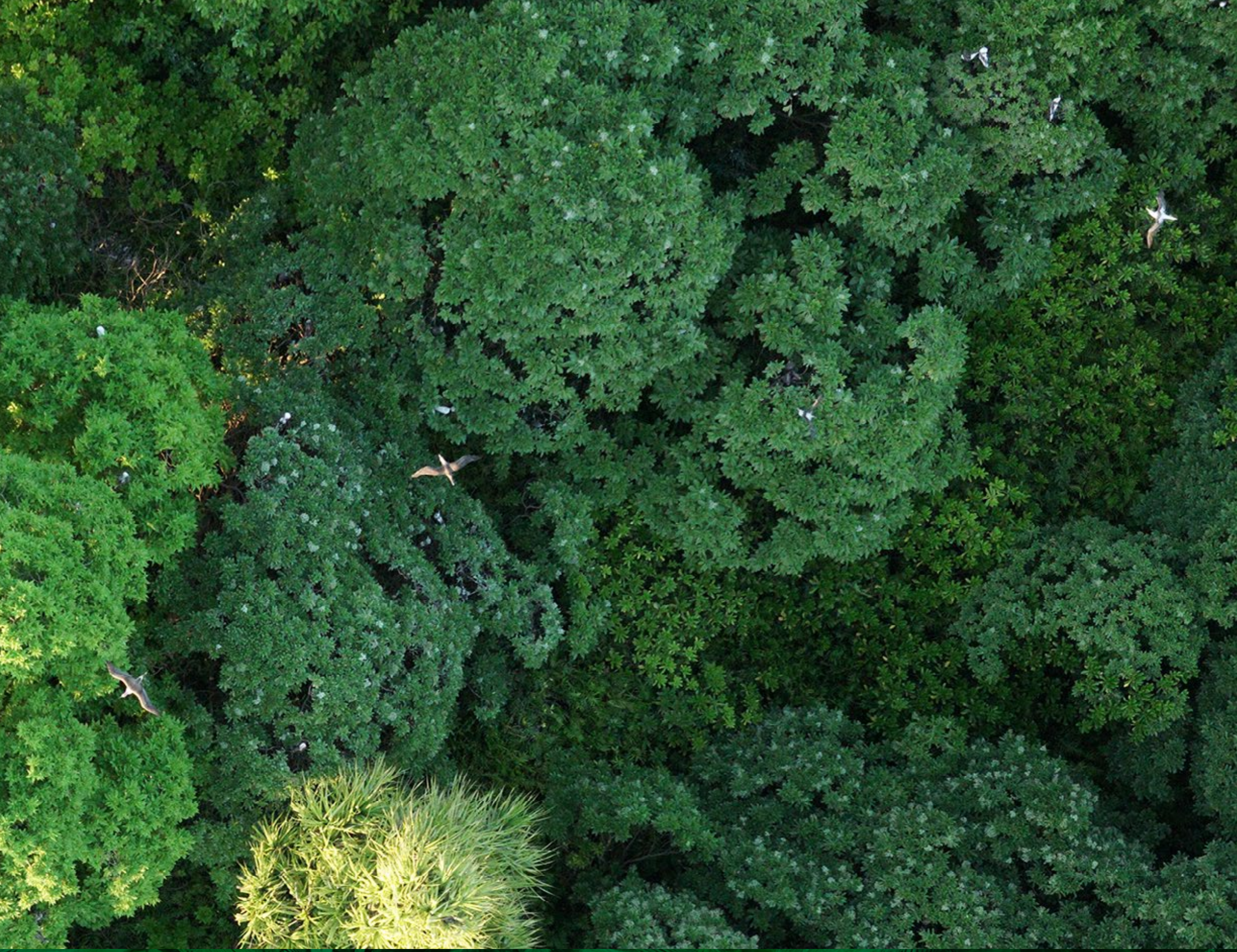

GEOSPATIAL CONSERVATION AT THE NATURE CONSERVANCY | *2023 Annual Report & Map Book*

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About the Cover

The Nature Conservancy and partners are working to restore seabird habitat within the rainforest at Palmyra Atoll by converting introduced coconut palms (bottom photo) to a forest dominated by native trees (top photo). Palmyra's native trees provide ideal nesting and roosting habitat for seabirds, whose guano is a crucial nutrient source for the entire atoll ecosystem. The goal of the rainforest realignment effort is to maximize the seabird-driven nutrient cycle and increase the atoll's resilience to climate-driven impacts. To measure the conservation impact of this project, TNC scientists are leading an effort to deploy state-of-the-art drones, remote sensing science and artificial intelligence detection models to estimate how many seabirds are currently at Palmyra and, as restoration work proceeds, measure changes in seabird abundance and distribution over time.

THIS PAGE: This lidar-derived image of the Mississippi River courtesy of Daniel Coe (dancoecarto.com) shows how the river has meandered throughout its historic floodplain. Each year, excess nutrients run off into the river, posing health hazards to people and wildlife, and contributing to the annual Gulf of Mexico dead zone. The Nature Conservancy works in the Mississippi River Basin (bit.ly/MissRiverTNC) to reduce nutrient pollution and restore floodplains at scale—protecting biodiversity and sequestering carbon in the process.

Observing Our World

CONSERVATION AT THE SPEED OF TECHNOLOGY

Katharine Hayhoe
Chief Scientist

In a world where each location has its story, advancements in Earth observation (EO) and geospatial technologies are revolutionizing how we understand and interact with our environment. From acoustic monitoring systems and autonomous drones to innovations in artificial intelligence and data analytics, technology offers increasingly profound insights into Earth's systems and how human activities are reshaping them. This report highlights how The Nature Conservancy (TNC) uses these tools to accelerate our responses to the climate and biodiversity crises and to meet our 2030 goals.

Thanks to EO technologies like satellites, drones and ground sensors, the volume of spatial data expands exponentially every year. This data surge is transforming our ability to track and respond to critical issues such as greenhouse gas emissions, biodiversity loss, natural disasters and deforestation. Long-term monitoring also helps us ensure freshwater supplies, agricultural lands and energy resources are sustainably managed.

Geospatial technology allows us to translate this growing volume of data into narratives that shape our understanding and decisions. Through its strategic application, we can prioritize resource allocation and efforts critical to our success and that of our global partners—from national governments tracking their climate and conservation commitments to other NGOs on the front lines of disaster relief.

Our goal is to leverage these technologies for effective conservation strategies that benefit both people and the planet. Geospatial technology is at the core of our work, providing essential cloud computing, data-sharing platforms and decision-support tools. Through equitable access to centralized resources, we allow data, code, analytical methods and derived products to be shared across the organization. These resources enhance our global information bank and support our more than 1,900 staff working at the intersection of conservation science and technology.

Earth observation and geospatial technologies offer timely and practical solutions that guide science and conservation efforts. I am encouraged by how these technologies help us identify the most effective ways to deploy our resources for the good of people and the planet. By providing access to data, geospatial information and analyses, TNC also helps governments, communities, organizations and investors make better decisions: from smart siting of renewable energy to optimizing conservation corridors that support wildlife migration.

We have no time to lose in tackling the interconnected climate change and biodiversity loss crises. By working together, we can ensure the health and well-being of all who call our planet home. Geospatial technology equips us to accomplish these endeavors more effectively, accelerating our trajectory toward a better, more sustainable future.

PHOTO: Vienna Saccomanno prepares to launch a sunrise drone survey of a kelp restoration site in Northern California. © Ralph Pace

2023 GEOSPATIAL ANNUAL REPORT & MAP BOOK

HARNESSING THE POWER OF

Earth Observation

The Nature Conservancy has a long history of leveraging geospatial technology to advance conservation science and planning. Storage, access, analysis, compute and resulting products are paramount to our work. These might seem like basic components of a GIS, but given the rapid advancements in Earth observation (EO), machine learning and generative AI, TNC must continuously track and keep pace with relevant technology to advance our conservation work.

This year, our annual report focuses on the role of Earth observation in advancing our science, policy and decision-making as an organization. EO uses remote sensing technologies to monitor land, freshwater, marine ecosystems and the atmosphere. It involves tracking changes in both natural and human environments. Increasingly, EO is advancing with the development of smaller and very high-resolution satellites, complemented by in situ instruments that can monitor Earth daily with higher accuracy. Our challenge is how to utilize these technologies for conservation gains most effectively.

Our most used remote sensing technologies and EO-derived data include satellites, aircraft, unoccupied aerial vehicles (UAVs) such as drones, and camera traps. These technologies can be further categorized depending on whether their onboard sensors passively capture the sun's energy reflected by the Earth's surface or atmosphere (e.g., optical/thermal sensors) or actively send energy and capture re-emission by the Earth's surface or atmosphere (e.g., radar, lidar).

These technologies fit into a larger TNC framework we're establishing to help us identify conservation priorities, implement solutions and meet our 2030 goals. A common framework for TNC's EO-related conservation work will enhance our ability to share knowledge, methodologies, data and compute resources across geographies.

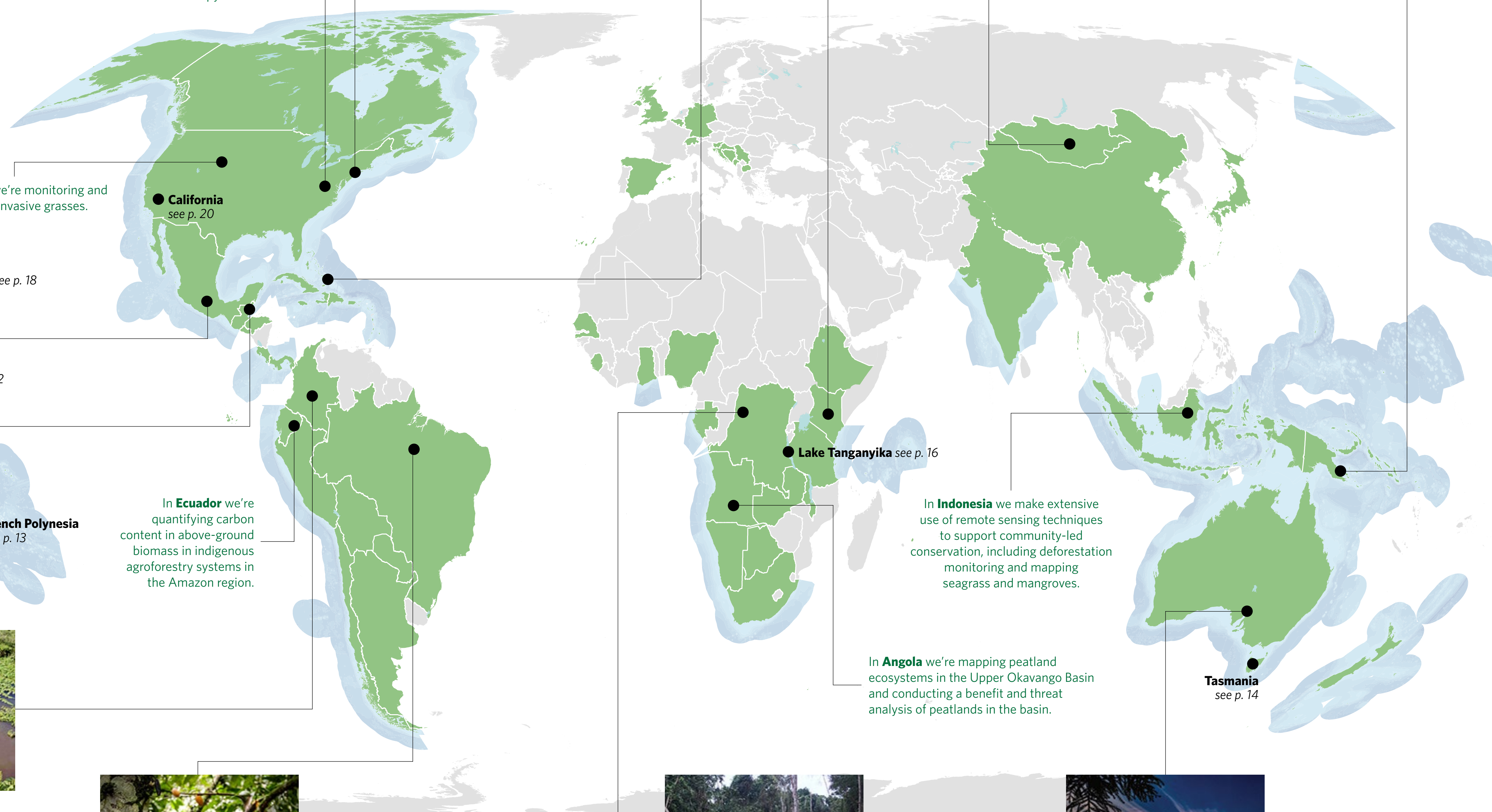
Throughout this publication, we highlight priority places where applying EO technologies, tools and methodologies advances our mission. In doing so, we hope to capture lessons learned about what's working well and establish centralized resources that uplift our global, science-based organization.

PHOTO: TNC scientists and partners collect in-water coral imagery in Moorea, French Polynesia to ground truth drone imagery. © Killian Domingo

Global Earth Observation Projects

As technology advances, the growth of Earth observation (EO) data from satellites, drones, aircraft and ground-based sensors offers a unique opportunity to measure changes in both natural and human environments consistently. Highlighted here is a small sampling of conservation projects around the world where EO is critical to advancing our 2030 goals.

Whether using drones to detect live coral species in French Polynesia, lidar sensors to track changes in New York City's tree canopy, or high-resolution satellites to assess the health and carbon storage potential of mangrove and seagrass ecosystems in the Asia Pacific region, we hope to galvanize our community of practitioners around the potential of EO technologies to achieve our conservation goals. And we hope you will be inspired by the difference we can make together.



In **New York City** we're tracking local changes in tree canopy using lidar-based data and convening a coalition of over 140 organizations to equitably achieve at least 30% tree canopy citywide by 2035.

In the **Central Appalachians** we're measuring the effects of prescribed fire to document the scale and magnitude of change to forest canopy structure.

In **Wyoming** we're monitoring and managing invasive grasses.

In the **Caribbean** we're supporting the identification and prioritization of mangroves for restoration and protection.

In **Kenya** we're mapping irrigation practices in regenerative food-scapes. *See foldout section, p. 22*

In **Mongolia** we're working to improve peatland mapping, assess climate change mitigation potential and enable peatland conservation and restoration through community-based organizations.

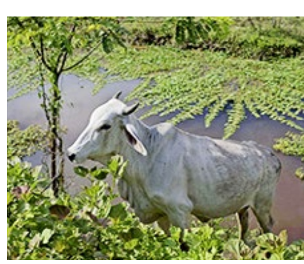
In **Papua New Guinea** we're mapping mangroves and contributing towards a national mangrove forest cover and blue carbon stock inventory.

In **Mexico** we're using high-resolution imagery to monitor and promote agroforestry techniques in the Tehuacán Valley.

In the **Belize Maya Forest** we're evaluating use of high-resolution imagery to map lianas (woody vines). Liana control may be a strategy for enhancing tree growth and carbon storage.

In **Ecuador** we're quantifying carbon content in above-ground biomass in indigenous agroforestry systems in the Amazon region.

In **Colombia** we're examining the impacts of silvopastoral practices on land cover and biodiversity.



In **Indonesia** we make extensive use of remote sensing techniques to support community-led conservation, including deforestation monitoring and mapping seagrass and mangroves.

In **Angola** we're mapping peatland ecosystems in the Upper Okavango Basin and conducting a benefit and threat analysis of peatlands in the basin.

In **Brazil** we're supporting the implementation of agroforestry systems with cocoa in deforested areas.

In the **Congo Basin** we're detecting logging roads with an objective to help inform sustainable management of legal forestry concessions.

In **Australia** we're supporting the restoration of coastal wetlands, which will contribute to carbon sequestration, biodiversity improvements and job and income creation for local communities.

PHOTOS (clockwise from top): New York © Charles Gleberman; Mongolia © Kurt Fesenmyer/TNC; Papua New Guinea © Duncan Bellet/TNC; Australia © Melissa Roberson/TNC Photo Contest 2021; Congo Basin © Peter Ellis/TNC; Brazil © João Ramid; Colombia © Paul Smith; Mexico © Isas Consultores

Annual Geospatial Survey & Trends

The Nature Conservancy conducted a fifth annual survey in June 2023 to assess the status and needs of our geospatial community across GIS, remote sensing and data science disciplines. We asked respondents about their use of cloud platforms, storage and compute needs, training, software usage and their specific geospatial areas of expertise and technology support. Since 2019, the responses have enabled us to track trends and build an effective enterprise geospatial system that supports practitioners and elevates our geospatial work to a higher level of excellence.

Note: Like all surveys, results are only as accurate as the response rate. Therefore, results do not necessarily reflect the status of the entire TNC geospatial community.

1,828
STAFF INVITED TO PARTICIPATE IN THE SURVEY

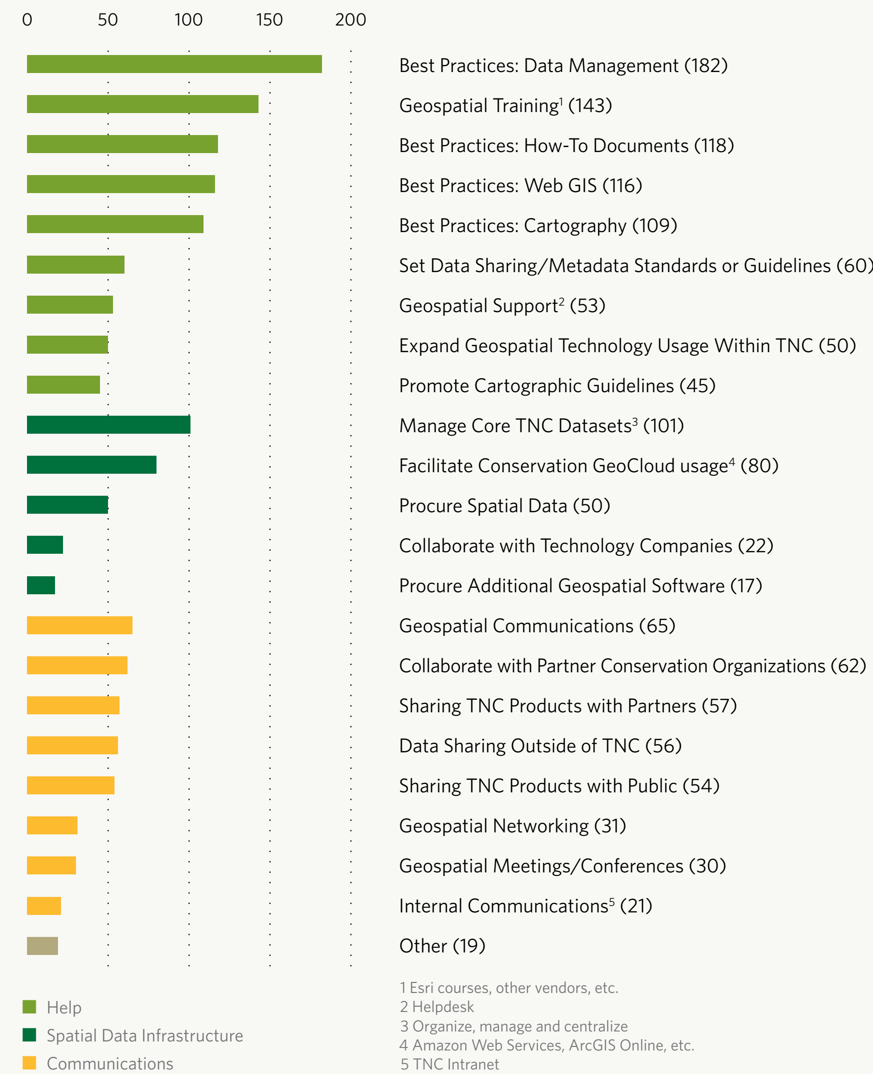
289
RESPONDENTS [88% COMPLETED THE ENTIRE SURVEY]

Defining TNC's Geospatial Community

1,897	GEOSPATIAL COMMUNITY MEMBERS
1,679	TNC STAFF USING GEOSPATIAL COMMUNITY MICROSOFT TEAMS
1,813	ACTIVE MEMBERS ON ARCGIS ONLINE
592	USERS ON CONSERVATION GEOCLOUD
50	EXTERNAL PARTNER ORGANIZATIONS SUPPORTED (BY EXTENSION) ESRI AUTHORIZED ENTITIES

Priorities of Geospatial Community

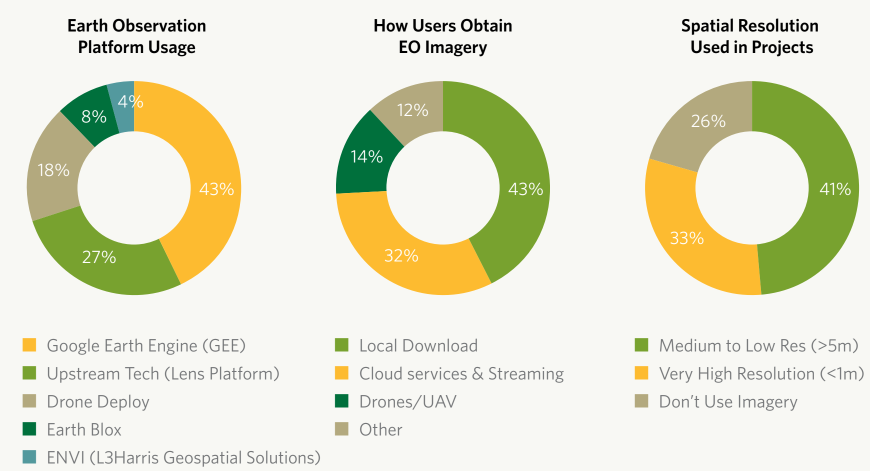
We asked respondents to identify the top priorities that the Geospatial Systems IT team should focus on in the next year to make the most significant impact on the community's work.



1 Esri courses, other vendors, etc.
2 Helpdesk
3 Organize, manage and centralize
4 Amazon Web Services, ArcGIS Online, etc.
5 TNC Intranet

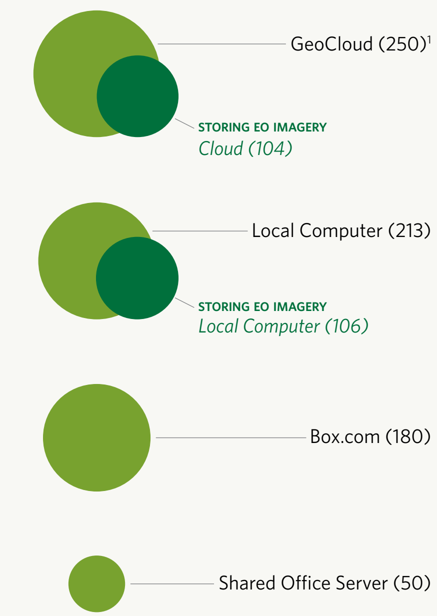
Earth Observation

Earth observation imagery sources include Planet Labs and Upstream Tech. TNC scientists use EO software by DroneDeploy, Google Earth Engine, Earth Blox, ENVI, Picterra and Lens (by Upstream Tech).



Storing Spatial Data

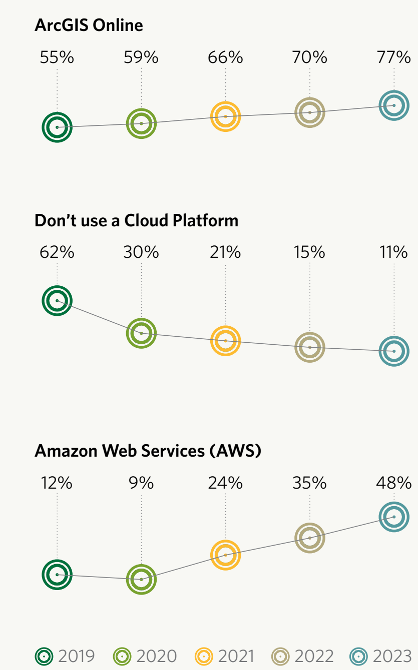
Most respondents now use TNC's Conservation GeoCloud to store their spatial data. Box.com and local computers are also widely used for this purpose. Notably, all on-premises geospatial data servers were discontinued in 2023. Users store imagery almost equally locally and in the cloud for Earth observation data.



1 Cloud platforms other than Box

Cloud Platform Usage

In the past five surveys, we have seen increased usage of cloud platforms, principally ArcGIS Online and Amazon Web Services. We have also migrated spatial data from outdated on-premises servers to the GeoCloud.



Mapping the Path to Achieving 2030 Conservation Goals

Vienna Saccomanno
Senior Scientist

The most efficient way to get to a destination is with a good map. For The Nature Conservancy, we can't protect what we can't see or adaptively manage what we can't measure. Earth observation allows us to understand how ecosystems and biodiversity are changing in response to anthropogenic pressures and to measure responses to conservation efforts. Many EO satellites orbit our planet, collecting essential observations. Sometimes, however the natural phenomena we are trying to observe are small and under the detectable limits of satellites. In these cases, other EO tools are needed, so TNC deploys small, unoccupied aerial vehicles, or drones, around the world.

Across the Pacific Ocean, we use drones to map and monitor critical marine ecosystems and species. From detecting rare seabirds on isolated atolls to surveying coral reefs and identifying sparse patches of kelp forests, drone platforms are essential for our scientists to gather data that inform thoughtful and strategic conservation. Drone imagery provides a rare, ultra-high-resolution bird's-eye view of the unique places we are working to protect. A single survey can yield terabytes of data that describe the dynamics of the world below, creating a puzzle for our scientists to put together with the help of state-of-the-art machine learning models and data science. Drones allow our pilots to collect data in some of the most isolated corners of the world and some of the most challenging conditions. But we do not work in isolation; instead, we work with local partners, combining cutting-edge science and age-old wisdom to strategically map a world where people and nature thrive.

Join us as we embark on an aerial journey across the Pacific to three unique ocean places we are working to protect.

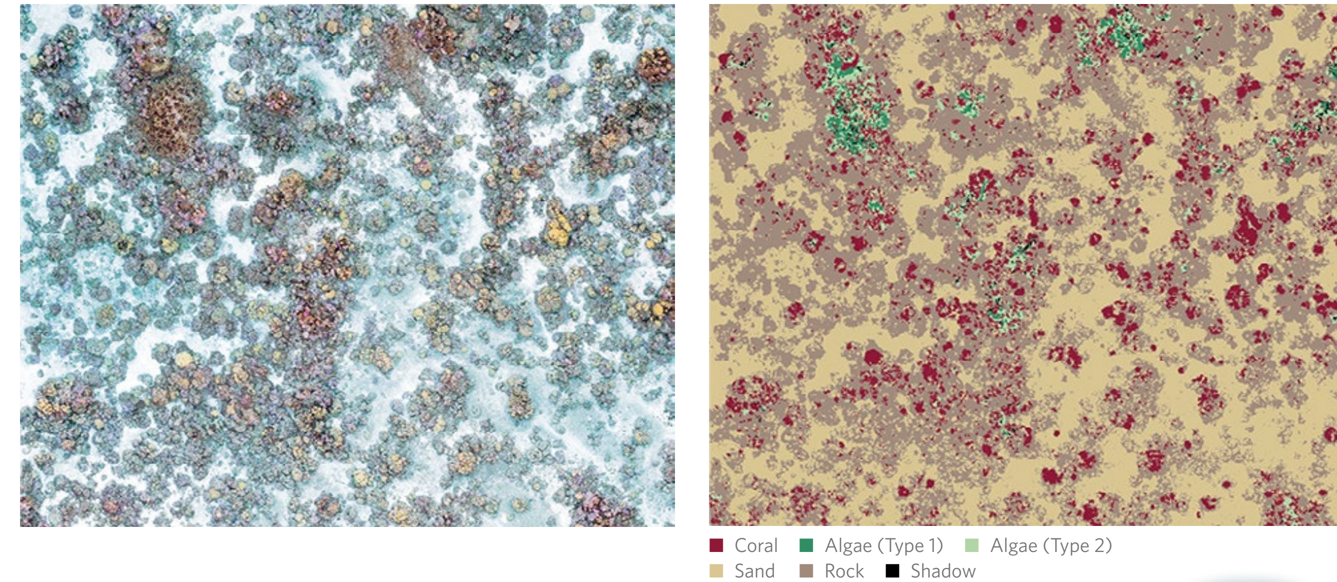
PHOTO: Rainforest realignment efforts underway at Palmyra Atoll with the removal of introduced coconut palm trees and their remaining "match sticks" to make way for native species preferred by seabirds. © Vienna Saccomanno/TNC

DETECTING SEABIRDS ON PALMYRA ATOLL

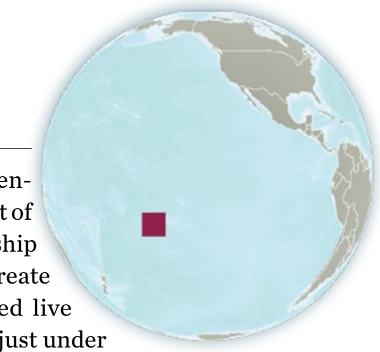
About 1,700 kilometers southwest of Honolulu, Hawai'i, lies Palmyra Atoll. With the support of a group of conservation champions, TNC purchased Palmyra Atoll in 2000 to protect a unique marine wilderness and establish a platform for applied conservation science. Seabirds are beneficial residents of Palmyra and atolls across the Pacific, as their guano is an essential nutrient source. But coconut palms, introduced for copra agriculture in the mid-1800s, are ill-suited for seabirds and have taken over land once dominated by native rainforest vegetation. TNC and partners are converting an abandoned coconut palm plantation to a rainforest dominated by native trees that seabirds prefer. We intend to restore ecological balance to the atoll, maximizing the seabird-driven nutrient cycle and increasing resilience to climate-driven impacts. We hypothesize that this restoration work will result in more native habitat for Palmyra's seabirds. The first question is, how many seabirds are currently at Palmyra? And as restoration work proceeds, can we measure seabird abundance and distribution changes to quantify our impact?

To answer these questions, TNC deployed drones to image the entire atoll and efficiently and accurately count seabirds before forest realignment work. The imagery created a baseline estimate of seabird abundance and distribution. Working from the assumption that tens of thousands of seabirds occupy the current extent of Palmyra's native rainforest, our scientists partnered with an artificial intelligence (AI) company specializing in automating the analysis of large, unstructured datasets, offering instant detection of seabirds at scale. Pairing EO data with AI-powered imagery analysis allowed our team to understand better the rate of change occurring on the atoll. Along the way, our team discovered two other seabird species previously believed to have been extirpated, or made locally extinct, during World War II: blue noddy (*Procelsterna cerulea*) and wedge-tailed shearwater (*Puffinus pacificus*). This discovery is a promising sign that these two species may return to nest at Palmyra in the future—and that decades of conservation at Palmyra by TNC and our partners is paying off. While a good map will show you where you need to go, the world still offers plenty of adventures and discoveries along the journey.

IMAGE: High-resolution drone image of a small portion of the Palmyra shoreline. The rectangles represent AI-generated detections of seabirds roosting in trees.



MAPPING LIVING CORAL IN FRENCH POLYNESIA



French Polynesia has over 100 dispersed islands and atolls spanning over 2,000 kilometers and is home to 170 species of coral. Coral reefs are among the most biodiverse ecosystems on the planet, supporting 25% of all marine life and coastal communities. Unfortunately, they are among the most threatened ecosystems because of climate change and increasing pressures from overfishing, pollution and coastal development. We have already lost 50% of our planet's coral reefs in the past 30 years, and 90% of the remaining coral reefs are at risk of disappearing by 2050.

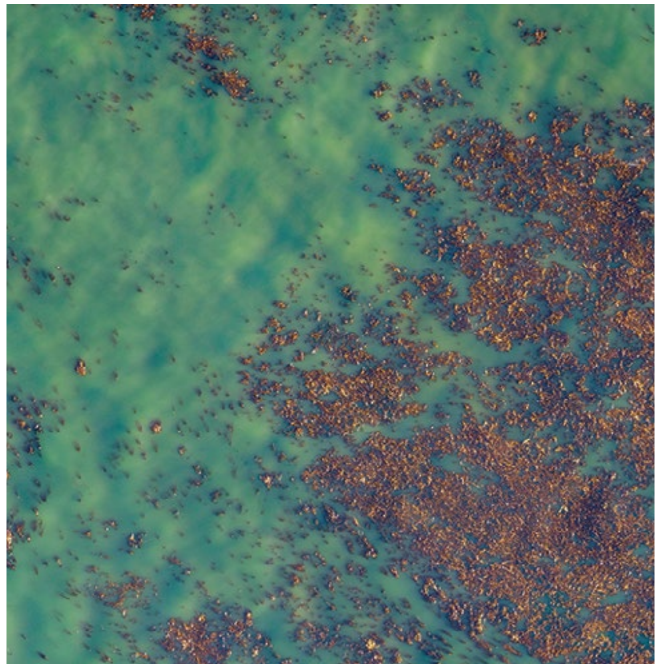
TNC is scaling up our coral reef restoration efforts to shift this tide. We're developing hardware and software tools to increase efficiency and reduce the cost of growing corals in nurseries and transplanting them onto reefs. To maximize and demonstrate the value of this approach, we have partnered with the local nonprofit Coral Gardeners in Moorea, French Polynesia, to establish a high-capacity onshore coral nursery. But growing corals in a nursery is only the first step in building resilient reefs; determining the best places to transplant corals is the next step in durable coral reef restoration. With over 30 square kilometers of lagoon area around Moorea that could support coral reefs, a roadmap is essential to help identify suitable restoration sites.

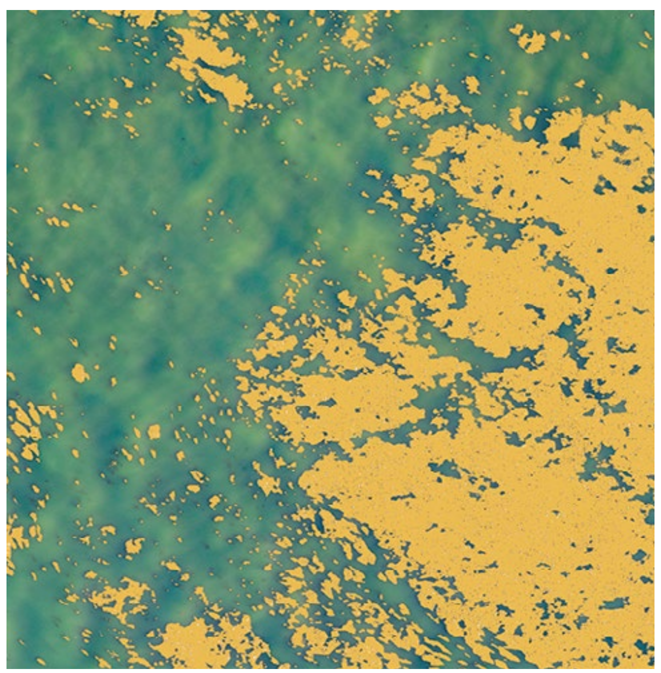
In 2023, a team of TNC scientists and drone pilots took a fleet of aircraft to Moorea, in partnership with the Coral Gardeners, to create the island's first drone-derived live coral map. The team surveyed just under 1,000 hectares of reef habitat with state-of-the-art drones, producing high-resolution imagery that offers a glimpse into a singular moment of the dynamic life of a coral reef ecosystem. After the team returned, we processed their imagery with computer software that uses AI to call attention to relationships, recognizing groups of pixels as objects—like living coral.

Building upon the drone imagery, we mapped which pixels contain living corals. These pockets of living corals that have thrived in the good times and survived through the hard times signal favorable in-water conditions. By analyzing additional factors such as water temperature and turbidity, our science team is creating a restoration roadmap of where transplanted corals will have the greatest chance of survival.

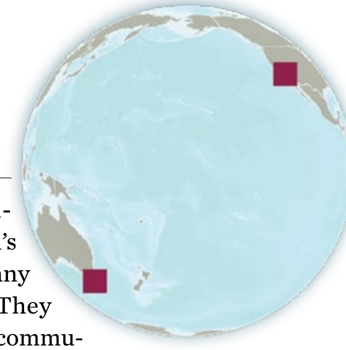
IMAGES: Small subset of a high-resolution drone image (left) and the AI-generated classified map of corals and other features (right)

25%	50%	90%
of all marine life & coastal communities are supported by **coral reefs**	of our planet's coral reefs **were lost** in the past 30 years	of the remaining coral reefs are **at risk of disappearing** by 2050





MAPPING KELP FORESTS IN TASMANIA AND CALIFORNIA



Kelp forests are complex habitats found along 25% of the world's coastlines and a foundation of many nearshore marine environments. They provide valuable services for coastal communities, are important nursery and foraging habitats for at least 1,000 species and help buffer shorelines from storms. Over the past few decades, though, canopy-forming kelps have been declining in many regions, including Tasmania and the North Coast of California. Given kelp's ecological and economic value, TNC and our partners are implementing restoration projects to help bring these ecosystems back in balance.

Canopy-forming kelp forests are distinguishable in EO data thanks to biomass that rests on the ocean's surface. Drones, therefore, provide a unique opportunity to detect and map the remaining kelp patches and, thus, guide strategic efforts to protect and restore these strongholds.

Consequently, TNC began surveying kelp along California's North Coast in 2019. The growth of these annual efforts has, we believe, made them the most extensive continuous marine-focused drone surveys in California history. In a given year, the team surveys thousands of hectares to map the locations and sizes of kelp patches. TNC works with the Hakai Institute, whose AI tool identifies kelp—pixel by pixel—based on the shape of the fronds and the unique way kelp tissue reflects light.

In 2023, TNC California's ocean science team collaborated in the field with TNC Australia colleagues, who recently launched the Tasmanian Giant Kelp Restoration Project, to share lessons learned and best practices for mapping kelp forests using drones. Together, the teams mapped some of Tasmania's most important remaining kelp patches to guide the program's restoration priorities.

IMAGES: Raw image showing kelp canopy (top) and AI-generated map of kelp patches over the image (bottom).

PHOTO (below): © Ralph Pace

CONCLUSIONS

At TNC, we believe a world where people and nature thrive is possible. Although that world can sometimes feel distant, this body of work has shown us that, together, we can leverage technology to get a little closer. But time may be our most limited resource in this determining decade for our rapidly changing climate. We don't have a minute to spare. We must be thoughtful, strategic and efficient, and that requires a good roadmap to show the best route to get to our destination and help measure our impact along the way. Earth observation technology and drone-generated data have transformed TNC's science of where and how we work, helping us achieve our ambitious 2030 goals.

Kelp canopy data collected with drones along the North Coast of California led TNC to establish three restoration sites, which we co-manage with a multi-million-dollar investment from the state. Without high-resolution drone maps, finding the kelp strongholds that anchor this restoration work would have been like finding a proverbial needle in a haystack. The cutting-edge ecosystem-recovery science that TNC and our partners are deploying can now be shared to help kelp forests around the world.

PHOTO: © Patrick Webster

Earth Observation Applications

INTRODUCTION

Increasingly, Earth observation data coupled with cloud-based software-as-a-service (SaaS) platforms are assisting TNC in ways that inform our conservation strategies like never before. For example, we can monitor large properties to detect ecological changes, identify invasive species or track changes in water temperature. This section highlights key projects and geographies where EO applications provide a comprehensive picture of our planet as a basis for making critical conservation business decisions.

LAKE TANGANYIKA: NEXT-GENERATION SPATIAL INTELLIGENCE FOR SMART AQUACULTURE GROWTH

Aquaculture is the fastest growing form of food production on the planet, with an annual growth rate of 3%. Its growth is particularly apparent in freshwater species; in 2020, aquaculture supplied more than 80% of freshwater fish consumed globally[1]. To ensure that the continued expansion of this industry does not contribute to habitat loss or degradation, TNC has implemented a Smart Growth approach. This includes the development of spatial science and tools that support evidence-based aquaculture siting and management. Together, these practices can advance a sustainable industry that benefits local communities, including those in and around Lake Tanganyika.

Lake Tanganyika is a globally important freshwater biodiversity hotspot. At 1.5 kilometers depth, the deepest lake in Africa is home to many endemic species, including more than 200 cichlids not found anywhere else on Earth.

Alongside Lake Tanganyika's wild capture fishery—which supports the livelihoods of more than 200,000 fishers, processors and boat builders and provides an important food source for the region—there is also an emerging aquaculture industry. Given the environmental and social importance of the lake for its four bordering nations—Burundi, Tanzania, Zambia and the Democratic Republic of the Congo—there is a need to ensure any aquaculture development provides benefits to local communities and minimizes negative impacts to the lake's sensitive habitat and biodiversity. TNC's Smart Growth approach combines the best available science tools and a robust regulatory framework to support the goals of the countries and its partners.

Siting is the most critical consideration for sustainable aquaculture to mitigate negative impacts. In collaboration with local and regional governments and other stakeholders, TNC recently completed an aquaculture site suitability analysis for the section of Lake Tanganyika within Tanzania's borders. Employing the next generation of spatial intelligence, a continuous suitability scoring scale and building on existing aquaculture development guidelines from the region, the analysis identifies areas more appropriate for aquaculture development and those that should be avoided.

This robust and forward-looking model accounts for various economic, social and environmental factors. This included accounting for potential climate impacts on lake surface temperature by creating a monthly predictive dataset based on 20 years of lake-wide water temperature trends from NASA's Multi-scale Ultra-high Resolution (MUR) satellite observations. We also characterized turbidity using a special algorithm from NASA's MODIS satellite instrument. The algorithm, called diffuse attenuation coefficient at 490 nautical miles (Kd490), can identify areas with high sediment loading from various sources, including runoff from land use changes. Equipped with this information, Lake Tanganyika's aquaculture industry, if properly regulated and incentivized, is better poised to grow sustainably in a way that benefits people and nature.

1 FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO. https://doi.org/10.4060/cc0461en

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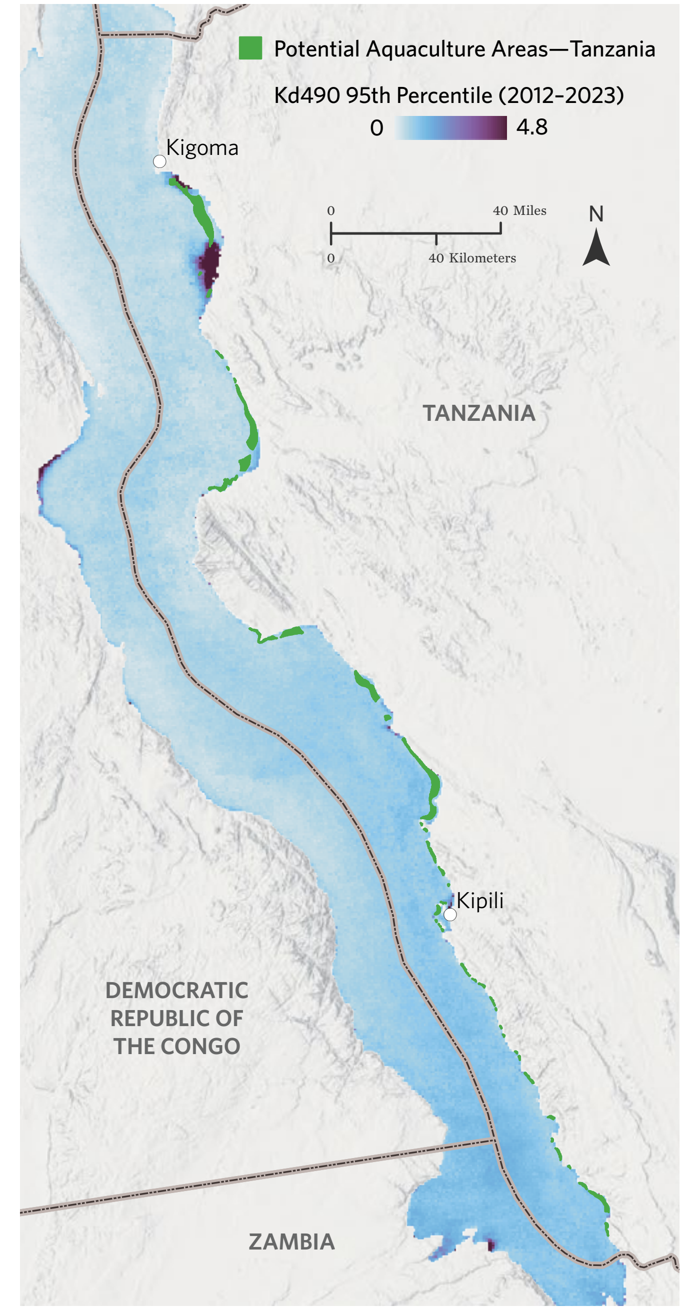
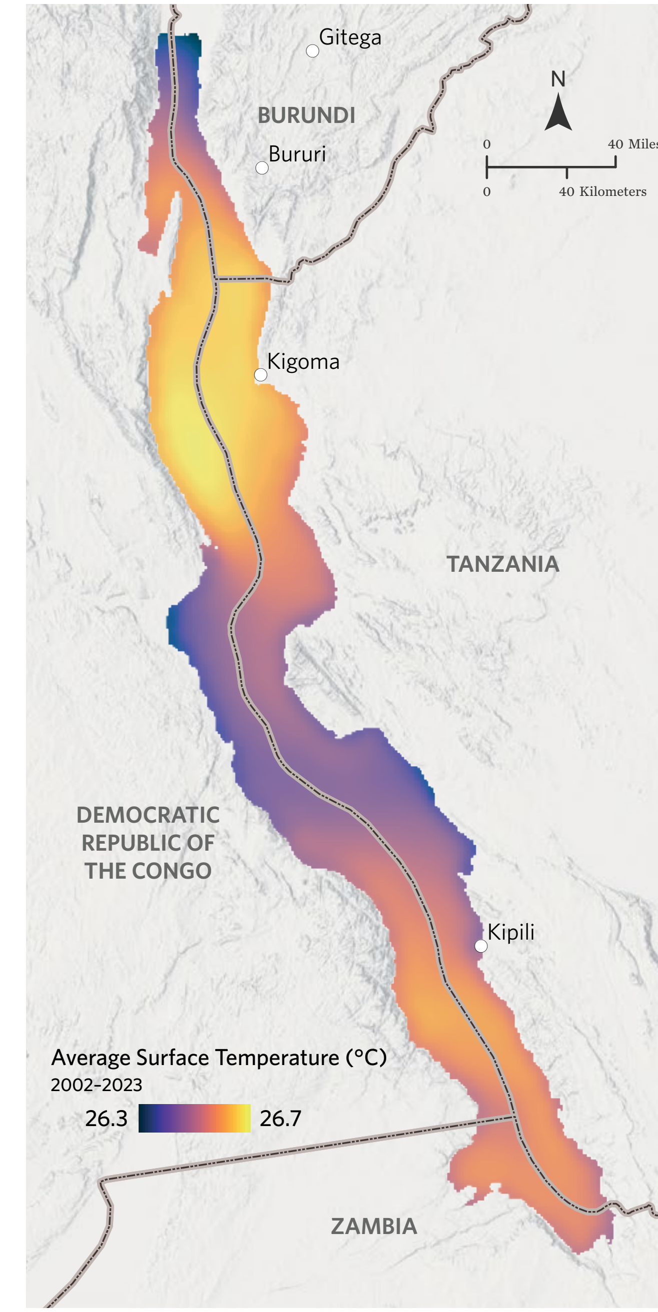
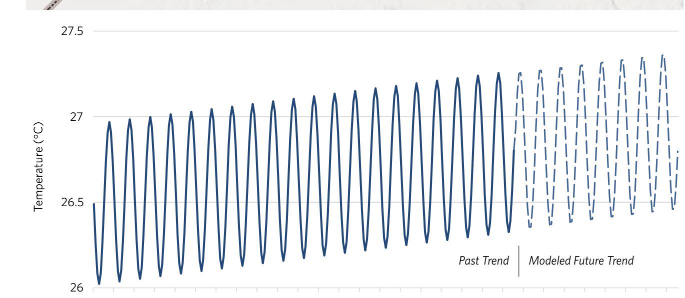


MAP 1: ↑ Kd490 represents the turbidity of the water. A high value of Kd490 relates to areas with cloudy water with high amounts of sediments, typically around the mouth of a river. These areas should be avoided for aquaculture development, as turbid water can directly affect fish health.

PHOTO: Pilot-scale fish farm cage in Kigoma, Tanzania
© Jonathan MacKay/TNC





MAP 2 AND PLOT: ↑ Understanding how and where temperature changes is important when planning for aquaculture development. This map and plot of water temperature show how temperature varies by location and season on the lake. Utilizing 20 years of MUR water temperature data, we can plot this change and help predict monthly temperatures to the year 2030.

DATA SOURCES: TNC, NASA, Natural Earth

UTILIZING HIGH-RESOLUTION AERIAL IMAGERY IN HAWAIʻI

Non-native, weedy plant species threaten fragile native Hawaiian ecosystems—the world's extinction capital with more than 400 threatened and endangered plant, arthropod and animal species. TNC protects 14 preserves totaling 27,000 acres across the island archipelago. Weedy species threaten to upset the biological integrity of our preserve system. However, with innovative tools to identify and monitor those threats, we now have more efficient methods for detecting and removing invasive species. Using high-resolution aerial imagery and partnering with various tech companies specializing in artificial intelligence and machine learning (AI/ML), we attempted to identify where two of the worst weedy species occur in Hawaiian forests.

We invested in a portfolio of natural color, high-resolution aerial images and video collected via drone, fixed-wing and helicopter-based cameras. To automate workflows, we analyzed the utility of three AI/ML platforms and different types of imagery to identify two priority weeds, Himalayan ginger (*Hedychium gardnerianum*) and Australian tree fern (*Cyathea cooperi*).

Himalayan ginger ranks among the world's most invasive species and is known to alter hydrologic cycles and impact watershed and ecosystem function. Within TNC's Waikamoi Preserve and adjacent areas, our ginger control strategies focus on containing the spread from core populations and eliminating outlier plants that emerge in native plant communities. Australian tree fern alters habitats because it is large, grows fast and forms dense colonies that can ultimately replace native plants. On Kauaʻi, they have escaped cultivation and spread into native forests, altering their diversity.

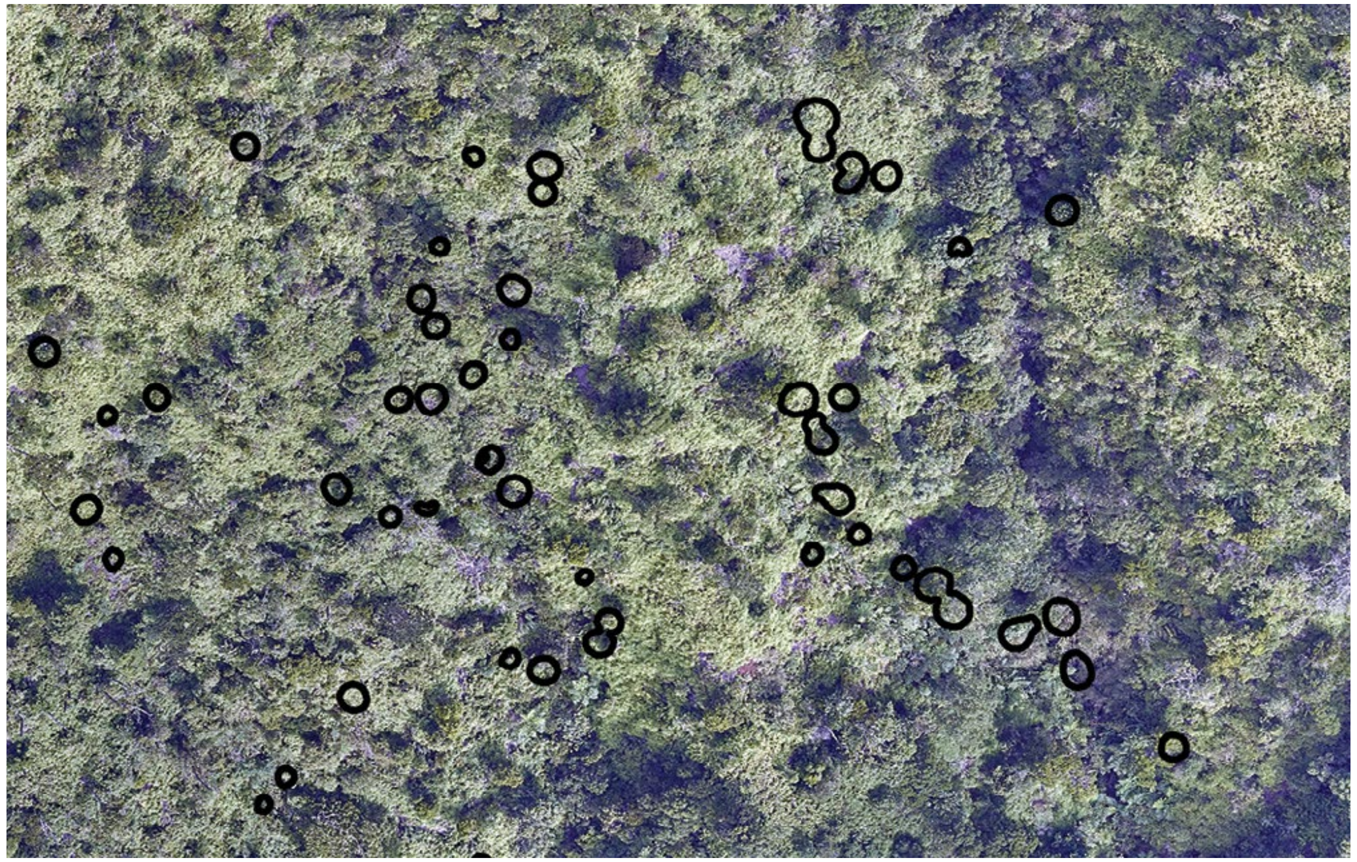
Our platform analysis involved creating datasets to train the AI/ML models. This method did require extensive support from data scientists to identify false positives. Note also that a self-serve platform with no training and minimal support from data scientists was unsuccessful at identifying Himalayan ginger. We would need a less restrictive data set and improved image quality to make this model successful.

For another analysis platform, we used drone video to identify Himalayan ginger. We loaded high-resolution imagery into an annotation explorer. For a training dataset, we identified rule sets and drew bounding boxes around ginger. In the initial proof of concept, this platform was 75% successful at identifying ginger. The main issue with this trial was obtaining enough drone footage from areas with ginger.

We will continue to explore new options while improving the imagery that feeds into available platforms. Meanwhile, AI/ML platforms continue to evolve rapidly. More vendors, finer-tuned algorithms and enhanced image collection hold real promise for AI/ML to improve invasive species control in Hawaiʻi.

PHOTO: Blooming Himalayan ginger © TNC/Ethan Welty

MAPS: ↑ Automated prediction of Himalayan ginger locations in a high-resolution drone image.
↓ Predicted locations of Australian tree fern in high-resolution imagery.

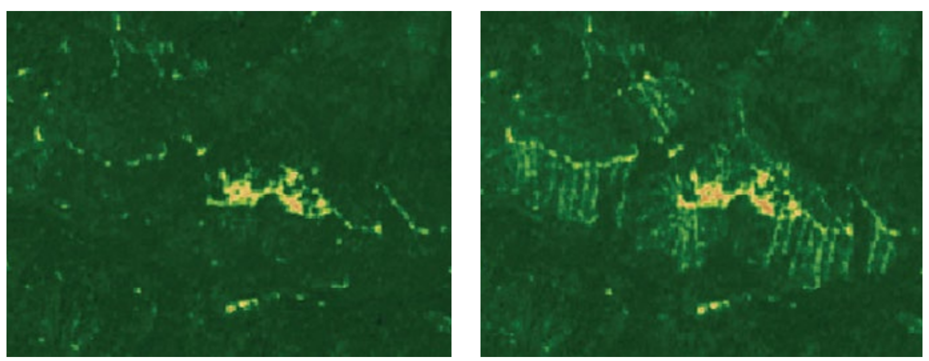


EFFICIENT AND EFFECTIVE REMOTE MONITORING

In 2019, TNC California collaborated with Upstream Tech to create a remote monitoring software platform to address the growing challenges of in-person, on-the-ground property monitoring. Called Lens, this new platform was designed to make annual compliance monitoring more consistent, efficient and effective across geographies. Today, more than 250 organizations globally are using Lens to monitor over 160 million acres. Further, from data we've collected over the past few years, we found that remote monitoring saves these organizations 1) 62% of staff time on average compared to in-person monitoring and 2) significant travel and other expenses, even accounting for investments in the technology. With various scale and time-dependent imagery sources available, organizations use Lens to inspect new land deals, plan restoration, and monitor and assess climate impacts. Read on for examples that demonstrate the benefits of remote monitoring in vital geographies where TNC owns property or partners with other land trusts.

California

TNC and land trusts use Lens for annual compliance monitoring to detect, contextualize and document natural and human-induced changes to property. Year to year, detecting change requires comparing current-year and prior-year imagery. High-resolution imagery (+/- 1 sq ft pixels) is critical for detecting specific changes but can become costly for larger properties. When conducting annual monitoring on large properties, such as the Garcia River Forest Conservation Easement (23,779 acres, owned by The Conservation Fund), we can first screen the property for broad changes using free public satellite imagery. We can then purchase high-resolution imagery for places where a significant change bears closer inspection.

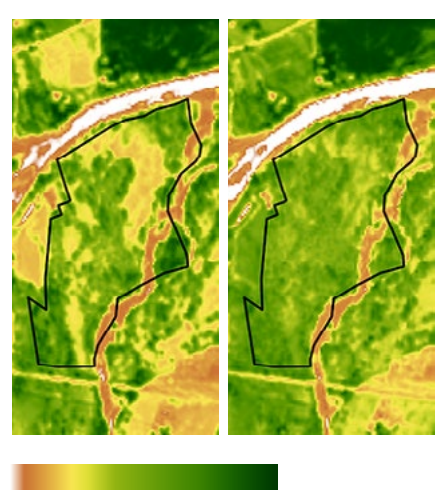


↑ The first two images represent a yearly comparison of vegetation vigor derived from freely available Sentinel-2 satellite imagery (from the European Space Agency).

↑ The monitor's careful year-over-year comparison reveals small but significant areas of vegetation change that can be inspected more closely with recent high-resolution imagery (© 2021 Airbus Pleiades).

Montana

TNC uses the Lens platform in over 30 U.S. states. In Montana, our land stewards use Lens' higher-frequency/lower-resolution imagery to compare rangeland trends. By comparing the same date year over year using Sentinel-2 10-meter resolution imagery, we can analyze vegetation vigor on the ground and share findings with landowner partners to help them make better management decisions. Additionally, the Lens surface water and moisture index can show late-season increases following in-stream restoration projects such as installing artificial beaver dam structures designed to improve riparian habitat.



← A year-over-year comparison of a property indicates higher vegetation vigor in the most recent image (right side) (Satellite Imagery © 2022–23 Sentinel).

Before our adoption of remote monitoring technologies such as Lens, if land trusts wanted to take advantage of remote sensing to complete their required annual monitoring of properties, they typically had to cobble together various platforms and imagery. New platforms for remote monitoring have significantly advanced an essential component of land trust work by offering easy access, simplicity and compatibility with a wide range of imagery.

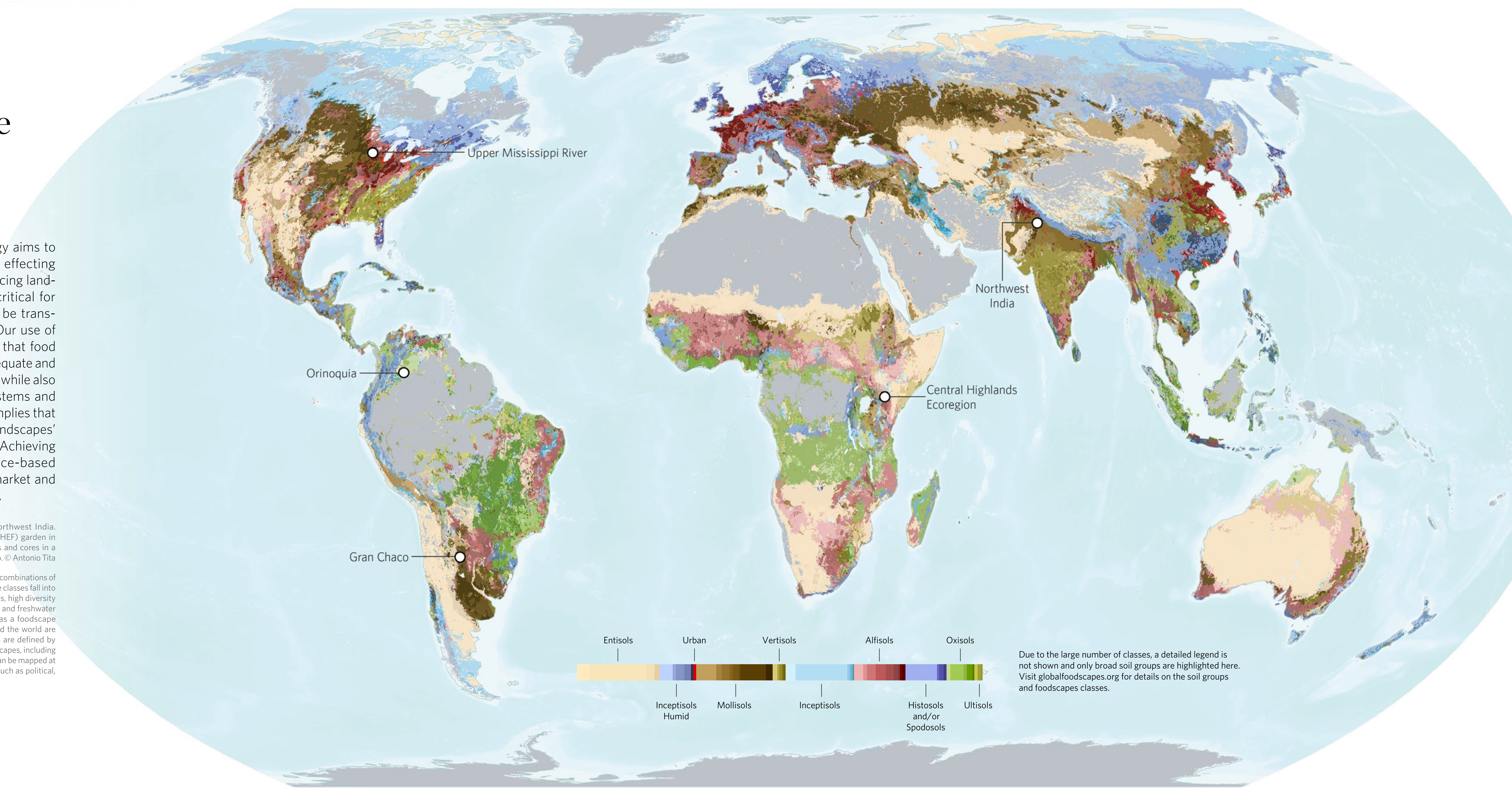
PHOTO: The Garcia River Forest Project is restoring 23,779 acres of productive forest on California's north coast. In 2004, the Conservancy and The Conservation Fund acquired this heavily cut forest property to restore important habitat and to help reduce the impacts of climate change by removing greenhouse gases from the air and setting a new model for sustainable forest management by a non-profit organization. © Bridget Besaw

Regenerative Foodscapes

TNC's Regenerative Foodscapes strategy aims to achieve a systemic transformation by effecting change across a portfolio of food-producing landscapes. These living laboratories are critical for demonstrating how food systems can be transformed and galvanizing global action. Our use of the term *regenerative* conveys the idea that food systems have the potential to provide adequate and healthy food for people around the world while also protecting and restoring natural ecosystems and mitigating climate change. *Foodscapes* implies that food production is tightly woven into landscapes' ecological, political and cultural fabric. Achieving change in foodscapes requires a place-based approach that addresses the cultural, market and political forces shaping food production.

PHOTOS (from top): Harvesting tomatoes in Haryana, Northwest India. © Smita Sharma; Central Highlands Ecoregion Foodscape (CHEF) garden in Laikipia County, Kenya © Roshni Lodhia; Conservation buffers and cores in a regenerative agricultural landscape in the Argentinian Gran Chaco. © Antonio Tita

MAP: This map shows 80 foodscape classes, areas with specific combinations of biophysical characteristics and food-production attributes. These classes fall into five broad production categories around the globe: breadbaskets, high diversity areas, rangelands & pasture, little or no food areas, and marine and freshwater areas. Foodscape classes are not the same as foodscapes, as a foodscape can comprise many classes. Many breadbasket regions around the world are relatively homogenous, while many smallholder food systems are defined by their heterogeneity. This map is limited to the attributes of foodscapes, including biophysical and agricultural management characteristics, that can be mapped at a global scale. It omits some critical elements of a foodscape, such as political, social, economic and cultural factors.



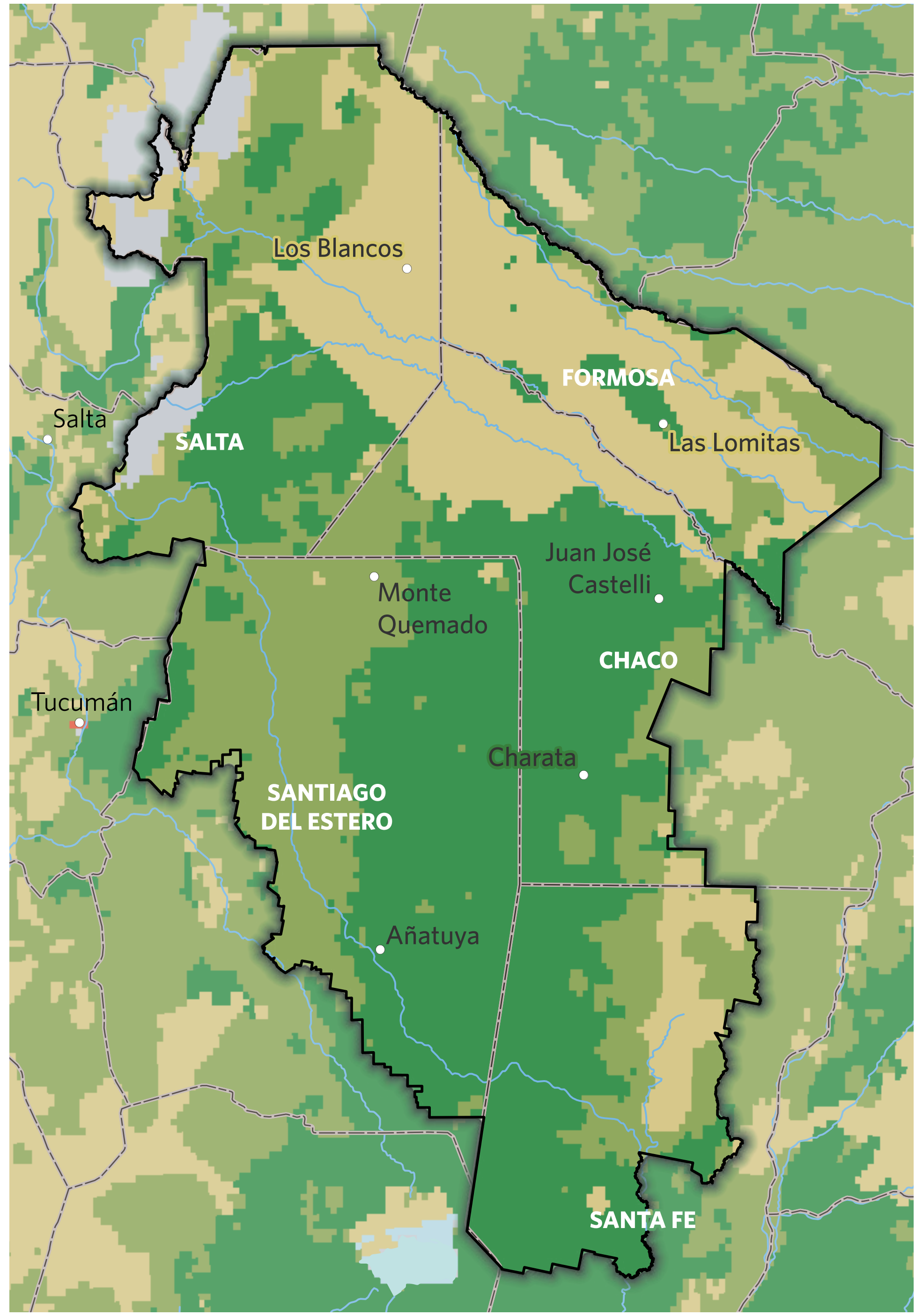
Through this portfolio of projects, TNC aims to demonstrate how to engage local producers and communities, the private sector and policymakers to accelerate regenerative practices. By scaling deep in a portfolio representing the diversity of geographic and food production archetypes, TNC is looking to develop a set of living laboratories that can be replicated and scaled for global impact.

These maps use the same data as the overall foodscapes layer shown on the global map; however, the mapped classes have been further aggregated to reflect three levels of food production intensity.

- Scattered cropland and grazing
- Mixed and diverse food cultivation
- Irrigated and/or intensive food production
- Areas with little or only subsistence food production
- Highly urbanized land
- State/Province/Department Boundary*

0 100 Miles
0 100 Kilometers
Scale for all maps

*Subnational boundaries of Kenya are counties that are too detailed to include at this scale.

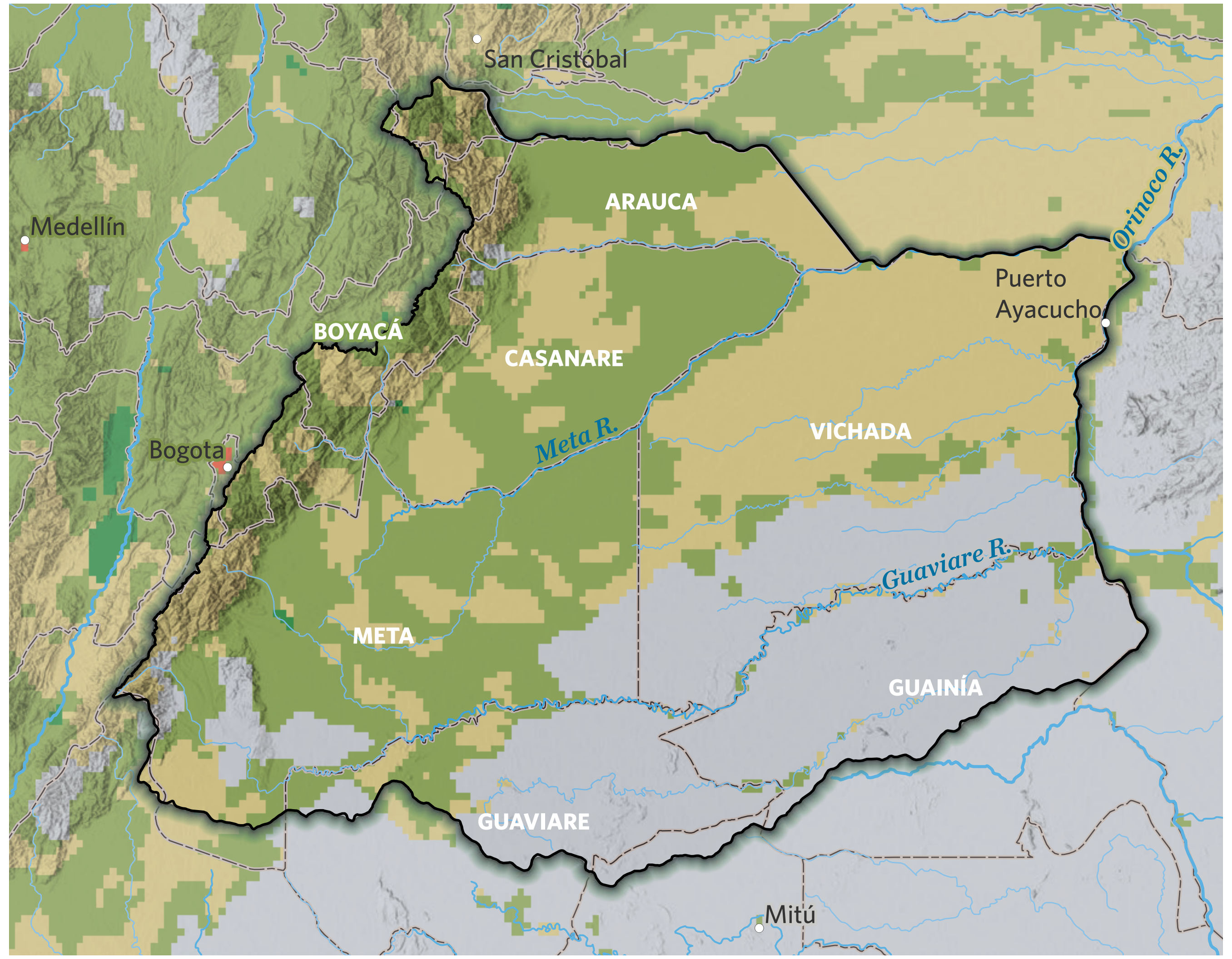


← Argentinian Gran Chaco

The Argentinian Gran Chaco covers 33 million hectares of threatened tropical dry savanna habitat. *Chaco* means "hunting territory," evoking the region's biodiversity, featuring jaguar, giant armadillo, tapir and giant anteater. But more than a third of this natural habitat has been converted to agricultural production, primarily to support beef supply chains. Cultivation has led to cycles of biodiversity loss and degradation of agricultural lands. TNC seeks to demonstrate how corporations, policymakers, local producers and communities can deploy regenerative food production practices in the Gran Chaco foodscape to protect healthy ecosystems and tackle climate change. Collaborating with production hubs and platforms, such as the Argentine Round Table for Sustainable Meat, and with traders, such as Syngenta, Bunge and the Louis Dreyfus Company, we have developed the online Agroldeal system and other technologies to help soy traders make sustainable cultivation decisions.

↑ Upper Mississippi River

The Upper Mississippi River (UMR) foodscape is a biodiversity hot spot spanning four states. Much of the historic habitat here was converted to grow row crops and raise livestock. Natural habitats are fragmented and degraded, while communities are vulnerable to flooding. In lakes, rivers, streams and the Gulf of Mexico, aquatic life suffers from excessive nutrient runoff. TNC is building on our history of connecting conservation and agriculture. We're expanding partnerships in the UMR basin to help shift supply-chain incentives, expand market access to diverse crops and enhance policy incentives that support farmers who adopt regenerative practices such as cover crops, no-till, nutrient management, crop diversification and agroforestry. A key lever is more TNC engagement with the Diverse Corn Belt Initiative, the Midwest Row Crop Collaborative, the University of Minnesota and the Land Institute's Forever Green Initiative. Our foodscape work will also contribute to an expansion of agroforestry made possible by a USDA Partnerships for Climate-Smart Commodities $60 million grant awarded to TNC and partners.

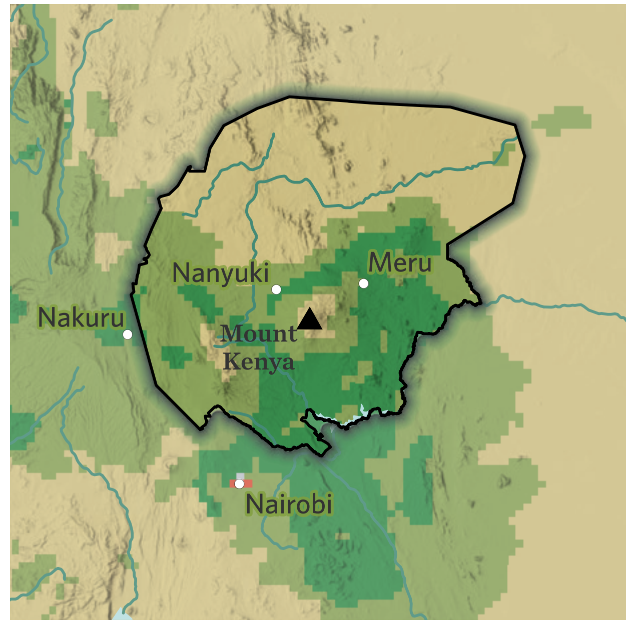


← Orinoquia

The Orinoquia foodscape covers the llanos savanna in Colombia's Orinoco River basin, one of the most extensive natural tropical savannas in the Americas. The recently established Manacacias National Park protects part of this region. Outside the park, the region contributes 28% of Colombia's agricultural production and is considered the "last great frontier for agribusiness development." This agribusiness expansion is converting native savanna to extensive cattle ranching with exotic pastures or rice, oil palm, soy or cashew cultivation. Every year, agriculture claims another 200,000 hectares of native savanna. The foodscape aims to protect and restore native savanna through market incentives, policies and regulations that encourage conservation and sustainable agricultural practices. One key mechanism is the Orinoquia Pact, which is a multi-stakeholder platform that seeks the sustainable development of this region, promoting food production, biodiversity protection and water governance.

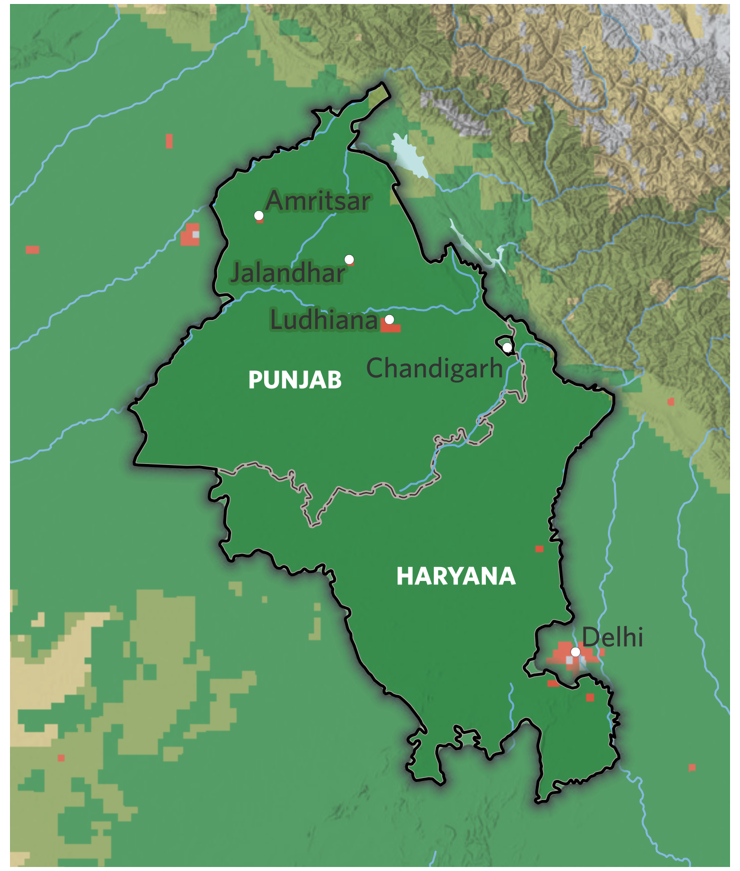
Central Highlands Ecoregion Foodscape →

Kenya's Central Highlands Ecoregion Foodscape (CHEF) spans from the water towers of Mount Kenya and the Aberdares down through high-rainfall farmlands and semi-arid production lands to arid rangelands covering wildlife conservancies and pastoralist communities. One of the most important areas for biodiversity in East Africa, the CHEF is also a critical supplier of fruits, vegetables, grains, cut flowers and livestock to markets in Kenya, Europe and the Middle East. Rapidly expanding agriculture—especially irrigated agriculture—is both a boon to food supply and economic growth and a threat to wildlife and livestock that depend on increasingly scarce water resources. The CHEF collaboration seeks to catalyze regenerative food systems by scaling improved practices, strengthening capacity, providing policy support and enhancing grassroots market systems that enable viable wildlife, pastoralist and cropping systems. The CHEF is developing an innovation hub incentivizing stakeholders to practice environmental sustainability and meet market demand. This central innovation hub will support farmer hubs in key communities of natural resource users to enhance optimal water and land use at scale.



Northwest India →

Northwest India is the most productive rice and wheat growing area in South Asia, providing almost half of the grain essential to food security in India. Technologies and policies enable farmers to grow high-yield rice and wheat crops at a vast scale—nearly 4.4 million hectares. They have also created substantial environmental and human health challenges. Irrigation is depleting aquifers, and the short window between rice and wheat crops has incentivized farmers to burn fields following harvest. The smoke and particulates from residue burning contribute to respiratory disease as well as greenhouse gas emissions. The goal of the Northwest India foodscape is to support farmers with alternatives to burning, to reduce excessive groundwater pumping, and to diversify crops and revenue streams. The foodscape works at the intersection of policy, behavior change, agronomy and market development to foster a systemic shift in Northwest India's food production.



Map Spotlight

A MONTH IN THE LIFE OF A SOUTHERN CALIFORNIA MOUNTAIN LION

Ira Koroleva
California

Mountain lions, *Puma concolor*, are a keystone species of California. Their habitat extends across the state, including large portions of undeveloped natural areas of Southern California. The latter geography surrounds expansive urban and suburban development in Los Angeles, Orange, Riverside and San Diego counties; the remaining natural areas have limited connectivity in places due to habitat conversion and fragmentation by roads and development. Mountain lions can quickly cover long distances and need large intact areas for hunting and mating. A decades-long study being conducted by UC Davis Wildlife Health Center in collaboration with The Nature Conservancy aims to understand the population and movement patterns of mountain lions in Southern California, with a specific focus on survivability, identification and protection of critical corridors and creation of wildlife crossings where highways are a barrier to movement.

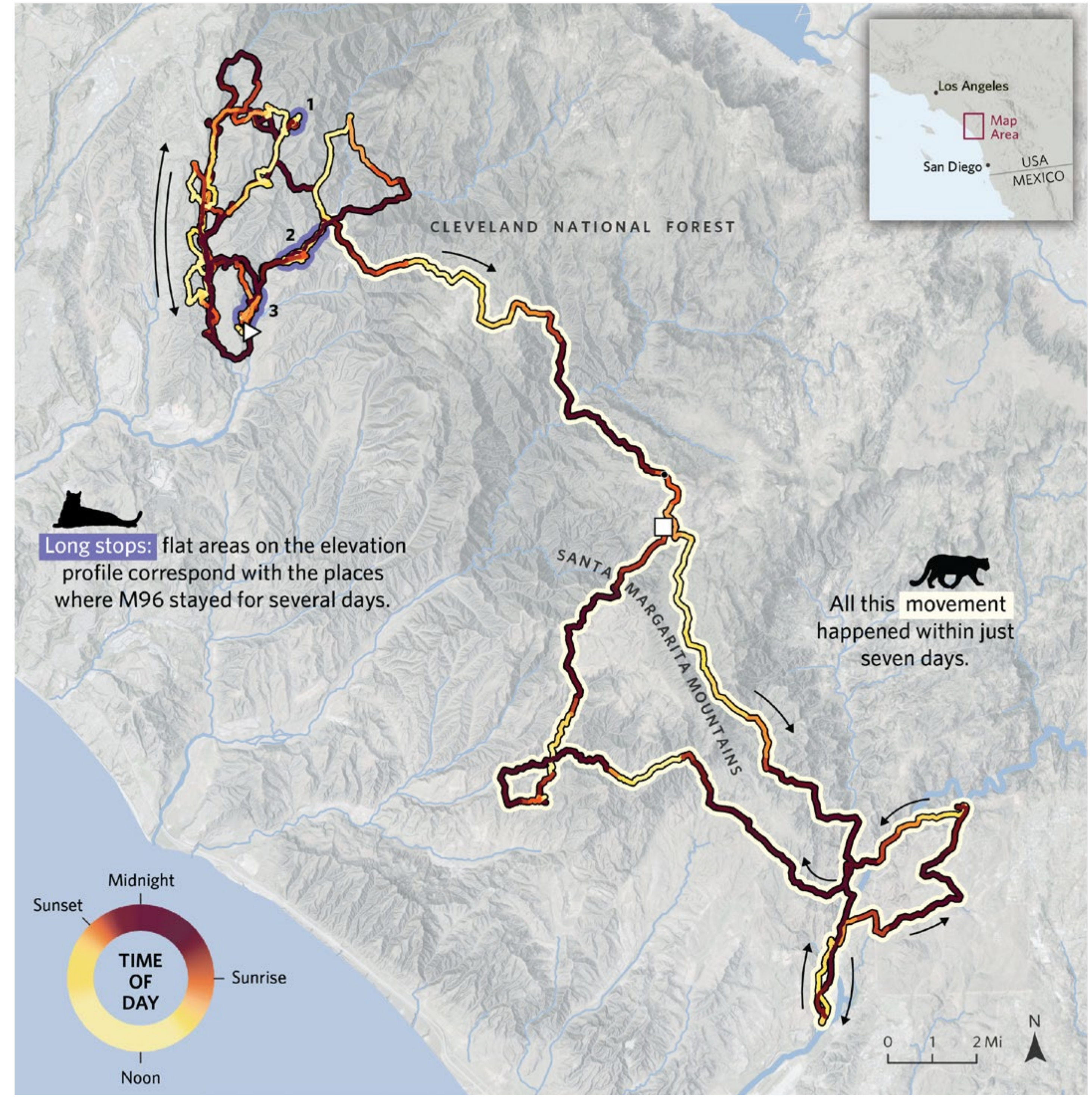
MAP: The data provided by UC Davis Wildlife Health Center contains tracking points of GPS-collared mountain lions whose movements were studied in Southern California between 2001 and 2023. Points from select individual mountain lions registered every 5 minutes, illuminating the precise path that an animal followed during the day and night and distinguishing movement from stops. This map explores the movement of an adult male lion named M96 that was tracked in the spring of 2012 in the Santa Ana Mountain Range. In May 2012, the lion spent most of the time circling a small area in a canyon by a stream, then suddenly proceeded on a long rapid journey with infrequent daytime stops.

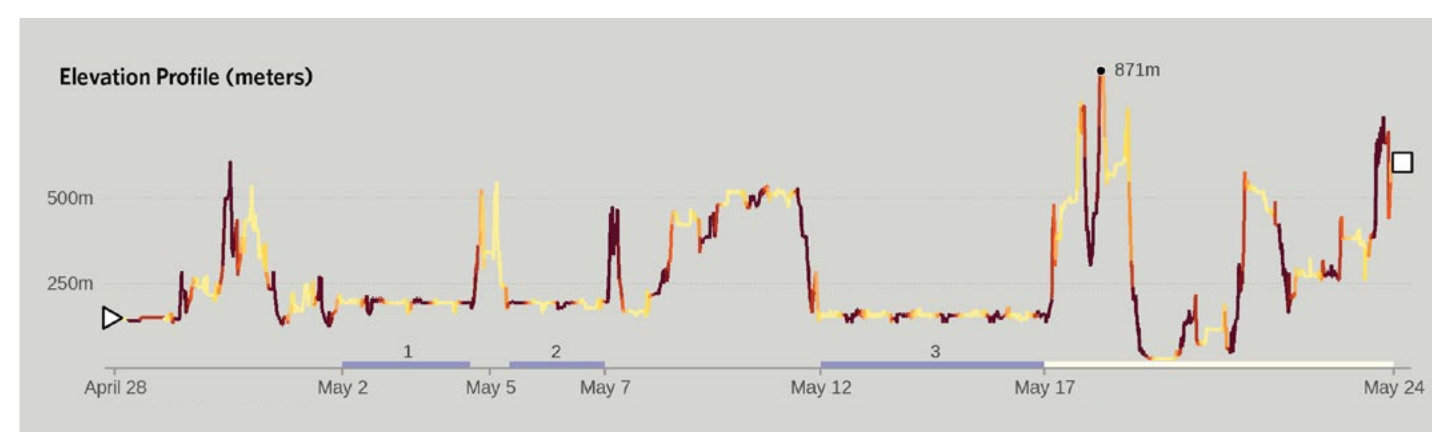
SOURCES: UC Davis Wildlife Health Center (track), Esri (hillshade), PhyloPic (walking icon)

SOFTWARE: ArcGIS Pro, R, and Adobe Illustrator

Ira Koroleva is a former Conservation Technology Associate, who supported California projects and teams with GIS, data analysis, mapping, and data management.

PHOTO: A trail camera captures a female mountain lion at night on the western edge of the Santa Ana Mountains in Orange County, California. © Donna Krucki





Looking Ahead: 2024

Geospatial technologies and Earth observation sensors, paired with the rigorous scientific methodologies highlighted in this report, are helping us modernize our work, make a valuable contribution to conserving our natural world and improve people's lives. Our geospatial science community works to provide equitable access to resources and technologies, making it easier to establish consistent methods and measures to track progress toward our 2030 goals. We will reach our objectives sooner with efficient and effective use of EO science and its data and platforms.

However, we have identified several areas of need, including equal access to consistent, analysis-ready, high-resolution imagery. Historically, freely available resources have been concentrated in northern latitudes and wealthier countries. We recognize this problem and are working diligently to share what we have learned from priority areas for application to other regions.

To this end, TNC has partnered with Planet Labs. Following several successful prior engagements, we have now embarked on an enterprise agreement with Planet Labs, where we are providing imagery to projects and programs around the world that are generating data to track goals towards 2030. Here we focus on applying consistent methods to extract specific ecosystem features, serving as an incubator for successful use cases and partnerships, and facilitating comparisons of results across geographies.

To ensure our scientists are successful in their research and analyses using Earth observation data, our Geospatial Systems IT team (in coordination with and under the guidance of our Global Geospatial Leadership Council) is working to provide equitable access to data storage, sharing and compute resources. Of course, providing the data is only one step toward ensuring that our conservation science communities are successful. We also collaborate internally and externally to support our science programs on the long-term curation of our most valuable data assets. At the same time, we continue to explore new trends in the geospatial field, such as advances in AI/ML, cloud-computing services and platforms to advance and modernize our conservation science work. This is how we support one another, reduce duplication of effort and continue to learn from one another. After all, we share a common goal to conserve what is most important to us.

Acknowledgements

This fifth edition Geospatial Conservation Annual Report & Map Book has been a collective effort between TNC staff in Information Technology, Marketing and various Conservation Science departments. A big thanks goes to Jan Slaats for conducting and synthesizing our annual survey, Rae Schultz and Alicea Halsted for developing a digital companion to this report, and Jay Sullivan for his always outstanding support for print publication. Danielle DeGarmo (contractor) did the incredible layout and design work, and a special thanks goes to Danny White for his editing review.

Durable and representative conservation doesn't happen in a vacuum, and there is a team of incredible and passionate people who helped make the EO science highlighted in this report possible. Vienna Saccomanno contributed this year's feature story and worked with a large team of TNC colleagues and partners across the Pacific, including Alex Wegmann, Nick Holmes, Katie Franklin, Dana Sabine, Joe Pollock, Breonna Jones, Steve Schill, Tamaki Bieri, Irina Koroleva, Annick Cross, Norah Eddy, Kirk Klausmeyer, Tristin McHugh, Ben Grime, Tom Bell, Luba Reshitnyk, Kyle Cavanaugh, Kate Cavanaugh, Emelly Villa, Simon Reeves, Kirk Dahle, Simon Branigan, Scott Breschkin, Paul Tompkins, Vera Rullens, Alice Howie and our colleagues at the Coral Gardeners in French Polynesia. We would also like to thank our partners in the Palmyra Atoll Rainforest and Reef Resilience Project: the U.S. Fish and Wildlife Service and Island Conservation. This work was done in the traditional and ancestral territory of the Tahitians in French Polynesia, the Northern Pomo and Coast Yuki peoples in California and the Tasmanian Aboriginal peoples.

Jonathan MacKay, Theresa Menard, Kerri Fay, Sue Pollock and Ethan Inlander contributed additional stories and content. Thanks to Tim Boucher, Stephen Wood, Alison Surdoval and Lyndsey Dowell for their help featuring our work on global foodscapes. Thanks also goes to Ira Koroleva in California for being this year's Cartographer featured in our Map Spotlight. In One Conservancy spirit, thanks to all these folks for their essential contributions. We also extend appreciation to TNC's global leadership in IT and Global Science, most notably Theresa Shaw, Mitch Head and Katharine Hayhoe, for championing the work of TNC's geospatial conservation community. Finally, we are most appreciative of our enduring partnerships with Esri, Amazon Web Services and Microsoft, as well as Earth observation partners Planet Labs, Upstream Tech, Picterra and Earth Blox in continuing to support this incredible conservation work. We are most grateful for your support!

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PHOTO: Drone imagery of a mangrove creek system in Shroud Cay, The Bahamas, one of many uninhabited islands within the Exuma Cays Land and Sea National Park. Founded in 1958, this park was the first land and sea park in the world and continues to be one of the most successful marine reserves in the Caribbean. The raw imagery is shown to the right, blended with the derived classified vegetation map to the left. © Steve Schill/TNC

The Nature Conservancy