ENVIRONMENTAL POLICY
INNOVATION
CENTER

HOW TO HELP CONSERVATION DATA TECH SPREAD

Our vision of a future in which new data technology originates from–and is adapted to–conservation so that we dramatically speed up the process of restoring & regenerating our planet.

ABOUT THE ENVIRONMENTAL POLICY INNOVATION CENTER

The mission of the Environmental Policy Innovation Center is to build policies that deliver spectacular improvement in the speed and scale of conservation. We focus on a narrow set of strategies:

- Improving policies that allow private sector funding or stewardship to expand or supplant public or charitable conservation work.
- Transforming government policies to focus on what matters – outcomes.
- Eliminating the organizational barriers that prevent public agencies from adapting to 21st century solutions.

We believe that innovation and speed are central to broadening efforts to conserve wildlife, restore special natural places, and to deliver people and nature with the clean water they need to thrive. To achieve those goals, conservation programs must evolve to accommodate our modern understanding of human behavior and incentives, and the challenges posed by humanity's expanding footprint. We embrace experimentation with novel ideas in conservation policy, to learn quickly from mistakes and iteratively design effective approaches to be even more successful.

EPIC is a fiscally sponsored project of Sand County Foundation. Sand County Foundation is a non-profit conservation organization dedicated to working with private landowners across North America to advance ethical and scientifically sound land management practices that benefit the environment.

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HOW TO HELP CONSERVATION DATA TECH SPREAD

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INTRODUCTION

New technology is being developed that could dramatically speed up our progress in protecting and restoring our planet. There are many examples of how this is already happening and huge promise for even more progress in the next five years. Unfortunately, there have been more stalled pilots, poorly designed products and financially unsustainable programs than successes. But we can learn a lot from the past five years of big data tool development and pivot to more impactful and widescale application of conservation data technology[1] in the next 5 years.

> This report is guided by our vision of a future in which there is prolific development of new data tech originating in conservation, and where promising technology from other spaces is quickly adapted to conservation, such that we dramatically speed up the process of restoring and regenerating our planet.

We wanted to understand why the uptake of new data technologies and methods is lagging in the environmental space[2] and how to change that trend. Dozens of spatial data tech tools and applications that have been developed both by nonprofits and for profits offer lessons for the future. We looked at current use, past development and application and future constraints for these tools, focusing mostly on data tools rather than physical sensors and hardware. We spoke with key personnel involved with the development or deployment of the technology and, in some cases, interviewed potential clients for that technology. We provide a set of in-depth case studies of a few of the programs, tools, and initiatives we analyzed across sectors, and then offer a broader analysis of the constraints on and opportunities for environmental data tech to be applied to the restoration economy.

We found significant barriers to almost every data technology that has been employed in conservation. Many of these setbacks could have been anticipated and perhaps avoided. Application of data tech in conservation is suffering from some of the same challenges that plague other business and planning tools: designing products that truly meet a market need[3], pricing those products correctly to capture enough users while sustaining operations, and sufficient marketing and product support to keep users coming back are all critically important. The dominance of nonprofits and government agencies in conservation – and the cultural conservatism that often defines their approaches – may make it harder for new conservation data tech to get broad adoption in this sector.

[1]Data technology for conservation involves collecting and manipulating large amounts of data to aid in decision-making, forecasting, monitoring or interpreting natural resource systems. An example would be drone-mounted cameras that use computer algorithms to create 3D maps of old mining sites undergoing restoration. Or systems of sensors and atmospheric data that can alert us to impending flooding and produce inundation maps. Or analyzing thousands of images of endangered wildlife to track their migration patterns and prevent poaching.

[2]Blair, Gordon S., Peter Henrys, Amber Leeson, John Watkins, Emma Eastoe, Susan Jarvis, and Paul J. Young. "Data Science of the Natural Environment: A Research Roadmap." Frontiers in Environmental Science 7 (2019).

[3]Iacona, G. et al., "Identifying Technology Solutions to Bring Conservation into the Innovation Era." Frontiers in Ecology and the Environment, vol. 17, no. 10, 2 Oct. 2019, https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2111.

Given EPIC's mission to build policies that speed up conservation, we were particularly interested in understanding where policy becomes a barrier to data tech innovation, and where it can open doors. Conservation, natural resource management and restoration activities overlap with activities by highly regulated industries like oil and gas, and mining. The needs and demands of those industries should be driving the development of data tools. However, we found that:

- Regulated industries will adopt technologies in which there is a business benefit, but not when the technology creates a regulatory liability. For example, a water utility might benefit from continuous information about their water quality, but if AI data analysis results in more false positives that trigger more regulatory requirements or enforcement than the sparse sampling regulators currently demand, they might prefer not to have more data or AI to look at it.

- Data tech tools aren't being quickly accepted by regulators to address compliance or reporting needs because there isn't a repeatable, quick process for regulators to develop trust of the outputs from those tools. This is creating barriers to market growth for data technology.

- Government agencies that manage conservation and restoration have the potential to be among the most willing future adopters of data technology to help them meet their own objectives. However, we found it's more common for them to reject technology, slow walk pilot projects, or reinvent the wheel by trying to redevelop tech applications themselves.

Nonprofits and universities are broadening their involvement in the development of data tech tools for conservation, especially to reveal environmental damage and enforcement opportunities. For university-based initiatives, too many tools are premised on the frequently incorrect hypothesis that documentation of a problem leads to action – it often doesn't. Their tools may serve scientists and researchers well but need a stronger theory of change to be adopted in practice at a wide scale by industry or by governments and law enforcement tasked with combatting deforestation, poaching and natural resource exploitation. For nonprofit created tools, supplying more data that shows environmental problems spurs positive member, public or donor reaction, it doesn't necessarily lead to industry or regulatory change. These mismatches allow nonprofit and university data platform creators to think their products have value even when they aren't having impact on the ground.

Of the technologies we reviewed, we found that the most promising area for development in conservation is the pairing of satellite data and machine learning (Page 6) to allow automatic pattern detection to replace current manual efforts to track, guide, or enforce environmental activities, regulatory compliance, or restoration portfolios. This is because the outputs it produces and questions it answers match up closely with non-AI tools that conservationists are already familiar with. In addition, some of these tools and applications allow users to still visually double-check machine outputs, providing users with a perception that they understand or can double check the assumptions and models built into the data tech tool.

ENVIRONMENTAL DATA TECH REVIEW

We reviewed dozens of data technology applications through interviews with innovators, user groups, salespeople, technologists, program staff and researchers, as well as additional background research into data tech applications, their programming and hardware, how they worked and how they delivered results.[4] Our priority questions included:

- How do you define success for the technology application you sell, use, or tested?
- What barriers prevent broader data tech deployment for conservation?
- What ideas or products have you seen launch and fail?
- What new data tech ideas are you most excited about and why?

The focus of our review was on data tech tools and software, rather than the physical technology embedded in satellites, drones, hyperspectral sensors, or DNA readers. And we focused on spatial data tools rather than sentiment analysis, automated language processing or other types of data technology. Our goal was not to suggest these tools don't have relevance to conservation, but we simply needed to find some way to produce a manageable analysis.

Most of the data tech applications we reviewed fit into one of four categories (Figure 1):

1. Real-time automated landscape change detection
2. Pattern detection through machine learning
3. Traditional Geographic Information Systems (GIS) analysis
4. Decision support for precision agriculture

We describe each of these below and give examples of their application. In the remainder of this paper, we share lessons learned from success and failure of data tech for conservation and explain what is driving and challenging the growth of this new field.

[4] We were fortunate to collaborate with the Electric Power Research Institute and several of their member electric utilities this year in a joint project. This allowed us to speak to many people who are researching data tech applications that could help utilities measure and manage their environmental impacts.

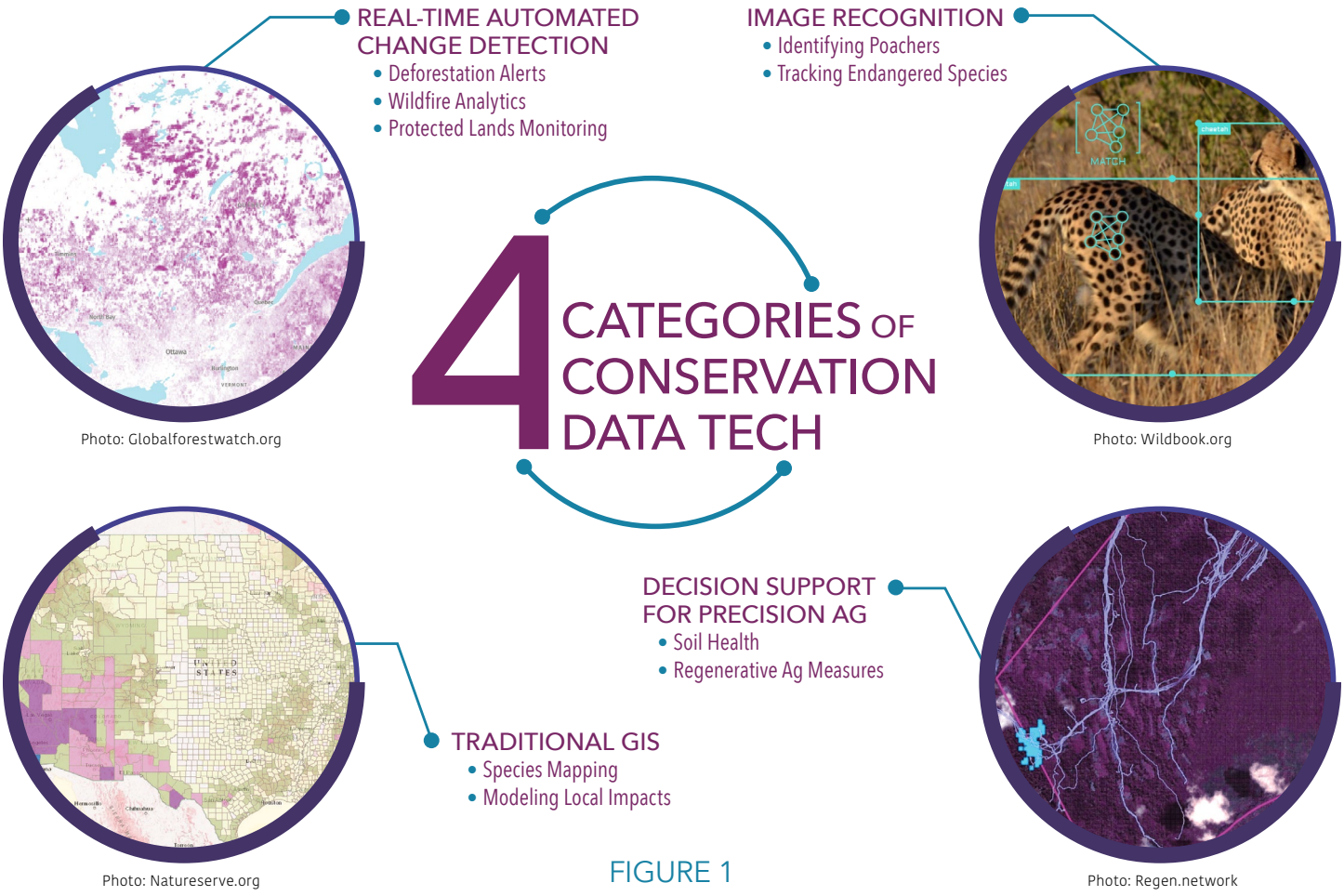


FIGURE 1

1 REAL-TIME AUTOMATED LANDSCAPE CHANGE DETECTION

Automated change detection is widely used in medicine, real estate, defense, and other fields and is also being applied to conservation. Change detection isn't new – it was part of the earliest use cases for GIS mapping technology and software. What's new is the automation of change detection. The technique simply involves having a computer—instead of a human—identify and categorize changes in data over time and alert users to the levels and types of changes detected.[5] The data might come from extremely high (or low) resolution satellite data, be collected by drones or other unmanned aerial vehicles, or even be derived from crowdsourced camera data. Here are some examples of automated change technology in conservation:

[5] To be clear, it can be very challenging or even impossible to automate some change detection due to lack sufficient ground truth data, and computers aren't yet capable of distinguishing between some classifications of images.

CASE STUDY: GLOBAL FOREST WATCH

NONPROFIT WITH BROAD FUNDING SUPPORT, SUCCESSFULLY DEPLOYING SPATIAL DATA TECH TOOL WITH WIDE APPLICATION IN CONSERVATION

Global Forest Watch is a successful spatial data tech tool developed by a nonprofit whose application is influencing global conservation. Since version 2.0 launched in 2014, more than 3 million people have visited the interactive portal to witness, track, or monitor near-real time data on the loss or growth of forests around the world. New uses of the tool happen organically, as government agencies, police departments, nonprofits, and local communities discover that it provides a relevant, accessible and timely source of priority information that isn't available from any other source – or at least not for free. This is made possible in part because Global Forest Watch's maintenance and continued improvement is supported by significant funding from donors like the government of Norway, the U.S. Agency for International Development, the UK Department for International Development and the Moore Foundation. The government of Norway is **investing $53 million** in purchasing high-resolution imagery of tropical forests that will be made freely and publicly available, including to Global Forest Watch. These grants create a level of resources that few other conservation data tools can match.

Global Forest Watch's tool is based on years of earlier product development and strategy. During the early years of development, satellite imagery was not as widely available, and computing resources were too slow to make the kind of impact we see today. Substantial improvements have since been made: NASA made their Landsat image archive freely available and computer processing has become efficient enough to process millions of images quickly and cost-effectively.

Global Forest Watch now touts a diverse customer base, consisting of local and state law enforcement personnel, federal natural resource agencies, civil society organizations, communities and global aid agencies. Based on their understanding of their users, they have begun building targeted tools for specific user groups. It's not easy to anticipate whether state or federal governments would want access to the data for enforcement and regulatory compliance. Across the tropics, deforestation is driven by poor or unclear land use policies, corruption, and lack of monitoring and enforcement of whatever policies do exist. Where it's tied to illegal logging, operators often have government connections.

Global Forest Watch collects success stories from their users. They heard directly from a police chief in Brazil who used their mobile app and shared it with other law enforcement. Dozens of indigenous groups have used their app to see incursions onto their land and share that data with local law enforcement. They've also garnered corporate users who have made anti-deforestation commitments and use their applications to see where they might have exposure to deforestation in their supply chains. Global Forest Watch is committed to providing its maps for free, and they remain a project of a nonprofit organization.

Global Forest Watch's success can be attributed to three factors: 1) it provides a combination of data and AI analysis unavailable through any low tech approach, 2) it has continuously improved data and user interfaces, driven by ongoing efforts to understand user needs, so the system's value to conservation users keeps increasing, and 3) significant investment in user outreach and support to ensure those who can most positively impact the fate of forests know about GFW and are able to make the most of it.

WILDFIRE ANALYTICS AND PREDICTION

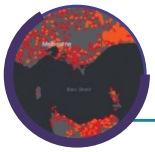
Wildfire is one of the easiest landscape changes to detect because the intense light and heat from the fires are easily sensed, and smoke plumes or blackened ground serve as helpful indirect measures. A few new wildfire analytic data tools have come on the market **(Figure 2)**, but they haven't had staying power primarily because NASA already provides data and services that largely meet the needs of the market. A new tool – **Jupiter Intelligence's Firescore** – has received funding and will launch soon. Firescore will use machine learning to predict wildfire risks and behavior in ways that make the information more relevant than existing NASA products to public safety personnel and infrastructure providers. Whether they will be successful is unclear, but at least their strategy recognizes they need to build beyond services already in the marketplace to offer new services and features.

We estimate that $7-$10 million in philanthropic support and government grants have been provided to develop non-governmental wildfire analytic tools. NASA's wildfire satellite data collection capacity and data services, and NASA's FIRMS website, are based on hundreds of millions in additional investment.

FIGURE 2

FIRECAST – CONSERVATION INTERNATIONAL

Conservation International launched Firecast in 2013 with a grant from NASA and maintenance of the software has been abandoned today. The tool was designed to interpret and share a change detection system (i.e. presence of fire) that NASA had already built and to provide alerts and forecasting for less developed countries in the tropics. It appears to have largely ceased operations and development by 2019 and NASA funding ended in 2017.

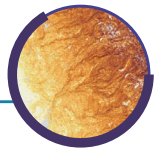


GLOBAL FOREST FIRES WATCH – WORLD RESOURCES INSTITUTE

Launched in 2014, WRI built a new portal to show fires, packaging data from NASA that was already available on their website and adding in the ability for users to receive alerts. The project wound down by 2017.

FIRMS – NASA

NASA's Fire Information for Resource Management System provides spatial data on active fires within 3 hours of satellite observation from MODIS and VIIRS satellites.

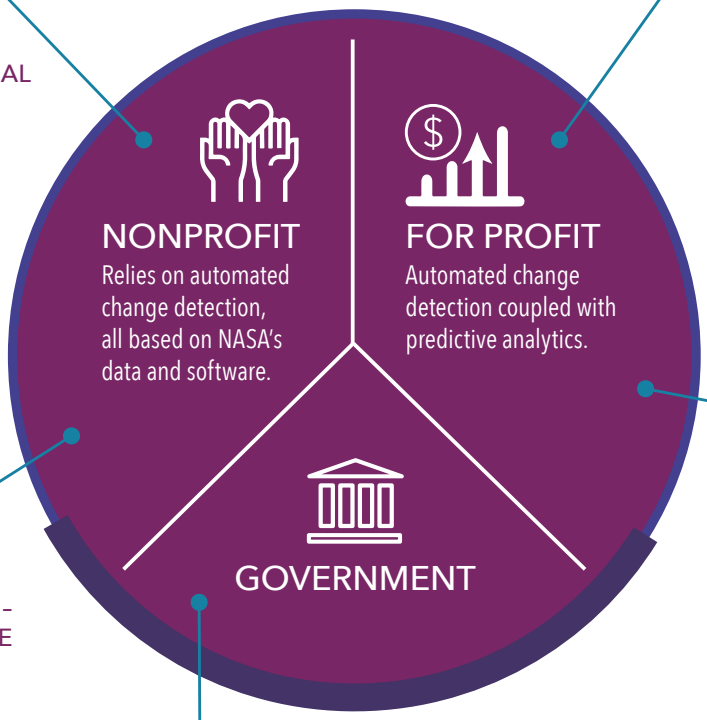


FIRESCORE – JUPITER INTELLIGENCE

In 2019, they received a $1 million grant from the Gordon and Betty Moore Foundation to make wildfire risk information available to local fire and emergency personnel in California. Firescore is still in development but more information is available here.

WILDFIRE DETECTOR – DESCARTES LABS

Descartes Labs launched their wildfire detector in New Mexico 2020. The detector uses algorithms to analyze near real-time imagery from two NOAA satellites, GOES-16 and GOES-17, for early detection of fire locations based on changes in the amount of heat detected.



PROTECTED LANDS

There is a lot of interest in using automated change detection in landscapes to gauge changes on protected lands. The protected lands space is dominated by land trusts, including The Nature Conservancy, who have welcomed applying data tech to supplement and bring down the costs of human monitors.

Remote sensing can identify where there's development or other degradation on eased lands and flag any changes for monitors to follow up on. **Upstream Tech's Lens Tool** uses machine learning programming to make sense of publicly available data for users who don't need to have a deep understanding of the technology. Using easement and property boundaries provided by conservation organizations, Upstream's Lens makes it straightforward for these organizations to access available satellite data of their conservation properties, enabling regular remote monitoring of properties that are large or difficult to access. Upstream Tech's technology allows the land trusts to view a satellite image of the land and easily compare imagery of the landscape at different points in time. Lens also offers an automated change detection tool for land trusts who can share their easement and property boundaries and receive alerts about violations of the easement terms. This platform offers vegetation and water details that are particularly important to land trust managers. Federal agencies might also be potential customers for these tools. Unlike land trusts, federal agencies significantly underinvest in monitoring their easements or lands, so the technology might appear to be a new cost; however, the efficiencies achieved might bring monitoring costs in line with government budgets because monitoring that is required now is often not carried out because of cost.

2 PATTERN AND IMAGE DETECTION THROUGH MACHINE LEARNING

We looked at a few efforts involving automatic discovery of regular patterns in spatial data – for example from images captured by drones – where algorithms and training data help machines identify spatial traits of interest in ecological restoration or management. We find this to be the most promising area of data tech for conservation and restoration because the technology more often appeared to deliver what was promised and because the outputs from the products are already in a format familiar to conservation staff (e.g. maps).

CASE STUDY: AIR SHEPHERD

NONPROFIT/FOR PROFIT HYBRID, CREATING DRONE-OPERATING WORKFORCE DEPLOYED IN CONSERVATION.

A university-led team has built a **predictive analytics** detection system to identify poachers in African game reserves at night, in real time, using unmanned drones. In partnership with Air Shepherd, a nonprofit working more broadly with drone-centered enforcement and anti-poaching strategies across southern Africa, the system has been deployed and successfully predicts where poaching is likely to occur and then creates a flight plan to send a silent drone with night vision to fly over high-incident areas. The drone cameras identify and distinguish humans from other mammals in nighttime tests. It's still early in the tool's deployment but it seems likely to be as accurate as similar systems to identify human shapes using thermal or visible spectrum imagery analysis in defense, security or other sectors. The tool's biggest challenge is that it depends upon significant on-the-ground enforcement presence (i.e. humans) to effectively combat poaching. In other words, there must be resources on the ground to stop poachers when they're detected, which is not a given. This UAV-based technology will make high enforcement capacity countries and regions more effective at their work (and safer in doing so) but it's unclear if the pace or scale of poaching enforcement in low capacity regions will change.

Air Shepherd started as a nonprofit (fiscally sponsored project) of a US charity that subcontracted much of its work to a for-profit drone company based in South Africa. The organizational structure of the venture is now focused around the for profit (**UAV & Drone Solutions, Inc.**), but a relationship with a **US nonprofit** allows it to take advantage of donations and grant support. This is a rare example we found of a conservation-focused venture that transitioned from nonprofit to for-profit, as opposed to the other way around. They are an inspiring example of a hybrid business model that helps prove market viability of the technology. More nonprofit funders should push their nonprofit grantees to explore partnerships with for profit data tech offerings.

We saw little evidence of progress in government and nonprofit recruitment of UAV-operations teams. Government policy and cultural taboos prevent the widespread use of drone fleets in government-led conservation work. For example, the U.S. and Canadian governments have been flying small planes in multi-million **waterfowl surveys** for more than 50 years. This entire effort could be replaced by drone operations, or camera systems and AI software used to detect and distinguish among duck and geese species. **Academic projects** have already shown that drone imagery and analysis from a desktop is equally or more accurate compared to plane-based deployment of biologists to identify waterfowl from the air. However, we believe that it's unlikely for the waterfowl survey to be automated anytime soon, not because of technology limits but because the personnel involved in the surveys don't want to give it up.[6]

[6] Some drone-dependent projects will likely be impacted by the latest efforts by the US Dept of Interior to **ground all Chinese-made drones** such as those manufactured by DJI.

MACHINE LEARNING AND DRONE IMAGERY ANALYSIS

The scale of investment in regulatory compliance and environmental planning dwarfs that of the enforcement focused markets (e.g. deforestation, poaching). For example, regulatory compliance drives more than **$4 billion in annual investment** in wetland and stream restoration and stormwater treatment, a large percentage of which is carried out by private restoration businesses or nonprofits. However, we found relatively few use cases for data technology among wetland and stream restoration practitioners. Instead, their use of data technology was mostly limited to traditional GIS (i.e. map) analysis and the use of drones to collect pictures for communications purposes as opposed to more sophisticated analysis.

We learned that lack of scaling is a consistent pattern with multiple technologies and it's a problem for these drone initiatives, too. A challenge in the drone imagery space has been that human observers still outperform automated analysis of data collected from drones. This is partly because sensors have limited ability to automatically recognize objects: computers must be trained to recognize thousands of natural features, from all angles and settings. Outside of conservation, this is the same challenge that **Tesla has in recognizing objects on and around roads** and having vehicles make specific choices in response to those objects. Extensive training datasets are often needed to lead computers through a human-supervised version of learning with labeled datasets in which objects have already been identified. Once training data has been used to improve the accuracy of object recognition and decision-making, computers can then work with unlabeled data to get better at object recognition themselves.

CASE STUDY: FOR PROFIT RESTORATION FIRMS USING DRONE TECHNOLOGY

We looked at two examples of restoration-industry firms using drone technology to plan and gauge the effectiveness of restoration activities. Both are offshoots of existing companies, one a global engineering, design and consulting firm and the other a smaller boutique restoration firm.

- One firm is employing drones equipped with multispectral sensors to collect imagery from large restoration sites associated with mining contamination and reclamation. The objective is to use the technology to detect patterns and reduce the extensive manpower required to walk and survey sites on foot.

- Another project uses drones to survey large landscapes under and around the highway network for Great Britain's federal transportation agency. The project aims to see if drones can be used to remotely and automatically identify and characterize habitat and future changes in habitat characteristics. The British government is under both European Union and **UK-driven policy directives to achieve 'no net loss' of biodiversity** through their operations and capital expenditures and a drone survey system is one option to develop a cost-effective way to do that. This no **net loss standard is a great example of a government policy** that drives rather than discourages data tech investment and deployment. The drone operator is using satellite data for this work supplemented by drone-based surveys to provide finer resolution pattern and feature recognition.

- One firm is attempting to use drone imagery and their own algorithms to pinpoint problem areas and recommend restoration projects that will have the biggest cost efficiencies. They can accomplish more project scoping and compliance monitoring more accurately and faster using drones and machine learning than on-the-ground biologists can. Armed with drone imagery and data on plant health and plant species across a broad landscape, they can work with clients in the water, transportation and power sectors to target limited funds to areas of proven highest concern. Despite what seems an otherwise high value proposition, they have encountered some regulatory hurdles. Regulations prohibit flying drones onto landscapes that have nesting birds, for instance, and it can be hard to get agencies to clarify restoration goals.

These efforts demonstrate a new use for drone images. Rather than capturing imagery simply for evaluation by people, it is paired with machine learning to draw conclusions and make predictions about restoration and biodiversity outcomes.

MACHINE LEARNING AND GROUND-BASED IMAGERY

CASE STUDY: WILDBOOK

USING AI TO IDENTIFY INDIVIDUAL ANIMALS, DEVELOPED BY NONPROFIT STAFFED WITH PROGRAMMING EXPERTS

Wildbook is an open source software platform developed through the nonprofit, **Wild Me**, that uses AI to recognize animals so researchers and wildlife managers can collect information about species locations and behaviors and draw conclusions about population size, migration patterns and human-animal interactions. Wildbook works for species that have unique print patterns (i.e. stripes, spots or other differentiating markings) that a computer can recognize in imagery. Their business is funded through a combination of contracts for service and grants.

Camera traps are ubiquitous, and their widespread deployment has generated far too many images for under-funded researchers to manage. Citizen scientists also contribute huge amounts of data through apps and special photography events. Wildbook can apply machine learning to handle these large datasets and make rapid identifications. Because it's free and open source, Wildbook can be used by a range of organizations and institutions and it will continue to be available even if its originating organization, Wild Me, were to lose funding or experience organizational upheaval.

Wild Me is rather unusual among nonprofit conservation groups because they employ machine learning and programming experts, as opposed to biologists, which has helped them gain their clients' trust as a neutral third party. A separate new initiative, called **Wildlife Insights**, brings together NGOs, museums, Google and governments to analyze an enormous camera trap dataset to quickly identify animals by species and aid in filling in data gaps for wildlife managers around the world.

3 TRADITIONAL GEOGRAPHIC INFORMATION SYSTEMS (GIS) ANALYSIS

Although GIS tools are not new, only in the last few years have they started to be extensively used in conservation. GIS is a framework for gathering, managing and analyzing data and mapping it over a narrow or broad geographic area. Hundreds of websites now exist that provide user interfaces and software capacity through a GIS tool. For instance, the Natural Capital Project's **InVEST open source software** allows users to examine the impacts of various land use and management decisions on a range of ecosystem services and view results through GIS software.

The dominant provider of software to conservation is **ESRI, Inc.**, a private company with more than $1 billion in revenue, through its ArcGIS software. ESRI is widely used for GIS applications in conservation, but both **Google Earth Engine** and **Microsoft's AI for Earth** also compete in this field. Each company uses donations of their software and, in the case of Google Earth Engine and AI for Earth, access to otherwise expensive satellite data to conservationists to attract use of their products. ArcGIS has a continuously evolving set of features, some of which revolve around artificial intelligence and machine learning, but we didn't encounter anyone putting those new features to use.

Private industry relies heavily on GIS to understand environmental and land use impacts and while it isn't a new technology, GIS may be having a sort of renaissance due to climate change, extreme weather events and population pressures that have led to more rapid changes in the way land is being developed by humans and used by species. Energy companies use GIS mapping to predict areas of high migratory and endangered bird activity so they can adapt their operations to avoid bird impacts as well as to predict the location of wetlands to avoid siting new infrastructure on prohibited lands.

CASE STUDY: NATURESERVE

NONPROFIT CREATOR OF WILDLIFE LOCATION DATABASE

NatureServe is an example of a nonprofit that got its start focused on GIS analysis and – as with Global Forest Watch – was dependent on a unique set of data that no one else had access to. NatureServe originated as a part of The Nature Conservancy and was a combination of two things: staff with GIS analytical skills and a network of collaborators, many of whom worked for state wildlife agencies, who were responsible for collecting and tracking all possible sightings information on rare species of plants and animals in the US. This database, combined with the ability to analyze patterns within it, became invaluable for more than a decade to conservationists focused on US biodiversity. Things might have evolved differently if NatureServe had been set up as a for profit rather than nonprofit. Biological data on rare species would perhaps be a bigger, richer market for technology innovation and industrial application.

In one of their latest initiatives involving AI, NatureServe aims to deliver predictive range maps for endangered species. Their biggest challenge has been the uptake of this product by the various state and federal agencies that are probably best suited to use it but who often have cultural biases against the adoption of new technology. Instead of working with NatureServe, the U.S. Fish and Wildlife Service has hired its own data team with five staff to duplicate the services they provide.

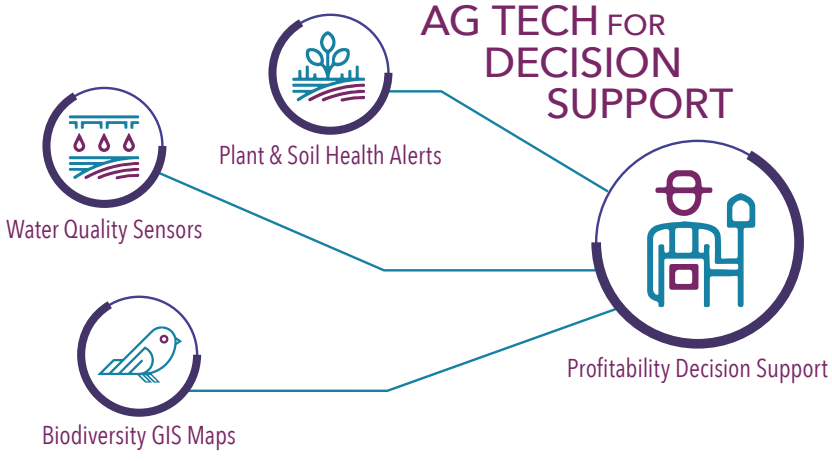
4 DECISION SUPPORT FOR PRECISION AGRICULTURE

Precision agriculture is almost certainly the biggest sub-sector of conservation data tech innovation. In most areas of our review, we found products and tools that had been developed for other purposes (e.g. defense, security) being adapted to use in conservation. But agriculture is such a significant economic sector with payors from government and the food retail chain that it appears to be a hub for truly novel and creative data tech development on its own. A glance at the **program** for the International Society for Precision Agriculture's 15th annual conference reveals how much the industry sees potential in data technology. Many of the scientific talks on the program relate to conservation-adjacent topics like efficient application of fertilizer, greenhouse gas emissions reductions and even preventing lethal shooting of birds through drone deployment.

The conservation-focused part of agricultural initiatives lacks regulatory drivers in the U.S. so this space will be driven by voluntary action until there is a price on carbon or mandatory soil health standards. However, in the United Kingdom and Europe, data tools are increasingly being used as the **basis for rural payments to farmers** who live inside or outside important wildlife habitat or water quality areas.

There is growing corporate demand for solutions that help the private sector meet ambitious sustainability goals, including reducing their carbon footprint, building healthy soil and engaging in regenerative agriculture. The American agriculture sector is driving demand for new data technology by way of their interest in verifiable environmental outcomes. One example is Danone North America, makers of both dairy products and non-dairy alternatives, which claims to be the largest public benefit corporation and Certified B Corporation in the world. They have hundreds of US dairy and crop farms in their supply chain and they are committed to reducing their carbon footprint in part through a **focus on soil carbon** on the farms that grow feed for dairy cows. Their ambitious sustainability commitments are driving their demand for better data technology-based analysis of which on-farm practices are most efficient at delivering healthy soil. They **partnered with** Sustainable Environmental Consultants, owners of the **EcoPractices** data collection and analysis platform that helps farmers understand the economic and environmental impacts of their practices. Sustainable Environmental Consultants provides third party sustainability tracking and data based on field level data.

Just as Danone North America is driving technology implementation in the US dairy farm sector, buyers of regenerative cacao and wool products are driving technology for verification and certification purposes in those sectors. **Regen Network** (a recent **Techstars Sustainability Accelerator** company) aims to reward regenerative ag practices by using **satellite data to measure soil carbon** paired with a blockchain platform that tracks verified ecological data through the supply chain.



LESSONS LEARNED

STRATEGIC CHALLENGES TO SUCCESS

Data tech for conservation is certainly a growing field, but among the tools we explored many are struggling to overcome one or more of four key challenges:

1. They lack an understanding of—and a strategy for reaching—their intended user group;
2. They don't offer automated or semi-automated processes that go beyond what is already supplied by existing technology
3. They fail to build in a funding mechanism to support an optimal level of growth and staffing
4. Outdated policy and bureaucracy prevents them from demonstrating a true value proposition[7]

Anyone contemplating launching a new data tech initiative, including entrepreneurs, funders, nonprofit leaders and investors, needs a plan for how to address these four barriers.

Users need to be considered from the start; any new tech needs to be designed to not only meet user needs for information, data and analysis but do so in a way that makes the technology truly accessible. If tech products require advanced or specialized expertise, many users will be excluded. And tech products must offer something novel or else users will have no reason to switch from whatever methods they're already using. A significant amount of funding has been wasted on the construction of websites meant to share spatial data insights and on GIS tools that promise to be accessible to non-technical people but are not. The most successful and/or scalable tools build upon existing platforms; that is, rather than being built as stand-alone websites, they're designed to allow other tools to plug into their API. They take advantage of the way many successful tech tools already work, which is to act as part of an ecosystem of tools that communicate with each other. New websites that build everything from scratch or repackage information that's already available elsewhere don't add enough value to be viable in the long run, but they keep getting produced because they offer a tangible way to show funders without data tech expertise the content they are paying for.

Sufficient funding is critical for launching, managing and sustaining data tech products over the long term. Some projects have enough funding to launch but then lack the resources to update products, respond to users' needs, and maintain marketing functions. This can be especially challenging in the nonprofit space where funders are often unwilling to support high ratios of overhead and where organizations wish to fulfill a public benefit mission by offering technology products at no cost to users. Hybrid models like Air Shepherd are particularly compelling, as is a new initiative to **integrate Global Fishing Watch's illegal fishing boat data with the Bloomberg Terminal** (a paid service).

[7]A reminder that this analysis only applies to data tech, not hardware technologies like water sensors, soil sensors, drones and other physical hardware.

Any technology that requires fast regulatory approval – or use and adoption by a bureaucracy – as a strategy to achieve its intended impact should be considered with caution. Proposed data tech tools should be useful to private business, researchers or nonprofits first and have an adoption strategy for those markets. Some technologies could also be directly relevant to the public in such an overwhelming way that government is forced to adapt to them (e.g. rideshare services) although it's difficult to see many areas of restoration data tech that have broad consumer appeal. Alternately, potential technologies should have strategies to work around government or regulatory barriers or to use higher level support within government to overcome staff level resistance, if they are going to succeed in highly regulated sectors of environmental activity. Later in the paper we discuss various ways to overcome the regulatory barriers to successful adoption of data technology to address our planet's needs for restoration and conservation.

Looking at how these four barriers impact the viability of new products, we see four potential pathways for data tech tools and applications in conservation:

1. Successful projects that deliver conservation outcomes and have sufficient funding to support sustainable operations.
2. Projects with good design for viable technologies but where bad strategy limits use.
3. Projects with viable technology, good strategy and sufficient funding that are stymied by outdated policy and bureaucracy. These are initiatives with real promise -- they are successfully solving a real-world conservation problem, but regulatory barriers are getting in the way.
4. Projects that are doomed to fail because the technology was not ready or capable of providing the services advertised.

Categories 2 and 3 are the most interesting because they have strong technological potential if barriers to use and adoption can be overcome. **We think overcoming these barriers to use and adoption should be a critical objective in the next five years to achieve a desirable increase in the speed and scale of conservation in the US.**

BARRIERS TO GROWTH

In addition to enterprise-specific strategic failures like insufficient funding and poor success reaching intended users, there are also barriers to growth in the field as a whole. More mature fields have infrastructure in place that helps enterprises build knowledge and expertise, recruit the best possible talent and overcome shifts in market needs and preferences. We found at least four barriers to growth of the field of data technology for conservation:

1. A lack of cohesion, including cross-pollination and communication opportunities
2. Insufficient training datasets
3. Lack of pathways for connecting tech staff to conservation projects
4. Need for intermediaries and aggregators
5. Regulators are not adapting quickly enough

Here we describe them all in more detail and point out where we think resources, time and energy could be invested over the next five years to make progress in overcoming these barriers.

1 DATA TECH FOR CONSERVATION SECTOR LACKS COHESION

Our research found that there is very limited communication happening across the data tech-for-conservation sector. More is needed so that innovators and regulators can share lessons learned, build some common vocabulary, share resources and avoid duplicating each other's work (or do so in ways that create better products). Today, there are very few industry organizations, partnerships, conferences or meetings that incorporate a data tech-for-conservation component. There are conferences that focus purely on the technology (AI, machine learning, big data) but not on its application for conservation.[8] Likewise, there are conservation conferences and workshops that incorporate very little discussion of data technologies. The few convenings that occur seem to focus on a small number of themes, and with limited cross-pollination with other sectors and users.[9]

There are a few exciting efforts to bring some cohesion and communication to this sector to help expand skillsets, share lessons learned and develop better products. For example, EPRI is a research institute that has fully embraced building out a data tech initiative and focusing it on environmental impacts and stewardship. In 2019, EPIC partnered with EPRI to research the gaps in knowledge and application of data technology in the electric power sector related to environmental impacts and compliance needs. Our two organizations co-hosted a 2-day workshop for about 35 EPRI members, staff and academic and private sector data tech innovators. The workshop focused specifically on helping attendees get acquainted with the diverse range of data tech applications in the sector, connect with research institutions that can help with cutting edge application development, and generally open up dialogue and introduce opportunities for collaboration among sector players. This workshop revealed that there's a language barrier and learning curve that convenings and regular communication can help overcome. EPRI is committed to carrying out follow-up convenings and generally making data tech a bigger part of their environmental research. They can be a repository for a data tech library, initiate and support new research, connect members with vendors and directly address their members' questions.

Microsoft's AI for Earth hosts a grantee convening each year. As mentioned above, they also participate in challenges and RFPs to directly support new tech enterprises through their own technology, grants and partnership. They lend legitimacy to broader efforts to professionalize the conservation data tech sector.

[8] However, agriculture tech is a growing market and convenings and meetings are starting to arise focused just on this application of data tech to an environmental field.
[9] **NOAA workshop on Leveraging AI in Environmental Sciences**, **AI for Good Global Summit**

2 INSUFFICIENT TRAINING DATASETS

One of the biggest challenges in advancing data technology for conservation is the lack of standardized and labeled learning or training datasets. "Training data" refers to sets of text descriptions, images and video for which people have labeled the important information to train the machine. For example, **Tesla has more than 2 billion miles** of data from sensors and cameras that record what human drivers do and from which its AI systems can learn. Sophisticated technology may be capable of overcoming this to some degree, but large amounts of data that contain enough repeat information are still needed to help systems learn. This is a particular problem in conservation where there are just fewer people involved than in other areas of commercial AI applications like transit and agriculture. In our interviews, we heard that there are often enormous amounts of data held by private companies and conservation NGOs that remain unlabeled or unorganized because of the costs and time associated with those activities. In the case of water, few datasets even exist in the first place.

We propose developing an 'OpenEcoMap' to help fill this gap and provide a training dataset that many future applications could be built from. **OpenStreetMap** is a nonprofit run annotated map service that underlies many commercial geographic products and is particularly important as a training platform for machine learning to use to recognize human-built features. No similar resource exists for the environment: a tool to accurately identify very specific, semi-permanent natural features as opposed to the human-created ones on OpenStreetMap. A data annotation platform for satellite imagery of natural features could transform how environmental assets are integrated into everyday products we use. Examples of ecological data annotation – essentially human-assisted computing – include: the manual identification of abandoned mine openings and water pollution plumes below them, identification of tree species and height profiles to assist future drone flight path modeling, or identification of migratory bird detections on radar into predictive models to understand where millions of birds land after each nights' flight and valuation of the habitat they stop in. Such an effort does not exist today, and it would need to be staffed by an executive who would help build formal partnerships with organizations like National Geographic that have volunteer networks that could contribute annotation services and a technical team to develop the platform on which annotation would occur and be collected into.

Purchasing data can also be an option, but sometimes it is cost prohibitive to nonprofits and academic researchers. For commercial ventures that rely on high resolution data, realistic data acquisition costs are built into their business model; they either invest in first-hand data collection or pay for vendors' data. Successful data tools we examined budget for access to the best data resources.

3 LACK OF PATHWAYS FOR CONNECTING TECH STAFF TO CONSERVATION PROJECTS

A few organizations and initiatives are led by highly skilled data scientists and technologists building products that support a conservation mission, including Upstream Tech and WildMe. But it is still more the exception than the rule that data science initiatives for conservation are championed by teams that have the full suite of expertise in both conservation and technology. We found a range of approaches for marrying conservation work with tech skills, including partnerships, consulting, secondment and targeted recruiting.

- For profit efforts like Google Earth, Microsoft's AI for Earth and ESRI's Nonprofit program give away software and data access (and sometimes hardware) but generally have not provided their staff time and expertise to conservation data tech ventures.

- We found an example of a **successful public private partnership** between AT&T and the American Museum of Natural History's Center for Biodiversity and Conservation in which AT&T staff on loan to the museum worked on a wildlife distribution modeling project to develop open-source software for use by anyone doing species modeling. This type of secondment model could potentially work in a range of cases so long as there is sufficient senior management buy-in from participating organizations.

- The **US Digital Service** is an exciting example that has worked to bring experts from the private sector into government at a high level to develop projects, some of which are AI- or data tech-centric.

Pairing conservation experts with firms that build, manage and support AI products may have potential for success in the near term. Firms like **NVIDIA**, a major provider of AI technology, aren't often approached to work on conservation projects. They offer AI solutions for healthcare, autonomous vehicles, smart cities, robotics, humanitarian assistance and a lot more. But conservation hasn't made it into their portfolio.

Even when tech-savvy staff can be brought into conservation temporarily, there still need to be senior people within the organization they support with whom they can work and that understand and have power in the bureaucracy they must navigate. Especially in our review of government data tech initiatives, we reviewed a number that stumbled because they had only low-level support and few translators within career staff to network them into organizational decision-making. Projects without buy-in risk resulting in orphaned projects that drain staff time and resources and ultimately result in limited adoption.

Could the field of conservation or restoration data tech grow more quickly and usefully if intermediaries with deep understanding of the technologies arose to better connect buyers (e.g. land trusts, fish and wildlife agencies, transportation agencies) with technology developers and vendors?

Organizations like The Nature Conservancy or government agencies – in theory – have the organizational capacity to hire internal technology teams who can efficiently evaluate and deploy cutting edge data tech. However, that is not what we see these organizations do. Instead, they contract with service providers who develop bespoke technologies or applications, or they bring technical teams in-house who don't have the senior leadership representation to advocate for more systemic adoption of technologies and technology mindsets.

In contrast, small organizations which are the dominant business model throughout conservation nonprofits, philanthropic foundations, and the restoration industry are unlikely to ever have the resources to hire dedicated data technology 'mavens' who could help the organizations efficiently incorporate cutting edge – or even older – technologies. They need to have trusted peers or service providers who can offer such services across the field. Thus, if conservation is going to more rapidly adopt technology (and simultaneously create demand that fuels further development of those technologies), what can we learn from intermediary services provided in other sectors?

4 NEED FOR INTERMEDIARIES AND AGGREGATORS

There are at least five models of intermediary that provide these services. Primarily, we looked at tech intermediaries in the water sector where the annual $104 billion in capital investments made by utilities and government have fueled a more robust demand for and diversity of technology services.

- **Consulting engineering** firms like **AECOM** often have open-ended contracts with water utilities to help with everything from planning and design to construction and facilities management. These firms are increasingly playing a role in providing technology advice to water utilities.

- **Integrated water technology providers** are rapidly evolving to provide a one-stop shop for technology services. These companies use large pools of investment capital to buy startups and products, allowing them to deliver an integrated set of diverse technologies that can meet utilities' needs. **Evoqua Water Technologies** and **Xylem** are two such companies.

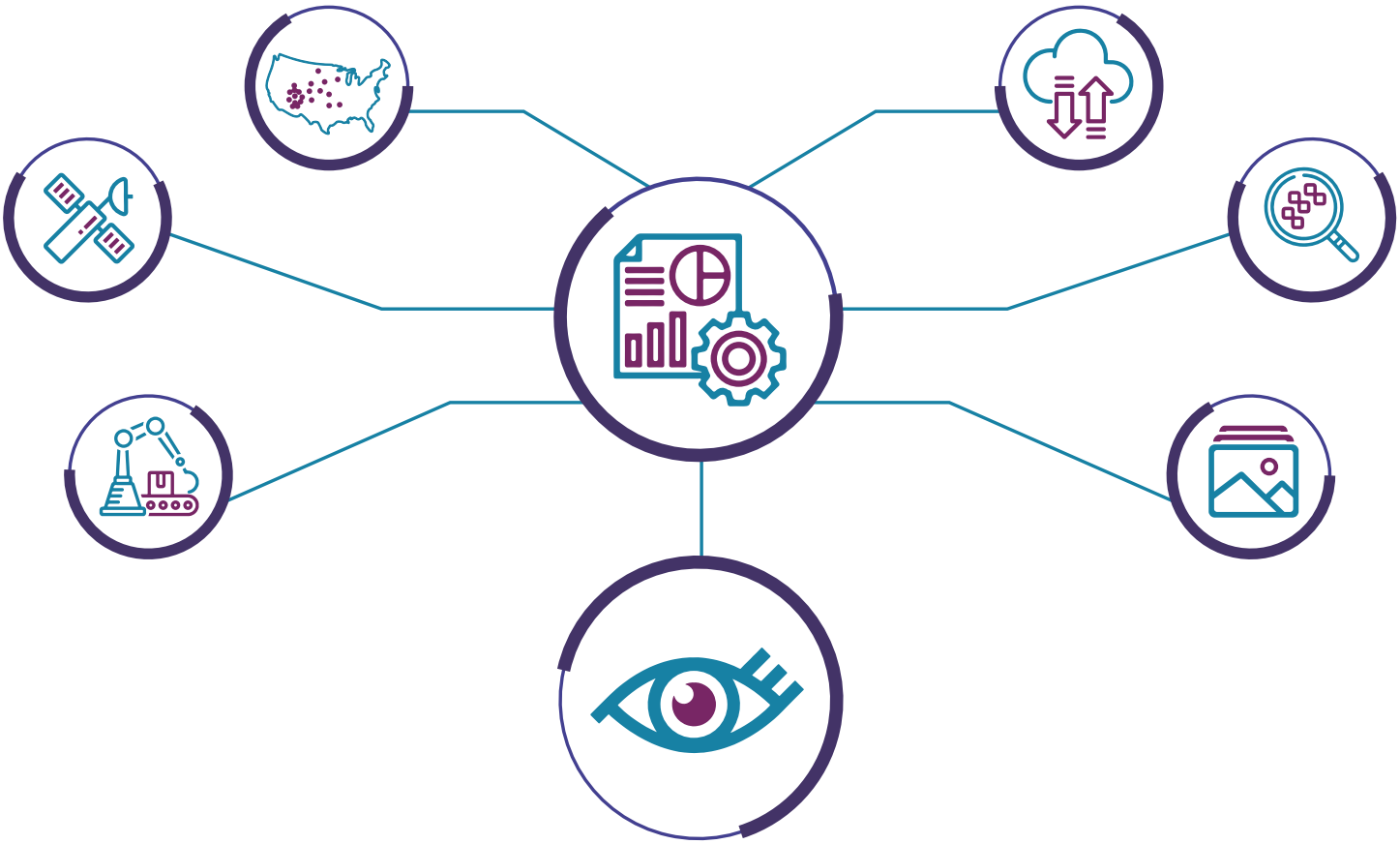
- **Accelerators** have staff that continuously explore and seek a high level of understanding of new technology solutions and resource those companies in ways that can help them take off, including by helping match the companies with buyers among water utilities. For example, **Imagine H2O** helps advance the water sector through an accelerator and connections to investors. They help raise the profile of new technologies for water conservation – primarily physical sensors and hardware - and they play an important role in helping make connections between key players in the water sector and the latest in data technology. They have an expansive network, deep expertise and a growing international presence.

- **Focused innovation connectors** don't have a stake in specific companies; they evaluate particular technology solutions to common water utility problems and can provide all the relationship services needed to help utilities – especially smaller ones without a lot of specialized staff capacity – set up contracts with providers whose technology is well matched to an inefficiency in the utility's operations. **Moonshot Missions** is one nonprofit example.

- **Diffuse innovation connectors** don't have a stake in a specific company or technology, but like **The Atlas** provide a trusted storytelling and communications platform for buyers – especially municipal or local government – to understand how others have made use of technologies and tech providers in specific situations and thus how they might use it in a similar situation.

We don't see a lot of evidence that these kinds of services exist yet for conservation data tech but expect they are needed. Conservation goals could be advanced by the creation of an accelerator-type service, perhaps backed by both philanthropic and profit seeking investors, that could provide consulting and advisory services directly to thousands of nonprofits and philanthropy but also under contract with government agencies to help all of those entities embrace more tech innovation and also make better choices when they do.

We also think more progress in conservation and restoration would occur if organizations, be they nonprofit or for profit, arose that served as trusted data tech innovation connectors to help the restoration sector make more and better choices in the use of technology. Services could include everything from advisory services to help with developing hiring criteria, recruiting, structuring contracts and bidding processes to analytical work to match perceived needs with their best data tech solutions.



5 REGULATORS ARE NOT ADAPTING QUICKLY ENOUGH

It takes a long time for regulators to accept even the best solutions-oriented technology for sectors like energy, farming and fishing. This is not a new problem and it will almost definitely not go away soon. Government regulation moves slowly: almost 70% of US regulations have not been revised since they were first adopted.[10] Agencies are focused on how to achieve past mandates, enforce regulations and protect citizens and natural resources, and they have little to no direction to help data technologies thrive.

In the absence of major staff turnover, agencies will overwhelmingly remain focused on prescriptive regulation of the methods by which a regulatory objective is met, rather than the environmental goal of that regulation, though **firms like Deloitte are promoting** ways that regulators can both adopt technology to serve the needs of government and pave the way for innovation that offers a public good. We see an opportunity for the next presidential administration to shift this status quo and create environmental agency agendas that prioritize development of data tech tools to meet public environmental goals and compliance needs.[11]

We encourage agencies to focus on adopting standards rather than protocols. Innovators offering breakthrough continuous water quality monitoring that could transform our understanding of water quality parameters are stymied by EPA's reluctance to change their approach. Rather than focus on prescribing approved water quality testing methods, EPA could establish design standards that set requirements on how outcomes are tracked and how procedures and algorithms can be sufficiently transparent and let more technologies be automatically approved if they can meet those standards. Or at minimum, the agency could host an annual process where they review submissions for technologies, for example, that meet national standards for arsenic testing, and then select five or fewer to add to the list of approved or provisionally approved technologies.

The European Union has put in place policies that broadly require disclosure of algorithms with which AI tools make decisions. A similar policy on environmental data tech in the US – coupled with a relaxation of other regulations that are a barrier to data tech – could open the door for far more innovation.

[10] Daniel Byler, Beth Flores, and Jason Lewris. 2017. Using advanced analytics to drive regulatory reform: understanding presidential orders on regulatory reform. Deloitte white paper.

[11] Robert L. Glicksman, David L. Markell & Claire Monteleoni, ***Technological Innovation, Data Analytics, and Environmental Enforcement***, 44 Ecology L. Q. 41 (2017), https://doi.org/10.15779/Z38C53F16C.

EFFECTIVELY GROWING THE FIELD

There are four strong drivers of growth for data technology for conservation and restoration outcomes. We can take lessons from these as we look to the future and consider where organizational and policy resources will have the highest impact. These four demand drivers are:

1. Private sector demand coming from voluntary commitments
2. Industry response or reaction to regulation
3. Conservation organizations' mission
4. Government and NGO competitions and challenges

We describe each of these in more detail below with the understanding that even though these have been important and effective drivers of growth, there might be better ways to catalyze growth of new conservation data tech over the next few years.

1 VOLUNTARY CORPORATE COMMITMENTS

Private sector companies, through voluntary initiatives focused on climate, water, soil health and deforestation impacts, are driving development and deployment of new data technology. They are also **feeling the pressure from investment funds** that have recently increased their focus on reducing risk for their clients through combatting climate change throughout their portfolio companies' supply chains. We don't expect this commitment to decline any time soon and innovators (both new start-ups and long-tenured service providers) that can figure out how to affordably deliver large corporates the sustainability metrics verifications they seek will be positioned for success. Above, we touched on a couple of examples from the regenerative and sustainable agriculture sectors, which are using data tech to support reporting on voluntary corporate commitments, likely because they have been hammered by consumers and activists concerned about the food system's impact on the environment.

In addition to using data tech to understand direct impacts, AI can also be used to help companies understand which non-financial issues are material to their operations. **Datamaran** is a firm that developed and sells software that uses artificial intelligence and natural language processing to synthesize information from corporate financial and sustainability reports, news and media sources, regulations and social media (e.g. Twitter) to deliver clients information about the state of their industry and a range of non-financial performance measures. Their software effectively takes over tasks that human sustainability directors would normally perform and helps those sustainability directors focus more on the issues of material significance to their industry and company. Datamaran analyzes millions of data points and gives companies information much faster than they can collect it from sending out surveys to stakeholders. Datamaran uses visualizations and dashboards to help clients, who don't need to be tech-savvy to get value out of their products, quickly interpret the data the computer collects.

2 REGULATION

Regulatory policy has a hand in driving the growth of data technology for conservation but not because regulation expressly asks for tech or regulators use it. Rather, regulated industries are turning to data tech to help them fulfill compliance requirements and proactively anticipate regulatory issues. Unfortunately, we found it's common for companies to invest in data tech only to discover that regulators will not accept the results of the technology. Below are three scenarios in which industry favors shifting to data tech solutions but where government agencies' distrust of technology or stubborn rule-making processes have hampered tech innovation.

Energy. The highly-regulated energy sector is subject to the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. Energy companies are responsible for ensuring limited interaction with Golden Eagles and Bald Eagles at energy transmission and distribution sites. **Duke Energy's** Wyoming wind farm was found at fault for eagle take and they had to commit to turning off wind turbines to avoid future eagle strikes. Following marginally effective and costly results of employing human observers to identify eagles and turn off wind turbines accordingly, Duke worked with Boulder Imaging, Inc. to develop a camera-based eagle detection and classification system that was better at identifying eagles. The system is a combination of hardware (i.e. the cameras) and data tool that is effective at automated pattern recognition of specific species of birds. The camera system, called **IdentiFlight**, has been hugely successful at recognizing eagles and curtailing the turbines with a 562% increase in large bird detections when compared to human observers. However, regulators have settled on a conservative model for estimating eagle mortality on wind farms that currently does not make accommodations for industry-led efforts offering more accurate eagle mortality data and avoidance methods. Therefore, Duke is not currently receiving regulatory "credit" for the success of IdentiFlight despite a significant capital investment in the technology. However, Duke chose to use the IdentiFlight technology and prefers it over earlier strategies to reduce eagle collisions because it's a better and more efficient use of staff time and energy and reduces safety risks associated with people deployed in harsh environments for long periods of time.

Water. Water is another area with a proliferation of new data tech products targeted at meeting regulatory requirements. The number of companies creating water monitoring technology is overwhelming. In fact, water utilities frequently speak of being overwhelmed with choices and thus unable to prioritize acquisitions. As a result, there are nonprofits and for profit 'advisory' organizations arising just to advise water utilities on technology investments. For example, **Waterstart** (based in Nevada) and **Moonshot Missions** (Washington DC) both exist to help prioritize technology acquisitions for water utilities. Water utilities have shown interest in data tech that will help them get the best ROI for any infrastructure replacement expenditures. Several new firms, like **Ketos**, offer on-site, in-pipe water quality testing but EPA has trouble accepting continuous data sources (i.e. thousands of data points) and still rely on testing a small number of 'grab' samples that are analyzed by third party labs.

Fishing. The fishing sector has seen growth in the development of "**smart boat**" infrastructure that uses data technology and machine learning to help fishermen reduce overfishing and comply with reporting requirements, at least in part driven by regulatory policy. Fishermen are required to report their catch—identifying all affected fish by species—and this has typically relied on human observers who are expensive to employ and who commit errors or who take up valuable space on a fishing vessel. The fishermen who've tested the technology largely prefer electronic monitoring over human observers and now that the technology uses AI to distinguish between species, it can substitute for human observers with a little human-led auditing of the video footage for verification purposes. However, regulators at NOAA remain hesitant to move beyond the "proven" method of human observers and proposed new rules that add another layer of auditing could make the electronic monitoring alternative just as expensive as human observers.

In addition to the scenarios we describe above where government agencies distrust technology or have stubborn rule-making processes that can't be changed fast enough to accommodate tech innovation, political leaders in government may also have reasons to disregard data tech insights when it conflicts with other priorities. For example, a machine learning-based algorithm was developed by a **team at the University of Michigan** to predict which houses in Flint, Michigan would be most likely to have lead pipes, without digging up anything. The tool was more than 70 percent accurate in predicting the presence of pipes and use of the tool was built into the city's budget for lead pipe removal. However, after a year, the city abandoned it, in favor of doing pipe replacement in all political districts of the city instead of just the areas the algorithm was predicting lead pipes in. The city's success rate dropped below 20 percent and it took court action to get the city to agree to use the AI tool again starting in 2019. Why? Because it meant that jobs and government spending would happen in every political district and that voters would have the perception that progress was occurring (even when the progress was not connected to an actual problem but to a perception of one.) It's not just that regulatory systems cannot handle or incorporate the features and peculiarities of AI-based tools, sometimes governments don't actually want the answers AI can provide.

So, we see private industry turning to data tech to address regulatory compliance requirements only to be blocked by regulators from actually relying on the technology. One way to turn around this pattern of rejections is for regulators to focus on standards and outcomes rather than methodology. If regulators can accept measurements, data, monitoring and results that meet their needs, rather than dictating the methods that must be used to reach them, data tech has the potential to scale up and find paying customers.

3 NGO MISSION

Several nonprofit conservation organizations have launched their own data tech tools aimed at making environmental damage more visible to governments and citizens around the world. Sites like Global Forest Watch, **Global Fishing Watch** and **Skytruth** show where deforestation, illegal fishing and oil and gas development is occurring or might be occurring. **WWF** has launched an effort to deploy a new low-cost satellite tracking system designed to combat the illegal wildlife trade, called **PandaSat**. **MethaneSAT** is a new project from **Environmental Defense Fund**, **Harvard University** and the **Smithsonian Astrophysical Observatory** to assess the sources and size of methane gas emissions.

Citizen scientist apps like **iNaturalist**, **Wildbook** and Seattle's **Carnivore Spotter** can be an effective way to collect a huge pool of geo-tagged images while also engaging everyday people in wildlife appreciation and activism. The key challenge is actually having the funds, computing power and expertise to get something out of the large imagery datasets. With the right machine learning software, researchers can draw conclusions about population size and location, migration patterns and human-animal interactions. These technologies primarily have a researcher and wildlife manager audience; unfortunately, they can also be exploited by the illegal wildlife trade.

These sites and tools have opened up a whole new way of seeing environmental damage but they are not always connected to action; for them to have the desired impact on stopping deforestation, poaching and pollution, governments and local law enforcement need the resources and wherewithal to act. In the next phase of conservation data tech development, strategies that focus on connecting these data collection and visualization tools to specific conservation actions will have the greatest potential for impact.

4 COMPETITIONS AND DATA CHALLENGES

The fourth driver is data challenges and competitions. A great example of a government data challenge helping drive the growth of data technology is the US Department of Transportation's 2015 **Smart City Challenge** which offered $40 million to the winning city of a competition to address traffic and transportation challenges with sensors, big data, IoT and other technologies. The DOT ultimately helped seven cities build out their transportation solutions via the initial challenge. The challenge also jump-started the "smart city" movement. This example highlights the important role that cities can play as early adopters of new technology. Cities have conservation and restoration needs for water quality testing, stormwater management, green infrastructure development and agricultural sustainability strategies and they are likely to be more nimble and responsive to new approaches than slower-moving states and federal agencies. Federal agencies and states are in a better position to issue challenges: we could envision the DOT putting out a wetland restoration challenge, USDA an ag tech challenge, or the EPA a pollinator challenge.

Conservation X Labs, a nonprofit, runs challenges aimed at catalyzing technology for conservation but without an express focus on data technology. The challenge they're currently running is for innovations that improve the environmental sustainability of artisanal mining (largely outside of the US and Europe). They'll select a prize-winner, but their challenges ultimately accomplish more than awarding prizes. They are building connections between innovators and partners with resources and on-the-ground expertise, getting new innovations in front of the media and investors and generally raising the profile of technology that offers an environmental positive. Their challenges are compelling because their innovator participants need to demonstrate not only the viability of the product or service they produce, but also their competitive advantage and a financial plan for the enterprise.

Microsoft's AI for Earth partners with organizations like Conservation X Labs and NatGeo to find grantees via challenges and RFP-based grant-making. They offer two other types of grants: one for labeling datasets (we have heard time and again how critical and expensive this need is) and another for the use of Microsoft's Azure cloud computing service (which includes a broad range of AI applications).

Competitions and challenges won't ultimately serve all the needs of the conservation data tech space, but they can offer a useful combination of exposure (to the public and potential partners and investors), rigor and connections for lesser-known and niche data tech innovations. They are an efficient way to get bright ideas already in development more exposure and market access, but data challenges will only work if the conservation outcomes sought are broad enough to attract multiple participants. Selecting too specific an environmental goal of interest will limit participants and creativity.

RECOMMENDATIONS

Data technology innovations are creating new ways for conservation and ecological restoration to be implemented, succeed and adapt. Machines are teaching themselves to learn about nature in fields where we haven't ourselves been able to keep pace with scientific and technical learning in conservation. The rapid shift in the potential of these technologies and growing valuation of ecological services and outcomes by the public, corporations and governments is also shifting the scale of resources being invested in conservation and its outcomes. However, our review of a suite of current and former data tech tools and applications suggests particular areas that may be more successful than others for data tech to thrive:

- **Real-time automated landscape change detection:**
  Particularly useful for nonprofit and government monitoring of easements and protected lands.
- **Pattern detection through machine learning:**
  An exciting area of development with huge potential to help quickly and accurately categorize changes at a fine scale, from endangered species behavior to biodiversity measures.
- **Traditional Geographic Information Systems (GIS) analysis:**
  An older tool that will continue to have very road application for government and private industry.
- **Decision support for precision agriculture:**
  High potential for speeding up and measuring conservation outcomes on ag lands.

INVEST IN AUTOMATED CHANGE DETECTION

Automated pattern recognition and change detection from satellite data is a very exciting and promising area of data tech development. The technological hurdles appear modest and are continuing to diminish as new satellites are deployed and AI capacities improve. Understanding patterns and change on a parcel or watershed scale is also something that nonprofits, scientists, and government agencies are familiar with. Thus, the outputs will be familiar and fit into existing workflows and priorities, even if the method of delivering them has changed.

We still do not see government agencies making an easy wholesale embrace of these technologies, but we see it as easier than other areas of data tech we reviewed. We expect the tech to rapidly develop for near real-time agricultural land use and yield mapping, forest health and growth, tracking large mammal populations, surface water coverage, disaster tracking and some restoration effectiveness monitoring. These areas of technology development in conservation will likely continue to be dependent on philanthropic financial support for some time.

AG TECH NEEDS DIFFERENT FUNDING TO BRING IT TO THE AVERAGE FARMER

The best market for conservation data tech is farming. The agricultural sector of data tech is exploding, driven largely by major corporate investors, venture capital and a modest amount of government investment. These technologies continue to face hurdles, especially in reaching a large share of the market of farmers, dairies and ranches that could benefit from new ecological and sustainability tools. Venture capital will continue to go to high value farming operations and crops, like vineyards, fruit orchards and organic agriculture, but the highest conservation need is in conventional row crop corn, wheat and soybean farming where many smaller or marginal farms operate. Government could play an important role by subsidizing access to data tech tools by these operations and supporting networking, communications and coalition building that helps data tech proponents in agriculture organize and have a more effective role on policy and programs, especially leading into the 2023 Farm Bill authorization in Congress.

LOCAL GOVERNMENT – AS ALWAYS – IS AN ENGINE FOR INNOVATION

Local government is a more promising arena for environmental data tech development than state or federal government and tools focused on local government should be given strong consideration. It was the private sector pushing urban data tech solutions that convinced cities to consider “smart city” initiatives and projects, and that subsequently won federal and state support. Entrepreneurs will keep pushing new water quality testing approaches, change detection solutions and agricultural sustainability strategies, some of which will be relevant to local government. Local data challenges at the city level could be replicated for ecological restoration initiatives like local wetland creation, hazardous dam removal, agricultural sustainability and locavore opportunities and recreational space upgrades.

EVERY FEDERAL AGENCY NEEDS A SENIOR INNOVATION OFFICER REPORTING TO HIGHEST POLITICAL APPOINTEE

Getting past current agency culture and bureaucratic roadblocks necessitates giving power to a new set of people, trained in data tech, who report directly to secretaries of Interior, Agriculture, Commerce, the administrator of the EPA, and agencies within those departments. Hiring people skilled in data tech and giving them staff should be the first priority for future federal administrations who believe that technology can make a contribution to solving far more environmental problems than it can reach today. Too often, administrations prioritize and promote communications personnel and Congressional staff into senior roles; recruiting tech personnel from startups and Silicon Valley will have a much higher return on investment for the planet.

ESTABLISH A NEW DIGITAL SERVICES FOR THE PLANET INITIATIVE

The Obama Administration created the US Digital Service as an office within the White House charged with bringing sophisticated technological expertise from Silicon Valley into government and giving it high level connections to administration leadership such that it had the power to accelerate change across the government in tech-related work. Senator Kamala Harris (D-California) proposed a Digital Services Act of 2019 that would provide federal support for states to do something similar. However, little of this capacity is directed at natural resource agencies who could promote the use of data tech in agriculture, conservation and water management; a Digital Service for the Planet could bring tech resources to conservation applications.

CONCLUSION

Data tech is still relatively new in conservation and restoration, but it has wide application in healthcare, defense, and manufacturing. Wherever possible, developers of new conservation tools should try to overcome cultural resistance to the use of data tech by coupling product development with training and learning opportunities and interaction between sectors.

It may not feel like it yet, but the 21st century will evolve into a century of restoration, where humans stitch back together the natural features of the planet that we will keep with us through future millennia. Technology is only part of that solution; we have to stop destroying our climate and natural habitats. Strong regulations, corporate standards, equitable wages, and robust educational systems must also be part of the solution. But data tech is beginning to show its potential to deliver profound successes in conservation and ecological restoration and we owe it to our planet to harness that potential.