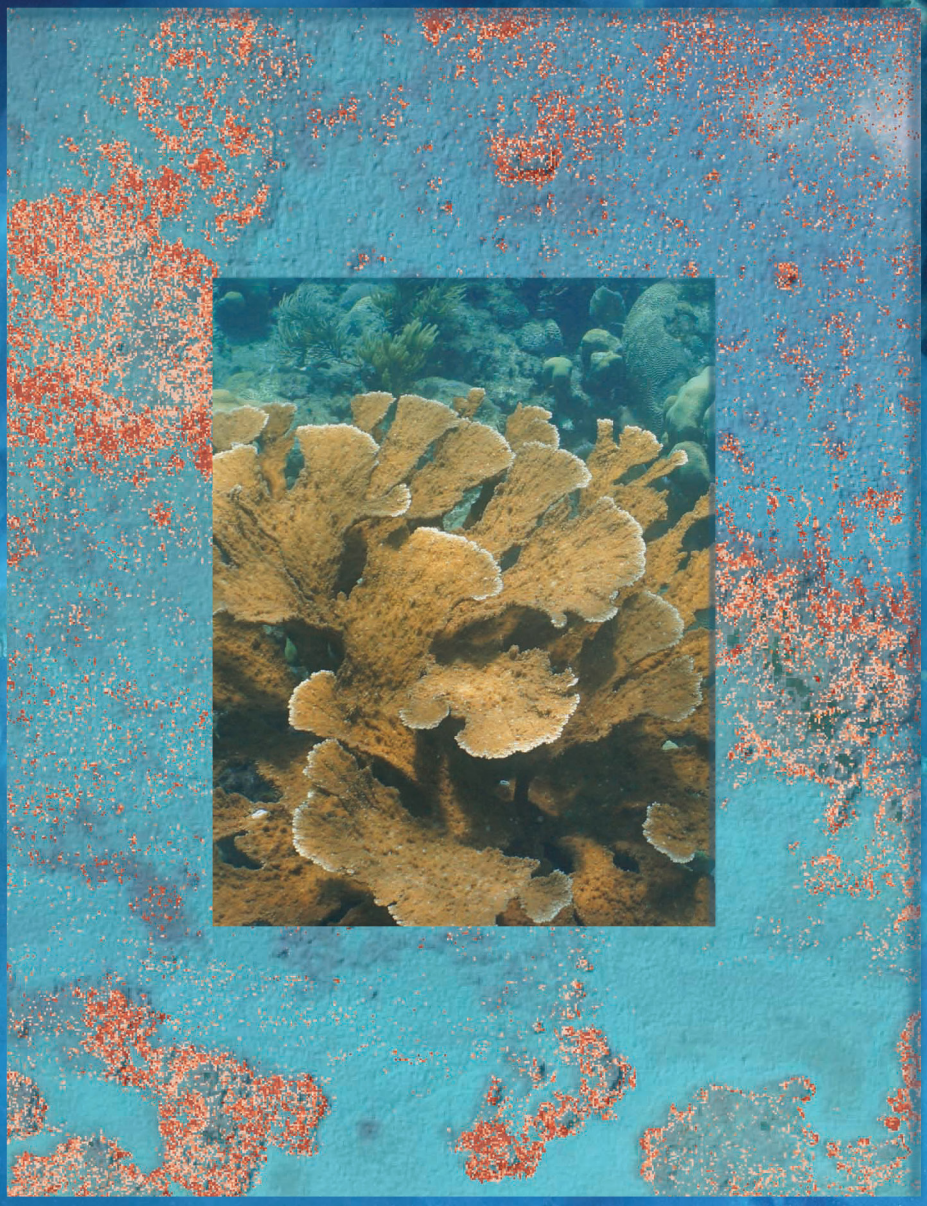
# GEOSPATIAL CONSERVATION

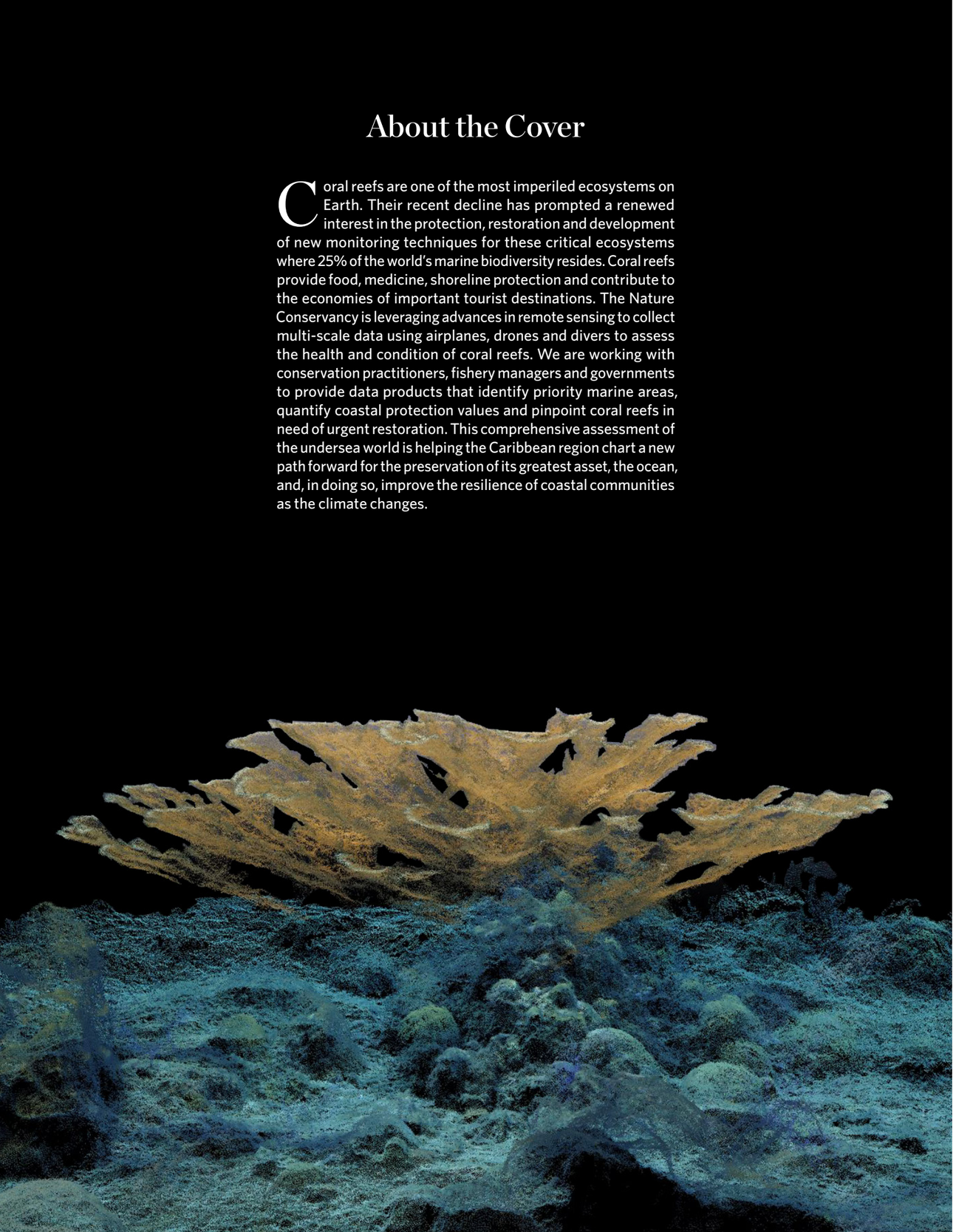
AT THE NATURE CONSERVANCY



2020 ANNUAL REPORT
& MAP BOOK

# About the Cover

Coral reefs are one of the most imperiled ecosystems on Earth. Their recent decline has prompted a renewed interest in the protection, restoration and development of new monitoring techniques for these critical ecosystems where 25% of the world's marine biodiversity resides. Coral reefs provide food, medicine, shoreline protection and contribute to the economies of important tourist destinations. The Nature Conservancy is leveraging advances in remote sensing to collect multi-scale data using airplanes, drones and divers to assess the health and condition of coral reefs. We are working with conservation practitioners, fishery managers and governments to provide data products that identify priority marine areas, quantify coastal protection values and pinpoint coral reefs in need of urgent restoration. This comprehensive assessment of the undersea world is helping the Caribbean region chart a new path forward for the preservation of its greatest asset, the ocean, and, in doing so, improve the resilience of coastal communities as the climate changes.





# Contents

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Ferdaña, Z., and Dettenmaier, M. (Eds.) 2020. Geospatial Conservation at The Nature Conservancy: 2020 Annual Report & Map Book, Arlington, VA: The Nature Conservancy.

# Acknowledgements

This second edition Geospatial Conservation Annual Report & Map Book has over 100 Conservancy and partner contributors. As such, TNC's entire geospatial community and our important conservation and technology partners deserve a big round of applause. In particular, we want to thank the Geospatial Systems team in IT as well as our Geospatial Leadership Council who guided and advised on this production. Jan Slaats, Jeff Zurakowski, Francesco Tonini and Craig Cheeseman (Geospatial Systems) are responsible for the strategic direction reflected in the annual survey and at the end of this report; the 22-person Council wrote and created most of the applications and maps. A special thanks goes to Megan Dettenmaier in the LANDFIRE group for her brilliant co-editing. Appreciation is also extended to TNC's leadership in IT and Global Science, notably Theresa Shaw (CIO) and Hugh Possingham (former Chief Scientist). And last but not least, thanks to TNC's Marketing team for taking on this project, leading the layout and design, compiling photos and championing the work of the geospatial community. A sincere thanks for all the effort and creative talent goes to Mrinal Joshi, lead designer for the report. Thanks also goes to Grace McMurry, Monica Chan, Jay Sullivan, Rolaine Ossman, Krista Schmidt and Christopher Johnson.





# Spatial Action Mapping

Conservation science and planning at The Nature Conservancy (TNC) can be boiled down to three overarching categories: predictive modelling, prioritization and impact evaluation. The field of systematic conservation planning falls squarely under prioritization, originally developed to help us decide where to create protected areas. This body of applied science served TNC well for at least two decades and led to influential ecoregional conservation plans that guided protection actions in the U.S. and around the world. This field has been generalized to "spatial action mapping," a holistic approach that considers both systematic planning and the cost and feasibility of any conservation action in space and time.

Spatial action mapping realigns conservation planning with conservation actions. We can deliver the greatest benefit to nature and people by prioritizing our conservation actions to help us decide what action to take, when and where to take it, and for how long.

Within systematic conservation planning many maps are generated highlighting biodiversity assets (species richness, concentrations of endemicity, foci of phylogenetic uniqueness) and threats to those assets. Policy makers and managers often believe these maps identify priority places for action—they do not. While these asset maps are an essential component of spatial action mapping, they should not stand alone in the process of directing conservation actions to guide our conservation and restoration strategies. **We need maps to tell us the places where specific actions will deliver the greatest return on investment.** These may be individual actions or bundles of actions such as pest control, fire management, anti-poaching patrols, easements, or acquisitions. Spatial action mapping helps us with policy reform, education, lobbying, gear restrictions for fishing and much more. Think conservation prioritization with the essential twist of action-oriented mapping. We need to focus on the actions that ensure ecological representation, connectivity and the long-term viability of ecosystems, the cost and feasibility of the action and what is likely to happen in a future climate facing other threats.

For example, if we encounter a spot in East Africa with the greatest diversity of mammals or a patch of mangroves in Indonesia with the greatest ability to fix carbon or protect people against a tsunami, should we protect it? It is essential to consider all the pieces that contribute to this answer: actions at these locations might be politically infeasible, ridiculously expensive, culturally insensitive, or prone to failure for technical, social or economic reasons.

The maps and use cases presented in this second Annual Report & Map Book contain spatial action maps from our scientists including return-on-investment maps, hydropower by design maps, resilient land and seascape maps, marine spatial planning maps and more. This holistic approach is reflected in this report and illustrates the best way forward for making impactful conservation gains. I am proud that TNC is leading the world in spatial action mapping.

© Bill Marr/TNC

**Professor Hugh Possingham**

DPhil (Oxford), FAA, FNAS, honorary doctorates (UBC, UAdelaide)
Chief Scientist for the State of Queensland
Chief Scientist of The Nature Conservancy (2016—2020)
Vice-Chancellors Senior Research Fellow, The University of Queensland

"As we seek to tackle the biggest challenges facing our planet, it is crucial to ensure that our teams and partners are able to leverage the most accurate and rigorous mapping data—and that geospatial professionals conducting this science reflect the diversity of the places we work."

Jennifer Morris

*Chief Executive Officer*
*The Nature Conservancy*





# Challenges and Opportunities in Geospatial Conservation

The Nature Conservancy is a global organization working to create a world where people and nature can thrive. Founded as a conservation nonprofit in the United States in 1951, TNC is one of the most effective and impactful environmental organizations in the world. We work across land, sea and freshwater ecosystems and influence conservation actions in 72 countries and territories across six continents. And yet, we have much more work to do. TNC has a strong track record utilizing geospatial technology, the combined disciplines of Geographic Information Systems (GIS), remote sensing and machine learning for conservation everywhere we work. As part of our annual geospatial survey, we took a moment to evaluate our professional workforce. While we did find a diverse array of global practitioners leveraging science for conservation action, we discovered this workforce was predominantly white, with the highest geospatial capacity located in the United States. Of the 1,577 staff invited to fill out the survey, only 18% of our global geospatial workforce identified as non-white and 68% identified as white (14% did not respond). Of these, 44% identified as men, 33% women, and 23% did not indicate. This survey highlights a significant challenge: identifying, addressing and removing professional obstacles that may be preventing the advancement of racially or ethnically diverse employees in our workforce. We need to do better and be intentional in doing so. It is imperative that we act, both as leaders in conservation and leaders in the creation of a diverse, equitable and inclusive workforce.

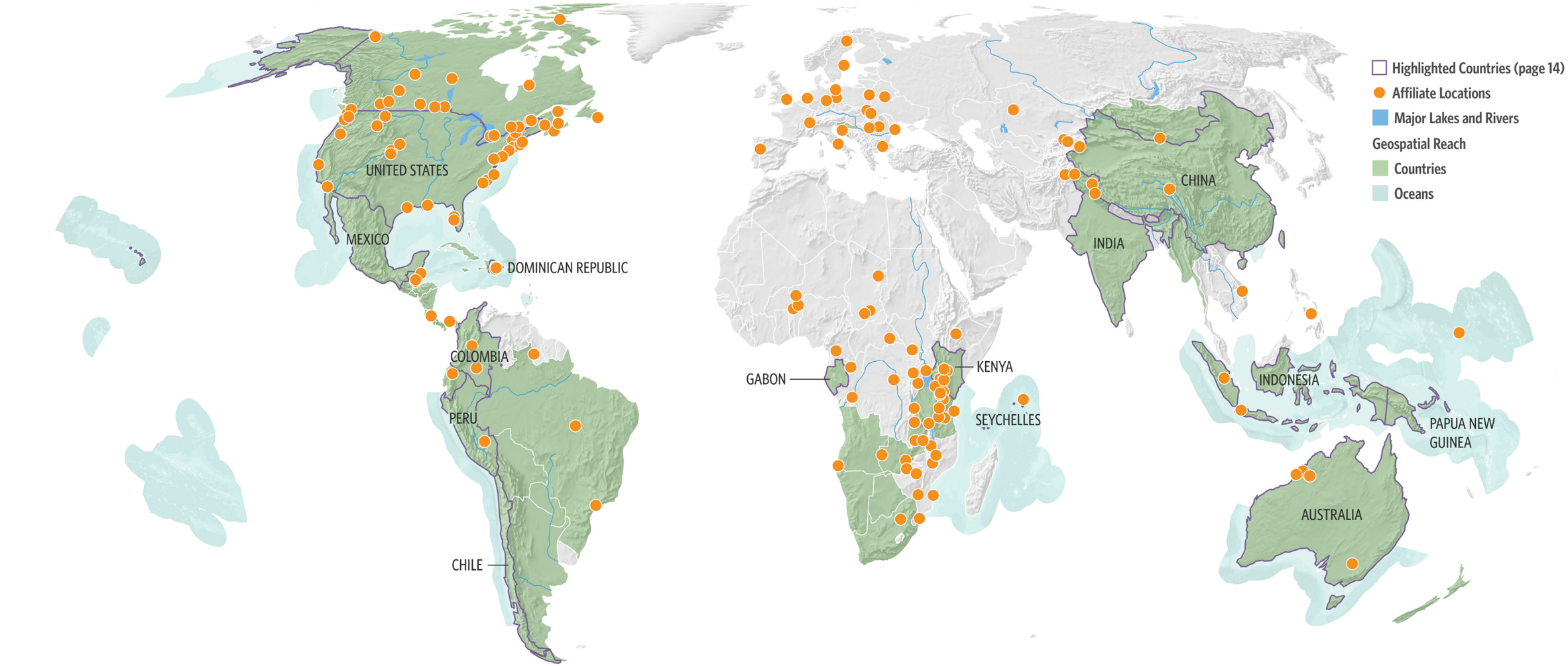
We are taking several steps in our geospatial community to immediately address diversity. First, our Geospatial Leadership Council is a global body of professionals dedicated to supporting and promoting a geospatial vision for the organization with a focus on representation by promoting diversity, equity and inclusion. We believe that having regionally diverse representation will greatly increase our conservation impact. The Council is made up of people from every region where TNC works. It is comprised of 22 staff (11 men, 11 women) from North, Central and South America, the Caribbean, Africa, Asia and the Pacific. Only by having many voices and perspectives will we reach our conservation goals. Second, earned through trust and experience, GIS mapping software market leader Esri has authorized TNC to distribute their GIS software licenses to global conservation partners. These nonprofit partners receive similar licensing benefits as TNC does, including unlimited access to Esri eLearning resources, technical support and assistance with software license distribution and management. We currently support 44 nonprofit conservation organizations from 49 countries (see page 8 for map). We are committed to supporting geospatial applications and providing resources to the people leading critical conservation decisions on the ground and in the water. Third, TNC's geospatial workforce has partnered with the largest global conservation GIS organization, the Society for Conservation GIS (SCGIS). With this partnership, we commit to serving this diverse international community by actively shaping SCGIS governance and programmatic activities, which include providing scholarships and training opportunities in underrepresented communities and offering technology and resources to support the inclusion of a new generation of geospatial professionals.

Geospatial technology allows us to harness the power of place and track changes through time in order to visualize our conservation gains. While our geospatial skills continue to grow at TNC, we know that the key to advancing conservation and protecting the planet lies in our ability to cultivate a work environment that promotes diversity, inclusion and equality for the people behind this technology.

Kind regards,

**Theresa S. Shaw**
Chief Information Officer
The Nature Conservancy

**Zach Ferdaña**
Geospatial Information Officer
The Nature Conservancy




# State of the Conservancy Map

Geospatial technology provides the foundation for TNC to leverage and expand the organization's conservation planning strategies. With over 1,300 geospatial staff or related positions, a Geospatial Leadership Council and a centralized Geospatial Systems team, we provide leadership and support to every region where the Conservancy works.

Adding to the global reach of our geospatial work that supports conservation science, planning and action, TNC also supports other nonprofit conservation organizations. Our principal GIS software provider, Esri, empowers us to distribute their software licenses to our nonprofit partners with similar conservation missions. Once vetted, these partners become Esri Authorized Entities or Affiliates who can order both Esri software and self-paced trainings under the terms of TNC's Enterprise License Agreement. This program has proven extremely valuable for smaller nonprofit conservation organizations who might otherwise not have the funding to purchase GIS software and training. This also allows the Conservancy to further leverage our global conservation reach within and beyond the countries where we work.

"GIS is a critical component of our conservation planning and stewardship initiatives. Our GIS and conservation staff use Esri's desktop GIS software on a daily basis, and our ArcGIS Server site forms the backbone of our internal and external data sharing capabilities. I can't overstate the value of these Esri resources to our organization."

JC Laurence
*National GIS Manager*
*Nature Conservancy Canada*
*An Esri Affiliate*

▲ Mapping for conservation science and action touches down in the countries and ocean Exclusive Economic Zones illustrated on this map, shown here as the Conservancy's "geospatial reach." This includes GIS training and capacity building, covering 59 of the 72 countries in which the organization works overall. Maps are central to TNC's mission in understanding and acting upon our conservation strategies. This report highlights 25 applications, plus a global map series, that explicitly link geospatial technology to conservation, shown here with highlighted country boundaries. The map also shows where we support other conservation nonprofits through Esri's Affiliate program. Nine new Affiliates joined the program in the past year for a total of 44.

**Cartography:** Chris Bruce, Virginia field office

# Annual Survey and Geospatial Trends

The Nature Conservancy conducted a second annual survey* to assess the status and needs of its geospatial community across GIS and remote sensing disciplines. Respondents were asked about creating and storing spatial data, training needs, software usage, their specific geospatial areas of expertise and their priorities for the Geospatial Systems team in TNC's global IT department. This information is helping us build an enterprise geospatial plan that supports practitioners and elevates geospatial work to a higher level of excellence.

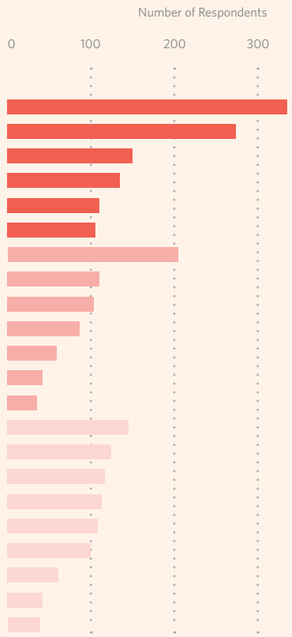
**1,577**
STAFF INVITED TO PARTICIPATE IN THE SURVEY

**577**
RESPONDENTS (**88%** COMPLETION RATE)

**As with all surveys, these results are only as accurate as the responses and therefore do not necessarily reflect the status of the entire TNC geospatial community.*

## Priorities of Geospatial Community

We asked respondents to help us identify the top priorities that the Geospatial Systems team in IT should focus on this year to make the biggest impact on the community's work.



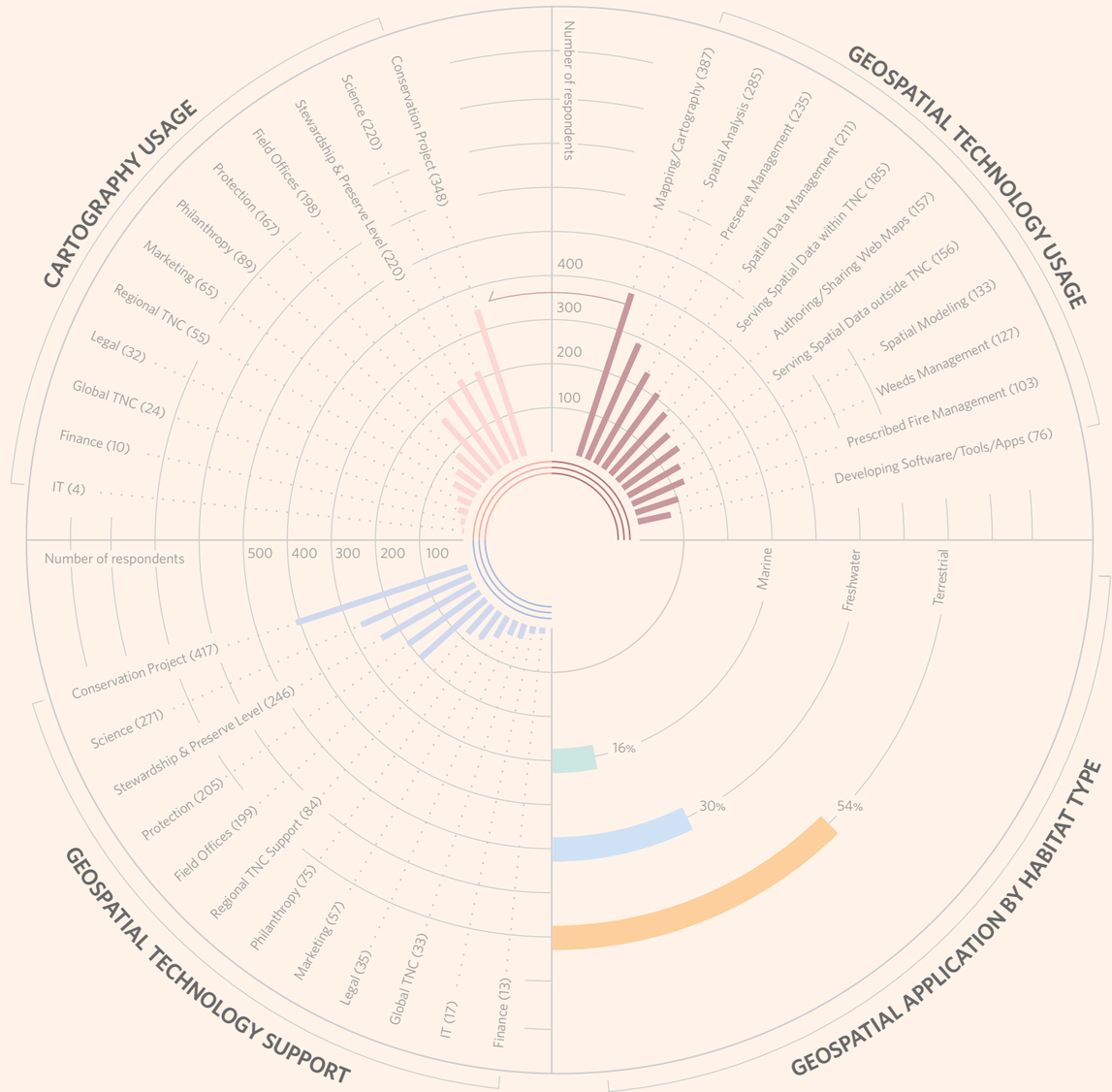

[1] Esri courses, other vendors, etc.
[2] Help Desk
[3] Compile, centralize and maintain
[4] Microsoft Azure, Amazon Web Services etc.
[5] TNC Intranet

## Increasing Geospatial Community

Our geospatial workforce favored these ways to increase a sense of community.




[1] Web publishing, cartography, earth observation, etc.
[2] Focused on a specific GIS topic of interest
[3] Esri User Conference, SCGIS (Society for Conservation GIS) Conference



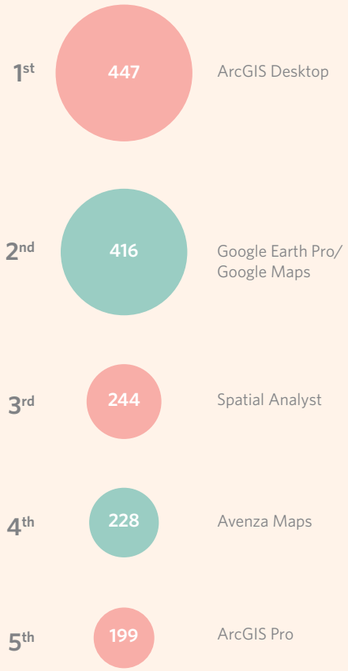

## Geospatial Use at TNC

The vast majority of maps that are created at TNC support conservation projects, science and stewardship work (upper-left quadrant). Map creation (cartography) and spatial analysis represent the highest activity, while preserve management and spatial data management are also very common (upper-right quadrant). The lower-right quadrant of the chart shows the majority of geospatial technology is applied to terrestrial work, and the lower-left quadrant demonstrates how TNC's geospatial community supports nearly every part of the organization.

# Software Usage

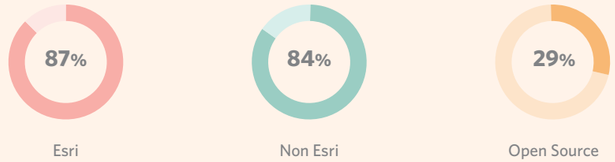
### MOST USED PRODUCTS

TNC's geospatial community's most popular software tools include the software products below. Esri's latest desktop GIS, ArcGIS Pro, is gaining popularity as it will eventually replace ArcMap.

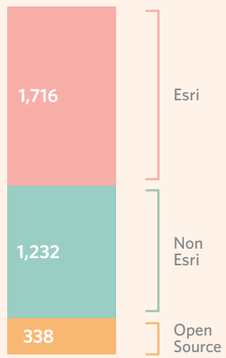



### USE WITHIN THE GEOSPATIAL COMMUNITY

Many in the geospatial workforce rely on a variety of software tools to achieve our conservation mission. While Esri's product platform is used the most, our community also uses products that complement Esri software, such as Collector Companion and XTools Pro, as well as open source options including QGIS, Open Street Map, GDAL and GRASS.



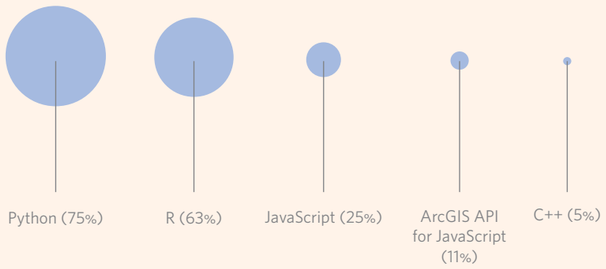

### INDIVIDUAL INDICATIONS OF USE




### NUMBER OF PRODUCTS USED

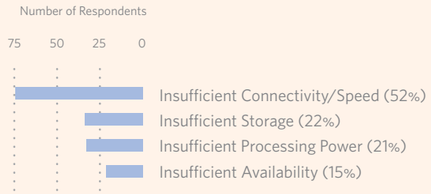

# Programming Languages

About a fifth of our geospatial community use programs or scripts to automate their workflows.




# Server Adequacy

Over a third of respondents who use TNC's on-premise physical server infrastructure report inadequacies.

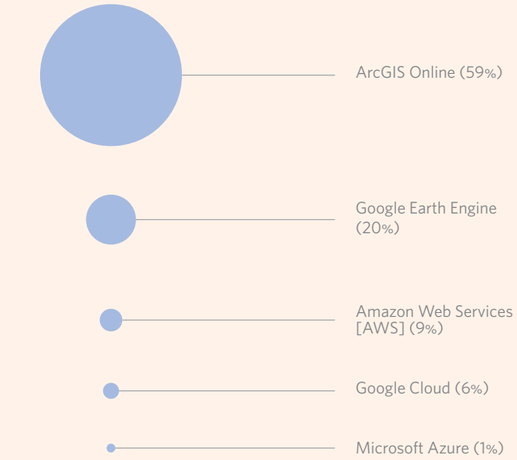



Note: percentages do not sum up to 100% as the respondents were able to choose mutiple responses.



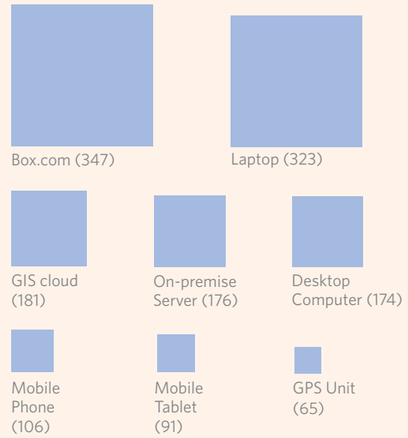
# Cloud Platform Usage

Almost three quarters of respondents would use cloud computing if it was made available. Of those who already use cloud platforms, they rely on:



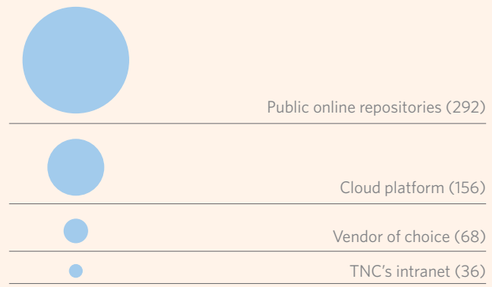

# Storing Spatial Data

Most respondents use Box.com to store their spatial data, and over half use their laptops. About an equal number of respondents store spatial data on either a cloud platform or on-premise servers.



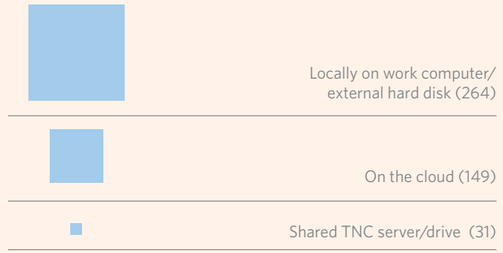

# Acquiring Satellite Imagery

Three of four respondents download satellite imagery from public online repositories for their conservation work. Over a third of respondents perform analysis directly on a managed cloud platform.




# Storing Satellite Imagery

Three quarters of respondents choose to store purchased or freely downloaded satellite imagery locally on their work computer or on an external hard disk. Since imagery file sizes are often large, many respondents also use cloud storage.




# Defining TNC's Geospatial Community

**197**
MEMBERS ON THE GIS COMMUNITY LIST SERVE

**500**
USERS ON OUR INTERNAL SERVERS

**815**
My Esri USERS

**1,372**
MEMBERS ON TNC'S ORGANIZATIONAL ArcGIS Online ACCOUNT

© Nick Hall

**Coastal waters next to a colony of 200 sea lions (**Otaria flavescens**) near the coast of the Valdivian Coastal Reserve near Chaihuin Village, Los Rios, Chile.**

# Applications

Geospatial technology remains an important tool for TNC's science-based approach to conservation, known as Conservation by Design*. Part of this approach is to map strategies and places through systematic conservation planning, which includes evaluating the impact of those strategies in comparison to broad conservation goals. Our geospatial conservation applications are rapidly expanding due to the newly updated Conservation by Design approach coupled with advances in data and technology. Over 1,300 of TNC's 3,600 staff use geospatial technology for their conservation work and over 500 apply it directly to conservation science and planning. Here we have selected 26 projects or programs that illustrate the range with which this technology is being used for conservation. This is a small glimpse of the breadth and depth of our geospatial work that continues to provide decision support and leverage meaningful conservation action. We have categorized these geospatial applications into three mapping types related to conservation science and planning:

## 1. Predictive Modeling

Using a quantitative approach to estimate process or the probability of an outcome with data models. These models are used to project future climate or development scenarios as well as changes in species, habitat or ecosystem conditions, or distributions.

## 2. Prioritization

### Asset & Threat Mapping

The mapping of species, habitats, ecosystems and their services, cultural values, and the threats to them. These assets, along with geospatial data on current and future human development pressures, are compiled and analyzed to identify place-based conservation priorities.

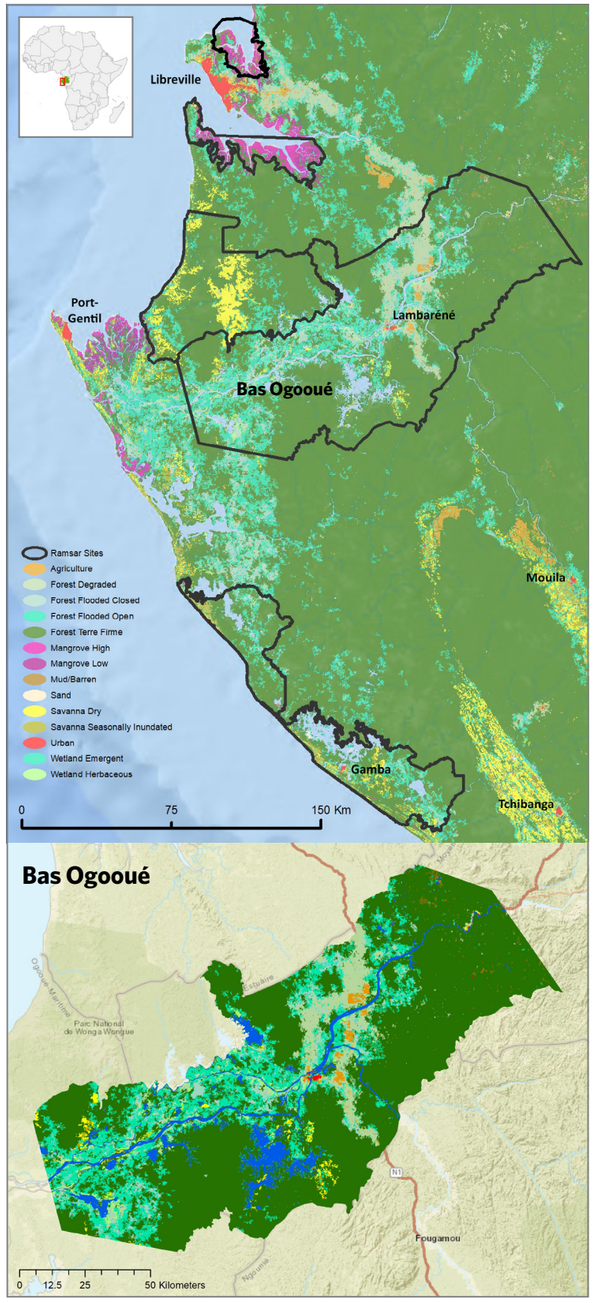
### Spatial Action Mapping

Mapping strategies and actions in priority places. Spatial action mapping realigns conservation planning with actions by considering the probability of success and return-on-investment for conservation interventions. These strategies inform decisions on when, where and what may be the best conservation actions to take.

## 3. Monitoring & Evaluation

Using geospatial data and analyses to monitor conditions, assess progress toward goals and evaluate impacts. This includes a periodic assessment of changes in status to evaluate whether desired conservation outcomes have occurred and if they can be attributed to a program's interventions.

*conservationbydesign.org




▲ Coastal wetlands of Gabon and Ramsar Sites. The wetland habitats of greatest interest for TNC are in the floodplain zone of the Bas Ogooué and its tributaries. **Cartography:** Emmanuel Mambela, Africa program and Steve Schill

# Mapping Complex Coastal Wetlands

Country: **Gabon**

The coast of Gabon contains Africa's third largest freshwater delta and possibly one of the most intact coastal ecosystems across the continent. Protecting and managing this mosaic of coastal lakes, rivers and wetland ecosystems is important because it contains six Ramsar Wetlands of International Importance that provide a multitude of ecological, economic and social benefits. To better understand and protect this extremely remote freshwater delta, our team collected field data using unmanned aerial vehicles (UAV) at strategic locations throughout the delta. We used these data to train and classify image objects derived from optical and radar satellite images across 100,000 km² of Gabon's coast. Our efforts resulted in the first 30-meter wetland map that is being used for zoning Gabon's coastal wetlands management plan. This work will help designate important areas of biodiversity and ecosystem services (e.g., flood control), and identify sites for socioeconomic activities (e.g., fisheries and logging).

This approach proved particularly valuable for mapping remote places, especially in tropical areas where ground-based surveys are difficult, optical satellite imagery is consistently hampered by persistent cloud cover and the baseline wetland data (e.g. digital elevation models, hydrographic maps, soils maps) are either not available or of low resolution or accuracy. In particular, the L-band radar imagery was significantly useful for identifying flooded forests and penetrating cloud cover. We identified 15 land cover classes; nine of these were wetlands. We conducted a post-classification accuracy assessment via helicopter surveys which resulted in an overall accuracy of 80%. The Gabonese government is incorporating our efforts to ensure this vital landscape is protected and properly managed. This is good news for Gabon, but it's also important to note that the benefits of these remote sensing techniques are applicable to other countries facing similar challenges.

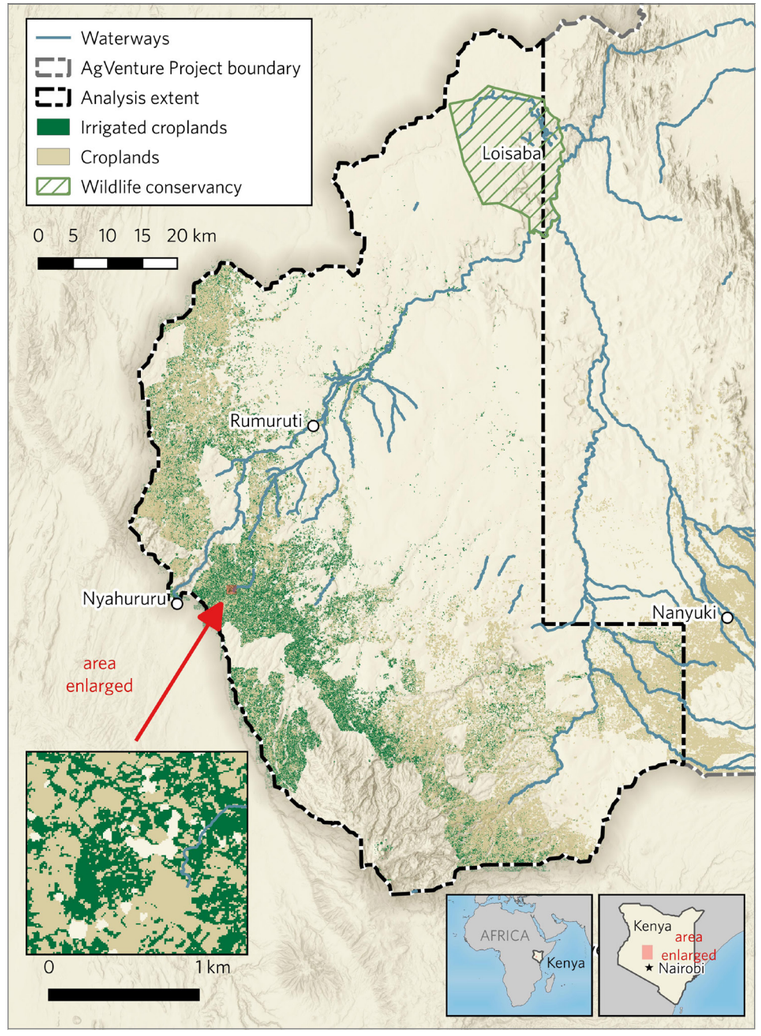
**Partners:** Agence National des Parcs Nationaux (ANPN)
**Website:** arcg.is/0Hb0eP **Publication:** nature.ly/3jKMCgT
**Software:** ArcGIS Desktop 10.7, ENVI 5.5 , eCognition 9.5
**Data Sources:** Landsat 7 and 8, ALOS PALSAR (L-band)
**Contact:** Allison Aldous (aaldous@tnc.org), Emmanuel Mambela (emmanuel.mambela@tnc.org), Steve Schill (sschill@tnc.org)

# Mapping Land Use to Reduce Water Resource Conflicts

Country: **Kenya**

Located in central Kenya, Laikipia County is a critical conservation area for many of the world's most at-risk megafauna. The expansion of agricultural land and water use in this region is creating conflict with wildlife over habitat and water resources. TNC's Africa program and teams from Global Soil Science and the Center for Sustainability Science have partnered to determine if regenerative agriculture practices may reduce the need for irrigation and free up water for wildlife. Cropland extent and irrigation data are essential inputs for the models used to assess the agricultural extent, however the expansion of cropping systems and irrigation practices in Laikipia is so rapid that existing land use and irrigation maps are quickly outdated. To address this, we are working with our partner, Quantitative Engineering Design (QED) to create readily updatable maps of cropland extent using desktop classification of land use with high-resolution images across a subset of Laikipia.

These data are used by machine learning models to extrapolate desktop classifications to a regional cropland map at 10-meter resolution. Estimating water savings potential also requires irrigation data. To estimate irrigation, TNC used Astraea's EarthAI and Earth OnDemand platforms to classify areas that have little change in vegetation indices between the rainy and dry seasons. Specifically, cropland grid cells with less than a 20% decrease in the Normalized Difference Vegetation Index (NDVI), between the rainy and dry seasons are classified as irrigated. **"We are excited to provide our EarthAI platform to conservation data scientists at TNC, empowering them to create solutions that better measure impact and promote sustainability at scale,"** says Daniel Bailey, CEO of Astraea. The suite of tools integrated into their platform have allowed us to make 10-meter resolution irrigation maps in Laikipia. We hope our efforts will enable a transition to water-saving agricultural practices that benefit wildlife and farming communities.




▲ Irrigated and non-irrigated croplands in Laikipia, Kenya. This work is part of a project modeling the impact of conservation agriculture on water resources. **Cartography:** Nate Peterson for the Africa program

**Partners:** QED, Astraea, Syngenta Foundation for Sustainable Agriculture, AgVenture Ltd.
**Software:** EarthAI, Earth OnDemand, Geosurvey **Data Sources:** Sentinel-2, MODIS
**Contact:** Stephen Wood (stephen.wood@tnc.org)

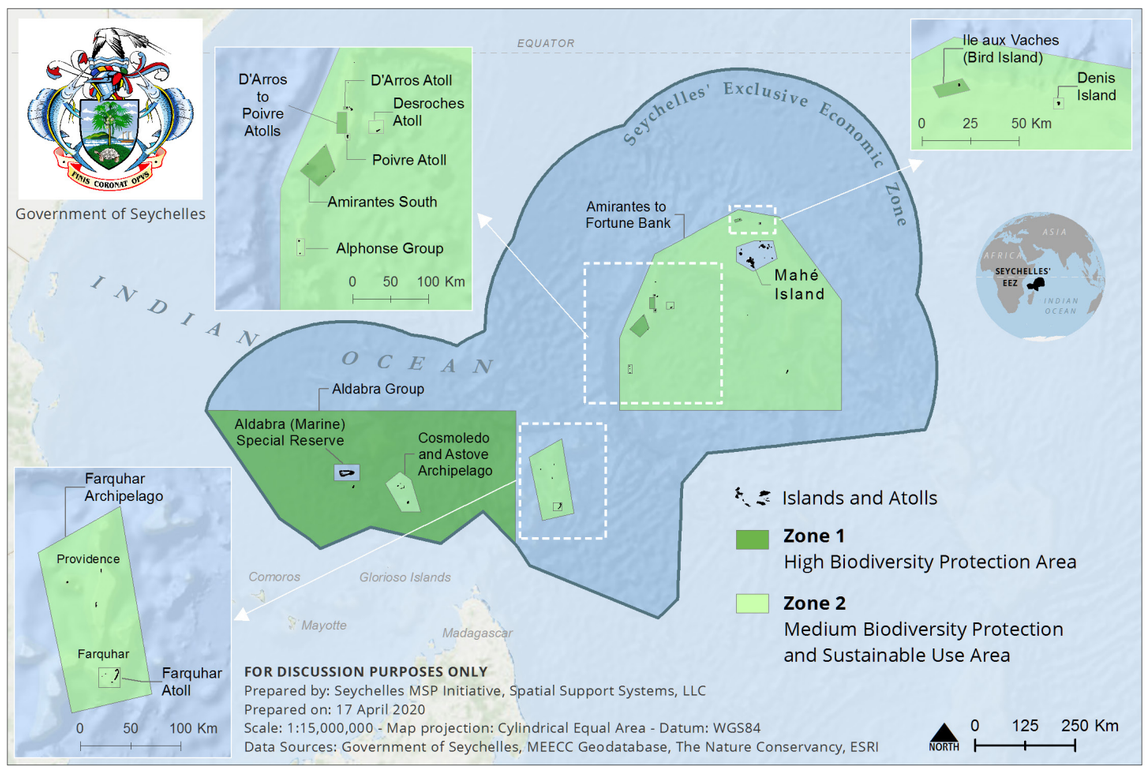
# National Debt Swap for Conservation

Country: **Seychelles**

**Partners:** Government of Seychelles, GOS-UNDP-GEF, SeyCCAT **Website:** seymsp.com, nature.org/seychelles **Software:** ArcGIS, Marxan, Marxan with Zones **Data Sources:** Esri, Government of Seychelles, TNC **Contact:** Joanna Smith (joanna_smith@tnc.org), Helena Sims (helena.sims@tnc.org)

The Seychelles is an archipelagic nation of 115 islands in the Western Indian Ocean encompassing 1.35 million square kilometers. The marine biodiversity in this region is an important natural asset for Seychelles that supports a luxury tourism industry and numerous fisheries. In 2012, the government committed to protecting 30% of its waters by 2020; this decision was motivated by concerns about sustainability, biodiversity loss and climate change. The Seychelles Marine Spatial Plan (SMSP) was initiated in 2014 to support this goal and is a condition of the world's first debt conversion for the ocean which turns debt repayments into long-term conservation funding. This agreement was signed between Seychelles and the Conservancy in 2016. The SMSP is a science-based process that plans for sustainability and the long-term health of the entire ocean surrounding Seychelles. This government-led initiative is supported through TNC-led science, process design and facilitation. This effort includes robust stakeholder and public engagement with more than 11 marine groups. In 2015, the SMSP developed a three-category zoning framework and an adaptive GIS database with over 100 datasets to support zoning designs for more than 200 workshops where stakeholders discussed marine spatial planning proposals. The SMSP has three zone types: **1.** biodiversity, **2.** biodiversity + sustainable uses and **3.** multiple use. Seychelles reached its goal in March 2020 and successfully designated 30% (410,000 square kilometers) of its marine waters including 13 new marine protection areas for completion and implementation in 2021. The Government of Seychelles and TNC are pioneering this new model for marine spatial planning that includes innovative financing to support long-term conservation, sustainable economies and improved ocean management.

▼ Seychelles Marine Spatial Plan Marine Protection Areas, 410,000 square kilometers in 13 new marine protection areas were established in March, 2020. **Cartography:** Rick Tingey, Spatial Support Systems, LLC for the Africa program







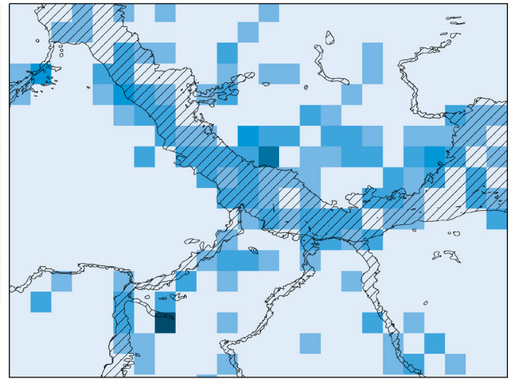

# Conserving Indigenous Community and Biodiversity Values

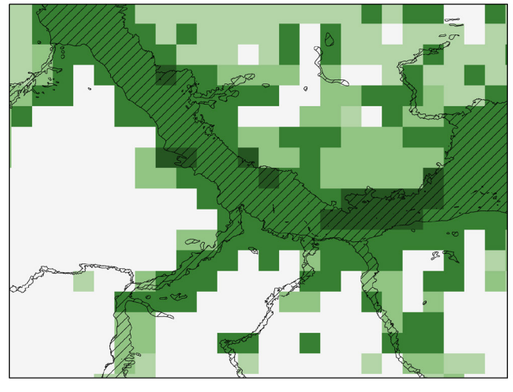
Country: **Australia**

Indigenous territories include one-quarter of the world's land, freshwater and marine habitats. Indigenous communities can be more successful at managing for conservation outcomes than government protected areas; however, Indigenous territories are often threatened by the expansion of mining, energy extraction and agriculture. Indigenous communities are regularly excluded from development decisions and face legal and technical challenges that undermine their ability to protect and manage their lands and waters. This is despite the fact that the UN Declaration on the Rights of Indigenous Peoples establishes their rights to Free, Prior, and Informed Consent (FPIC) to projects affecting them or their territories. Northern Australia has been home to Indigenous Australians for over 60,000 years. This region is characterized by the world's largest intact savanna with globally significant biodiversity and rich cultural heritage. Aboriginal corporations have Native Title to nearly 60% of this region through Native Title legislation that grants them the right to review and negotiate development plans.

In 2016, TNC partnered with Indigenous communities in northern Australia to find solutions that empower them to engage in development decisions and exercise their rights to FPIC. This work has helped Australian Aboriginal corporations define natural, cultural and social values through the Healthy Country Planning process and visualize these values by mapping them in a spatial planning framework. This framework enables communities to proactively assess and negotiate development proposals to protect habitat and cultural heritage. This partnership demonstrates how community based planning can support and protect Indigenous communities.

**Partners:** Walalakoo Aboriginal Corporation, Yanunijarra Aboriginal Corporation **Website:** nature.ly/3iBIH4C **Software:** Esri ArcGIS Desktop v10.3 and Python v2.7.8 **Data Sources:** Cultural heritage sites and features from surveys and participatory mapping, Biogeographic Regionalisation for Australia (2000), Schoknecht and Payne (2011), Northern Australia Fire Information MODIS (2000-2016), Landsat 8 OLI imagery (USGS/EROS), GeoScience Australia (2011) **Contact:** Michael Heiner (mheiner@tnc.org), David Hinchley (dhinchley@tnc.org)





▶ This figure shows the social and cultural heritage sites and threatened species habitat aggregated in a grid of 3×3 km cells. **Figure and locator maps:** Mike Heiner, Protect Oceans, Lands and Waters program

**Social/cultural values**

**Freshwater places:**
Floodplains & wetlands

**Cultural/heritage sites:**
Count of surveyed sites per grid cell

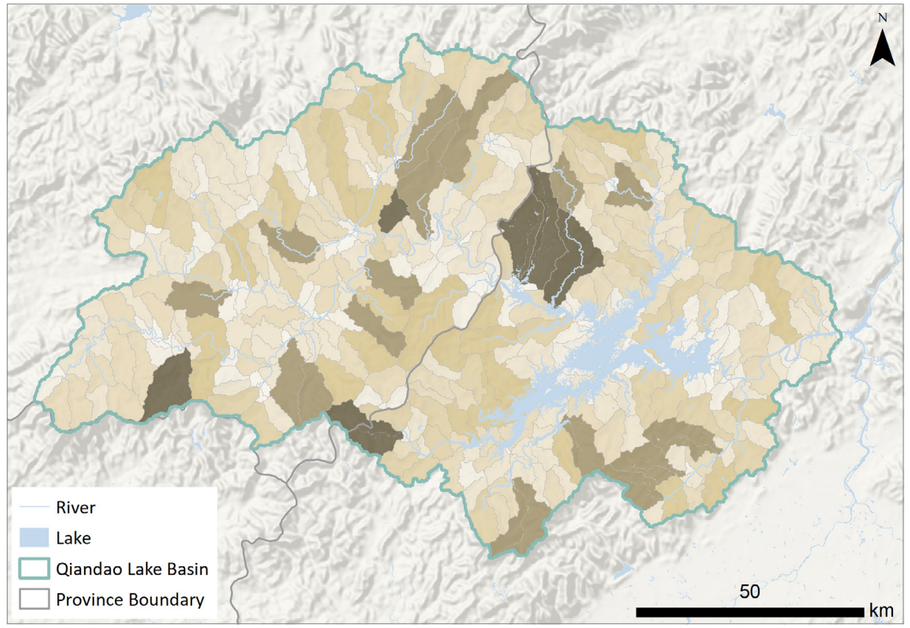
- > 20
- 11 - 15
- 6 - 10
- 2 - 5
- 1

natural habitat supporting native game animals and bush tucker/medicine plants

**Biodiversity values**

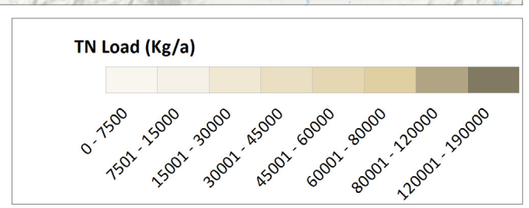
**Protected species:**
Number of species with potential suitable habitat occurring in each grid cell.

- 31 - 36
- 21 - 30
- 11 - 20
- 2 - 10
- 1




**Partners:** World Bank, The People's Government of Zhejiang Province **Website:** nature.ly/2Sv74qe **Software:** ArcMap 10.2, Soil & Water Assessment Tool **Data Sources:** Shuttle Radar Topography Mission, China Remote Sensing Survey and Monitoring Data of Land Cover (2010), FAO World Soil Database + Local Soil Database, China Atmospheric Assimilation Data, Monitoring Station Records (2016), Hangzhou Statistical Information Net (2016) **Contact:** Yongmei Luo (yluo@tnc.org)

◄ The spatial distribution of total nitrogen (TN) per acre by sub-basin in Qiandao Lake, China.
**Cartography:** Yongmei Luo, China program


# Non-Point Source Pollution Pattern Analysis for Qiandao Lake

Country: **China**

Qiandao Lake is located in Zhejiang Province, close to the provincial capital Hangzhou City. This human made, freshwater lake supplies water for about 10 million people in Hangzhou and nearby cities and serves as a water source reserve for the Yangtze River Delta. Currently, water quality in Qiandao Lake is classified as "good to excellent," however the total amount of pollutants discharged into the basin area is rapidly increasing from agricultural, non-point source pollution due to excessive use of fertilizer, pesticides and nearby breeding farms. To understand the sources and control measures of non-point source pollution, we conducted a Soil & Water Assessment Tool (SWAT) model approach and GIS analysis to construct the hydrological processes and simulate the temporal and spatial distribution patterns of non-point source pollution in and around Qiandao Lake. We examined the temporal and spatial distribution of total nitrogen, total phosphorus, and sediment loads and identified 20 sub-basins with higher nonpoint source pollution contributions which account for 1/4 of the total area and 1/3 of the non-point source pollution in the Zhejiang Province. We assessed the ecological, economic and social conditions of the selected sub-basins to determine appropriate management practices for pollution control. We simulated how different management practices might reduce non-point source pollution by adjusting management parameters through the SWAT model. Finally, we selected two of the most critical sub-basins as pilot areas to decrease agricultural non-point source pollution by reducing the use of fertilizers and pesticides. This analysis directs and supports the allocation of limited funds for investment in high-impact sub-basins to help managers meet their targeted management goals.





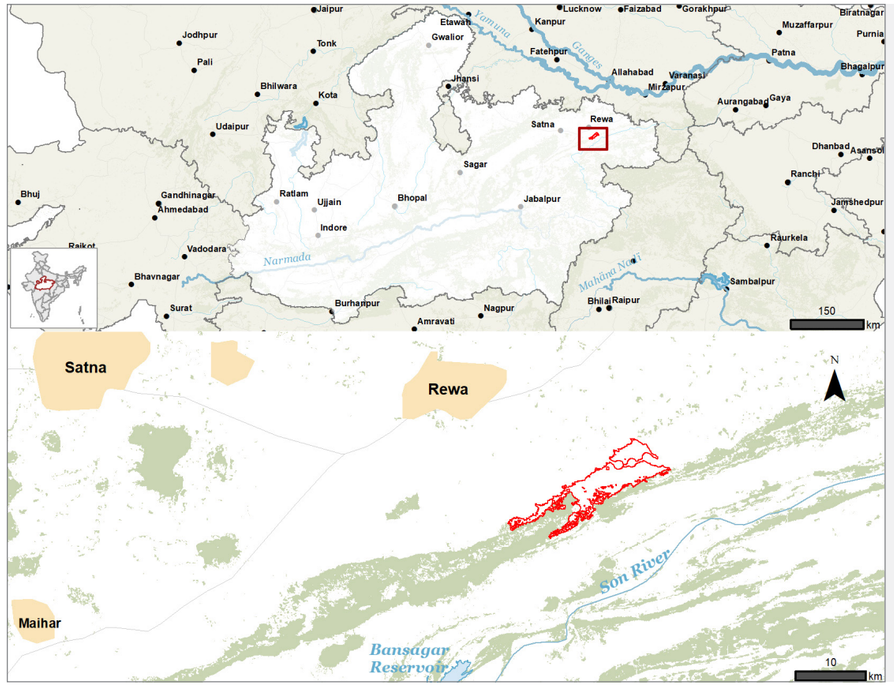
# Facilitating Low Impact Siting of Renewables

Country: **India**

Providing renewable energy (RE) infrastructure in India will require vast stretches of continuous land. While alternative energy initiatives are important for transitioning India to a low-carbon economy, poorly sited solar and wind projects can have significant impacts on wildlife and rural communities that rely on continuous, undisturbed habitats. Evaluating siting considerations early in the development of RE projects can guide them to areas of lower impacts and ensure the longevity of RE infrastructure in India.

To meet the need for properly sited RE infrastructure, the Conservancy and partners created an interactive SiteRight tool that identifies lower impact areas for RE development in central India. To identify low-impact sites, we combined the data on ecological and social values with spatial information on engineering and land-use constraints. We found that nearly 45 million acres of land may be suitable for solar and wind development in the two provinces for which the tool has been currently developed. This represents enough energy to support the national RE goals several times over. SiteRight allows a user to query and identify a low impact land parcel with a minimum capacity requirement in a certain administrative unit. This interactive tool facilitates lower impact RE siting that will help businesses, policymakers and investors increase project certainty by reducing permitting time, project costs and delays. Integrating SiteRight into the decision-making process for RE infrastructure planning will expedite India's transition to a low-carbon economy while protecting rural communities and sensitive wildlife habitat from development.

**Partners:** Center for Study of Science, Technology and Policy; Vasudha Foundation; Foundation for Ecological Security **Website:** tncindia.in/siteright/ **Software:** Esri ArcGIS Service R Programming Language, ArcGIS Desktop by Esri **Data Sources:** Indian Space Research Agency, Forest Survey of India, Wildlife Institute of India, BirdLife International, Open Street Map, Census of India, Vaisala **Contact:** Dhaval Negandhi (dhaval.negandhi@tnc.org)



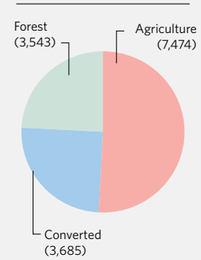

**MADHYA PRADESH SOLAR AND WIND DEVELOPMENT**

POWER GOALS (MW)

| | |
|---|---|
| 2022 Target | 11,875 |
| 2017 Installment | 3,708 |

*BAU- Maximum Resource Potential with rooftop solar*

ESTIMATED LANDCOVER IMPACTS (km²)




▲ The SiteRight tool is used to visualize and report on ecological and social impacts of development when siting potential wind energy areas.
**Cartography:** James Oakleaf for the India program

# Mapping the Past to Guide the Future

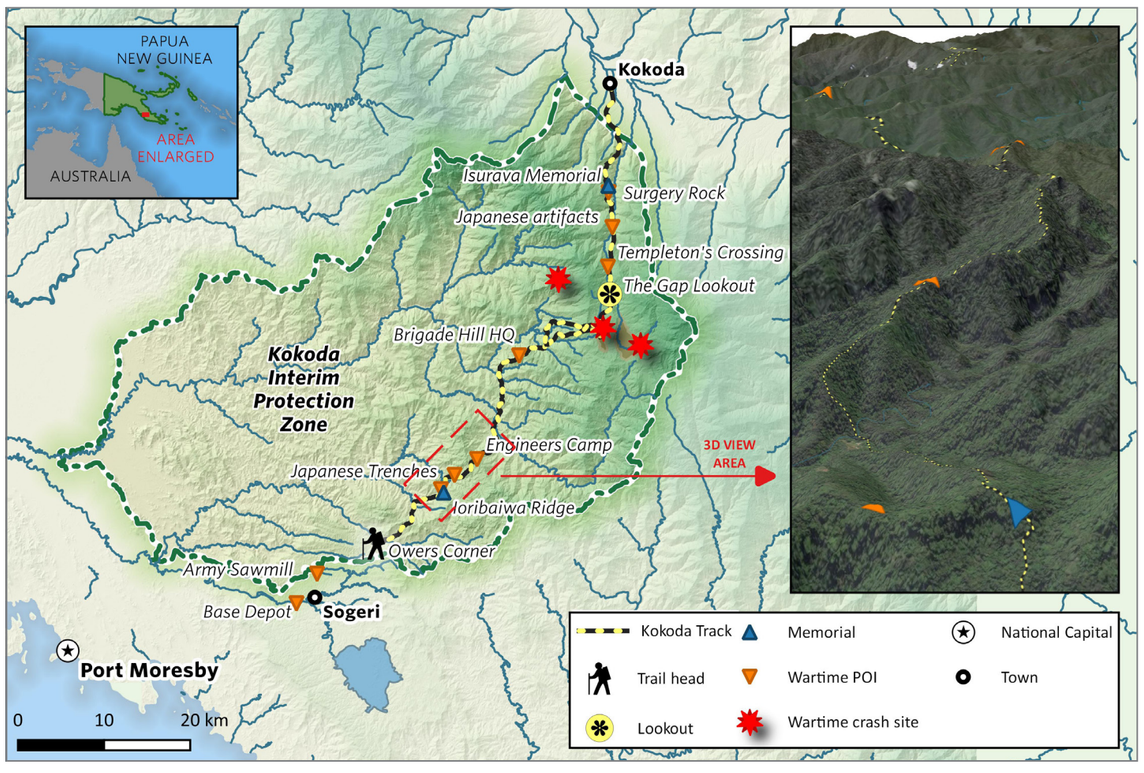
Country: **Papua New Guinea**

**Partners:** Kokoda Initiative, Papua New Guinea National Museum and Art Gallery (NMAG) Kokoda Track Authority (KTA), PNG government's Conservation Environmental Protection Authority (CEPA) **Software:** QGIS 3.10 LTR **Data Sources:** Kokoda Initiative, PNG National Museum and Art Gallery, the Kokoda Track Authority, and the PNG government's Conservation Environmental Protection Authority **Contact:** Nate Peterson (npeterson@tnc.org)

At the height of WWII, the mountains outside the coastal city of Port Moresby, Papua New Guinea (PNG) were home to an epic battle between Japanese and Australian forces. This was a defining battle for the two sides. If Japan was victorious, Japanese soldiers were likely to invade mainland Australia. The battle unfolded on the rugged 96 km trail known as the Kokoda Track. Today the Track represents the intertwined histories of both Australia and PNG. In 2005, the Kokoda Initiative was established to bring together stakeholders to catalogue and preserve the war history, promote and service the local trekking industry, and maintain the environmental values of this historically rich and ecologically diverse landscape.

The Nature Conservancy was approached to build a GIS flexible mapping tool for monitoring the landscape. We used the free and open source GIS program, Quantum GIS (QGIS) so the mapping tools could be easily shared across multiple agencies, interested partners and stakeholders. The "Kokoda Track GIS Platform" organizes geographic information such as historic military sites including old foxholes, ammunition caches, and memorials as well as tourist accommodations, bridges and other infrastructure. Managing these data with QGIS helps to overcome the logistical challenges of the region, including limited internet access and rugged terrain. This technology is critical for sustainable development and management of protected areas, but is often expensive. This valuable, freely available GIS tool contributes to the historical and ecological preservation of assets along the Kokoda Track.

▼ The Kokoda Track in the lush tropical jungles of Papua New Guinea was the home to epic WWII battles but is now host to modern day adventure tourism. **Cartography:** Nate Peterson, Asia Pacific program





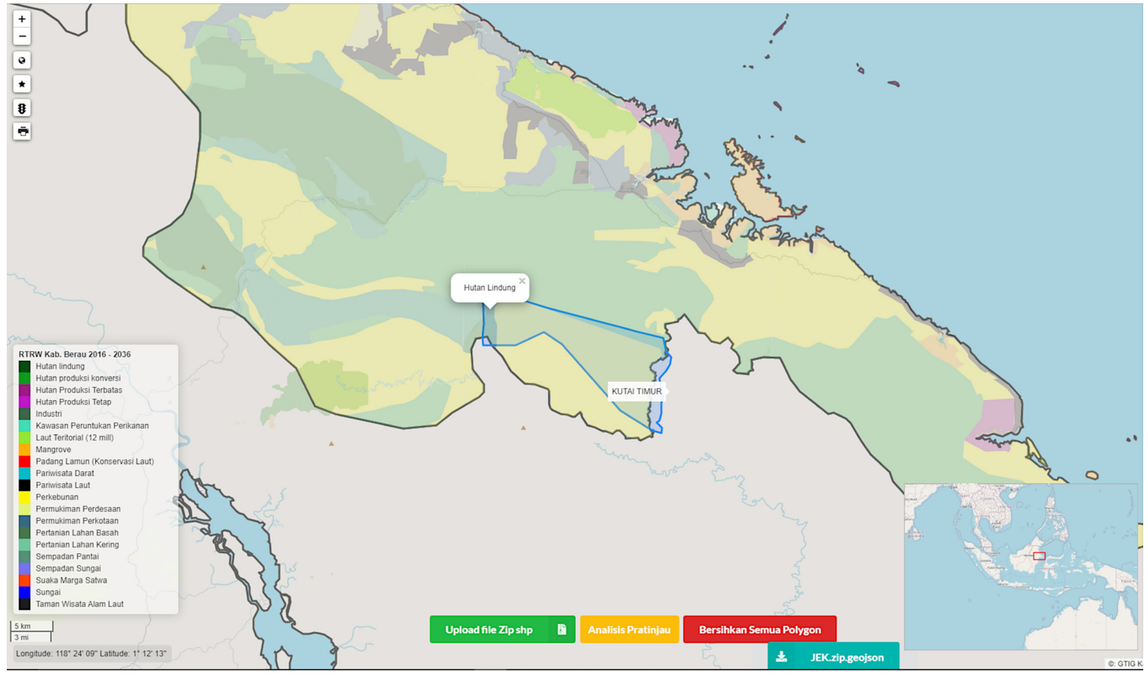



# Pre-assessment Permit for Palm Oil Concessions

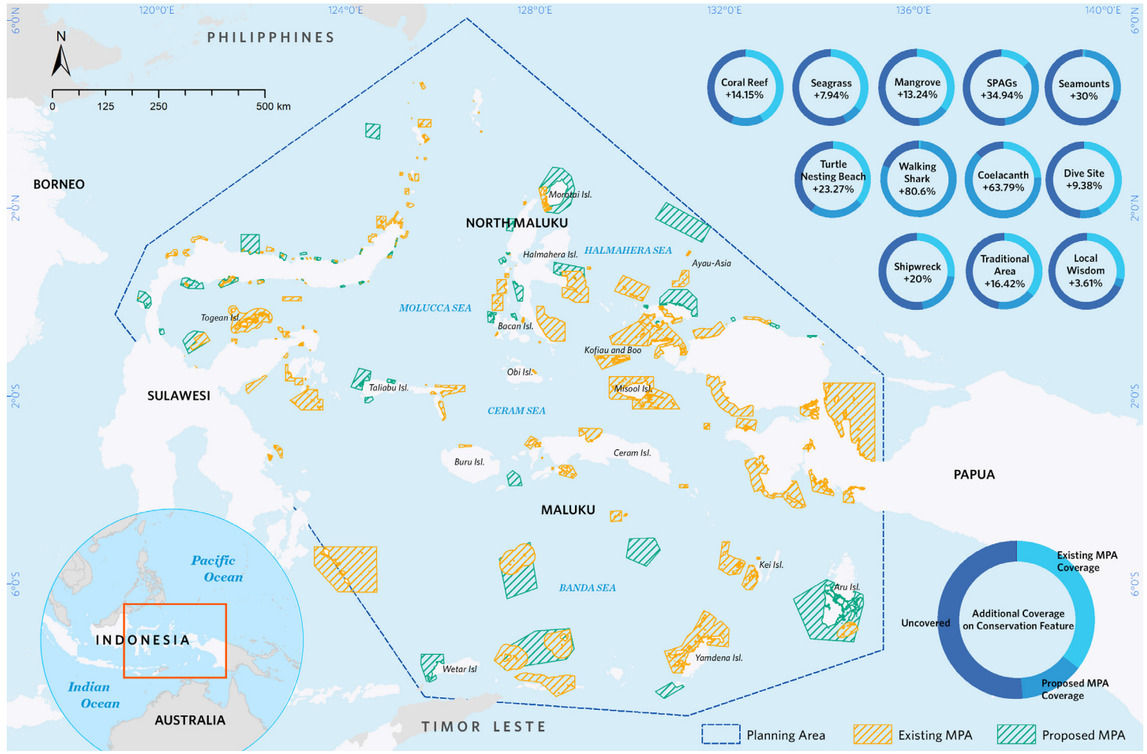
Country: **Indonesia**

Preassessment permit (Pratinjau Perijinan) is an online tool that utilizes the "one map, one data" policy issued by the President of the Republic of Indonesia. This policy is intended to improve data uniformity and decision-making for development planning at the national, provincial and district levels. Current permitting procedures leave vast expanses of orangutan habitat, karst ecosystem and rainforest vulnerable to development, particularly by palm oil plantation expansion. To unify and streamline land use data at the district level, the Berau District established a spatial data hub or geoportal where data from each production sector such as forestry, plantation, agriculture, mining, husbandry, industry and tourism is stored. However, it is difficult for developers and government officials to quickly assess land use data for permitting, so we developed the pre-assessment permit tool to help applicants gain quick access to spatial information before applying for a permit. Our objectives are to **1.** utilize data from the spatial data hub as an initial reference before permitting so applicants can evaluate the condition of the land and **2.** give users access to the latest spatial planning data including village administrative boundaries, historical land condition and land cover, and existing permits for plantation, forestry, agriculture, mining and high conservation areas. Our goal is to reduce land conversion in areas of high conservation value and minimize conflicts between investment developers both administratively and within communities. TNC in Indonesia is working with the Berau District to ensure the government can implement the one map, one data policy while providing certainty of area designation for various development and conservation investments. This will help avoid or reduce the development of palm oil plantations in important conservation areas.

**Partners:** Planning Office Berau District, East Kalimantan, Estate Crops Office, Berau District, GIZ-Low Emission Oil Palm Project. **Website:** nature.ly/2SzBqYI **Software:** Leaflet-Java Script **Contact:** Ida Bagus Wedastra (idabagus.wedastra@tnc.org)




▲ An online tool used by decision makers in Berau District, East Kalimantan Province provides critical land use information to assess permits, pinpoint existing land violations and identify impacts of future land use investments. **Cartography:** Ida Bagus Wedastra, Indonesia program




▲ MPA Network design for Fisheries Management Area 715 and six associated provinces in Indonesia. The large donut chart represents all conservation features, while the smaller charts are feature specific (i.e., 30% of seamounts would be protected within these proposed MPAs). **Cartography:** Lukman Hakim and Yusuf Fajariyanto, Indonesia Oceans program

# Designing Marine Protected Area Networks

Country: **Indonesia**

Indonesia comprises some of the world's most diverse tropical marine ecosystems that provide critically important resources for coastal communities. Many of these marine resources and their ecosystem services have been degraded or are threatened by a combination of local and global threats from fishing industries and other development. Marine Protected Areas (MPAs) are zoned areas with management objectives that range from limiting human activity to full protection or "no-take areas." MPAs can serve as a powerful conservation management tool that addresses local threats, enhances fisheries and food security, protects biodiversity, supports livelihoods and increases climate change resilience. Indonesia is committed to establishing 30 million hectares of managed MPAs by 2030. Currently, many of Indonesia's MPAs are not managed effectively and lack the rigorous scientific and spatial design that would help them achieve this bold objective. To fill this gap, we developed a scientific framework that includes spatial design criteria, MPA performance indicators and a training manual for MPA managers while considering Indonesia's unique biophysical, socioeconomic and cultural characteristics. We designed MPA networks at sub-national and provincial scales using the participatory expert mapping conservation planning tool called Marxan. We designed zoning plans for 14 individual MPAs spanning 2.04 million hectares in three provinces and identified priorities for establishing new or expanded MPAs totaling 5.3 million hectares in Eastern Indonesia. This has led to the integration of MPA networks with Marine Spatial Plans that meet multiple management objectives including Fisheries Management Areas. Our approach provides practical guidance for managers as they make critical conservation decisions within the MPA networks.

**Partners:** Ministry of Marine Affairs and Fisheries (MMAF), Indonesia; USAID SEA, CTC **Software:** ArcMap v.10.4, Marxan **Data Sources:** BIG, MMAF, Participatory Mapping with Expert, Global Fishing Watch, Global Seafloor **Contact:** Yusuf Fajariyanto (yfajariyanto@tnc.org)



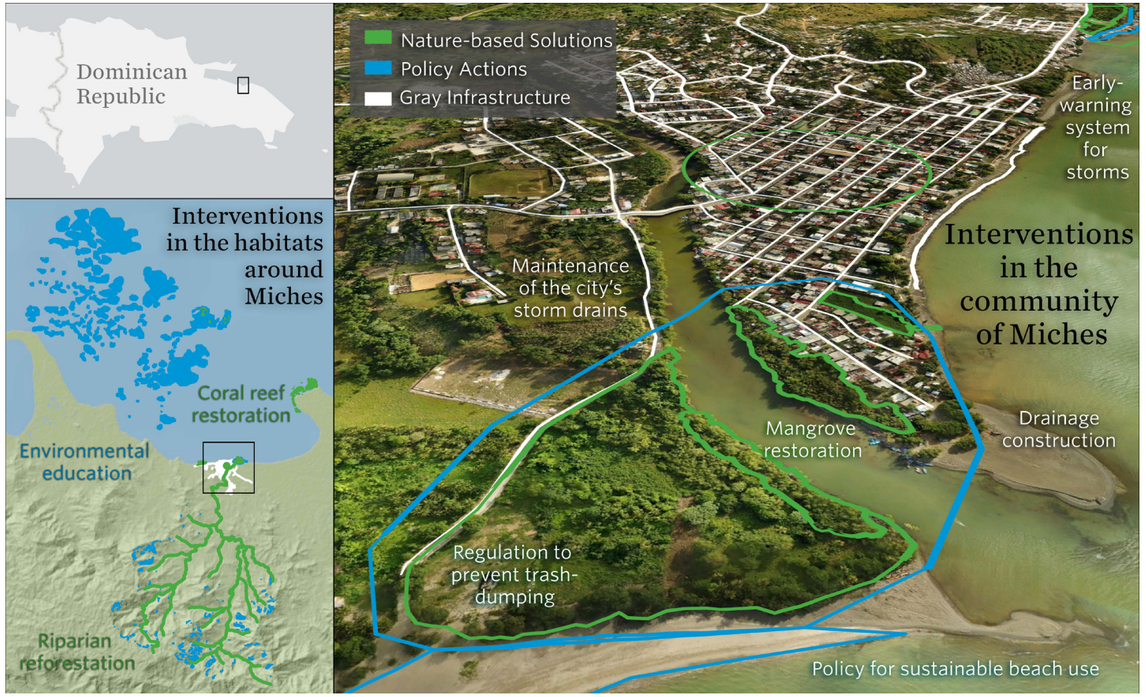


# Mapping a Pathway to Resilience

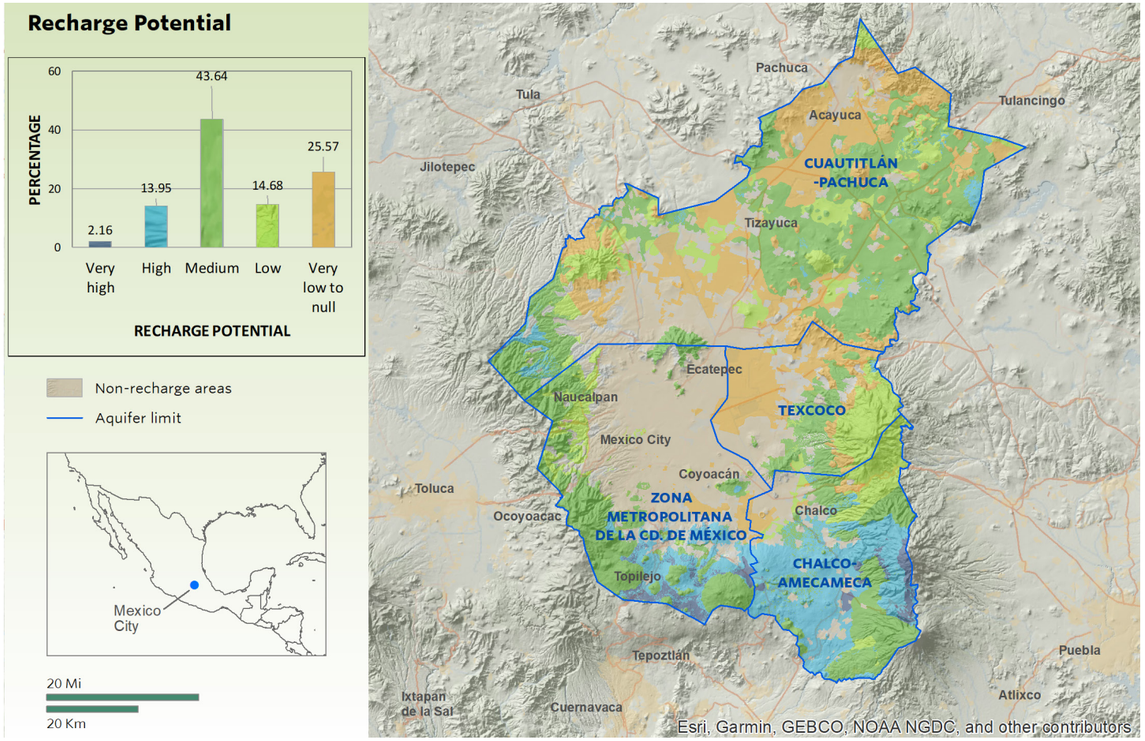
Country: **Dominican Republic**

Resilient Islands (RI) is a Caribbean initiative that identifies opportunities for leveraging nature-based solutions to reduce climate-related disaster risks in coastal communities across the Dominican Republic, Jamaica and Grenada. We identified priority areas for coastal habitat restoration and protection based on their capacity to buffer coastal communities from flooding and storm risks. This initiative empowered governments, partners and communities to implement sustainable development plans. In the Dominican Republic, a rigorous process using International Federation of the Red Cross (IFRC) prioritization tools and support from the Dominican Red Cross resulted in the selection of Miches, a small town of about 10,000 (mainly low-income) residents that have been greatly impacted by coastal erosion, sedimentation and riverine flooding. The RI team collected extensive underwater field data and drone imagery to support the development of a high-resolution habitat and land cover map using satellite imagery. Drone imagery was used to digitize infrastructure and plan for flooding impacts. Sedimentation sources were evaluated by intersecting areas of high slope and activities associated with high sedimentation risk (i.e. agriculture and mining). Resident experts and community officials provided local knowledge on coastal development and habitat changes. These geospatial and socio-economic datasets allowed the team to create a spatial action map of potential nature-based interventions, grey infrastructure solutions and policy actions that when combined, may increase the community resilience of Miches. This collaborative, community focused work is bringing a heightened awareness of nature-based solutions by protecting and restoring mangroves, slowing habitat degradation, reducing stressors on coastal habitats and increasing safety for coastal communities.

**Partners:** International Federation of the Red Cross and Red Crescent Societies (IFRC) **Website:** resilientislands.tnc.org **Software:** ArcGIS Pro 2.6, ArcGIS Online, StoryMaps, eCognition 9.5, ENVI 5.5, DroneDeploy **Data Sources:** Sentinel-2, WorldView-3 **Contact:** Catherin Cattafesta (catherin.cattafesta@tnc.org), Dr. Montserrat Acosta-Morel (m.acosta-morel@tnc.org), Valerie McNulty (valerie.mcnulty@tnc.org), Dr. Steve Schill (sschill@tnc.org)




▲ A combination of nature-based solutions, policy actions and gray infrastructure projects have been proposed to address drivers of vulnerability in Miches in the Dominican Republic. **Cartography:** Valerie McNulty, Caribbean program




▲ The map shows the results of a comprehensive analysis of biophysical factors related to groundwater recharge processes including Mexico City aquifers. **Cartography:** Francisco Reyna Saenz, Mexico program

# Groundwater Recharge Potential of Mexico City Aquifers

Country: **Mexico**

We conducted a comprehensive spatial analysis that emphasizes the importance of the hydrogeologic and hydrological processes in relation to the conservation of freshwater ecosystems and ecosystem services within the Mexico City watershed. This vast watershed encompasses 8,339.39 km² and provides water for human consumption and agriculture to over 20 million people. Developed as a GIS tool, our analysis provides information for investment decisions that support the conservation and restoration of recharge zones in subterranean aquifers. In the analysis we included elevation, climate, geology, lithology, land cover, and other variables to define the qualities of each aquifer, its viability and recharge potential. We categorized six values that offer a clear view of the importance of maintaining the viability of the aquifers to the major metropolitan areas on or near Mexico City.

This information is part of a larger study entitled *Hydrogeological Study of Aquifers Recharge Areas for Water Supply to Mexico City* (pending publication) by Moro Ingeniería S.C. under the coordination of TNC's Water Security Program in Mexico and Central America. Our spatial analysis provides a practical tool for resource managers to support decision-making for the conservation of hydrological processes and groundwater recharge zones in Mexico City. We hope this spatial analysis provides the foundation for ensuring that the watershed remains viable and supports the longterm socioeconomic needs of the community. This is an important contribution for the design of more effective actions that maintain and increase the recharge of aquifers in the region. This work represents an important contribution that will guarantee water security for the Mexico City Metropolitan Area.

**Partners:** Inter-American Development Bank, Latin America Water Funds Partnership, TNC, Moro Ingeniería, S.C. **Website:** moro-ingenieria.com.mx **Software:** Esri ArcMap, ArcGIS Spatial Analyst Toolbox, Model Builder **Data Sources:** Morales-Escalante R. et al. (2020), INEGI (2013), National Water Commission of Mexico, Esri **Contact:** Francisco Reyna Sáenz (francisco.reyna@tnc.org), Hilda Hesselbach (hhesselbach@tnc.org), Raul Morales (raul_agua@yahoo.com.mx)

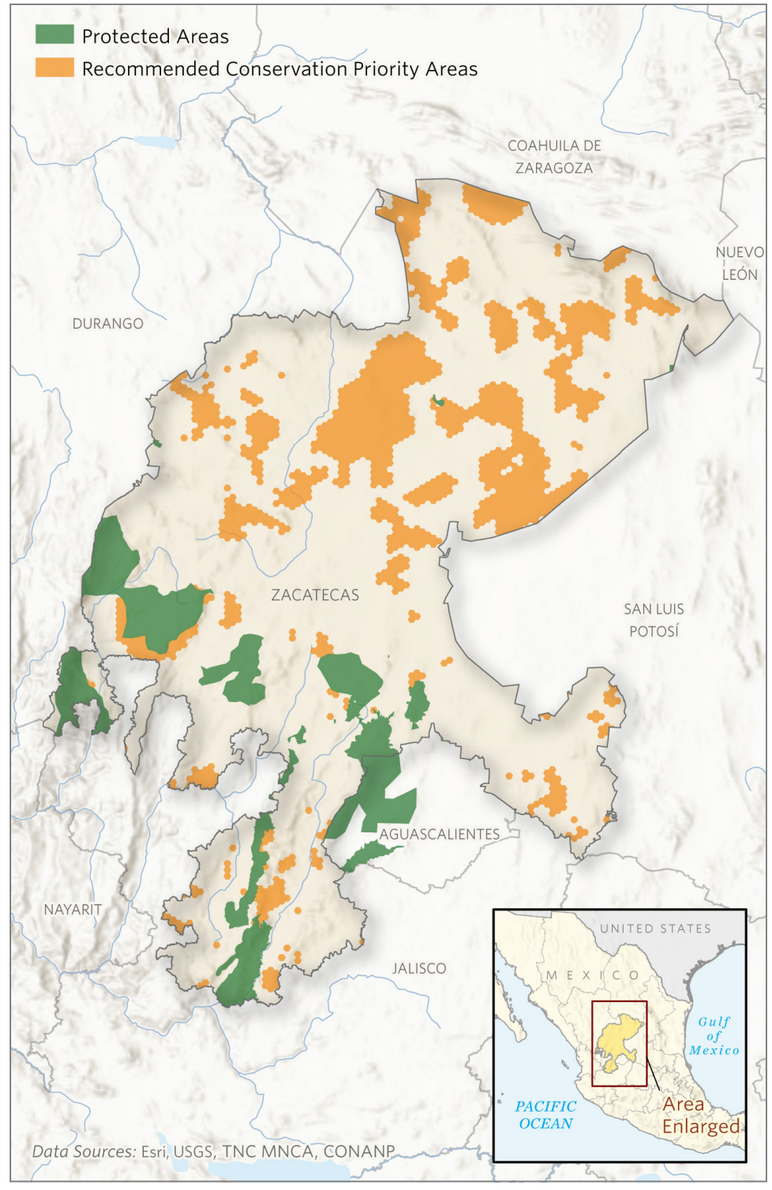




# Designing Conservation Priority Recommendations

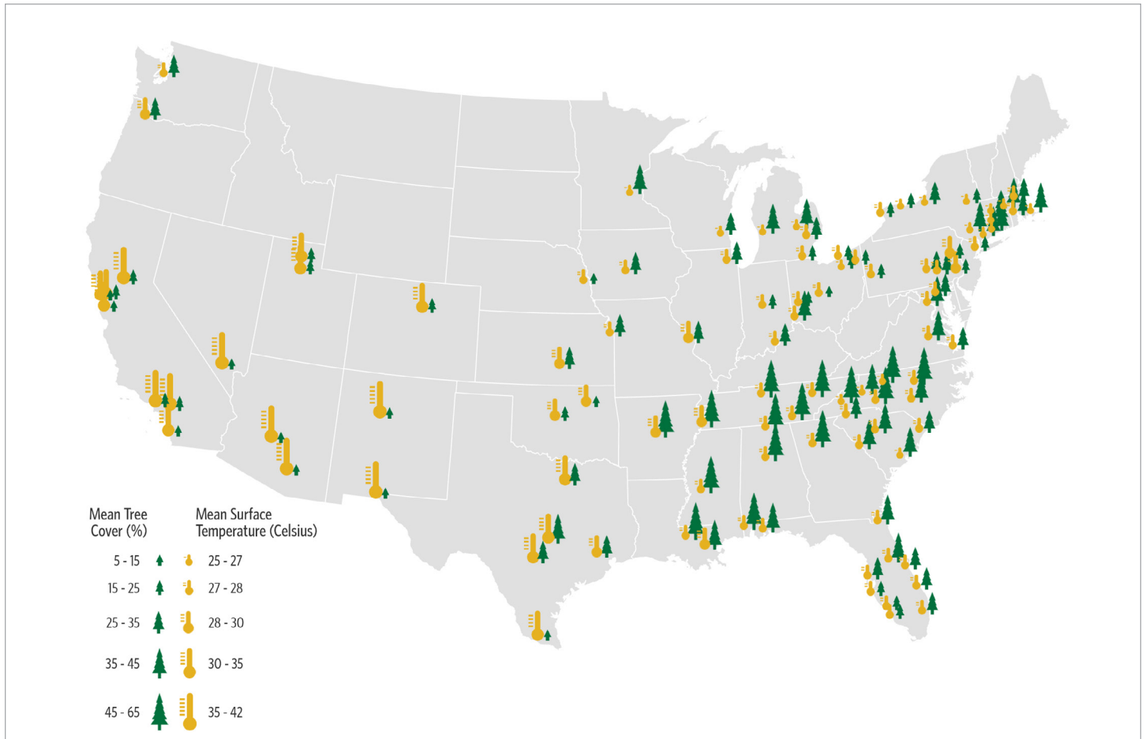
Country: **Mexico**

TNC's Mexico and Northern Central America Program(s) and TNC in New Hampshire formed a collaboration to design conservation spatial priority areas for the State of Zacatecas, Mexico. We provided support to a priority selection process for areas being considered for conservation and restoration as part of the Zacatecas Water Fund. In 2019, Grupo Modelo and TNC established the Water Fund to ensure sustainable water management in this semi-arid region that provides important water outflow to neighboring communities despite receiving only 455 mm of rain per year. We compiled and processed ecological, physical and socio-economic spatial data, and generated 500 species distribution models and a human impact model to run through Marxan, a spatial prioritization decision support tool. This analysis allowed our team to select priority areas that met our biodiversity and water targets or conservation goals in areas that were minimally impacted by humans. Through this work, we achieved our conservation targets for protecting 500 species, including 120 endemic vegetation types and 380 wildlife species (47 endemic). We avoided highly impacted areas characterized by mining concessions, agriculture, irrigation districts, dense populations and transportation infrastructure. The prioritization identifies 1,420,075 hectares that meet our conservation target criteria, helping to guide the Water Fund's conservation efforts. TNC's Water Fund project partner will use this plan to prioritize locations for restoration and reforestation with the objective of recharging aquifers.




▲ Spatial prioritization efforts for restoration and reforestation related to recharge aquifers as part of the Zacatecas Water Fund in Zacatecas, Mexico.
**Cartography:** Anna Ormiston for the Mexico program

**Partners:** Maxiterra Consultancy **Data Sources:** TNC MNCA, National Commission of Protected Natural Areas (CONANP), Esri, CGIAR, USGS **Software:** Marxan, ArcGIS Pro, R (SSDM R package), and QGIS **Contact:** Anna Ormiston (anna.ormiston@tnc.org), Francisco Reyna Saenz (francisco.reyna@tnc.org)



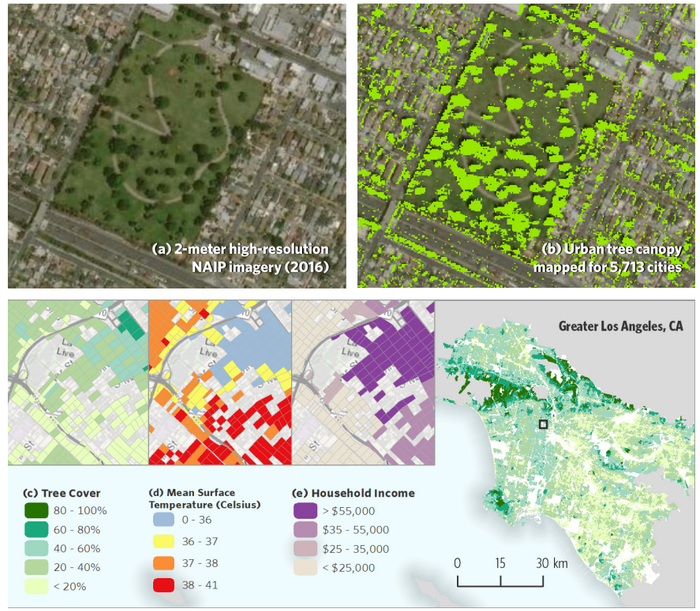

▲ TNC's California and Global Cities programs examined tree cover inequality across the United States. Urban tree cover was mapped across 5,713 U.S. cities showing an inverse relationship between tree canopy and surface temperature. **Cartography:** Chris Bruce for the California field office

## Inequitable Distribution of Urban Tree Canopy

Country: **The United States**

Urban tree cover provides multiple benefits to human health and emotional well-being, however previous studies suggest that tree cover is often inequitably distributed between low-and high-income neighborhoods in U.S. cities. To date there has been no nationwide survey aimed at evaluating the correlation between tree cover and income and/or racial/ethnic inequalities. In 2019, the Conservancy's Cities team partnered with the U.S. Forest Service and used the Google Earth Engine platform to map urban tree canopy cover (2 meter scale) and summer temperatures in more than 6,000 U.S. cities and towns (home to 167 million people). We analyzed tree cover and summer temperatures by income and race/ethnicity. In 92% of the urbanized areas surveyed, low-income blocks (the poorest 25% of households in the urbanized area) have less tree cover than high-income blocks (the wealthiest 25% of households in the urbanized area). On average, low-income blocks have 15.2% less tree cover and are 2.7°F hotter than high-income blocks. We found the greatest temperature difference in the Northeast U.S. where low-income blocks average 30% less tree cover and are 7.2°F hotter. This difference in temperature is significant because intense urban heat waves put residents of these areas at risk for heat stroke, exhaustion and other health complications. Low-income and minority neighborhoods are more vulnerable to these risks because of the disparity in tree canopy cover. Such risks may be compounded by the socioeconomic challenges that come with living in poverty in the U.S. This study reveals that the inequality in tree cover in the U.S. is leading to an environmental health disparity that will grow more acute without a concerted effort to plant, maintain and care for trees in low-income and vulnerable communities.

▶ We extracted tree canopy with Google Earth Engine (a-b) and summarized at (c) census block level. We compared population weighted mean tree cover to (d) annual mean summer surface temperature summarized from 2009 to 2019, and (e) household income from U.S. census conducted in 2010. In 92% of the urbanized areas surveyed, low-income communities on average have 15.2% less tree cover and are 1.5°C hotter than high-income blocks in U.S. **Cartography:** Tanushree Biswas and Charlotte Stanley, California field office.




**Partners:** U.S. Forest Service Northern Research Station **Webapp:** nature.ly/2GEYKBg **Software:** Google Earth Engine; Esri ArcGIS; R Statistical Software; Statistical Analysis System (SAS) **Data Sources:** Aerial photos from the National Agriculture Imagery Program (NAIP) **Contact:** Robert McDonald (rob_mcdonald@tnc.org), Tanushree Biswas (tanushree.biswas@tnc.org)

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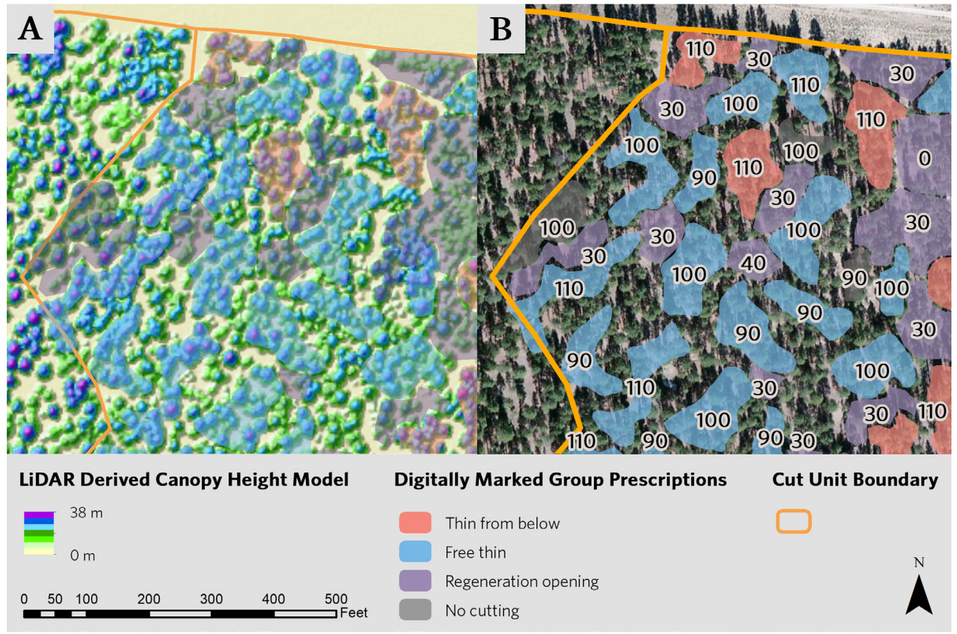
▲ Groundwork Dallas, nearby schools and TNC staff enter data about trees at Bachman Park.




▲ Map depicting a Designation by Prescription harvesting unit in an ecological forest restoration project for the Four Forest Restoration Initiative-Collaborative Forest Landscape Restoration Program: **A.** Prescriptions for individual groups and inter-space are digitally "marked" for harvesting operators. **B.** In-cab harvesting operator map translates spatial pattern of interspaces, prescriptions and basal area targets for individual groups. **Cartography:** Travis Woolley, Arizona Forest and Climate program

# Forest Restoration Goes Digital

Country: **The United States**

In 2017, The Nature Conservancy in Arizona initiated the Future Forest Project (FFP) by entering into a Master Stewardship Agreement with Region 3 of the USDA Forest Service (USFS). The focus of the FFP is to accelerate the pace and scale of forest restoration by developing advanced technology, forging partnerships and transforming USFS business practices. Applying digital prescriptions in lieu of the traditional method of painting trees for removal is a major innovation that applies advanced technology and changes business practices in ecologically based forest restoration in the Southwest. This innovative methodology allows USFS staff to use ArcGIS Online and Arc Collector applications on handheld tablets to digitally "mark" and create spatially complex forest structural prescriptions that can be used by harvesting operators. In this case, LiDAR-derived canopy height models were used to delineate forest features prior to field based marking.

The digitally mapped prescriptions can be accessed via harvester in-cab tablets and software that translate the spatial pattern of interspaces (area between groups where all trees are harvested except oaks and old-growth ponderosa pine trees), prescriptions (e.g., thin from below) and basal area (numbers inside marked groups) targets for individual treed groups. The process of mapping and displaying spatial prescription information is estimated to have saved the USFS approximately $750,000 from 2013 to 2018 by eliminating paint, increasing the efficiency at which acres are prepared and providing harvest operators an efficient means to meet desired ecological outcomes.

**Partners:** USDA Forest Service, Four Forest Restoration Initiative, Kaibab NF, Coconino NF, Campbell Global Forest and Natural Resource Investments **Website:** nature.ly/3dc86B3 **Software:** ArcGIS Online, ArcGIS Collector, R: A language and environment for statistical computing, ArcMap **Data Sources:** LiDAR(Quantum Spatial acquisition), aerial imagery(Esri), unit boundaries(USFS) **Contact:** Travis Woolley (twoolley@tnc.org), Jennylyn Redner (jennylyn.redner@tnc.org)



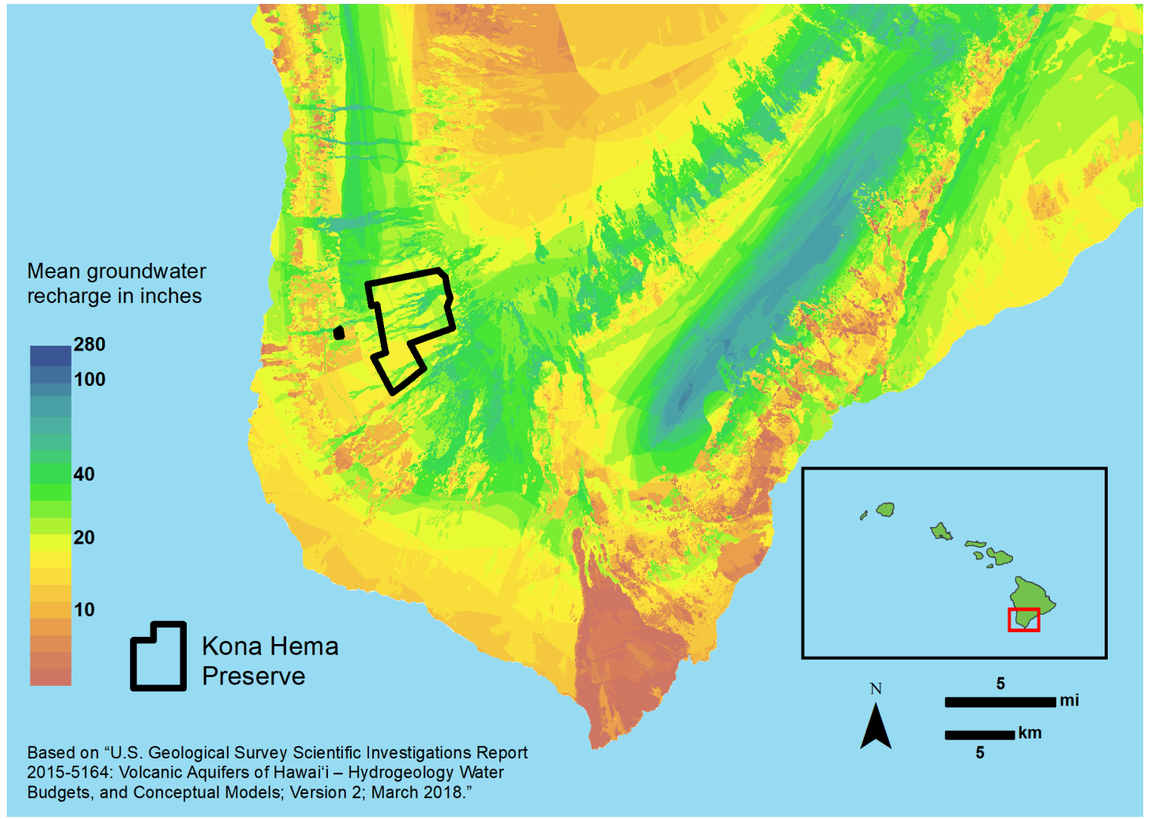


# Visualizing Carbon Sequestration and Water Security

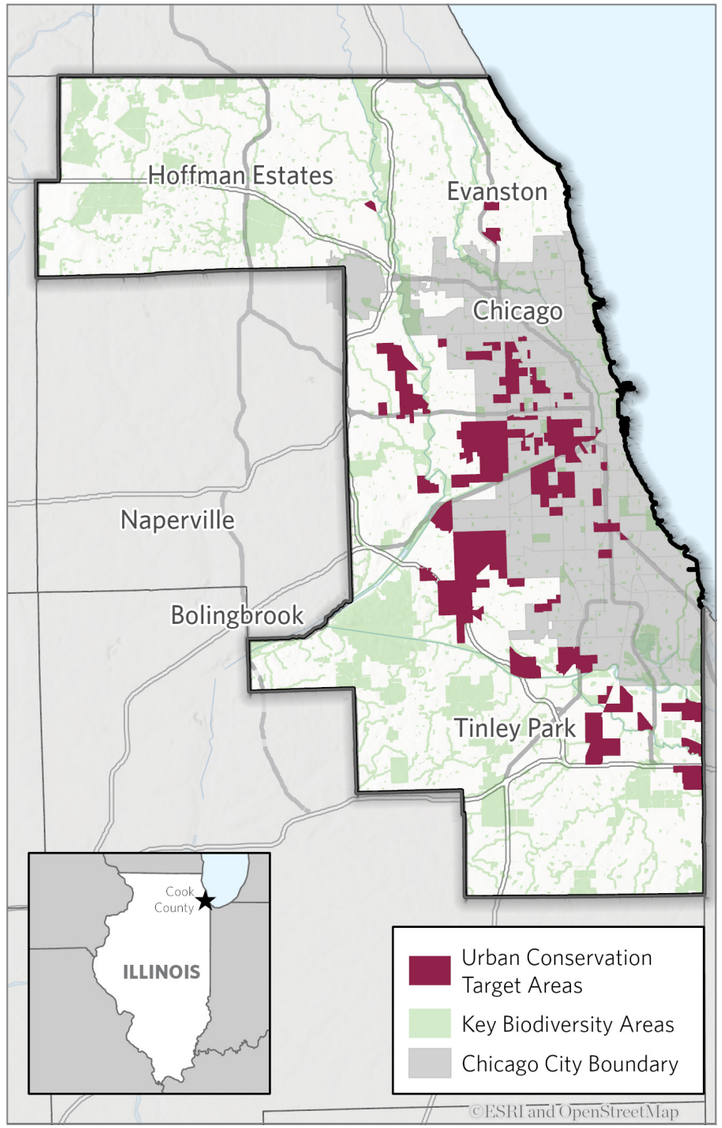
Country: **The United States**

**Partners:** Forest Stewardship Program, State of Hawai'i; Forest Legacy Program, US Forest Service; US Fish and Wildlife Service **Website:** https://arcg.is/0qq855 **Software:** ArcGIS 10.4, ArcGIS Online, ArcGIS StoryMaps, Google Earth Pro, YouTube **Data Sources:** Pictometry; Google Earth Pro; US Geological Survey Scientific Investigations Report 2015-5164; Statewide GIS Program, Office of Planning, State of Hawai'i; and aerial drones **Contact:** Theresa Menard (theresa_menard@tnc.org), Shalan Crysdale (scrysdale@tnc.org)

The Nature Conservancy owns the Kona Hema Preserve which is an 8,100 acre native Hawaiian koa-'ōhi'a forest in South Kona on the island of Hawai'i. We developed an Esri Story Map to share the beauty of the flora and fauna of the Preserve with interested nature-lovers, conservationists and donors. The Preserve was once trampled by grazing cattle and feral ungulates (e.g. pigs), however it was recently fenced to protect the understory and eliminate these threats. Aerial imagery shows the successful recovery of the understory which is now thick with native ferns and other native ground cover. Through the use of this interactive Story Map, we demonstrate a significant improvement in the health and biodiversity of the native koa-'ōhi'a forest. The Story Map gives viewers a unique opportunity to visualize the results of a GIS analysis that demonstrates the water recharge contributions of the Preserve to local aquifers. Our team plans to investigate and pilot a carbon sequestration project on the Kona Hema Preserve to demonstrate the feasibility of measuring and calculating carbon sequestration over time. TNC's long-term goal is to assist in the expansion of carbon projects across the state and generate revenue from the sale of carbon credits.




▲ The Nature Conservancy's Kona Hema Preserve comprises 8,100 acres on the island of Hawai'i and contributes 14.5 million gallons of water a day to local aquifers–enough to fill 22 Olympic sized swimming pools everyday. **Cartography:** Theresa Cabrera Menard, Hawai'i field office




▲ Highest risk areas showing the overlap between areas of high flood risk, poor air quality and high heat. The target areas are in Chicago and Cook County with higher vulnerability to these threats. **Cartography:** Sarah Hagen, Illinois field office

## Chicago and Cook County Urban Greenprint

Country: **The United States**

TNC in Illinois is using a technique called "urban greenprinting" to identify the Chicago neighborhoods most at risk for societal and environmental impacts from climate change. Most of the natural features that can provide cleaner air, relief from high summer heat and absorb and store stormwater have been lost across our cities, so there is no longer the natural resiliency that once existed. We calculated which Chicago and suburban neighborhoods are most at risk for increased flooding, increased summer temperatures and decreased air quality. We examined how ecological data paired with information on low-income areas and areas with high concentrations of children and older citizens. Doing this allowed us to identify areas that could most benefit from green infrastructure and other nature-based solutions, such as natural areas, rain gardens, bioswales and other options that help store and filter rainwater and keep it out of the sewer system. Re-imagining streetscapes, river banks and open lots may increase opportunities for people to connect with nature and help with the flooding that is increasing with climate change.

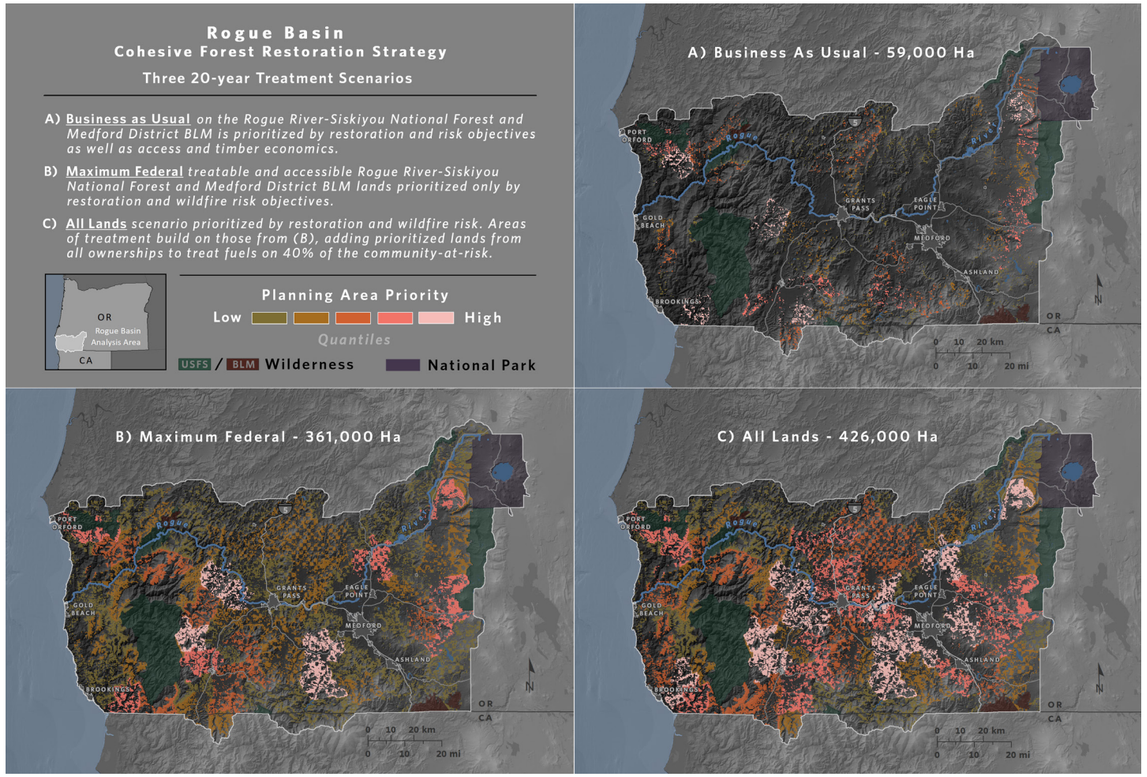
**Partners:** Chicago Metropolitan Agency for Planning and the Morton Arboretum. **Website:** nature.ly/33w1yJY **Software:** Esri ArcGIS **Data Sources:** US Census, Morton Arboretum, USGS LANDSAT, Chicago Metropolitan Agency for Planning, USEPA, IL Department of Transportation **Contact:** Sarah Hagen (shagen@tnc.org)

## Integrating Forest Restoration, Adaptation, and Proactive Fire Management

Country: **The United States**

Climate change and hyper-abundant fuels are driving increasingly frequent and uncharacteristically severe fires in natural and human communities. We developed a collaborative structured decision-making framework to facilitate the integration of fuels management, ecological forest thinning, prescribed fire and protections for species dependent on complex forest networks. This work quantified potential costs, reductions in wildfire risk and benefits to habitats in southwestern Oregon. We predicted management outputs with stand-scale modeled prescriptions. We mapped five landscape-scale objectives (**1.** local fire risk to communities, **2.** large wildfire risk to communities, **3.** landscape resilience, **4.** Northern Spotted Owl habitat recovery, and **5.** climate resilience) and used optimization software (Marxan) to prioritize treatment placement constrained by realistic access considerations and robust habitat protections. We compared three, 20-year scenarios which differed in their overall treatment footprint, land ownership addressed and prioritization among planning areas. The All-Lands scenario that treated 25% of the landscape performed best. Clear articulation of landscape objectives, a transparent economic assessment of contrasting scenarios and repeated collaborative involvement is leading to increasing co-investment on forest projects by multiple partners as they begin to implement the 20-year Rogue Basin Cohesive Forest Restoration Strategy.

**Partners:** Southern Oregon Forest Restoration Collaborative,Oregon State University, Medford District, Bureau of Land Management, USDA Forest Service,US Fish and Wildlife Service, Pyrologix LLC **Website:** nature.ly/2HRpdw8 **Software:** ArcMap 10.4, Marxan V 2.4.3, FSIM large fire simulator **Data Sources:** LANDFIRE 2010, LEEMA 2014, Haugo et al. 2015, Buttrick et al. 2015, Oregon Department of Forestry 2006 and 2013, USFWS 2013 **Contact:** Kerry Metlen (kmetlen@tnc.org), Aaron Jones (ajones@tnc.org), Michael Schindel (mschindel@tnc.org)



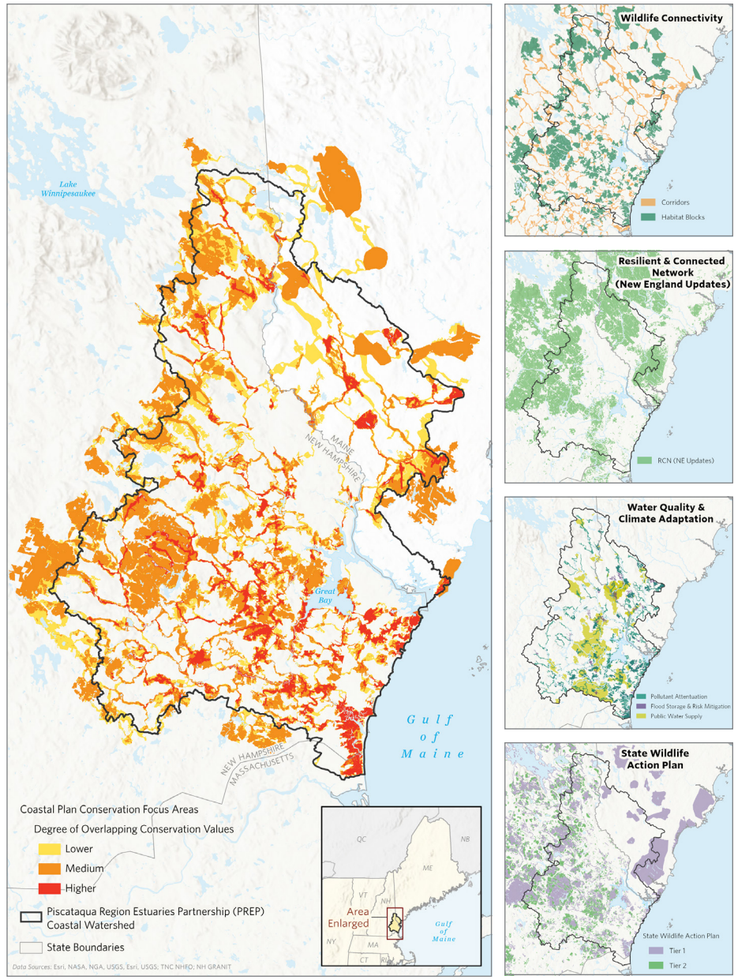

▲ Management scenarios for the Rogue Basin in southwestern Oregon showing priorities for ecological thinning and prescribed fire. Coloration represents potential treatment units symbolized by planning area priority. **Cartography:** Aaron Jones, New Mexico field office

# Protecting Resilient Lands and Freshwater with Climate Adaptation Opportunities

Country: **The United States**

TNC's Resilient and Connected Network (RCN) provides a framework for conservation practitioners to focus limited resources on strategic conservation projects in dynamic landscapes. The work presented below and on the following page demonstrate how the RCN can help prioritize landscapes in various regions at different scales while incorporating local knowledge and regional conservation goals to achieve meaningful impact.

TNC in New Hampshire and the Great Bay Resource Protection Partnership recently completed an update to the Land Conservation Plan for New Hampshire's Coastal Watersheds. The updated Plan incorporates metrics for climate adaptation, wildlife connectivity, climate resilience, and high-quality habitat areas and biodiversity. First developed in 2006, the Coastal Plan guided land protection priorities across the watershed with a focus on protecting intact natural systems and areas of irreplaceable biodiversity. To update the Plan, we incorporated the results of a recent conservation prioritization effort and used a weighted sum analysis to incorporate datasets representing ecological and climate priorities. The weighting scheme prioritized wildlife corridors and habitat blocks (i.e., networks of connected, ecologically significant lands), important water resources (areas for public water supply, flood risk reduction, and pollutant attenuation) and other critical habitat data from TNC's RCN and the state's Wildlife Action Plan. The resulting priorities cover 38% of the coastal watershed of New Hampshire, of which 32% is already conserved.




▲ This update to the Coastal Plan identifies key overlapping areas of conservation values in New Hampshire's coastal watershed. **Cartography:** Anna Ormiston, New Hampshire field office

We extended the prioritization outside the watershed to identify wildlife connectivity and habitat protection opportunities that intersected with adjacent conservation planning regions. This work supports a resilient and connected network for land and water and identifies nature-based, climate adaptation opportunities.

**Data Sources:** TNC, New Hampshire Fish and Game **Website:** nature.ly/2GuA2Uu **Software:** ArcGIS Pro **Partners:** Great Bay Estuarine Research Reserve, New Hampshire Fish and Game, Society for the Protection of New Hampshire Forests, and the Southeast Land Trust. **Contact:** Anna Ormiston (anna.ormiston@tnc.org)





# Resilient Management Action Mapping

Country: **The United States**

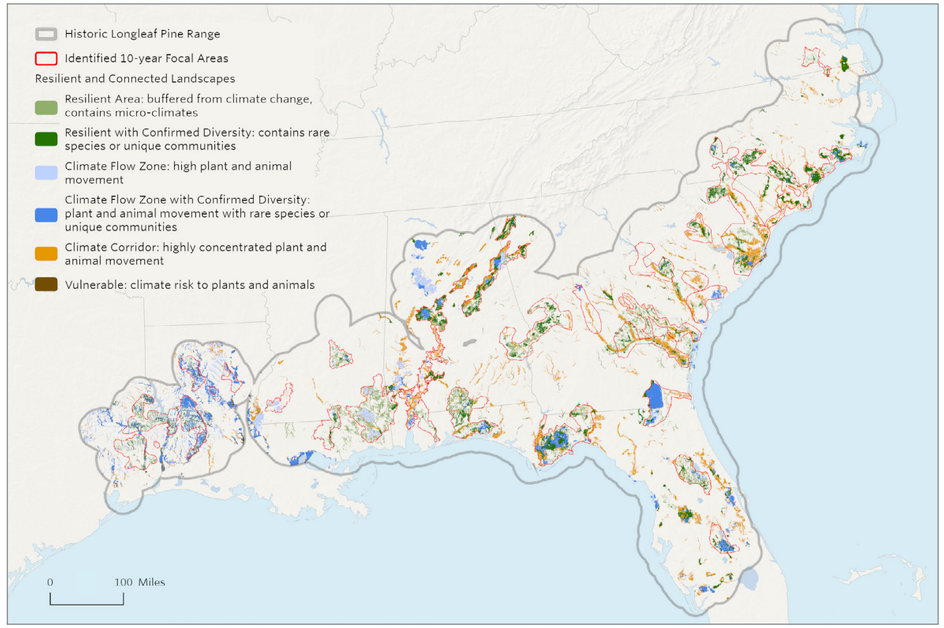
Over four million acres of endangered, longleaf forest types remain in the continental U.S. Longleaf forests have historically occupied over 92 million acres spanning the southern border of Virginia to eastern Texas, making it one of the most endangered ecosystems in North America. The diversity of unique plants and animals found in longleaf forests is nearly unmatched anywhere outside of the tropics. However, this fire-sustained landscape is at risk from conversion to agriculture and vulnerable to climate disturbances and habitat fragmentation.

Guided by the Conservancy's "Conserving Resilient Lands and Water" strategy, nine states across the Southern Division partnered with the Eastern Conservation Science team to adapt the organization's Resilient and Connected Network blueprint. This is the first study to comprehensively map resilient lands and significant climate corridors across Eastern North America with on-the-ground expert knowledge to more effectively identify longleaf pine priority conservation areas.

From that refined asset map, our team produced a Conserving Resilient Lands and Waters action map with 10-year focal areas where partners can collaborate on strategic land protection decisions. This will accomplish resilient land management objectives at a meaningful scale and identify the best areas for range-wide longleaf pine forest conservation that will yield the highest asset value return through land protection, management, policy and partner influence.

Within these focal areas we identified priority projects with a 5-year timeframe. Projects will emphasize increasing the amount of permanently protected longleaf pine, maintaining existing working forests, restorating forests that have been impacted (natural or human), planting new longleaf pine and regularly burning the most critical longleaf pine landscapes. These actions will support the larger 10-year vision for preserving and restoring longleaf pine within the historical range of this endangered species.

**Partners:** Southern Division (South Carolina, North Carolina, Georgia, Alabama, Louisiana, Texas, Virginia, Florida, and Mississippi), Eastern Conservation Science **Website:** nature.ly/2GuA2Uu **Software:** Esri ArcGIS, R **Data Sources:** TNC, NLCD (2011), HPMS (2015-2016), TIGER/Line (2017), US Census (2017) **Contact:** Colette DeGarady (colette.degarady@tnc.org)



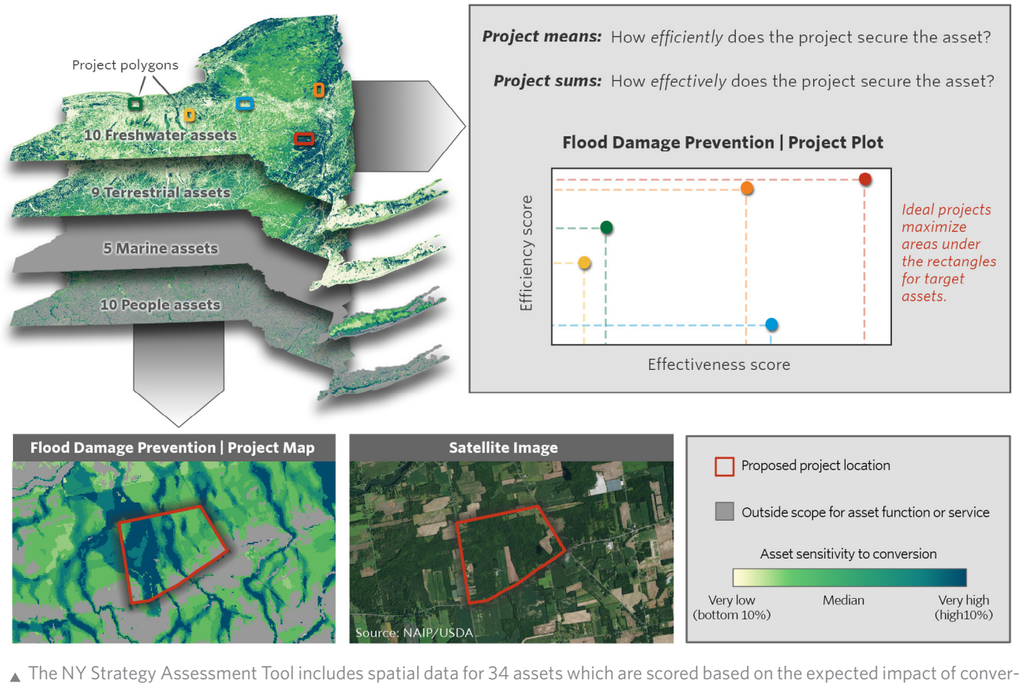

◀ The most vital longleaf pine focal areas are identified for conservation; core teams are selecting priority projects to be completed within 3-5 years to sustain a network of resilient sites and connected corridors that support LLPWS natural diversity. **Cartography:** Melissa Strickland, South Carolina field office

# Strategy Assessment Tool to Streamline Conservation Efforts

Country: **The United States**

The Strategy Assessment Tool (SAT) is a comprehensive, data-rich analytical tool that uses spatial data to assess, compare and evaluate high-impact conservation projects in New York State. The SAT includes spatial data on 34 scored conservations assets (features, functions and services) and a GIS-based tool for querying and summarizing those assets by project area. The SAT Query Tool helps users understand how well project areas can secure conservation assets when evaluating stand-alone opportunities, ranking and prioritizing across multiple areas and/or calculating Return on Investment (ROI) for different scenarios. The SAT also provides information on degree of conversion threat, human benefits and potential impacts on vulnerable communities. These metrics can be combined with opportunity and feasibility data to support spatial action mapping. This information allows us to evaluate tradeoffs and compare projects such as source water protection, carbon mitigation, forest management practices and resilient landscape conservation. We use the SAT for project screening of candidate properties for the NY Division Plan for Conserving Resilient Lands. By making comprehensive data readily accessible to practitioners, the SAT improves the efficiency of conservation decisions and provides a statewide perspective on conservation projects and opportunities.

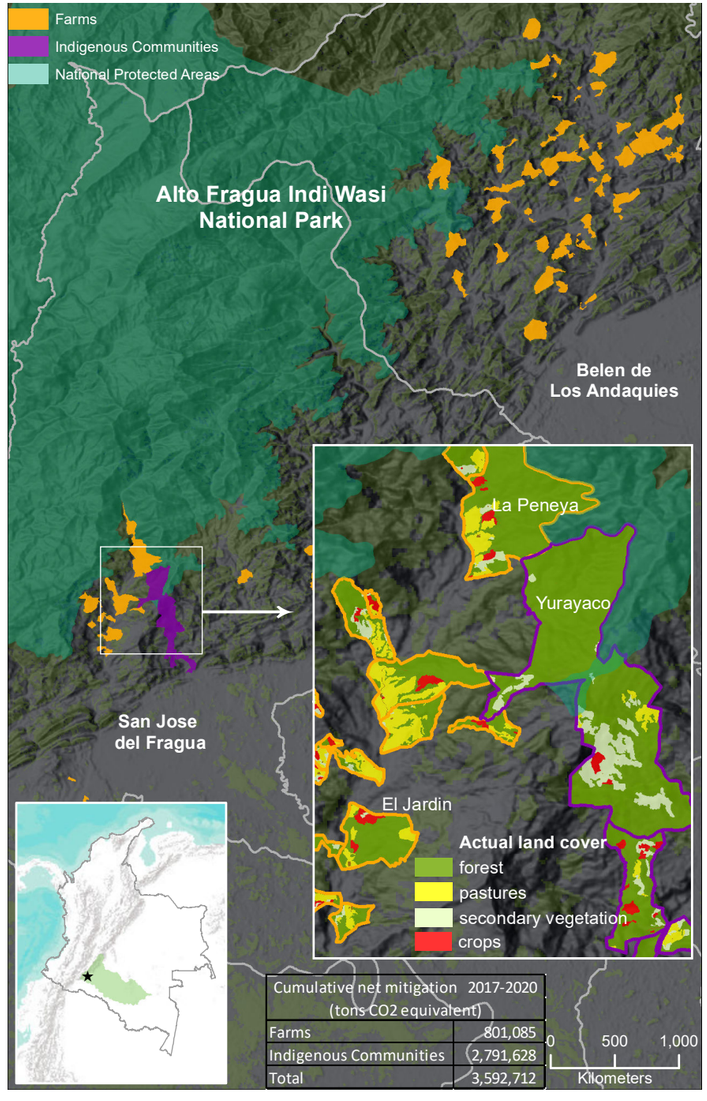
**Data Sources:** Adirondack Park Agency, Canadian Council on Ecological Areas, Esri/TomTom North America Inc., FEMA, Michigan Tech Research Institute, MRLC Consortium, NOAA, NYNHP, NYS DEC, NYS DOH, NYS DOS, NYSERDA, NYS GPO, NYS OPRHP, TNC, Network for Sustainable Climate Risk Management, USEPA, USFWS, US Census Bureau, USDA, USGS, United Way, University of Bristol, Woods Hole Research Center
**Software:** ArcMap 10.3; theSAT Query Tool is an Arc Toolbox coded in Python 2.7
**Contact:** Rebecca Shirer (rshirer@tnc.org)




▲ The NY Strategy Assessment Tool includes spatial data for 34 assets which are scored based on the expected impact of conversion (top left). A GIS toolbox evaluates how efficiently and effectively proposed projects secure assets (top right) and project maps facilitate the design and implementation of conservation actions (bottom). **Cartography:** Shannon Thol, New York field office








▲ The Caqueta Department is part of the Agroforestry for Conservation Project in the Colombia Amazon where farmers and Indigenous communities participate in land planning and conservation agreements. **Cartography:** Deissy Arango, Colombia program

**Data Sources:** Hydrology, Meteorology and Environmental Studies Institute, Agustín Codazzi Geographical Institute, Alexander von Humboldt Biological Resources Research Institute, Amazonian Institute of Scientific Research, National Natural Parks of Colombia, Maxar World view 02, World view 03, GeoEye-1 **Partners:** Amazon Conservation Team (ACT), German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Amazonian Institute of Scientific Research SINCHI(SINCHI), Ministry of Environment and Sustainable Development (MINAMBIENTE) **Websites:** maps.tnc.org/nasca-dashboard, maps.tnc.org/nasca-viewer/visor.html **Software:** ArcGIS 10.3, ArcGIS 10.4, ArcGIS Pro, ArcGis, QGIS, GeoODK, Avenza Maps Pro, AWS s3, R **Contacts:** Deissy Arango (deissy.arango@tnc.org), Maria Ordonez (maria.ordonez@tnc.org)

# Agroforestry for Conservation

Country: **Colombia**

In 2019 the Caqueta Department of the Amazon region in Colombia lost over 98,000 hectares of forest mainly due to land grabbing for mining and livestock grazing. To reduce deforestation in this region, TNC and the Amazon Conservation Team (ACT) designed and promoted a project called Agroforestry for Conservation. This project seeks to improve the quality of life for farmers and indigenous communities while focusing on forest conservation and climate change mitigation, specifically in the municipalities of San José del Fragua, Belen de los Andaquies, Cartagena del Chaira, Solano, and Solita. Our partnership includes work with 120 farmers and five indigenous communities across 12,227 ha where we have supported sustainable practices such as agroforestry and silvopastoral practices on 1,148 ha, forest conservation on 7,308 ha and farmland restoration on 1,250 ha. To visualize this, we conducted a spatial analysis so stakeholders could recognize the condition of their land and understand the implications of avoided $CO_2$ emissions when these sustainable practices are adopted.

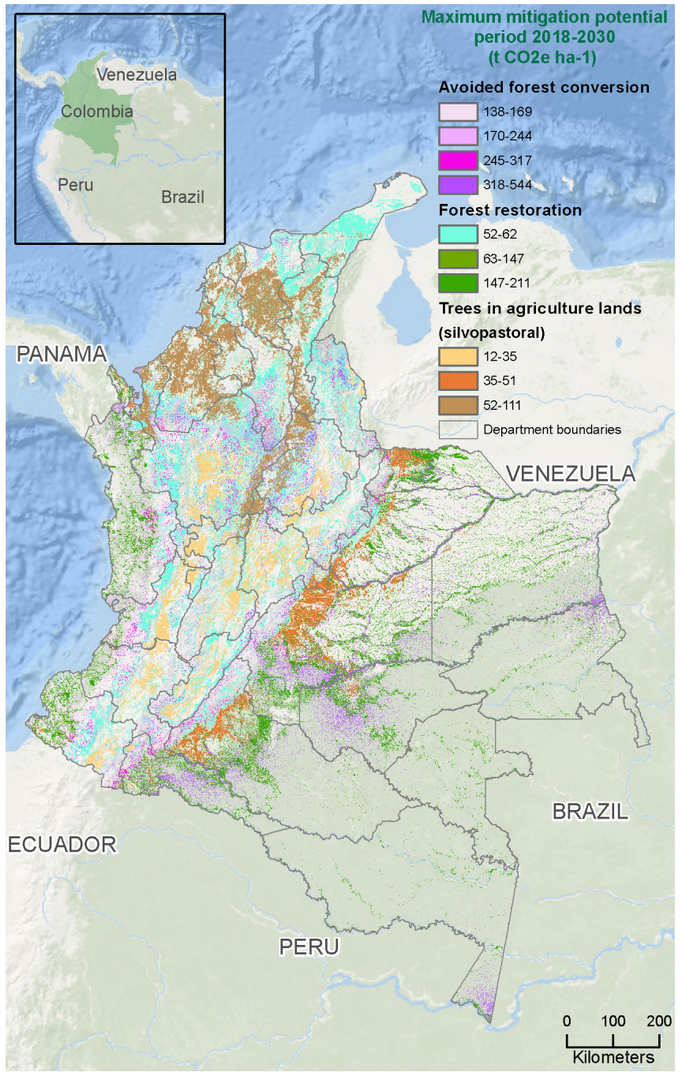
This analysis identifies areas where sustainable farming practices can lead to avoided carbon emissions and where mitigation actions through carbon sequestration can be achieved. Initially, we conducted monitoring with tablets, satellite images, interviews, and camera traps to identify species, carbon field sampling and spatial analysis. We have now trained community members so they can conduct their own monitoring. We established community agreements to begin sustainable farm planning, including the establishment of conservation, restoration and production areas. This includes monitoring land cover types, carbon stocks and biodiversity metrics to demonstrate how rural economies can be productive, profitable and leaders in the field of resource conservation and avoided carbon emissions.

# Mapping Natural Climate Solutions

Country: **Colombia**

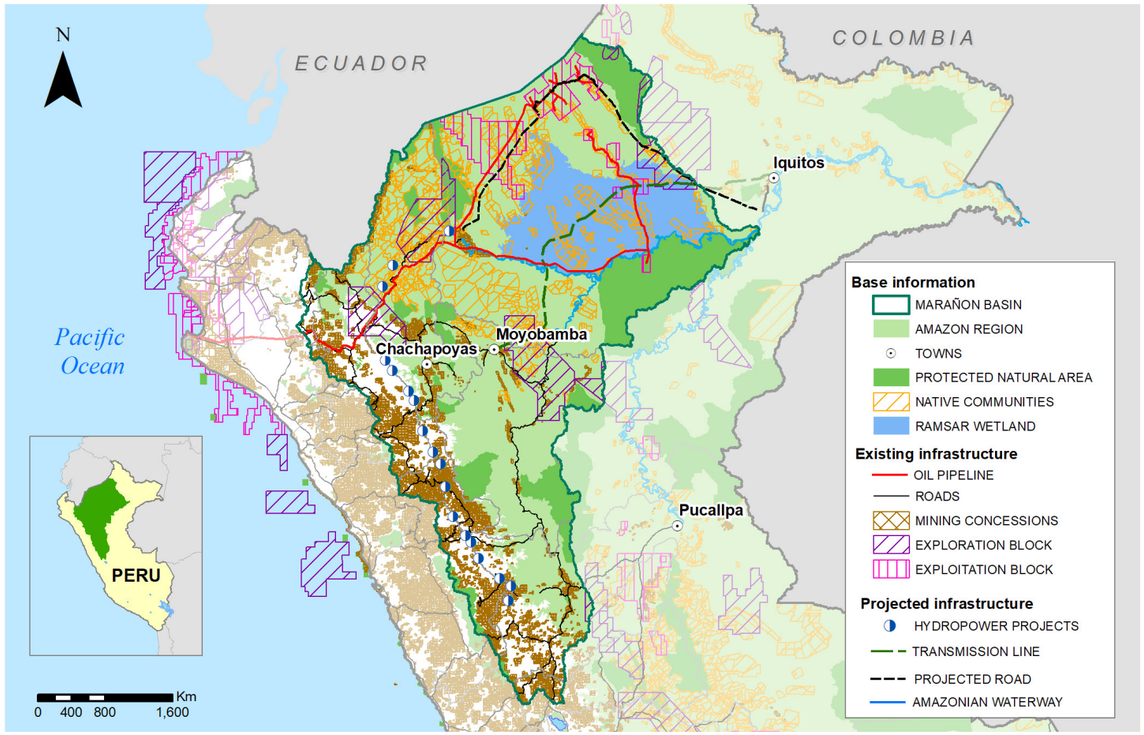
In Colombia, 62% of total greenhouse gas (GHG) emissions originate from the agriculture, forestry and other land uses (AFOLU) sector. The majority of GHG emissions come from deforestation (36%) and conventional cattle ranching (26%). In partnership with the Norwegian Agency for Development Cooperation (NORAD), TNC is implementing the "Unlocking Natural Climate Solutions to Implement the Paris Agreement" project in Colombia. Natural Climate Solutions (NCS; here referred to as climate solutions) are actions on conservation, restoration and/or improved land management that increase carbon storage and/or avoid greenhouse gas emissions. Nationally Determined Contributions (NDCs; here referred to as climate commitments) are the country's commitments of the Paris Agreement. The goal is for stakeholders to integrate better and broader climate solutions data to inform and direct Colombia's climate commitments. We ranked all possible climate solution pathways and identified three priorities: **1.** avoided forest conversion, **2.** forest restoration and **3.** trees in agriculture lands (silvopastoral).

We identified the maximum mitigation potential of each climate solution for the period 2018–2030 by using region-specific emission/removal factors. By 2030, the maximum mitigation potential for these climate solution pathways are: **1.** avoided forest conversion, thereby avoiding the emittance of 0.10 gigatons of $CO_2$ equivalent per year (gt $CO_2e$ yr-1, over an area of 2.9 million hectares (Mha); **2.** forest restoration, which avoids the release of 0.12 gt $CO_2e$ yr-1 over an area of 15.1 ha; and **3.** planting trees in agricultural lands (silvopastoral systems), that will absorb 0.08 gt $CO_2e$ yr-1 over an area of 10.7 Mha. We shared our findings with the government and neighboring countries with similar goals. These results demonstrate the potential of climate solutions to effectively mitigate and potentially slow climate change impacts.




▲ Maximum potential of mitigation for three Natural Climate Solutions (NCS) in Colombia from 2018 to 2030. This map integrates useful information pertaining to the climate commitments of the Paris Agreement. **Cartography:** Deissy Arango, Colombia program

**Partners:** Norwegian Agency for Development Cooperation (NORAD) **Website:** nature.ly/3nizDVV **Software:** ArcGIS 10.3, ArcGIS Pro, R **Data Sources:** Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM), Agustín Codazzi Geographical Institute (IGAC), Alexander von Humboldt Biological Resources Research Institute (IAvH), Rural Agricultural Planning Unit (UPRA), Ministry of Environment and Sustainable Development of Colombia MINAMBIENTE, WorldClim, TNC **Contact:** Deissy Arango (deissy.arango@tnc.org), Diego Navarrette (diego.navarrete@tnc.org), Juanita Gonzalez (juanita_gonzalez@tnc.org)




▲ Existing and projected infrastructure in the Maranon River Basin in the northern Peruvian Amazon. **Cartography:** Christian Contreras Otiniano, Peru program

# Territorial Planning

Country: **Peru**

Billions of dollars are spent each year on large-scale infrastructure development in the Amazon. This influx of money and infrastructure are transforming the Amazon as we know it. With support of the Gordon and Betty Moore Foundation, TNC in Peru conducted a territorial planning assessment within the Marañon Basin, with an emphasis on the Amazon region of Loreto to understand how the country could improve infrastructure decision-making while maintaining the ecological integrity of the region. Recently, infrastructure projects in this basin have increased and more are projected for the future including the construction of roads, hydropower plants, transmission lines and the expansion of oil exploitation. We conducted stakeholder interviews and workshops in Lima and Iquitos and analyzed national and subnational territorial planning instruments. We evaluated existing land use plans, strategic environmental assessments, development plans created by the Regional Government of Loreto and Indigenous peoples planning initiatives. We identified critical gaps, including non-binding planning mechanisms, poor coordination across governmental planning instruments, lack of implementation and budget discrepancies. We found that planning could be strengthened by including socio-economic, cultural and environmental priorities in the decision framework for sustainable development, land-use, natural resource management and conservation. By improving the sustainability criteria used for the National Investment System and the participatory budget processes, we can establish incentives for developers to voluntarily consider territorial planning in their project design. Territorial plans may improve infrastructure development by guiding decision-making to support multiple objectives while addressing environmental risks and human impacts.

**Data Sources:** INEI, ANA, IBC, MINEM, Perupetro, SERNANP, MTC, Projected roads: MTC, MINAM **Website:** nature.ly/2GidfeN **Software:** ArcGIS Desktop 10.2 **Contact:** Christian Contreras (christian.contreras@tnc.org), Luis Davalos (ldavalos@tnc.org)

▲ An aerial view of Colun Beach in the Valdivian Coastal Reserve, Los Rios, Chile.

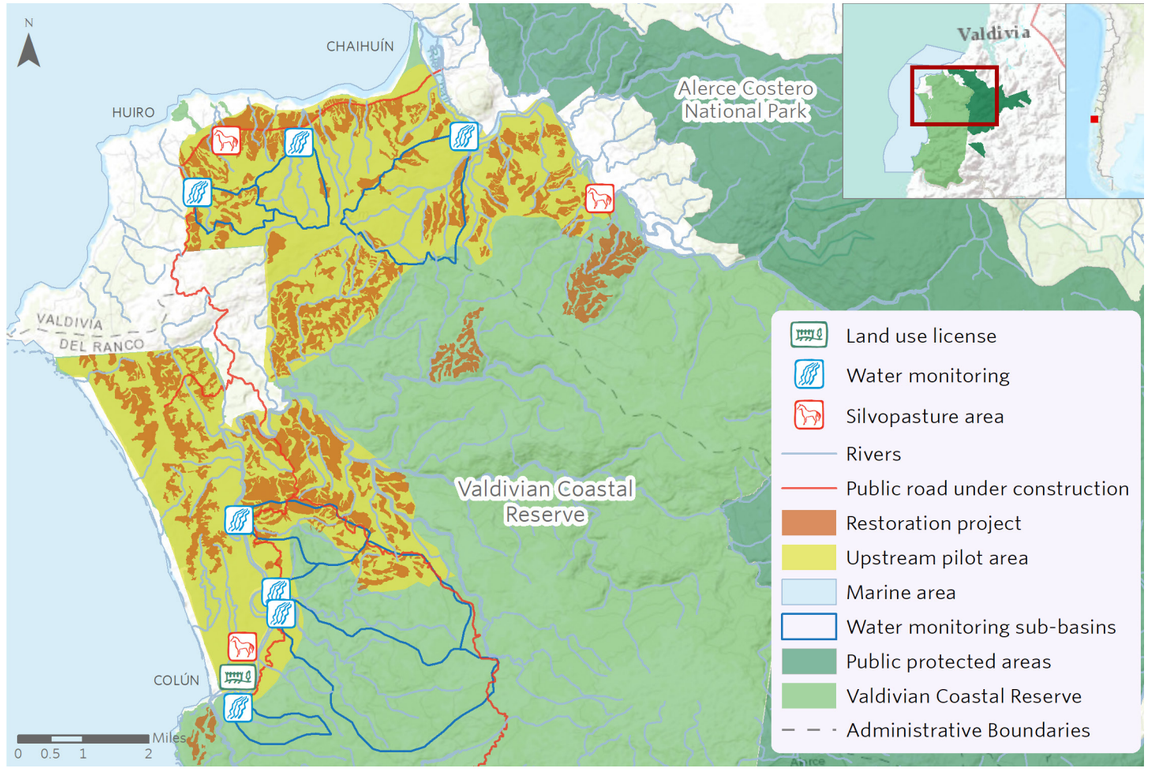
# Remotely Monitoring the Valdivian Coastal Reserve

Country: **Chile**

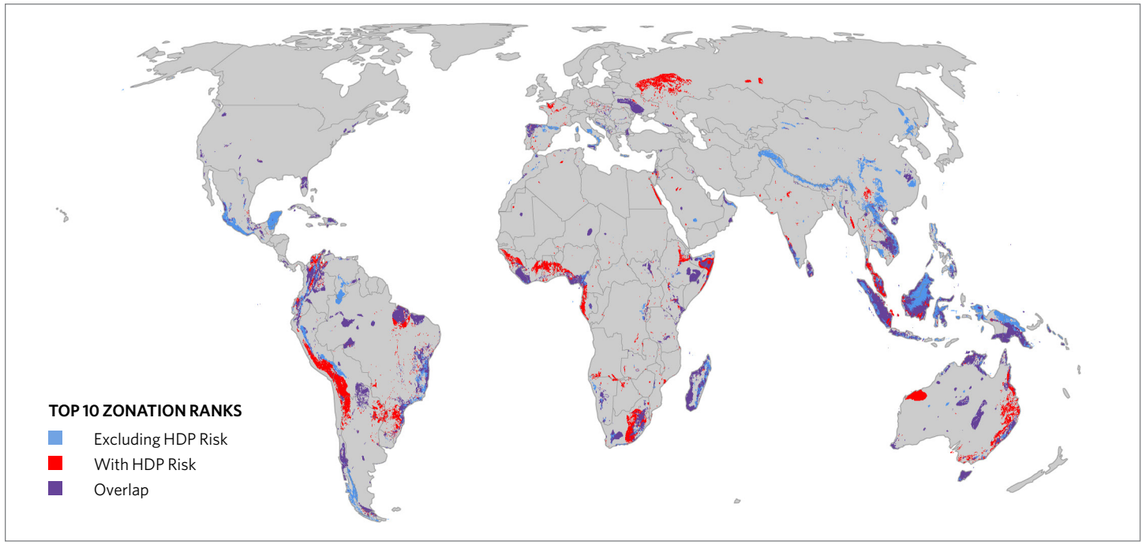
**Partners:** Upstream, FORECOS Foundation, National Forestry Service (CONAF)
**Data Sources:** Esri, Ministerio de Obras Publicas 2018, Corporación Nacional Forestal (CONAF) 2014, Valdivian Coastal Reserve Team and TNC Chile 2020
**Website:** nature.ly/34uC3bi **Software:** Upstream Tech Lens™, Esri ArcGIS
**Contact:** Mercedes Ibáñez (mibanez@tnc.org), Liliana Pezoa(lpezoa@tnc.org), Francisco Torres (francisco.torres@tnc.org)

The 124,000-acre Valdivian Coastal Reserve (VCR) overlooks southern Chile's Pacific coastline and is part of an ancient temperate rainforest that serves as a refuge for many endemic species. More than half of the world's temperate rainforests have been lost making the Reserve one of the largest remaining temperate rainforests on Earth. The Conservancy acquired the Valdivian Coastal Reserve in 2003, protecting it from conversion to commercial eucalyptus plantations and halting the planned construction of a coastal highway. More than 7,500 acres of evergreen forest were replaced by eucalyptus plantations before the creation of the Reserve, but these plantations are now being actively removed as part of a plan to restore the native forest. In partnership with Upstream Tech, we are working to improve remote property monitoring at the VCR. The Upstream TechLens™ remote property monitoring app is enabling the use of commercial satellite imagery to increase the efficiency and effectiveness of land monitoring and stewardship over time. Additionally, we found that remote monitoring offers a synoptic perspective of this unique landscape. For example, it has provided new insights regarding changes to the landscape, facilitating the detection of easement violations not visible during in-person monitoring as well as encroaching issues from adjacent properties. This has allowed us to mitigate safety issues on hazardous or hard to reach properties. TNC actively engages with the local community by monitoring compliance with conservation easements that are delivered to the State of Chile and other entities and individuals, generating early warnings and documenting evidence of impacts from the construction of bridges, roads and areas of public use, as well as monitoring the regeneration of native forests in the restoration project. The partnership with Upstream Tech has facilitated a comprehensive monitoring and conservation effort to protect and preserve this unique temperate rainforest. TNC's work in the Valdivian Coastal Reserve is pioneering conservation in Chile with initiatives to bring back native forests, leverage carbon credits for avoided deforestation and collaborate with partners for field research on local endangered species.

▲ **Image comparison:** The images compare a site planted with eucalyptus in 1992. These exotic trees were removed by TNC in 2012, replacing them with native "coihue de magallanes" forest (1,000 plants per hectare). The top Maxar image (0.5 m) was taken in 2016 and demonstrates how restoration was impaired due to the influx of animals that ate and trampled the new vegetation. The bottom Airbus image (0.5 m) from 2019 illustrates where the Conservancy is trying to restore the area and adopt silvicultural practices to promote native forest regeneration.




▲ The Valdivian Coastal Reserve is participating in an Upstream Tech pilot project to identify land use changes associated with the construction of a public road and track forest restoration where eucalyptus is being replaced with native tree species. **Cartography:** Mercedes Ibanez, Chile program




▲ Last chance places for threatened mammals depicting the top 10% most important places for maintaining species persistence based on two separate Zonation prioritization analyses. Areas in red are top places when future High Development Pressure (HDP) is included, blue areas are places when HDP is not considered and areas in purple represent the overlap between the two. **Cartography:** Nicolas Wolff, Global Science program

# Last Chance Geographies for Mammals

**Global**

Terrestrial mammals are one of the most imperiled groups of species on the planet. The biggest threat to them is habitat loss through land conversion. Risk of terrestrial mammal species loss is also a good indicator of the status of other biodiversity metrics as it signals where the conservation movement must redouble its efforts. For most mammal species, their global distribution is composed of multiple populations that often function independently. Therefore, the risk of a population going extinct depends on both the effective size of the population and the life-history characteristics of the species. The weak relationship between the portion of a species range that is protected and extinction risk is well-recognized as a challenge for global conservation planning. Here we tackle this challenge by linking population level range maps with life-history characteristics of threatened (vulnerable, endangered, critically endangered) mammal species to determine habitat extent and the probability of extirpation relationships for each independent population. These layers and relationships are then integrated with a global optimization using the software Zonation to quantify where habitat loss would result in the greatest change in extinction risk. Results demonstrate that species richness is a poor proxy for identifying priority areas for maintaining species persistence. There are many areas that are important for avoiding extinction that have relatively low species richness, such as portions of Europe, western Mexico and Patagonia. The inclusion of future conversion risk within Zonation identifies additional important areas for protection, such as western Russia and western Africa.

**Partners:** Heini Kujala (University of Helsinki), Piero Visconti (University College London), Luca Santini (Radboud University), Jelle Hilbers (Radboud University) **Website:** nature.ly/34uDBSV **Software:** Zonation (run using MS Azure, Linux based platform), ArcGIS Pro 2.4.3, Matlab R 2018 **Data Sources:** Mammal population maps (Luca Santini) **Contact:** Nicolas Wolff (nicholas.wolff@tnc.org), Edward Game (TNC), James Oakleaf (TNC), Christina Kennedy (TNC), Joseph Kiesecker (TNC), Joseph Fargione (TNC), Hugh Possingham (TNC)





# Prioritizing Conservation in the Anthropocene

The Anthropocene defines the most recent geologic time in which human activity has been the dominant influence on climate and environmental processes. These activities and their increasing impacts include sustained industrial development, agricultural expansion, urbanization, energy and mining extraction and infrastructure growth. Finding the balance between conserving the Earth's natural systems and meeting the increasing needs of its nearly 7 billion people is one of the greatest challenges of our century. To effectively meet this challenge, we must fully understand the current condition of the world's landscapes and navigate toward conservation strategies with a clear picture of the threats that lie ahead.

To this end, scientists at the Conservancy and partners produced up-to-date, comprehensive, global conservation asset and threat maps that provide a rich spatial context for describing conservation priorities and anthropogenic impacts worldwide. These maps provide an important snapshot of the status of the world's terrestrial ecosystems and help identify last chance opportunities for global biodiversity protection. Perhaps most importantly, they identify at-risk natural areas that, if protected, could be critical for ecosystem conservation and provide safeguards from future development. Ultimately, these maps should be coupled with thorough return on investment calculations, including analyses of opportunities, costs, cultural values, social norms, political will and policies, as well as potential threats from climate change. As a collection, we hope these maps serve as a powerful guide for decision-making and strategic action in advancing global conservation.

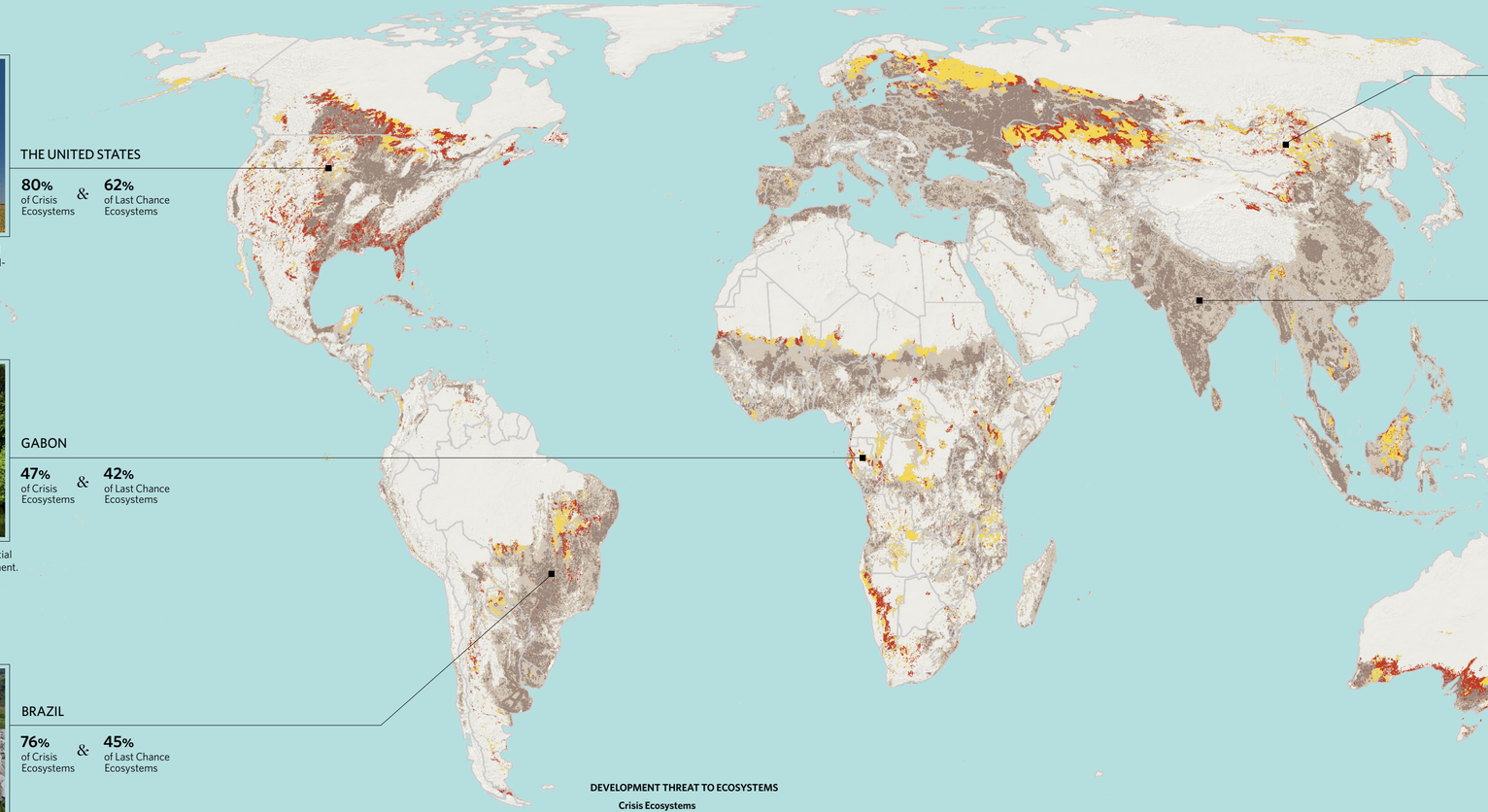
**Photo:** Sunset on a ranch near the Verde River, Arizona.

# Last Chance and Crisis Ecosystems Under Future High Development Pressure

Energy sprawl is the largest driver of land use change in the United States, and TNC is offering science and tools to help site new development to avoid lands with high conservation values.
© Richard Hamilton Smith

TNC is leveraging its expertise in freshwater conservation and spatial planning to guide lower-impact sustainable hydropower development.
© Roshni Lodhia

Agriculture is a key threat to Brazil's natural systems. TNC is working with partners to implement zero deforestation practices and commitments. © Christian Rodriguez/Prime Collective



## THE UNITED STATES

**80%** of Crisis Ecosystems & **62%** of Last Chance Ecosystems

## GABON

**47%** of Crisis Ecosystems & **42%** of Last Chance Ecosystems

## BRAZIL

**76%** of Crisis Ecosystems & **45%** of Last Chance Ecosystems

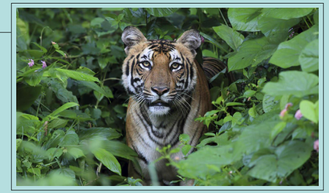
## MONGOLIA

**55%** of Crisis Ecosystems & **33%** of Last Chance Ecosystems

To ensure that Mongolia's landscapes remain intact, TNC has developed regional conservation plans to guide protection of natural lands from the impacts of mining and other infrastructure.
©Joseph Kiesecker

## INDIA

**54%** of Crisis Ecosystems & **7%** of Last Chance Ecosystems



With a national policy to conserve a third of native forest cover, TNC is advancing development plans to meet the needs of people and reach climate goals. © Chethan Ramesh/TNC Photo Contest 2019

## AUSTRALIA

**90%** of Crisis Ecosystems & **72%** of Last Chance Ecosystems

TNC is working with Indigenous peoples, landholders and governments to protect and manage internationally-significant wetlands, woodlands and other important ecosystems. © Annette Ruzicka

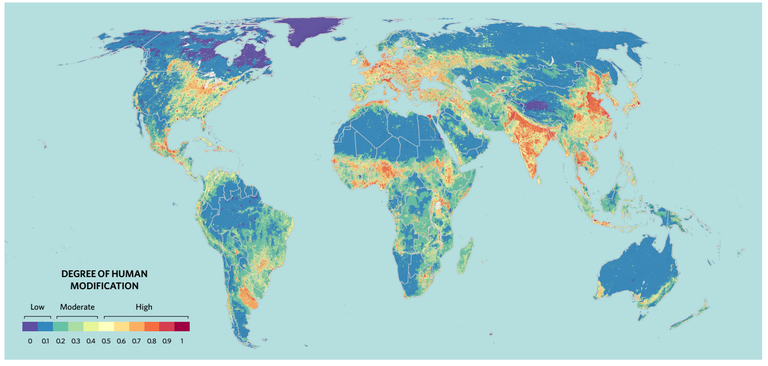
**DEVELOPMENT THREAT TO ECOSYSTEMS**

**Crisis Ecosystems**
- Under High Development Pressure
- Lacking High Development Pressure

**Last Chance Ecosystems**
- Under High Development Pressure
- Lacking High Development Pressure

**34%** OF CRISIS ECOSYSTEMS & **65%** OF LAST CHANCE ECOSYSTEMS ARE UNDER HIGH PRESSURE FROM FUTURE DEVELOPMENT

**Crisis Ecosystems** and **Last Chance Ecosystems** are vulnerable to future development pressure. Crisis Ecosystems are places that have lost most of their original habitat and are poorly protected. Last Chance Ecosystems are 9.8% of areas within Crisis Ecosystems that still have the opportunity to be protected as these are natural lands that are relatively undisturbed or only lightly modified by humans. High development pressure areas are highly suitable lands for development expansion by commodity-based sectors due to the presence of large quantities of unexploited resources and infrastructure to support their extraction or transportation. See backside for information on individual maps.

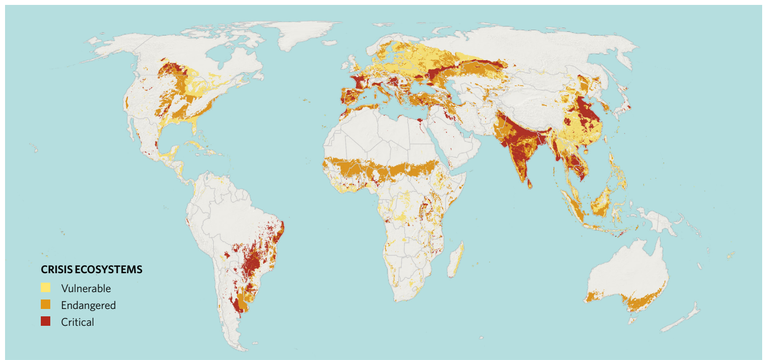



## Current Human Modification of Terrestrial Lands

**Global Human Modification (HM)** map represents current land condition based on the spatial extent and magnitude of human impacts on the world's terrestrial landscapes (not including Antarctica). HM ranges from 0 (no modification) to 1 (fully modified) and reflects the proportion modified by existing human settlement, agriculture, transportation, mining, energy production and electrical infrastructure. This map reveals that 49% of lands are under low modification (no more than 10% modified), 34% are moderately modified (over 10-40% modified), and 17% are highly modified (more than 40% modified) by human activities.

For more information: Kennedy et al. 2019 (nature.ly/320b8nB)

**84%**
OF THE EARTH'S LAND SURFACE IS EXPERIENCING MULTIPLE HUMAN IMPACTS

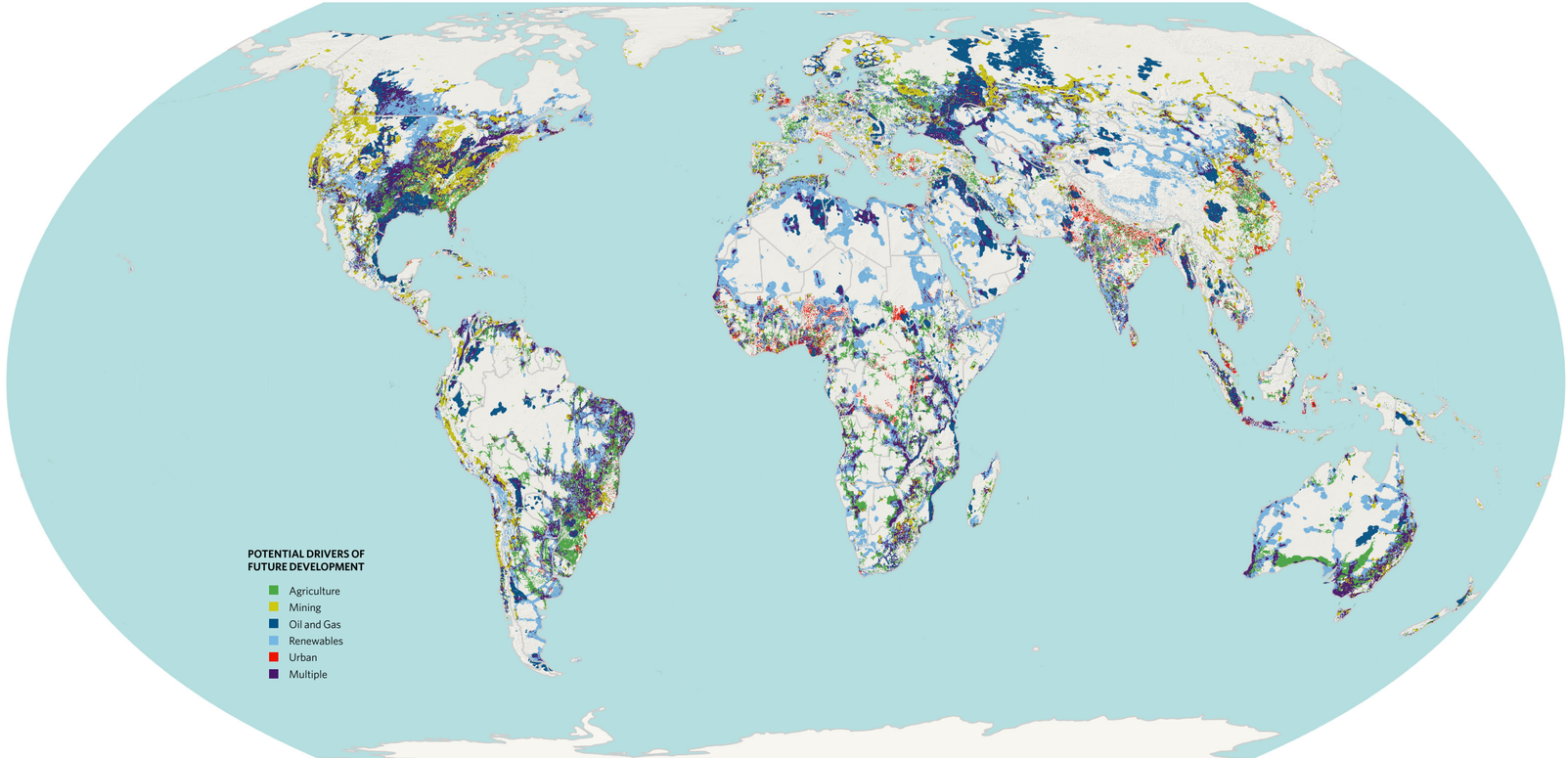



## Current Crisis Ecosystems

**Crisis Ecosystems** represent 26% of the Earth's surface where much of the original habitat has been converted by humans, and the remaining habitat remains poorly protected. There are three levels of threat in crisis ecosystems: Vulnerable (less than 30% protected and more than 30% converted), Endangered (less than 17% protected and more than 50% converted), and Critical (with less than 17% protected and more than 80% converted).

For more information: Sayre et al. 2020. (nature.ly/3kBDKuE)

**24%**
OF THE WORLD'S ECOSYSTEMS ARE IN CRISIS




## Future High Development Pressures

**Global High Development Pressure (HDP)** identifies lands that are highly suitable for development expansion by commodity-based sectors due to the presence of large quantities of unexploited resources and infrastructure that supports extraction and transport of those resources. Derived from 14 development potential indexes, the HDP map reveals that 35% of high pressure areas are associated with renewables (photovoltaic solar, concentrated solar, wind, hydropower), 17% with agriculture (crop and biofuels expansion), 13% with oil and gas (conventional and unconventional), 12% with mining (metallic, non-metallic, coal), 2% with urbanization, or 21% with some combination of these different sectors.

For more information: Oakleaf et al. 2019. (nature.ly/31GjfFG)

**37%**
OF EARTH'S TERRESTRIAL SURFACE HAS HIGH DEVELOPMENT PRESSURE

"Two and a half years ago we took our first step in using the power of the cloud — data, compute, services and applications — to accelerate a more environmentally sustainable future by launching Microsoft's AI for Earth program. We put artificial intelligence technology in the hands of TNC's leading ecologists and conservation practitioners and began a partnership that supports our goal of protecting more land than we use by 2025. We are thrilled to be a part of The Nature Conservancy's geospatial innovations that support healthy lands, water and oceans, climate mitigation and resilience."

Dan Morris
*Lead for AI for Earth*

**Partners:** Conservation Planning Technologies, Institute on the Environment at University of Minnesota, USGS, and Esri **Data Sources:** *Human modification:* Gridded Population of the World, Global Human Settlement Layer, Unified Cropland Layer, Gridded Livestock of the World, OpenStreetMap, DMSP-OSL Stable Nighttime Lights (see Kennedy et al. 2019 for additional data sources) *Development Pressure:* USGS, US Energy Information Administration, VAISALA, OpenStreetMap, NOAA, WORLDCLIM, European Space Agency, United Nations (see Oakleaf et al. 2019 for additional data sources) *Crisis Ecosystems:* World Ecosystems (Sayre et al. 2019), IPCC Climate Data, Hammond Landforms, European Space Agency Land Cover, Potential Natural Vegetation, World Database of Protected Areas (April 2019), Wallace's Zoogeographic Regions, Human Modification Map. **Software:** Esri ArcGIS10.7, Spatial Analyst, R **Contacts:** Dr. Christina Kennedy (ckennedy@tnc.org), Tim Boucher (tboucher@tnc.org), James Oakleaf (joakleaf@tnc.org), Joseph Kiesecker, Edward Game, and Nicholas Wolff **Website:** nature.ly/34uDBSV, nature.ly/2TTGOBv **Web tools:** gdra-tnc.org/; nature.ly/31IBuKu

# Maps

Fundamental to TNC's mission is a focus on geography. Maps are core to our mission in helping us understand the places we work and in engaging audiences through the stories they reveal. Through the establishment of a cartography working group, the maps in this report illustrate emerging guidelines and best practices in developing a cartographic vision for the organization. These guidelines revolve around TNC's visual identity defined by three initial components.

## Typography

Our visual identity creates a systematic approach to typography using two primary font families, Chronicle and Whitney (shown below), with the exception of the Chinese character sets.

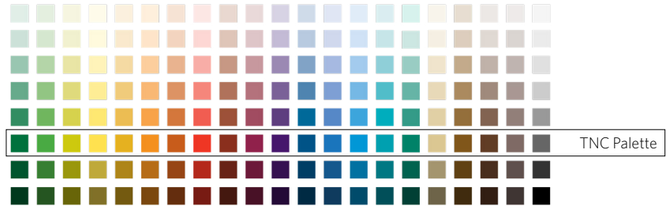
| | **Chronicle** |
|---|---|
| English | Nature |
| Spanish | Naturaleza |
| Portuguese | Natureza |
| French | La Nature |
| Swahili | Mazingira |
| Bahasa Indonesia | Alam |
| Chinese* | 自然 |

| | **Whitney** |
|---|---|
| English | Nature |
| Spanish | Naturaleza |
| Portuguese | Natureza |
| French | La Nature |
| Swahili | Mazingira |
| Bahasa Indonesia | Alam |
| Chinese* | 自然 |

* Alternative typefaces for Chinese character sets are Adobe Ming Std and Source Han Sans TW

## Color

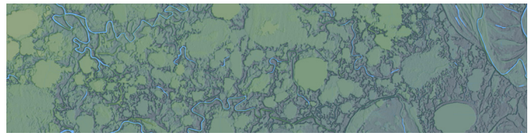
Building on TNC's visual identity guidelines, we have expanded the color palette with a selection of hues for depicting natural and thematic features.




## Natural Features

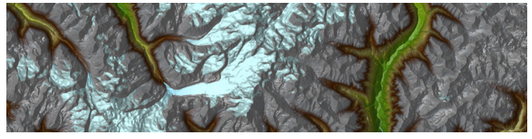
We are mapping natural features across many of the world's ecosystems (Sayre et al. 2020, nature.ly/3kBDKuE), developing specific color gradients for use as base maps. The color gradients combine elevation or bathymetry, terrain or landform, hydrography and vegetation with other natural elements on land and in the ocean. The example below depicts polar, boreal and cool temperate ecosystems.

Low Elevation Range

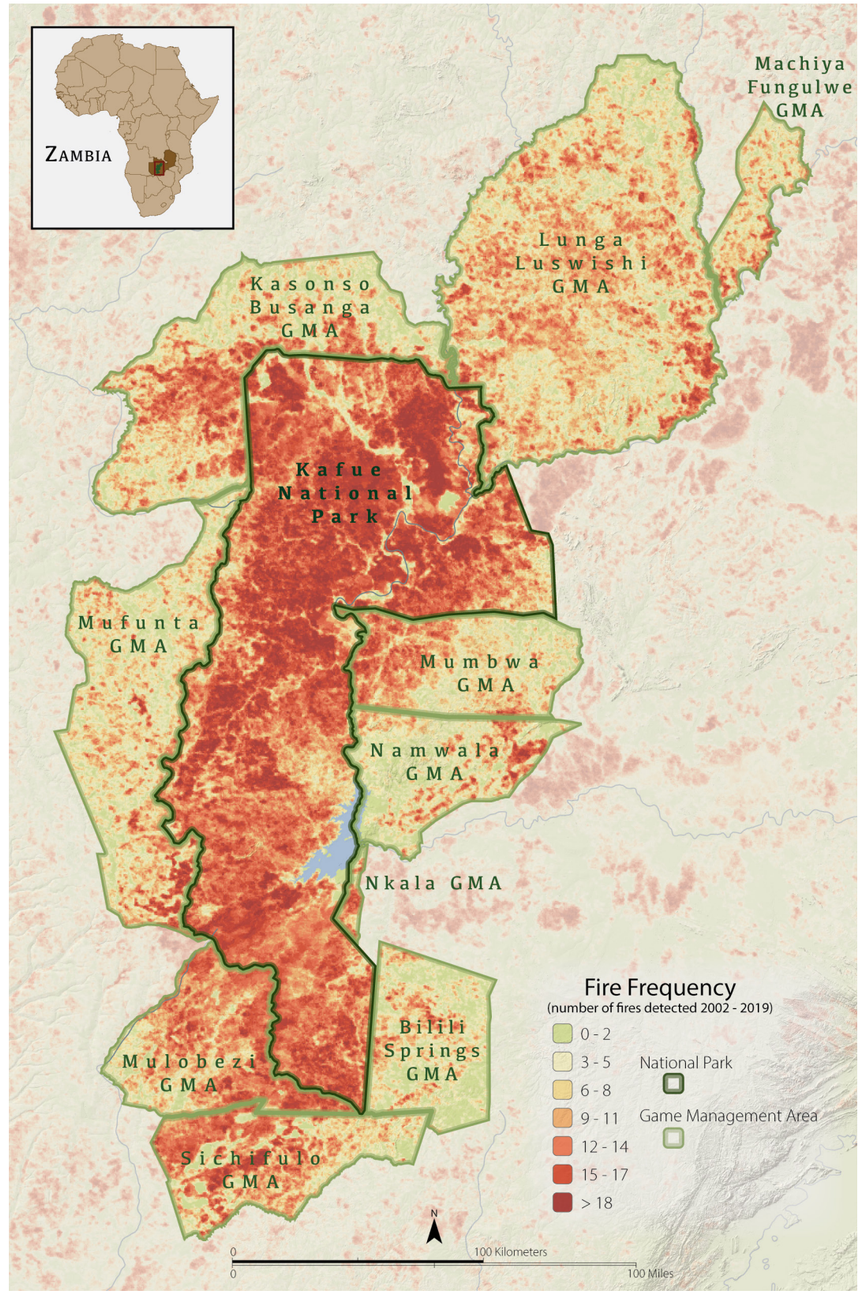


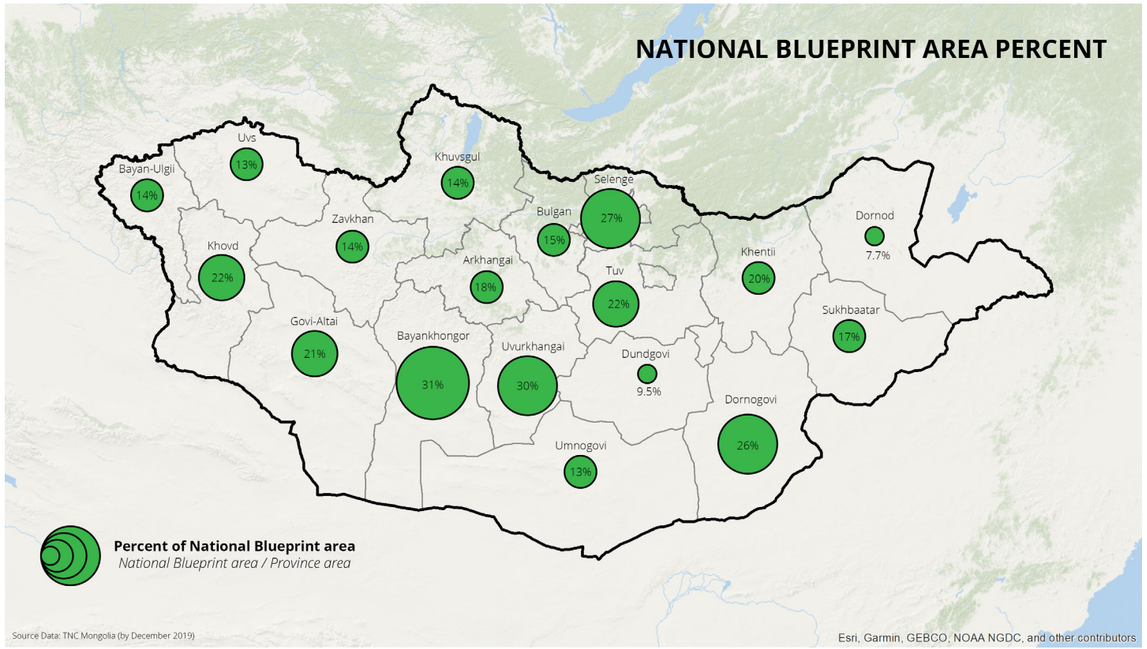
Medium Elevation Range

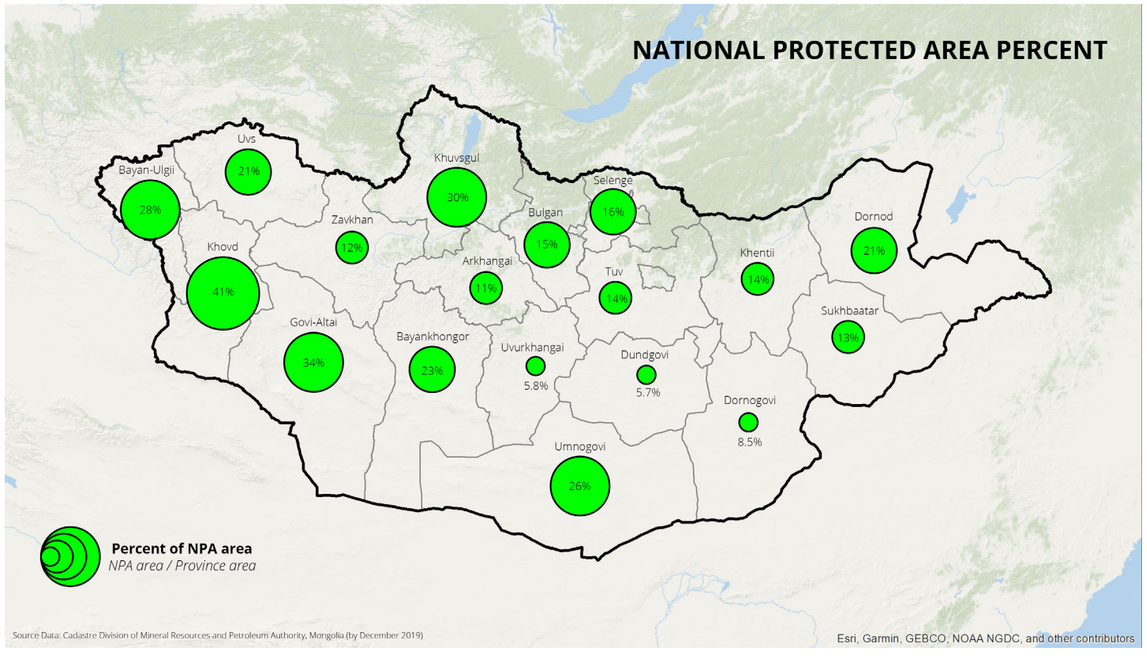
High Elevation Range



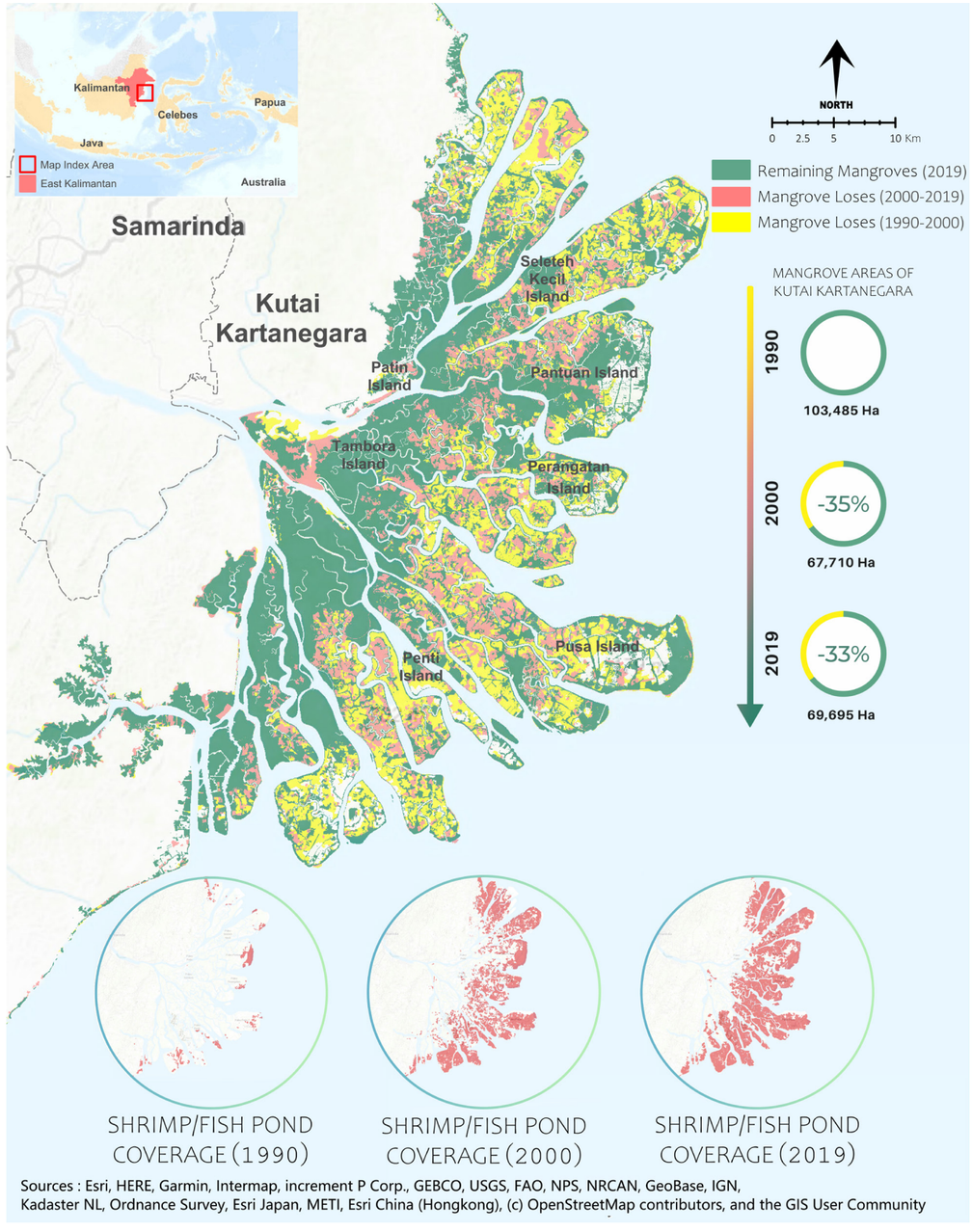
▶ Kafue National Park is central to the conservation of the 16.7 million-acre greater Kafue ecosystem. Approximately 50% of this landscape burns annually, threatening conservation efforts in the region. In 2012 The Zambia Wildlife Authority, the Conservancy and other groups partnered to address this issue. This collaborative partnership has conducted a series of "Fire as a Management Tool" training workshops for the Department of National Parks and Wildlife and interested partners in Zambia, Africa. Over 200 participants from six national parks have attended the 5 to 10-day training. **Cartography:** Nathaniel Robinson for the Africa program





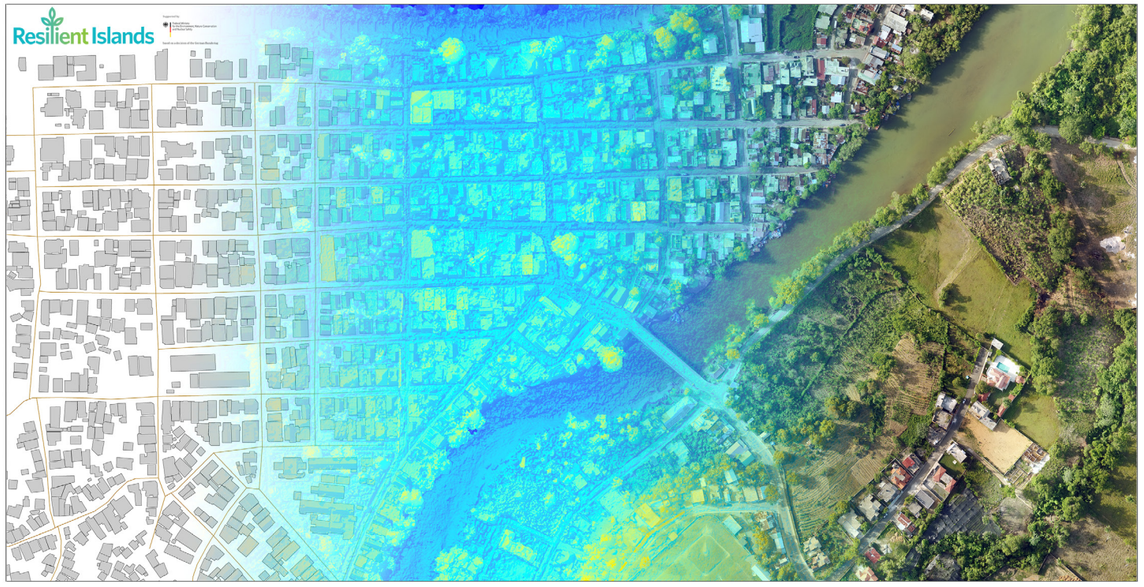




▲ National protected areas are permanent designations approved by the State parliament of Mongolia which include four different categories: **1.** strictly protected areas, **2.** national parks, **3.** nature reserves and **4.** nature monuments. The National Blueprint is the Conservancy's identified set of ecologically important areas that if protected, could maintain the biodiversity and ecological processes representative of the region. **Cartography:** Purevbaatar Ganbold, Mongolia program




▲ This map describes the dynamic of mangroves and pond changes in East Kalimantan from 1990 to 2019. We conducted a spatial analysis of satellite imagery data including an automated method through the Google Earth Engine platform, Multispectral Classification Method (Random Forest), GEOBIA Classification Method, Mangrove Cover Density Model and ground-truthing for land change, cover density and in-depth interviews regarding the history of changes in mangrove land. **Cartography:** Aldo Restu Agi Prananda, Dzimar Akbarur Rokhim Prakoso, Indonesia Oceans program

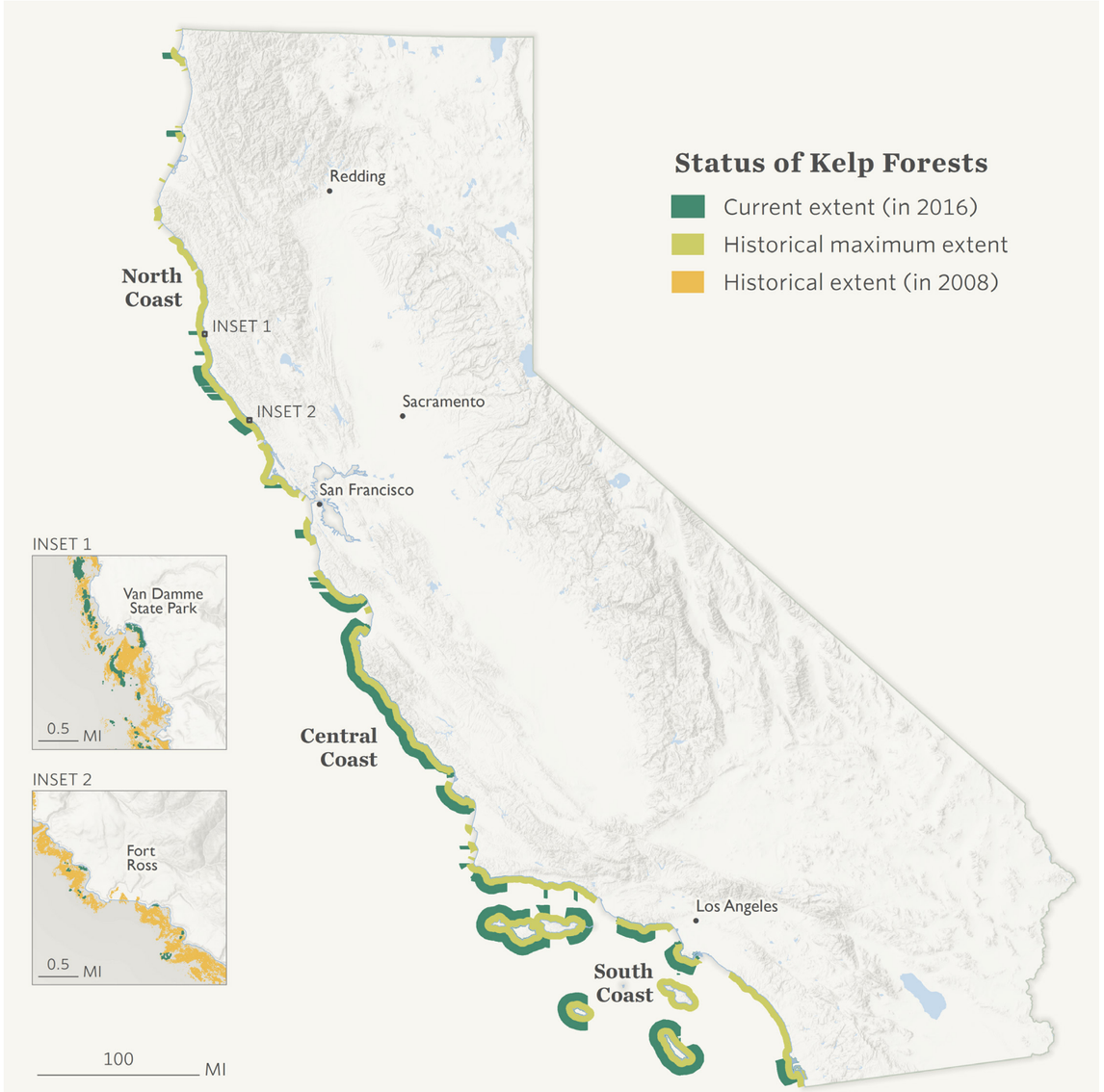

▲ This map illustrates a mangrove coverage classification using high resolution satellite imagery (Worldview-2) analysis of the Muara Angke Wildlife Reserve in Jakarta, Indonesia. The classification map informed the design of the masterplan for the Reserve which is the location of one of the last mangrove forests in Jakarta's coastal area. **Cartography:** Dhika Rino Pratama, Indonesia Oceans program



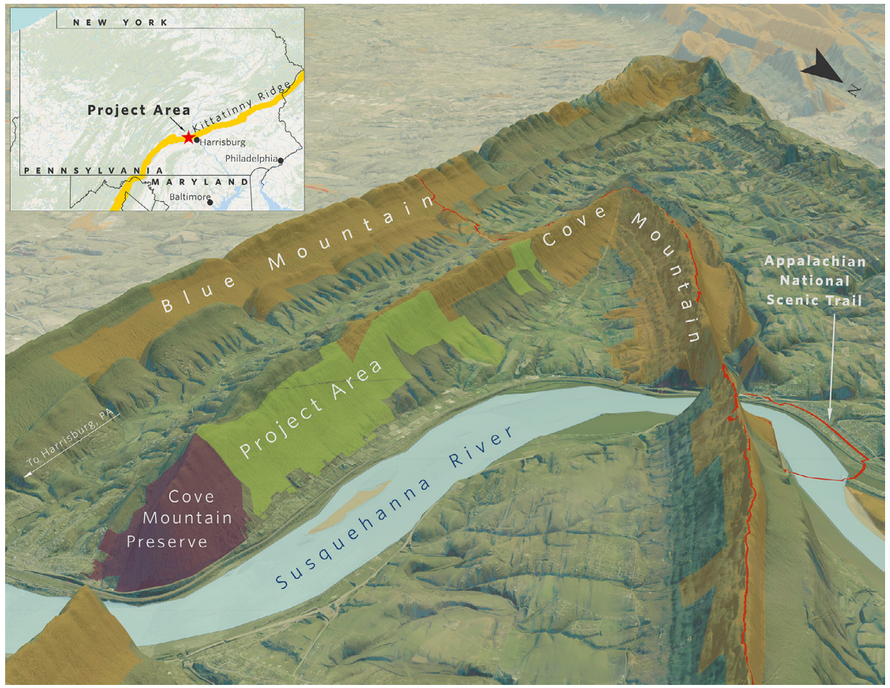

▲ A blended image of three UAV-derived drone products in Miches, Dominican Republic (left to right: structures and roads vector data, Digital Surface Model, aerial imagery). TNC has mapped this coastal community to identify flood prone areas and other drivers of vulnerability as part of the Resilient Islands project, a collaboration between TNC and the International Federation of the Red Cross (IFRC) and Red Crescent Societies. **Cartography:** Valerie McNulty, Caribbean program



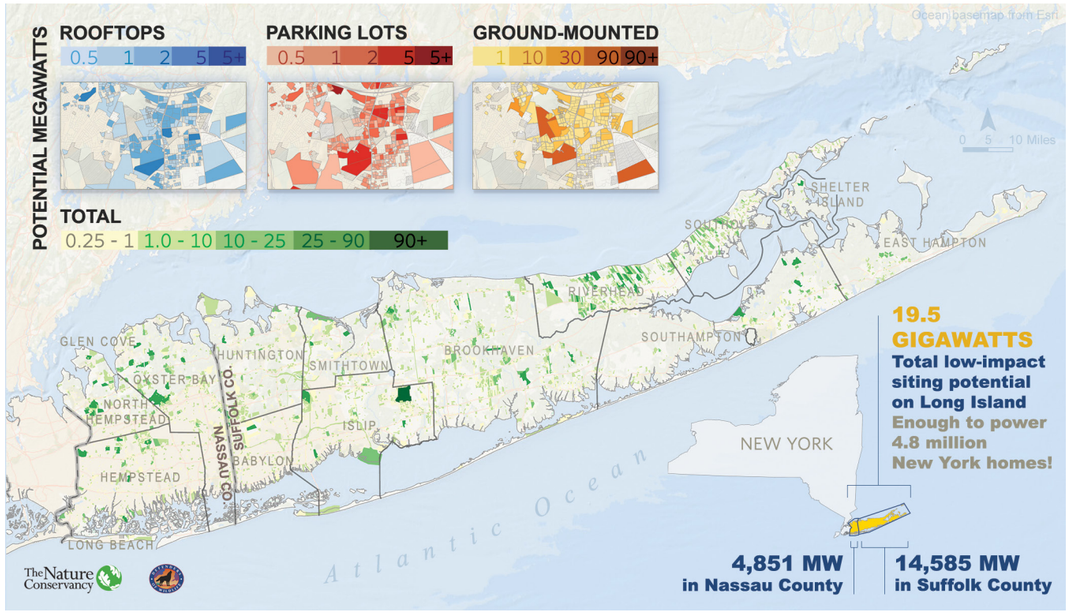




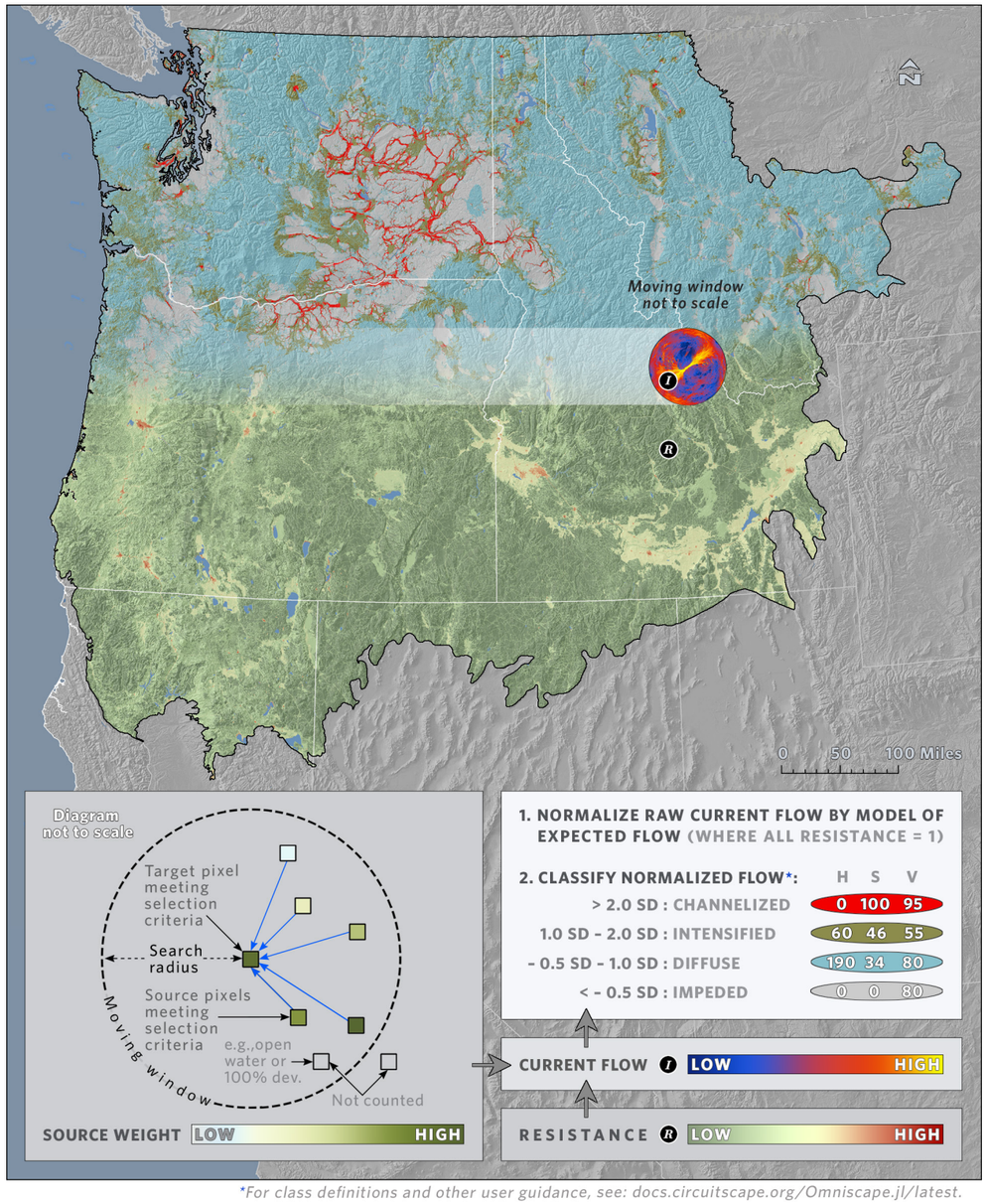

▲ This map depicts the maximum historic extent of kelp cover compared to the most recent surveys in 2016 along the entire California coast, including two inset maps for Sonoma and Mendocino Counties. These show in greater detail the loss of over 90% of bull kelp along the North Coast between 2008 and 2016. **Cartography:** Megan Webb and Charlotte Stanley, California Science




◀ Running through Pennsylvania for 185 miles (298 km), the Kittatinny Ridge (yellow line on locator map) is one of the most important wildlife corridors in the United States. The Conservancy is working to complete a 14-mile (22-km) long corridor of protected land along the Ridge by purchasing a 1,200-acre (486-ha) parcel adjacent to our existing Cove Mountain Preserve.
**Cartography:** Emily Doerner, Pennsylvania/ Delaware field office

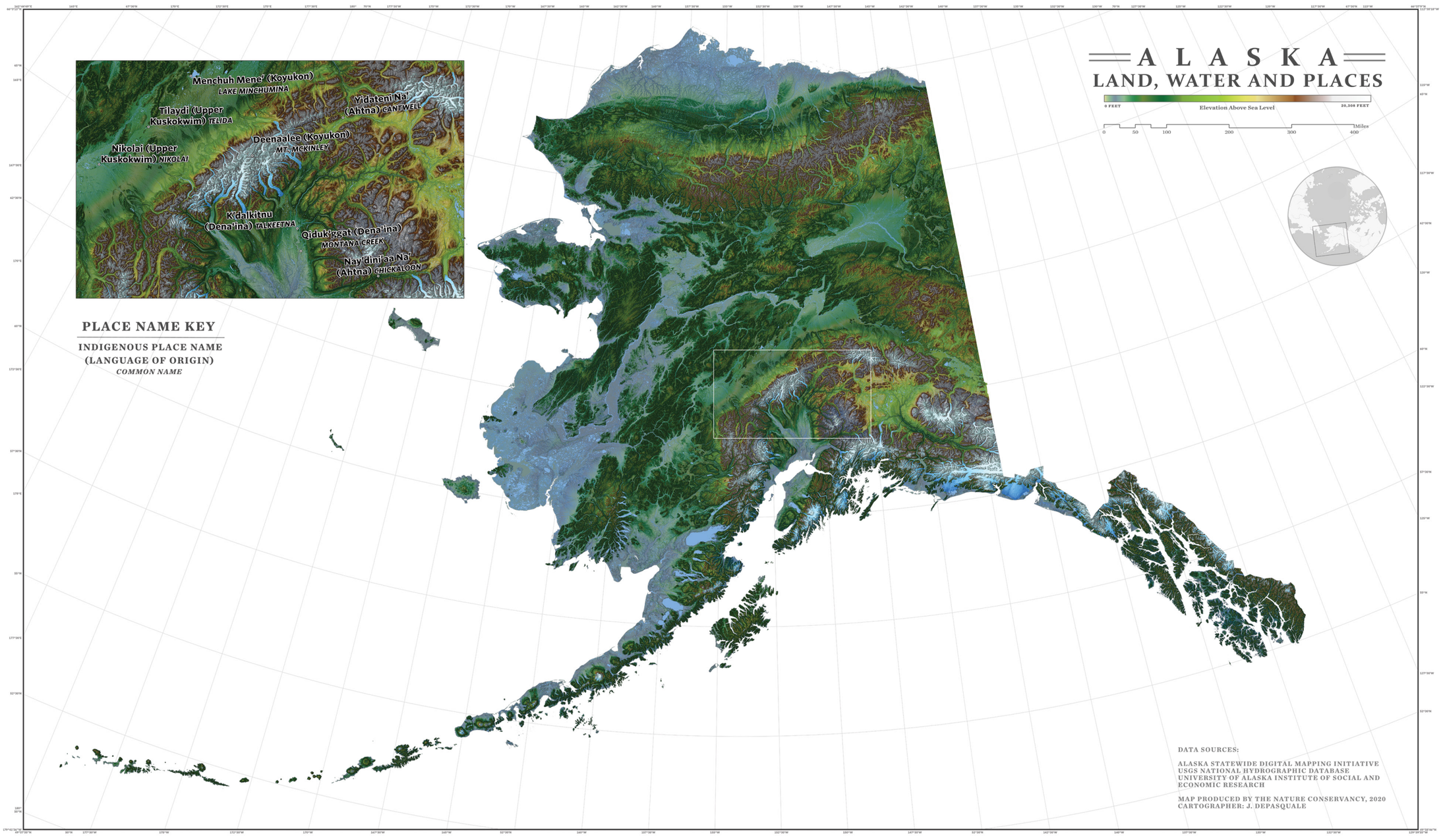



▲ The Long Island Solar Roadmap aims to accelerate large-scale solar power that minimizes environmental impacts, maximizes benefits and expands access to solar energy, including access by traditionally underserved communities. Each parcel shown can support at least 250 kilowatts in some combination of rooftop, parking lot and ground-mounted solar. For more information, visit solarroadmap.org. **Cartography:** Karen Leu, New York field office




*For class definitions and other user guidance, see: docs.circuitscape.org/Omniscape.jl/latest.

▲ Circuitscape, developed by Brad McRae (1966-2017), leverages algorithms from electrical circuit theory to predict ecological flows (e.g., species movement, gene migration) across landscape mosaics. With collaborators at Conservation Science Partners, we updated Omniscape, a moving-window version of Circuitscape, first introduced by McRae et al. 2016 (nature.org/resilienceNW), that brings a continuous and "omni-directional" perspective to landscape connectivity that includes relative movement probabilities reflecting the complex nature of connectivity. Categories of current flow can be linked to strategic action: narrow, channelized high-flow areas indicate where protection strategies may be critical to sustain landscape connectivity, whereas connectivity across broad, diffuse zones of moderate flow may be maintained through a wide range of land use policies and practices. See the 'circuitscape.jl' and 'omniscape.jl' repositories at: github.com/Circuitscape.
**Cartography:** Aaron Jones, New Mexico field office




▲ Our work takes place on lands that have been continuously inhabited and stewarded by Alaska Native People since time immemorial. From Klawock to Utqiagvik, TNC Alaska is prioritizing ways to support Indigenous-led conservation. We continue to seek out opportunities which support the economic, environmental and social vibrancy and resilience of Indigenous and rural communities. The 270 Indigenous Place Names on this map (only inset map showing labels due to scale) demonstrate the vast geographic breadth of traditional lands in Alaska and represent the thousands of years of human occupation by Alaska's First People. We will continue to add original names and locations of Alaska Native Places across all languages to this map to help us understand the historical relationship of Native Alaskans to the lands and waters of Alaska. The statewide Digital Elevation Model (DEM) was constructed by assembling over 5,000 individual IfSAR-derived DEM tiles made available through the Alaska Statewide Digital Mapping Initiative. **Cartography:** James DePasquale, Alaska field office

# Northern Great Plains

## Northern Great Plains Region

Spanning over 136 million acres in the USA, this region is 1 of only 4 remaining largely-intact temperate grasslands in the world where grassland-dependent livelihoods and land ethics support the diverse habitats and species of the region.

## Grasslands & Waters

75% of grassland systems remain intact in the region. These large interconnected landscapes along with the waters they contain are crucial for the survival and adaptation of Plains species and the peoples who rely on them.

## Disturbed Area

25% of the region has been degraded or completely converted to row crop agriculture, mining for oil, gas and coal, and urban development. Protecting the remaining landscape will enable intact, resilient lands and waters.

## Focal Preserves

The Conservancy manages preserves that protect key biodiversity and connectivity. These preserves facilitate collaborative learning and as demonstration ecological sites for blended ranching and conservation practices.

## Tribal Nations' Lands

7 of the 12 largest reservations in the contiguous US fall within the region, spanning 15 million acres. This, however, represents a fraction of the diverse Tribal Nations' interests and rights for lands and waters.

## Resilient & Connected Network

Conservancy scientists have developed models to identify lands well-suited to sustain productive and healthy grasslands, and other habitats, as the climate changes.

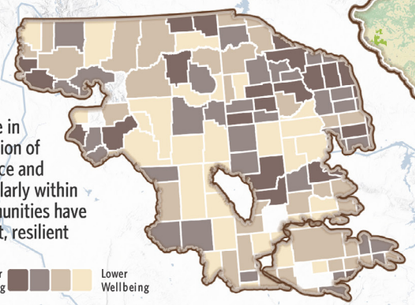
## Protected Areas

5% of the national grasslands, conservation easements, community trust lands, and other designations that accommodate both cultural and conservation values.

Mapping by GreenInfo Network | March 2019

## Community Wellbeing

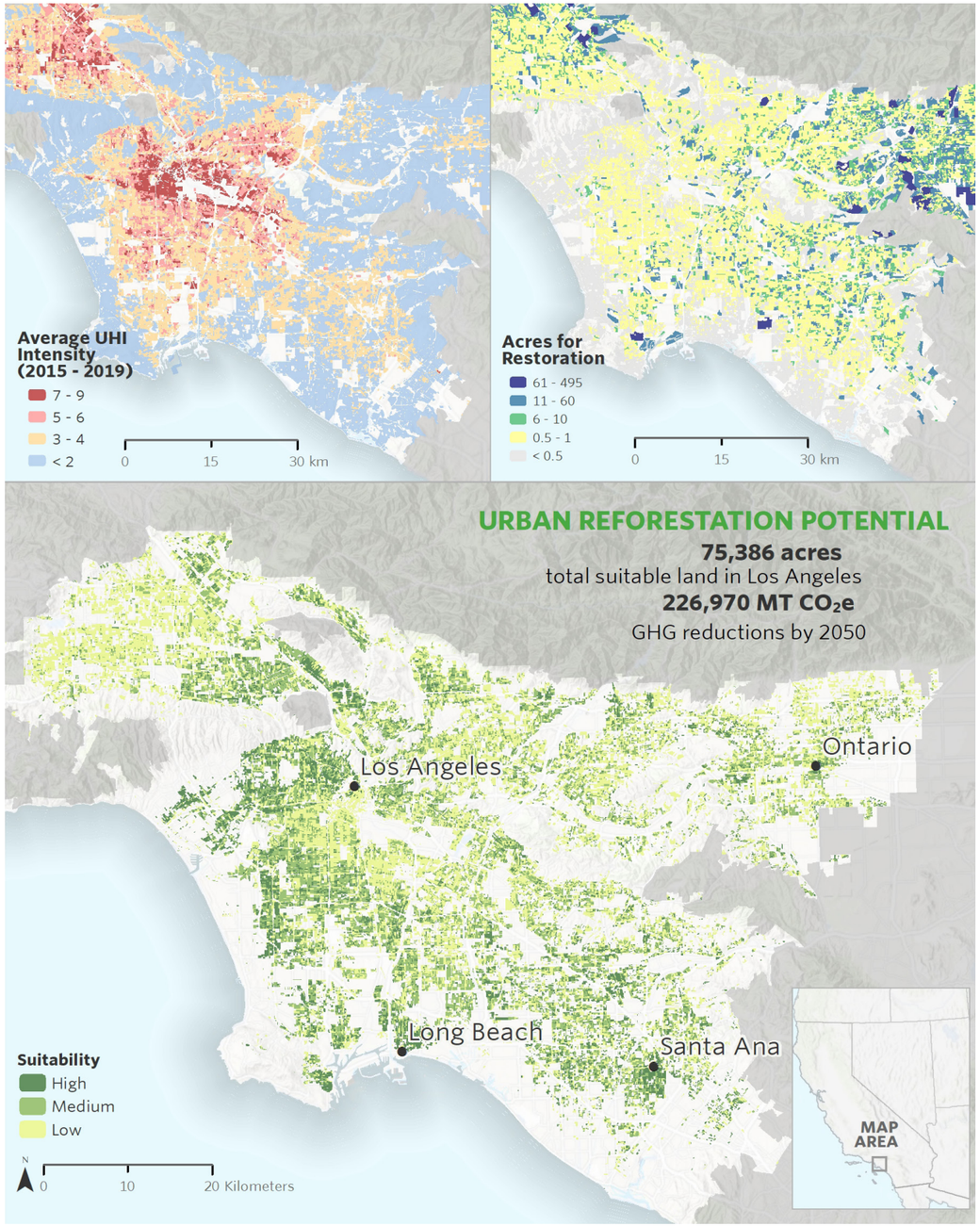
Communities within the region range in estimations of wellbeing, an integration of health, economic, education, resilience and equality data at county level. Particularly within this region, vibrant and strong communities have sustained and are sustained by intact, resilient lands and waters.







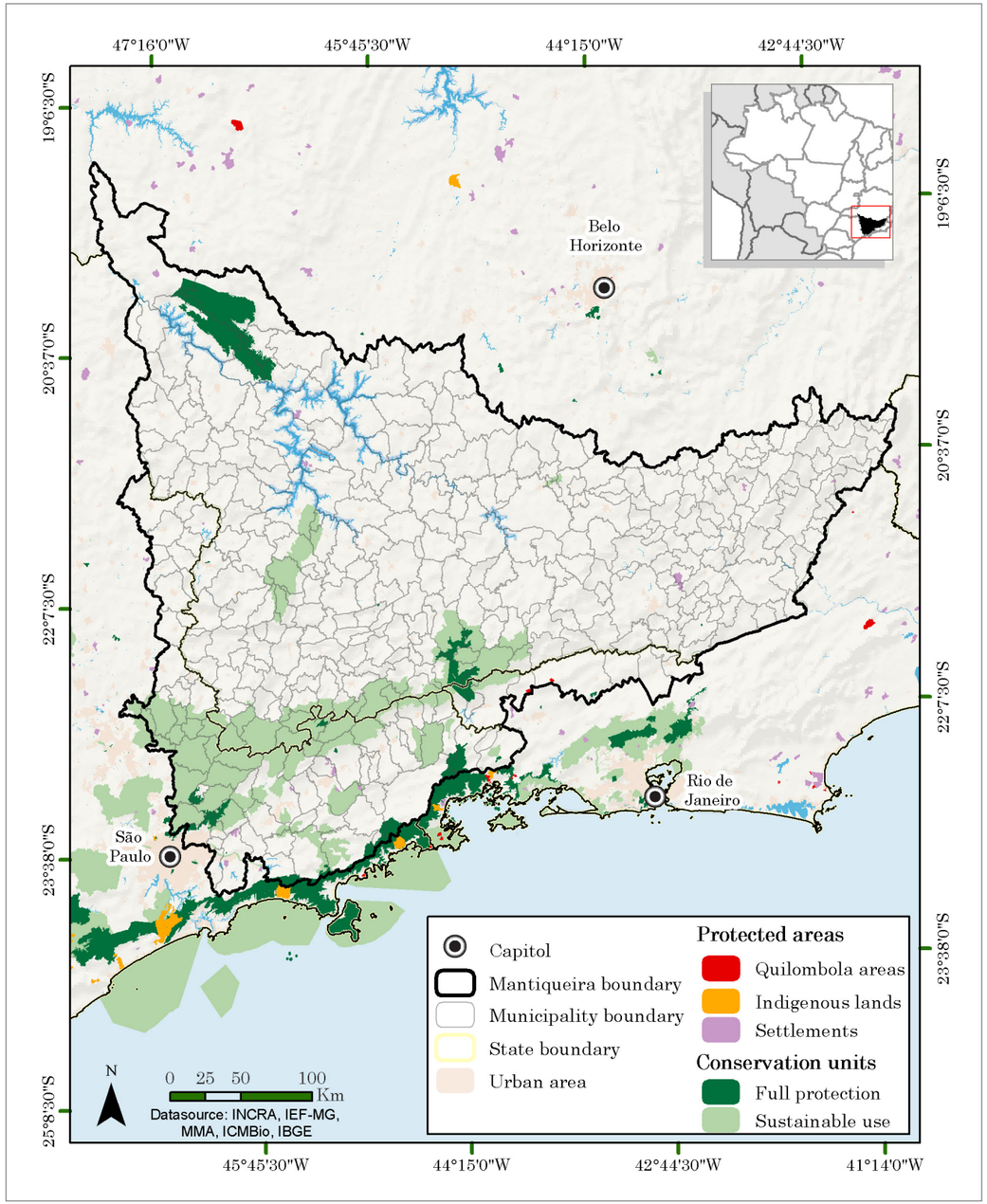
◀ In this map series we aim to visualize the importance of the iconic Northern Great Plains; from its resilient and connected lands network to community well-being and Tribal Nations' Lands. This map was awarded first place in the map series or atlas category during the 2020 Esri Virtual International User Conference.
**Cartography:** Maegan Leslie Torres, Green Info Network for the North America Science program



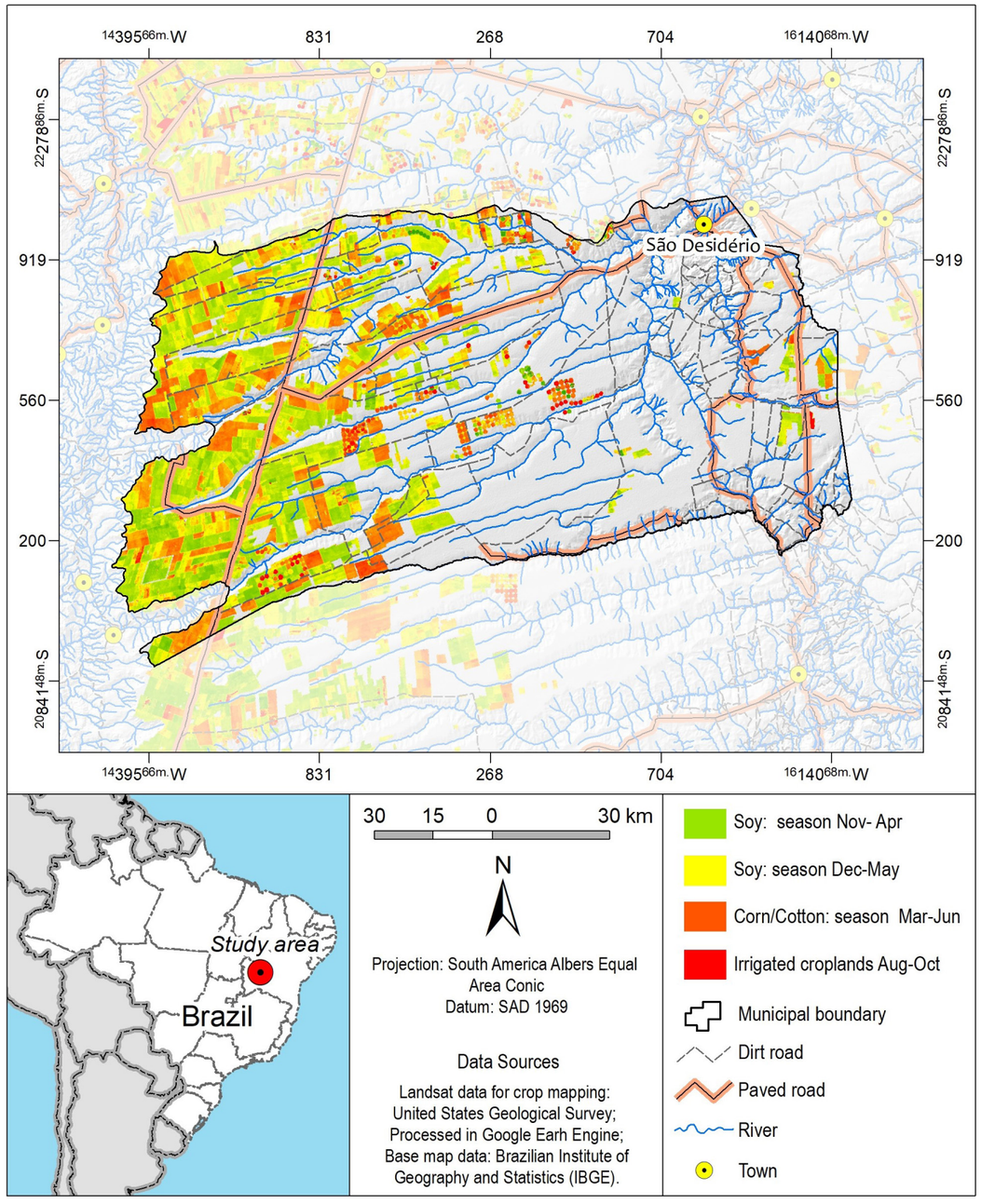

▲ Climate change is expected to intensify Urban Heat Island (UHI) effect that would disproportionately impact disadvantaged and low-income neighborhoods. We identify areas suitable for urban reforestation that address the inequality in tree cover between low- and high-income neighborhoods. Increasing canopy cover would reduce UHI impacts and Greenhouse Gases (GHG) that disproportionally impact underserved communities. **Cartography:** Tanushree Biswas, California field office








▲ The Conservador da Mantiqueira action plan seeks to increase forest restoration in the Brazilian Amazon, generating significant environmental benefits in the most populated and economically important states: São Paulo, Rio de Janeiro and Minas Gerais. This collective initiative to promote landscape restoration in the Serra da Mantiqueira region is building a solid case for using reforestation to address climate change while demonstrating how protecting watersheds and adopting agroforestry can improve the incomes of rural landowners. **Cartography:** Maria Tereza Leite Montalvao, Brazil program




▲ Brazil is the second largest soy producer in the world and 50% of the soy production occurs in the Cerrado biome. We used Google Earth Engine to combine Landsat and MODIS earth observations with field samples to classify soy fields annually in order to map the expansion of soy crops in Brazil. Approximately 30% of the soy expansion in the last ten years replaced Cerrado native vegetation, especially in the west Bahia region where more than 70% of the soy expansion occurred on native lands. **Cartography:** Osvaldo Jose Pereira, Brazil program





# Geospatial Systems

Geospatial systems at TNC continues to refine its key objectives around an enterprise geospatial plan, including centralizing and managing TNC preserve and protected area spatial data, transferring the Conservancy's geospatial data to GIS cloud architectures and leveraging earth observation technologies.

## Monitoring & Evaluation

The Nature Conservancy owns more than 5.7 million acres of private conservation lands representing every ecological region across the continental U.S. For almost 70 years we have built and managed this portfolio to protect biodiversity, promote good stewardship and engage donors and local audiences. Our objective is to manage these land holdings by creating a standardized information system to collect, utilize and archive land asset data. Our comprehensive database will streamline preserve management, fee and easement monitoring, ecological monitoring and facilitate preserve stewardship. While we are tracking conditions and improving the efficiency and safety of our operations in the U.S., we are designing similar monitoring efforts internationally.

The Loisaba Wildlife Conservancy in Kenya is part of the Protected Area Management (PAM) and Authorized Entity program with Esri. The Loisaba Conservancy is currently deploying Esri's ArcGIS Solutions for PAM. By using mobile field data tools, rangers can collect and visualize observations in ArcGIS Online and track environmental conditions through spatial analyses. These tools help rangers reduce wildlife poaching, prevent human-wildlife conflicts and encourage the return of tourism. Once successful, TNC plans to adapt and expand these practices in Africa.

"Just like our motto says, 'Land Connected-Life Protected,' Loisaba Conservancy provides essential habitat to a variety of both vulnerable and threatened species that migrate across the vast grasslands of Laikipia County. TNC continues to provide technical support to Loisaba Conservancy on wildlife monitoring and security patrol. Esri's mapping software and capacity building has allowed Loisaba to swiftly and regularly access information on wildlife distribution, population status and trends. This time-sensitive information is used by park rangers, managers and researchers to implement wildlife protection."

**Horris Wanyama**
*Loisaba's Conservation Officer*

"We are thrilled to collaborate with The Nature Conservancy's talented team of conservation scientists and geospatial planners to enhance cloud-based geospatial computing. This project brings together TNC's expertise working with geospatial modeling and processing, along with the scale and agility of AWS, to more effectively leverage public and private geospatial data sources to drive critical conservation decisions."

**Joe Flasher**
*Open Geospatial Data Lead at AWS*

## Enterprise GeoCloud

The Conservancy manages an internal, on-premise geospatial server production fleet for storage, access and large geoprocessing tasks as well as cloud instances hosting web GIS and data science applications. We are developing an enterprise geospatial solution called the Enterprise GeoCloud that will transfer the majority of TNC's geospatial data holdings to the cloud to support the over 950 employees that rely on GIS and remote sensing. Our cloud-based decision support system will deliver long-term resource-management and facilitate the largest geospatial cloud migration and data transformation process the Conservancy has ever undertaken. This process is essential in facilitating effective conservation science and informing the organization's strategies.

Our three-step approach for the Enterprise GeoCloud includes migrating geospatial data to the cloud, consolidating and leveraging web GIS capabilities while transitioning from ArcGIS Desktop to ArcGIS Pro and supporting advanced geoprocessing. Migrating data to the cloud will increase access to critical information, scale our systems to accommodate spatial data storage needs and reduce data redundancy. With virtual desktop infrastructure and centralized file-based data storage, we are leveraging elastic capabilities on Amazon Web Services (AWS) to increase compute capacity and support dynamic workloads. Streamlining our geospatial architecture allows us to consolidate present capabilities supporting tile, feature and database services to ArcGIS Online and accommodate spatial analysis functionality on AWS. Lastly, we are supporting geospatial modeling and advanced geoprocessing for conservation scientists that need more compute power. Our objective is to enhance conservation planning by providing access to resource-intensive remote sensing and machine learning tools.

## Earth Observation

Earth observation data is derived from satellite, aircraft, or drone imagery. Traditionally, our earth observation-related conservation work has been decentralized across different field offices requiring that imagery and analyses be processed and stored locally. However, recent shifts in conservation easement monitoring and an increasing need to conduct regional and global analyses has led to the development of imagery resources that can be shared organization-wide. As an accredited Land Trust, TNC must monitor each conservation easement property at least once per calendar year, requiring a tremendous amount of on-the-ground effort. Recently, TNC leveraged a new technology called remote property monitoring that combines airborne and satellite imagery with a seamless web-based platform. Remotely monitoring TNC's properties has enabled field offices in the U.S. to meet their annual compliance monitoring obligations and combine remote imagery analyses with in-person property visits.

Our conservation work and reputation relies on the generation of quantifiable, trustworthy, high-resolution metrics to measure and track ecological conditions. Our geospatial scientists need technologies that enable them to focus on methods and analyses and less on computational infrastructure. Our technology partners now offer distributed data processing platforms that optimize the collection, storage and analysis of raw earth observation data, presenting an enormous opportunity to accelerate our conservation work. These platforms empower us to scale-up and optimize compute-intensive spatial analysis tasks, for example, in classifying an array of imagery resolutions using machine learning to identify land cover or habitat types. This information allows for the detection of landscape change at different scales, from managing cheatgrass and other annual invasive species in the Great Basin of the U.S. to creating an agroforestry classification across multiple countries to determine carbon storage capacity. These efficiency gains facilitate effective land management in priority conservation areas.



▲ Chantal Migongo-Bake from TNC's Africa program and ecotourism guide Sam Brown view a map of the Loisaba wildlife conservancy.



# Looking Ahead: 2021

The Nature Conservancy's geospatial work is intricately linked to our broader community and partnerships as we address the challenges of social inequity and climate change. As mentioned in the introduction, we see opportunities to diversify our workforce to include representation across the globe. This means advancing partnerships with other conservation nonprofits and supporting a new generation of geospatial professionals in collaboration with the Society for Conservation GIS. In the next year we will create a series of papers and forums to clarify how we most efficiently conduct our geospatial work, share our data and communicate best practices on data management, cartography and earth observation technology. As our world battles COVID-19, we are adapting our work by establishing protocols for remotely monitoring our preserves, consolidating our geospatial data on the cloud to easily access critical information and better communicate through our Geospatial Conservation Atlas (geospatial.tnc.org). The Conservancy is committed to creating a world where people and nature can thrive. Mapping the reach and range of our conservation efforts is an essential part in conveying this commitment.

"To truly conserve biodiversity, ecosystem function and keystone species we need global participation and engagement with local and Indigenous people around the world. Geospatial technology can help inform issues of social inequity and climate change but this requires that we listen with empathy, contemplate and take actions together that are well-informed by science."

David Gadsden
*Esri Conservation Director*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