GSMA

Exploring barriers and incentives to digital solutions in Natural Resource Management

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REVERSING ENVIRONMENTAL DEGRADATION REDAA IN AFRICA AND ASIA

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Busara

BUSARA The Busara Center for Behavioral Economics is an advisory and research organisation focused on advancing and applying behavioural science in the global south in pursuit of poverty alleviation. Busara was the research partner for this study.

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Executive summary

Biodiversity loss, driven primarily by human activities such as habitat destruction and over-exploitation, pollution and climate change, is one of the most pressing environmental challenges of our time. Up to one million species are at risk of extinction, while 75 per cent of land surface has been significantly altered by human activities and over 85 per cent of wetlands have been lost.[1] These pressures on nature not only threaten the survival of countless plant, fungi and animal species, but also have far-reaching consequences for human welfare, including the provision of food, water, and livelihood security.

Indigenous people and local communities (IP&LCs) have long been the primary caretakers of natural resources. While Indigenous people comprise around six per cent of the global population, they are protectors of an estimated 80 per cent of the world's biodiversity.[2] Land rights are under attack around the world; to date, governments have acknowledged their legal right to use or own just 18 per cent of land worldwide.[3] Although the effects of exploitative resource extraction are felt most strongly by IP&LCs, they often receive far less than their share of resource-derived wealth.

Digital technology unlocks new potential to address these interconnected challenges and help IP&LCs manage natural resources by reducing and reversing biodiversity loss.[4] Research reveals strong examples of digital solutions improving the efficiency, efficacy and equality of natural resource management (NRM)[5] activities in the global south.[6] From the use of big data to predict air pollution[7] and restore mangroves,[8] to GPS technology and remote sensing to track and protect wildlife,[9,10] the application of diverse technological interventions is on the rise. Furthermore, initiatives such as MappingForRights[11] and Cadasta[12] have leveraged digital tools to help empower IP&LCs to map and monitor their resources and reclaim their rights.

However, if the IP&LCs who take responsibility for the management of natural resources cannot directly benefit from the use of such technologies, long-term uptake and impact will be challenging to achieve. Currently, evidence on how to improve digital technology adoption and its success among IP&LCs is fragmented, making it difficult for stakeholders to learn from best practices, replicate success or identify opportunities for collaboration.

With this evidence gap in mind, the FCDO-funded Reversing Environmental Degradation in Africa and Asia (REDAA) and GSMA ClimateTech programmes collaborated to carry out research identifying barriers and best practices for digital technologies designed to help local communities in low- and middle-income countries in their efforts to manage natural resources sustainably. Drawing from desk research, stakeholder consultations and lessons learned from three case studies in Asia and Africa, this report presents common challenges faced when designing digital solutions for NRM and recommended approaches for developing new ones.

1 IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E.S., Settele, J., Diaz S., and Ngo, H.T. (editors).
2 World Bank (2022). Indigenous Peoples
3 www.rightsandresources.org/tenure-tracking/forest-and-land-tenure (accessed 14 March 2023)
4 See for example: Nitoslawski, S.A., et al (2021). The digital forest: Mapping a decade of knowledge on technological applications for forest ecosystems. Earth's Future.
5 Natural resource management refers to the sustainable use and management of the planet's natural resources, including forests, watersheds, oceans, air and a diversity of plant and animal species.
6 GSMA (2020). Digital Dividends in Natural Resource Management
7 GSMA (2018). Big Data for Social Good. Case Study: Telefónica Brazil
8 https://unfccc.int/climate-action/momentum-for-change/ict-solutions/connected-mangroves
9 https://giraffeconservation.org/programmes/twiga-tracker
10 https://connectedconservation.foundation/technology
11 https://www.mappingforrights.org
12 https://cadasta.org

Barriers to uptake of digital NRM solutions

The research highlighted four key barriers for the success of digital solutions in NRM:

Structural barriers, such as poor internet connectivity, limited smartphone access in communities or costs associated with access to technology. This impacts not only the digital solutions available, but also who in the community benefits from them. For example, it is common for smartphone access to be concentrated among members of communities, particularly those who are younger and male. As such, solutions designed solely for smartphones have the potential to exclude harder-to-reach groups and risk reinforcing existing community inequalities.

Technical barriers result from the limitations of the technology or digital solution itself. Technical issues can pose problems both for the tool's performance and its perceived value among users. If the user considers the technology to be overly complex or confusing, they are unlikely to maintain interest in it. Moreover, it should not be assumed that 'high tech' is always the best solution; 'low tech' can be equally successful. Both the technological infrastructure and enabling environment influence the extent to which different types of solutions should be considered.

Social barriers reflect how communities interact among themselves and prevalent social norms. Existing power dynamics can pose challenges to inclusive and equitable outcomes. For example, women in the community may have less mobility, a limited role in NRM decision-making or lower digital literacy, which could be further exacerbated if such factors are not considered carefully within the digital solution's design.

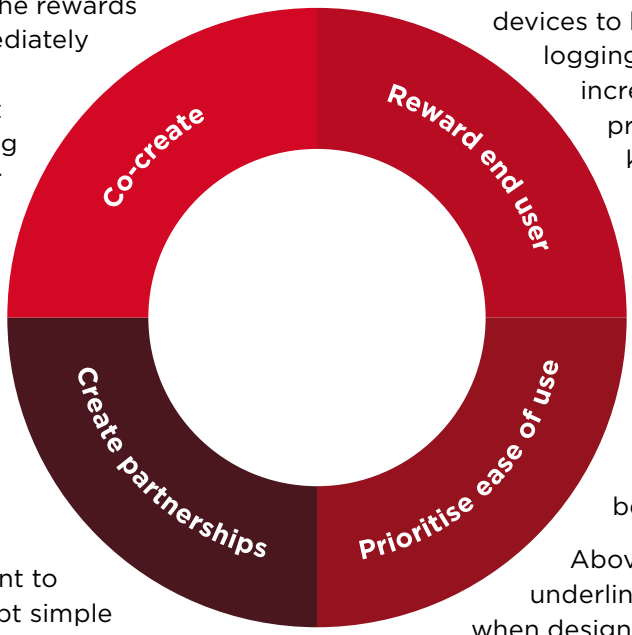
Motivational barriers are a result of human tendencies to behave in certain ways. In any new project, the uptake and continuous use of a digital solution will always be balanced against individual concerns such as limited attention spans, personal circumstances or resistance to change. If the end user does not feel the solution is directly and tangibly solving a problem in their daily lives, attrition is more likely.

By considering the different levels of influence on an individual or community's behaviours, projects can develop targeted interventions to address the specific factors that inhibit the desired NRM outcomes and identify the most effective strategies for promoting technology adoption.

Best practices for driving uptake of digital NRM solutions

The research identified best practices while attempting to digitalise the management of natural resources that are applicable across different geographies, type of natural resource and variety of technology usage.

The most salient driver in the success of a digital solution is its ability to **provide clear and direct rewards for the end user**. Tangible benefits, such as financial incentives, were found to be particularly successful in mobilising and securing longer-term community engagement. An example of this is the Fairtree[13] pay-to-grow system which uses the Treetracker mobile application to incentivise users in East Africa to grow and maintain trees with direct mobile payments. As the rewards of reforestation are not immediately felt, Fairtree circumvents the potential loss of engagement among end users by providing financial incentives at regular intervals after a new tree has been planted. This both incentivises the survival of the trees, as well as creating a meaningful source of income for tree caretakers.



Solutions must be intuitive and easy to use. Regardless of the technology being designed (ranging from low tech to frontier), it is important to ensure user interfaces are kept simple and engaging to improve uptake among local users. For example, India Observatory[14] developed the Composite Landscape Assessment and Restoration Tool (CLART) mobile application to improve the planning and management of soil and water resources in communities across India. The app translates complex data into colour-coded maps available in local languages, which can be easily navigated by users with low literacy levels. Solutions should also build on IP&LC's knowledge and practices already in place, with a 'bottom-up' approach to understanding the local context.[15] This helps to ensure solutions are designed in a way that aligns with, and elevates, long-standing or traditional community activities.

Working in partnership is central to long-term success. A critical best practice for digital NRM solutions is to partner with trusted community members or established local organisations to introduce and champion the solution, as well as build the capacity of local users to maximise engagement with technology. This helps to overcome potential pushback from community members against external actors, given that local partners are best placed to navigate the power dynamics in each area and advocate for the solution. For example, in Sumatra, Indonesia, Rainforest Connection[16] partnered with an established grassroots non-governmental organisation (NGO) KKI Warsi[17] to introduce their solar-powered acoustic monitoring 'Guardian' devices to help protect forests from illegal logging or poaching. The partnership increased buy-in with end users, provided context-specific knowledge and maximised the impact of the tools. The research also highlighted that when a digital technology is built upon or embedded within local community structures, existing government programmes or widely-adopted digital payments systems, it tends to be more trusted and used.

Above all else, the research underlined the **value of co-creation** when designing digital solutions for NRM. Co-creation in this context recognises that IP&LCs have a deep understanding of their environment and the challenges they face, and their knowledge can inform the design of more effective and sustainable digital solutions. This has been exemplified by the Group on Earth Observations (GEO) Indigenous Alliance, who use hackathons[18] to co-design creative digital solutions with Indigenous communities.[19] By involving end users and other key stakeholders in the design process, alongside individuals offering technical expertise, solutions can be better tailored to meet the specific needs and contexts of the communities they are created to serve. This can result in greater purchase and long-term sustainability of the solutions, as well as more equitable outcomes.

13 https://fairtree.org
14 https://www.indiaobservatory.org.in/tool/clart
15 REDAA ESRC Scoping Paper (2022). Low tech, bottom-up, place-based approaches
16 https://rfcx.org/
17 https://warsi.or.id
18 The GEO Alliance virtual hackathons are hardware and software marathons that take place online. Participants are given a limited timeframe (e.g. 44 hours) to work towards solving a pressing challenge co-designed by Indigenous communities around the world.
19 https://earthobservations.org/geo_indigenous_alliance.php

Recommended steps for designing a digital NRM solution

With these barriers and success factors in mind, the report recommends five steps for practitioners to consider when designing digital solutions for NRM.

The guidelines outline key factors to consider to empower local communities with tools to protect their surrounding ecosystems. The steps include:

1	**Align and build trust**	Before any solution is considered, the establishment of mutual trust between all parties is of utmost importance. This can be fostered by discussing shared learning needs, creating safe-space communication, and ongoing relationship building. Alignment helps to ensure all relevant stakeholders are on the same page. End users, funders, developers and partners should be united in the expectations and goals of the project. When key decision-makers do not have the same vision from the start, it can lead to issues with sustained usage and community buy-in down the line.
2	**Understand**	Talk to end users and other key stakeholders. Ask questions about the NRM problem you are trying to solve, the relationship between the local community and the resource, and the existing power dynamics and structures that exist in the target user population. At the end of this step, you should be able to clearly define the central NRM problem and its implications on various stakeholders. This will help to avoid duplication of efforts and unsuccessful solutions, ground the technology in the specific context, and ensure local participation.
3	**Co-design**	Use co-design workshops to develop locally relevant solutions to tackle the identified problem(s). Rank options to identify the most feasible and impactful ideas. Test low-fidelity prototypes of the top ideas with key stakeholders for feedback on ways to improve design, exploring how the solution may help or hinder NRM efforts. Use these insights to choose which prototype to move forward with and how to improve the effectiveness of the solution.
4	**Pilot**	Use a pilot rollout of the solution to assess the uptake and impact of the technology among end users. Clearly define what is meant by impact before you measure it; for example, if it is being considered from the perspective of the natural resource itself, or the users' empowerment to participate in NRM decisions. Use this as an opportunity to learn more about the solution and iterate accordingly. If the solution has failed to achieve the desired level of uptake and impact, revisit steps one to three.
5	**Learn**	Develop key performance indicators to monitor engagement with the tool, allowing for prompt identification of new or emerging challenges. When you have a co-created and contextualised digital NRM solution, make sure to share lessons learned. Creating meaningful insights for others to learn from and apply in different contexts can help create impact beyond your own end users and strengthen NRM efforts elsewhere.

Mobile and digital technology holds immense potential for empowering IP&LCs in their vital role as caretakers of the world's natural resources. By facilitating efficient and sustainable NRM, digital solutions can help to reverse the loss of biodiversity and safeguard the well-being of crucial species.

However, the full potential of these tools can only be realised by addressing the barriers to adoption and implementation, including structural, technical, social, and motivational challenges. Through strategies and approaches that keep IP&LCs at the centre of every design, digital solutions can play a transformative role in empowering communities to conserve the natural resources upon which we all depend.

Introduction

Biodiversity loss is an urgent societal challenge, with disproportionate impacts on the poor and vulnerable.

Biodiversity loss is happening at an alarming rate worldwide. Human activities have altered an estimated 75 per cent of the Earth's terrestrial land,[20] with 10 million hectares of tropical forest lost each year.[21] Meanwhile, overfishing and pollution are contributing to the declining health of the world's oceans, with over 90 per cent of global fish stocks either fully or over exploited.[22] This crisis is closely interlinked with two other global emergencies: climate change and persistent poverty (worsened since the COVID-19 pandemic) and rising inequality.[23] The destruction of ecosystems and wildlife populations are depriving people of vital resources such as food, water and medicine, and exacerbating poverty in vulnerable populations around the world.

Low- and middle-income countries (LMICs) are the most impacted and the least equipped to mitigate the effects of these rapid changes. Over 25 per cent of the world's population rely on forest resources for their income, while three billion depend on marine and coastal biodiversity.[24] Meanwhile, biodiversity loss increases vulnerability to natural disasters by reducing the ability of ecosystems to provide protective services, such as flood control and coastal protection. Up to 300 million people are at increased risk of floods and hurricane damage because protective coastal habitats have been lost.[25]

A lack of tailored resources and solutions to address these changes is predicted to result in a 'climate apartheid' by 2100 where "the wealthy pay to escape overheating, hunger and conflict while the rest of the world is left to suffer."[26] The impacts are felt particularly by IP&LCs, even though land owned, managed or occupied by these communities sees degradation at a less severe rate.[27] Addressing this crisis will require concerted efforts to protect and restore habitats, reduce pollution and over-exploitation, and address the underlying drivers of biodiversity loss. This need for concerted action was recognised through the Kunming-Montreal Global Biodiversity Framework agreed at COP15, where countries collectively committed to protect and conserve at least 30 per cent of global land area by 2030.[28] The 30x30 effort will proceed in a way that recognises IP&LC's territories while emphasising the areas that offer critical ecosystem services, such as clean water, food, air, and climate stability, which are essential for human well-being. As such, it becomes increasingly important to consider the implications of intersectional inequalities within local communities, and their relationships with the natural resources they protect.

Digital solutions can be a useful tool to address biodiversity loss and benefit local communities, if used wisely.

The use of digital technology in NRM, such as mobile devices, satellites, the Internet of Things (IoT) and artificial intelligence (AI), has grown steadily in recent years. There is increasing evidence that when developed and applied in a customisable and scalable way, digital solutions can strengthen NRM activities.[29]

However, the mere existence of a digital intervention does not guarantee uptake and continued use; various sectors and stakeholders must work in alignment to ensure contextualised digital solutions can succeed. Research highlights the benefit of local engagement in ensuring the equitable uptake of digital solutions in NRM.[30] It is therefore essential to better understand how best to involve and engage local communities and stakeholders in the development, implementation, and monitoring of digital interventions to ensure their sustainability and effectiveness in NRM activities.

20 Living Planet Report IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E.S., Settele, J., Diaz S., and Ngo, H.T. (editors).
21 FAO and UNEP (2020). The State of the World's Forests 2020. Forests, biodiversity and people.
22 FAO (2018) The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals.
23 Hou-Jones, X., et al (2021). Nature-based Solutions in Action: Lessons from the Frontline. IIED.
24 FAO and UNEP (2020). The State of the World's Forests 2020. Forests, biodiversity and people.
25 IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E.S., Settele, J., Diaz S., and Ngo, H.T. (editors).
26 UNEP (2020). Indigenous peoples and the nature they protect
27 IPBES (2019). Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating' IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E.S., Settele, J., Diaz S., and Ngo, H.T. (editors).
28 Conservation International (2022). Statement: Kunming-Montreal Global Biodiversity Framework Solidifies 30x30 Target
29 GSMA (2020). Digital Dividends in Natural Resource Management
30 See for example: Eilola, S. et al (2021). Lessons learned from participatory land use planning with high-resolution remote sensing images in Tanzania: Practitioners' and participants' perspectives

Research objectives and methodology

While the number of providers of digital solutions for NRM is growing, there is a fragmented understanding of what works. What causes so many well-intentioned digital solutions to fail? How do others reach scale across different contexts and communities? What is the role of local communities in digital interventions for NRM? The research sought to gather insights for these questions to help develop best practices to improve digital technology uptake and impact in local communities, particularly among IP&LCs. The research was completed through the following steps:

Review of global trends

First, a comprehensive desk review and landscaping exercise was carried out to understand recent projects adopting or scaling digital NRM solutions among communities in South Asia, Southeast Asia and Sub-Saharan Africa during 2020-2022. The search strategy sought to understand changing trends across digitally-enabled NRM activities and factors that influenced organisations' capacity to develop and implement effective solutions.

Case studies

Building on this understanding of the overall trends across the sector, three digital interventions were selected to explore the issues of local implementation in greater depth. Projects were chosen to capture diversity in geography, types of digital solutions and natural resources managed. Twelve interviews were completed with stakeholders in varying roles across the three case studies, ranging from creators of the digital solution and IT managers, to local partners and community mobilisers. Given the challenges of securing interviews with community-based stakeholders, particularly with end users, research conducted by the organisations was also reviewed where available to better understand community perceptions. The case studies were used to map the challenges each digital solution faced, and classify them into a type of barrier (structural, technological, social and motivational). The interviews also highlighted common factors that contributed to the successful adoption and use of the digital solution.

Analysis and stakeholder consultations

The initial research findings were validated among 27 stakeholders (including academics, technology practitioners and project implementers) at the 'Digital Tools for Reversing Environmental Degradation Symposium' in January 2023,[31] with inputs used to refine research conclusions. Three further stakeholders in the tech-for-NRM space were interviewed to contextualise findings from the case studies and evidence from the desk review.

Development of best practices

Drawing upon the previous stages of the research (desk review, case studies, stakeholder consultations), combined with Busara's expertise in social and behaviour change projects, best practices and recommended steps for developing participatory digital solutions for NRM were finalised.

31 Royal Academy of Engineering Symposium: 'Digital Tools for Reversing Environmental Degradation', 9-19 January 2023. Further details can be found here (accessed 14 March 2023).

Landscape: Exploring digital trends

Review of digital NRM solutions 2020-2022

In 2020, the GSMA ClimateTech programme undertook research to explore the digital dividends of various types of technology on NRM in LMICs.[32] This included a review of 131 NRM activities in LMICs. While there was great diversity in the objectives, structure and scale of these projects, in almost all cases digital technology was being used in one of the following ways:

- To enable real-time monitoring and data collection;
- To support community engagement in NRM activities; or
- To allow organisations to store, analyse and visualise data.

Three categories of digital technology usage

Real-time monitoring and data collection

Connected devices and other technologies are used to support data collection and the monitoring of species, people and assets, often in real time or near-real time.

Common technologies used: Sensors, Satellite, Drones, Camera Traps and Mobile Devices

Engaging and informing communities

A broad range of technologies and approaches are used to influence positive behaviours or to provide communities with the tools they need to actively participate in NRM projects, to access information or support, or to receive payments for ecosystem services.

Common technologies used: Call Centres, Interactive Content, Peer-to-Peer Content, Push and Pull Content, Mobile Payments and Mobile Devices

Data management and analysis

Artificial intelligence and other data management tools are used to provide real-time analysis, support decision making, predict trends and promote efficiencies.

Common technologies used: Inventory Management Tools, Blockchain, AI, Data Visualisation Software

32 GSMA (2020). Digital Dividends in Natural Resource Management

The literature review picked up where the Digital Dividends report left off, covering the timeframe between 2020 and 2022, focusing on organisations that saw inception or significant expansion of operations during this period. Geographic regions of interest were Southeast Asia, South Asia and Sub-Saharan Africa to align with the REDAA programme scope. The list of projects and technologies reviewed can be found in Appendix A.

The landscaping exercise identified 44 projects across 15 NRM activities, using a combination of 13 technologies. These were identified by first revisiting the existing projects reviewed in the Digital Dividends report, followed by searching for key terms to identify relevant projects online. Analysis was conducted to understand trends across NRM technologies and applications.

The review focused on the application of technology, rather than the scale of its uptake. As such, it is difficult to conclude how many individuals use these solutions and the extent of their reach. Similarly, impact data is often not publicly available, particularly for newer solutions still gathering evidence.

Key takeaways from the review:

- **Existing or new digital technologies were most commonly used in activities addressing forest management, anti-poaching, and wildlife tracking.** This is likely because digital technologies are already well-established within these three areas, which helps to facilitate the scale up to new contexts and build on previous lessons learned. Fewer emergent solutions were seen in other NRM activities such as marine species preservation, wetland management, wildlife habitat protection, or air pollution prevention.
- Among the 44 projects reviewed, **monitoring technologies were the most used solutions.** This includes sensors and, to a lesser extent, Internet of Things infrastructures.[33] Monitoring technologies remain the most widely used solutions in NRM largely because of their versatility across diverse activities, which can be adapted to specific user needs. They see a particularly high adoption in projects concerned with anti-poaching and tracking of wildlife. For example, the Giraffe Conservation Foundation[34] uses the Twiga Tracker, a GPS tracking technology to better understand and track giraffe spatial ecology. Real-time visualisation data of giraffe movements and habitats provides a valuable tool for conservation managers and rangers on the ground. To date, the Twiga Tracker has been used to track and help protect nearly 300 giraffes across 12 countries in Africa.
- The review of projects from the last two years saw the **expansion of frontier technologies** such as blockchain[35] and non-fungible tokens (NFTs),[36] as well as an increased use of artificial intelligence technology and IoT. For example, IoT sensors are used to support NRM in a variety of ways, including analysing tree growth, measuring air and water temperatures, tracking vulnerable species, detecting chainsaws and optimising ranger patrol routes.[37] IoT use is implemented through the Long Range Wide Area Network (LoRaWAN)[38] across many countries—particularly in wildlife conservation. Elsewhere, Black Rock Rhino,[39] a rhino conservancy in South Africa, partnered with blockchain technology firm Virtual Nation Builders to raise funds for the protection of endangered rhinos via the auction of rhino horn NFTs.
- While frontier technologies offer great potential to be further developed to support NRM activities, the **review and stakeholder interviews found some caution in the use of blockchain, NFTs and cryptocurrencies within NRM**.[40] It is acknowledged that these technologies have the potential to improve data management, increase transparency, and facilitate efficient transactions in NRM activities. However, there are also concerns about the potential unintended consequences they can lead to, such as exacerbating existing power asymmetries or environmental impacts, alongside ethical and legal questions about the commodification of nature.

33 Internet of Things (IoT) is a network of internet-connected objects that can collect and exchange data using embedded sensor technologies. Data can allow devices in the network to 'make decisions' autonomously based on real-time information.

34 https://giraffeconservation.org

35 Blockchain is the underlying technology that supports bitcoin and other cryptocurrencies. Distributed ledger technology (DLT) includes blockchain and decentralises the process of accounting for and verifying changes in information across a network.

36 Non-fungible tokens are non-interchangeable assets that represent ownership of a unique digital item. NFTs have one owner, which is recorded on a blockchain to secure ownership. A blockchain is a shared, immutable ledger for recording transactions and tracking assets.

37 GSMA (2023) IoT for Development: Use cases delivering impact

38 LoRaWAN is a technology designed to wirelessly connect devices to the internet using unlicensed spectrum. The development and promotion of LoRaWAN technology and its ecosystem is led by the LoRa Alliance, which includes more than 500 member companies.

39 https://www.rhinos.one

40 See for example: Howson, P., (2020). Climate Crises and Crypto-Colonialism: Conjuring Value on the Blockchain Frontiers of the Global South

Exploring power dynamics in NRM

With the varied interests and incentives of different parties, it is important to note the power dynamics at play within and between local communities, governments, corporations, NGOs and conservationists. As governments try to balance the land and natural resource rights between extractive business interests and IP&LCs who place cultural, spiritual and emotional value on many natural resources, competing aims can play out on an uneven battlefield.

When applied well, digital technology can help to address inequalities and power dynamics in NRM by increasing transparency and accountability, enabling participation and representation of marginalised groups, and facilitating the sharing of information and knowledge. For instance, the MappingforRights[41] initiative uses participatory mapping and mobile technology to empower Indigenous peoples and local communities in Africa to map their lands and resources and assert their rights. Similarly, Cadasta[42] provides diverse digital tools and technology services, such as GIS[43] mapping services, to enable vulnerable communities and partners to easily document and secure inclusive land and resource rights. In doing so, Cadasta's digital tools have helped strengthen the land and property rights of over one million people.

However, if digital solutions are designed poorly, they can reinforce inequalities in NRM. For example, solutions may not account for the social and cultural contexts of local communities, resulting in the exclusion of certain groups from decision-making processes. Furthermore, digital solutions may not consider power asymmetries among different stakeholders, leading to the perpetuation of existing inequalities by catering only to the needs of individuals with existing resources, such as those with access to smartphones or higher digital literacy.

Even when considerations of equity are part of programming, outcomes are not always realised.[44] Digital interventions geared at NRM activities are often high tech (complex and costly to maintain) and top-down (where decision-making is guided by high-level officials, or a digital solution is introduced without consulting the local community).[45] Indeed, interviews with key stakeholders highlighted the unintended consequences of some NRM digital technologies being used and ethical questions

that must be considered when designing solutions. For example, the use of surveillance technology such as acoustic devices or camera traps have been effectively used to track and protect wildlife and bring valuable data into the hands of local residents working to protect these animals. However, this information can fall into the wrong hands and inadvertently help poachers. Similarly, some stakeholders reflected on incidences where surveillance devices can affect community interaction within this space, such as women no longer travelling to these areas or modifying their behaviour due to the discomfort of being captured on camera. Without contextually-sensitive approaches, driven by local demand and the inclusion of IP&LCs, digital solutions risk negatively impacting communities.

Finally, excluding IP&LCs from the design and implementation of digital technology to address biodiversity loss represents lost opportunities to unleash the potential of citizen-science and better use traditional knowledge to sustainably manage natural resource use. The literature review found that, when strategically designed and applied, digital technology can empower IP&LCs to assert their rights in natural resource governance by providing them with access to information, resources, and tools to monitor and advocate for their interests.

41 https://www.mappingforrights.org/forestlink
42 https://cadasta.org
43 Geographic Information System services include the use of technology and data to create, manage, analyse, and visualise geospatial information. These services involve the collection, storage, analysis, and display of geographic data on maps or other visualisations.
44 See for example Bidaud, C. et al (2017). The sweet and the bitter: intertwined positive and negative social impacts of a biodiversity offset.
45 REDAA ESRC Scoping Paper (2022). Low tech, bottom-up, place-based approaches.

Case studies: Exploring the realities of implementing a digital NRM solution

The following chapters of the report explore in greater depth how digital solutions are used in NRM across three cases:

Case Study 1: CLART app, India

Case Study 2: Treetracker app, East Africa

Case Study 3: Guardian bio-acoustic devices, Indonesia

The case studies were chosen to capture diversity in geography (Sub-Saharan Africa, Southeast Asia, South Asia), types of digital solutions and purposes, and which natural resources they help to manage. This includes solutions that monitor natural resources, aid their sustainable use, and drive regeneration. Priority was given to case studies with strong localised design and partnerships guiding them.

The three examples utilise different technologies, ranging from mobile-based solutions in India and East Africa, through to solar-powered acoustic monitoring devices backed by AI in Indonesia. All three are at different stages in their journey to scale. Guardian devices can be found in forests across several countries, the CLART app is now in use across 18,000 villages in India, and the Treetracker app is used by several communities in East Africa.

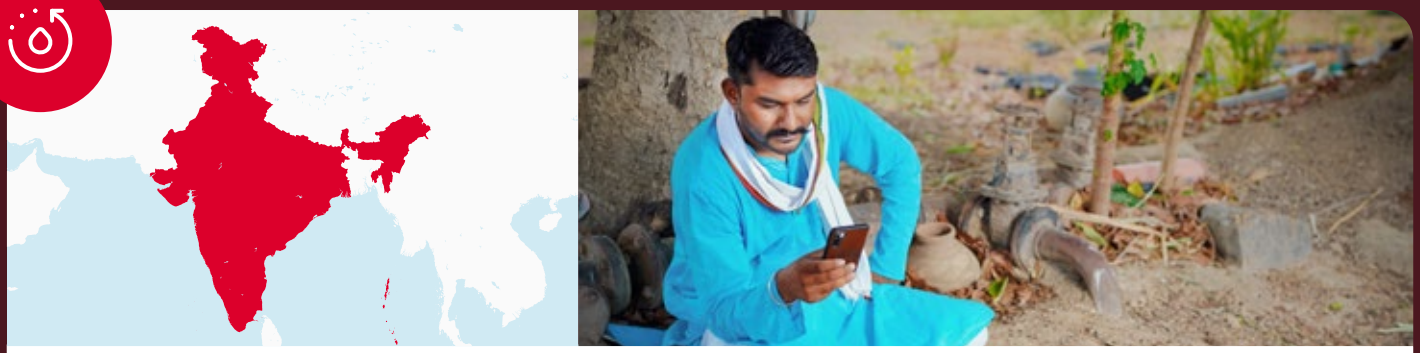
Interviews with key stakeholders working on the design, rollout and sustainability of these solutions highlighted the varied and context-specific challenges they faced, as well as the factors which have contributed to their uptake and impact.

In the following case studies, barriers have been classified as follows:

- **Structural barriers** from existing institutional, environmental and governmental structures.
- **Technical barriers** include the limitations of the technology or digital solution itself, as well as its applicability to the local context.
- **Social barriers** arise from how communities interact, power dynamics, and prevalent social norms which may influence attitudes and behaviours related to both the natural resource or digital solution.
- **Motivational barriers** are a result of human tendencies to behave in certain ways and how individual priorities or perceptions impact behaviours.

Across all three examples, we see that the key principles underpinning the solutions' success include working with local community members to ensure the digital solution is developed or adapted in close consultation with key stakeholders, introduced and championed by trusted local community members, is intuitive and easy to use, and directly benefits the lives of end users.

Case studies: At a glance



Case study 1:

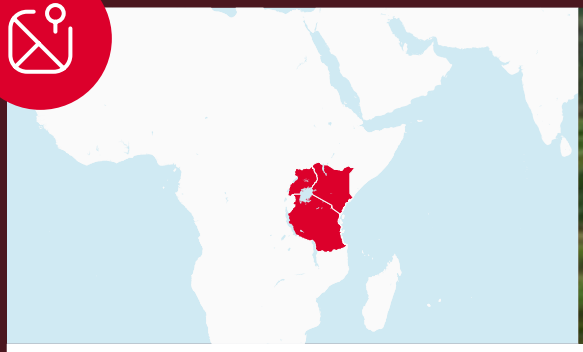
Democratising water and soil management in India

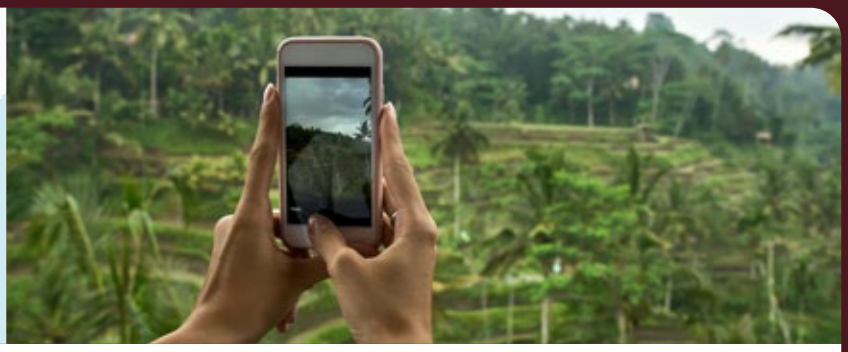
Digital solution: CLART (Composite Landscape Assessment and Restoration Tool), a Geographic Information System (GIS) -based Android app created by the India Observatory.

What the solution aims to achieve: CLART aims to improve the planning of local soil and water management by making information available in a user-friendly mobile app. Local community members can identify suitable sites for new water structures in their area to help secure government funding for communal conservation activities, as well as support end users make more informed decisions on how to manage water and soil resources.

Technologies used: GIS mapping, data visualisation.

Uptake and impact: CLART is used in five states in India, across over 18,000 villages with approximately 62,000 users.





Case study 2:

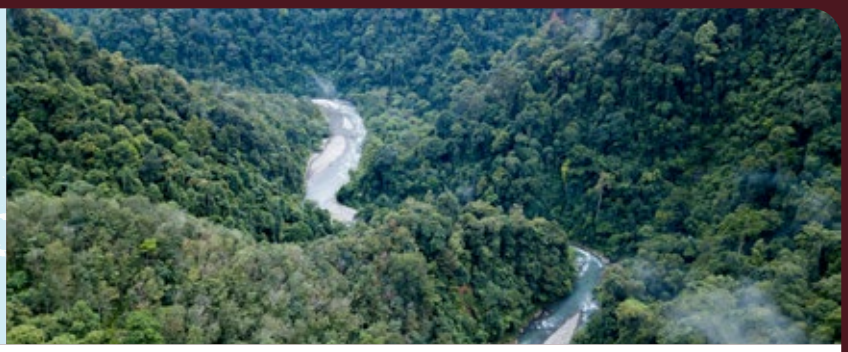
Payments for planting and managing trees in East Africa

Digital solution: Pay-to-grow using the Treetracker mobile application, from Fairtree

What the solution aims to achieve: The Treetracker app makes direct payments to community-based users to plant and maintain trees. The app allows users to upload pictures of trees planted and receive payments into their bank accounts. By paying local community members to plant and manage trees in their own communities, the app helps to drive reforestation and support livelihoods.

Technologies used: Geo-tagging, mobile money payments.

Uptake and impact: Fairtree has helped growers plant 250,000 trees across Uganda, Tanzania and Kenya.



Case study 3:

Protecting forests and wildlife through acoustic monitoring in Sumatra, Indonesia

Digital solution: Guardian Platform, backed by AI and machine learning, by Rainforest Connection

What the solution aims to achieve: The Guardian devices enables the protection of forests and wildlife from illegal activities, such as logging and poaching, in Sumatra. Guardians collect audio recordings from the surrounding area and apply AI models to the recorded audio files to identify sounds associated with illegal logging (e.g., chainsaw noises). Local village guards in Sumatra are then notified of the potential illegal logging activity through alerts on their phones, allowing them to respond in real-time.

Technologies used: AI and machine learning.

Uptake and impact: Alongside its use in Sumatra, Guardian devices are also deployed to address illegal forest activities in several countries across the world including Brazil, Peru, Ecuador and Cameroon.

Case study 1:

Democratising water and soil management in India

Context

In India, an estimated 900 million people live in rural areas and depend heavily on natural resources for their livelihoods. Tapping into natural ecosystems and sustainably managing their use thus becomes a key component in the fight against poverty, linked to several Sustainable Development Goals.[46] In India, the ecological importance of natural ecosystems and their role in generating income is hindered by remnants of a colonial past. Common lands - categorised as 'waste' under colonial rule due to their high tariff, low revenue potential for the government - are subject to weak legislature. While property laws are improving, it remains difficult for local communities to claim rights to pooled land resources, along with the soil and water resources they hold.[47] As a result, around 26 per cent of India's landmass does not generate income. To address these challenges, India Observatory (IO), a collaborative technology initiative, has developed digital solutions to empower rural communities in India to help manage and benefit from these resources. IO's projects seek to strengthen water conservation, land restoration and biodiversity conservation, as well as support local governance in NRM.

46 In particular Sustainable Development Goals 1, 2, 3 and 6.

47 India's Ministry of Tribal Affairs enacted The Forest Rights Act (FRA), 2006, which recognizes the rights of the forest dwelling tribal communities and other traditional forest dwellers to forest resources, on which these communities are dependent for a variety of needs, including livelihood, habitation and other socio-cultural needs.

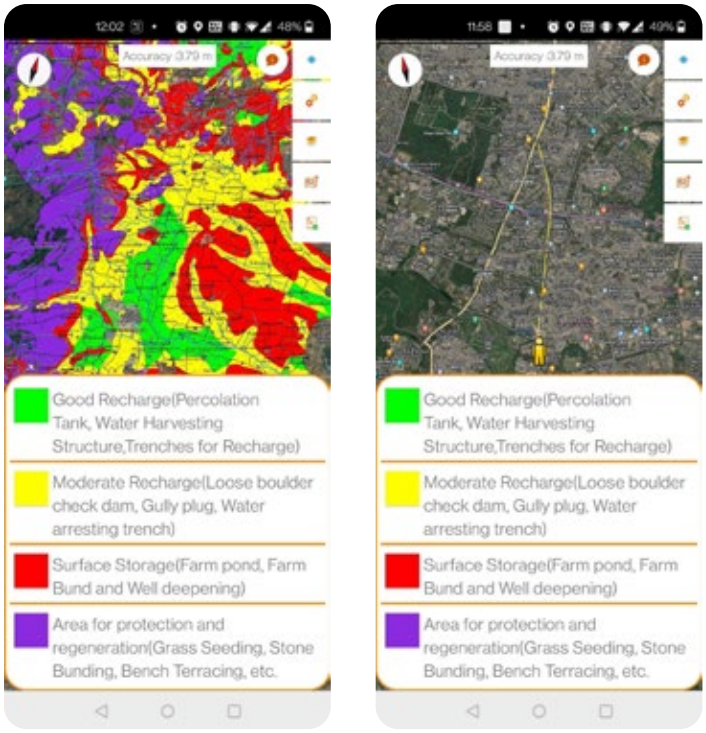
The solution: CLART Android app

This case study focuses on one of the technology solutions first developed by IO in 2014, the **Composite Landscape Assessment and Restoration Tool** (CLART), a Geographic Information System (GIS) based Android app. GIS services are data visualisation tools that can be used to gather, integrate, manage and analyse data which can help users identify patterns to make more informed decisions.

Using government and publicly available data, algorithms enable the CLART app to map soil and water resources, allowing community members to access data for improved conservation planning and NRM. CLART suggests context-specific soil and water conservation structures and helps design, measure and prepare financial budgets for them. It does this by translating scientific data into simple colour-coded maps that can be easily understood by semi-literate or illiterate end users. After identifying a location-specific intervention, the user can input basic measurements such as length, width and height of the proposed activity (such as building a new water structure) into the app-based estimation tool.

CLART generates an estimate of approximate cost, labour days and a sketch of the engineering design for the new intervention. This information can be submitted to the local governing body who would then visit the proposed site. CLART recommends treatments for interventions specific to the chosen location. This helps with water resource management by providing timely and accurate information on water availability and demand, allowing stakeholders to make informed decisions. It also helps rural communities better understand the topography of their land and make better decisions on how to both conserve and use soil and water in their areas. Given that the app estimates groundwater recharge using satellite data and hydrological models, it supports rural farmers and other stakeholders to make more sustainable use of groundwater resources.

CLART app



By providing this information through a user-friendly interface, the CLART app allows communities to access information about their land which is otherwise inaccessible to them, such as groundwater level and potential recharge capacity. Community members can simply choose a location mapped in the CLART app and fill out an application for local governments to approve and provide funding for their plans. This includes, for example, the recommended structure for the chosen area, groundwater level, manpower and time requirements. This speeds up the government approval process for community plans and improves efficacy of ground level implementation by providing village-level decision-makers with the information required to prepare funding applications for the most suitable structure. To date, CLART is used in five states in India, across over 18,000 villages with approximately 62,000 users.

User journey

- After clicking on the CLART app, a detailed colour-coded map of the selected area appears.
- When the GPS is switched on, it will locate the user on the map, even if they are offline.
- The user can open the colour-coded map to identify the soil and water conservation measures suitable for that location.
- After choosing a particular intervention, a new screen appears which prompts the user to select the village, the recommendations and the interventions.
- The user can then download data in their area by selecting the state, district and block and save the dataset on their mobile phone.
- The entire information can be synced with the server once the user is online.
- When that is done, the user can access the CLART web portal to submit recommended measures for an existing or new project.

Key stakeholders

A range of stakeholders influenced the success and uptake of the CLART app – as detailed below.

Users

The primary CLART users are village communities and Panchayats (village councils chosen by the local community). However, it is also used by NGOs and government officials working on conservation structures, making the tool relevant for a diverse range of end users.

Design and implementation

India Observatory identified a pressing need to simplify the process of restoring soil and water resources for community members in rural India. CLART was designed to solve this problem and make the data available to those who could most benefit from it. After comprehensive user testing, the CLART tool was rolled out in collaboration with local government departments. This helped to support its credibility and uptake among rural communities.

Funding

CLART was initially funded by short-term grants from the likes of the Hindustan Unilever Foundation and Vodafone Foundation. However, the ongoing use of the app has been funded through government welfare programmes and employment schemes.

Collaborators

The CLART tool is underpinned by partnerships with regional governments, universities, non-profits, private organisations and multilaterals to form a community driven to create impact by sharing data, tools and analytics.
For example, in Meghalaya, the government's Soil and Water Conservation Department provides outreach and training on the ground for CLART to support comprehension and useability of the tool.

Disseminators

Volunteers from the local community are trained to introduce the app and teach others how to use CLART. Volunteers are most likely to be facilitators identified as influential figures – for example, members of village employment councils.

Barriers to local impact

Interviews with IO staff members highlighted several challenges faced when introducing CLART in a country as populous and diverse as India.

Structural barriers

Inequalities of access

Structural challenges—such as low smartphone penetration, the cost of data, and mobile network connectivity—posed barriers to uptake.

Smartphone ownership is concentrated among young, male, educated populations in most rural locations. As such, they are more influential in the uptake of CLART in many communities. For example, in the Khasi region in Meghalaya, one of the reasons for lower uptake of CLART is the relatively low rates of smartphone ownership. IO sought to address this in some areas by providing mobile tablets for the community but technology ownership remains a barrier in other locations.

Technical barriers

Technical capacity among end users

Learning how to use the CLART app can be a time-consuming process through which users must be kept engaged. As such, the technology must be designed to be accessible and engaging for local community members, otherwise there is a risk of resistance and attrition when technical difficulties are faced. IO has sought to address this by using colour-coded maps that are easily understood to overcome potential language and technical barriers.

Social barriers

Local governing systems and power structures

The success of this type of technology varies at a regional and local level based on existing community dynamics and modes of governance.

For example, in Garo, which is typically governed by the state, CLART sees high uptake due to official endorsement.

On the other hand, in Khasi and Jaintia, tribal kings hold more influence over the community. Communities governed under this structure are more reluctant to work with 'outside' organisations, including the government.

Motivational barriers

Balancing short-term and long-term incentives for users

The rewards of NRM are not always immediate for local communities. For example, users of CLART must meet costs of time and energy to identify locations on which to develop new soil and water conservation projects, apply for funding and attain the manpower required to build them. They must then wait for funding to come through before they can enjoy the benefits of a new water supply. When rewards are not immediate, communities are sometimes deterred from using the tool.

Exploring incentives for uptake

IO has conducted extensive research among key CLART stakeholders—such as end users within the community and village institutions—to help understand the barriers and levers across the user journey which could improve adoption. Key factors influencing the successful uptake of the CLART app are outlined below.

Engaging interface

The final map the user sees is colourful, intuitive and easy to interpret. CLART achieves this by offering simple, fit-for-purpose interfaces to present the otherwise complex findings. Engaging visuals and a clear call to action for users increases the tool's useability and impact.

Localisation

When scaling CLART, localisation was of key importance; what worked in one village could not be directly implemented in another. A contextual understanding of the target community was key, for example aligning the app to reflect the local language and dialects of the end users. Another way that CLART adapted to local needs was to make features of the tool available offline for communities that face problems with connectivity. This type of iteration is made possible through research with end users and a strong community mobilisation and outreach system to ensure the app reflects the context of the local area.

Aligning CLART with government initiatives

Rather than the app serving community members only, CLART has been successfully integrated within government welfare programme's core activities in certain states in India, with its design matching the approval process of village-level water and soil conservation plans. As such, communities are motivated to use it because it helps them obtain government approval of funding faster. By matching CLART to existing government initiatives, its rollout and scaling go hand-in-hand with programmes delivered by local authorities and has helped ensure its longer-term financial backing. In some locations, the CLART tool was picked up by the local government after years of building credibility and use among the community.

Introducing CLART via trusted stakeholders

Across villages, the successful uptake of CLART by end users was largely driven by trusted individuals or groups introducing it within the community. Local government endorsement encouraged more village authorities to use the tool, which in turn encouraged high use among community end users.

CLART's success provides an example of how human-centred design can create an effective digital NRM solution. The tool's biggest challenge was effectively catering to communities with varying degrees of technology access and digital literacy, alongside ensuring the solution reflected the cultural and economic diversity of the end users it sought to support.

CLART's impact is underpinned by two key factors: app localisation and working within existing social structures. Adapting the app to be colour-coded and accessible in local dialects is a product of keeping the end user at the crux of both the development and iteration of the tool. IO were also able to identify the formal and informal structures through which CLART could be introduced into communities, ensuring that existing power dynamics were considered throughout the dissemination strategy to drive uptake and long-term commitments to the solution.

Further information about India Observatory's range of digital tools can be found here, including CLART's User Manual here.

Case study 2:

Payments for planting and managing trees in East Africa

Context

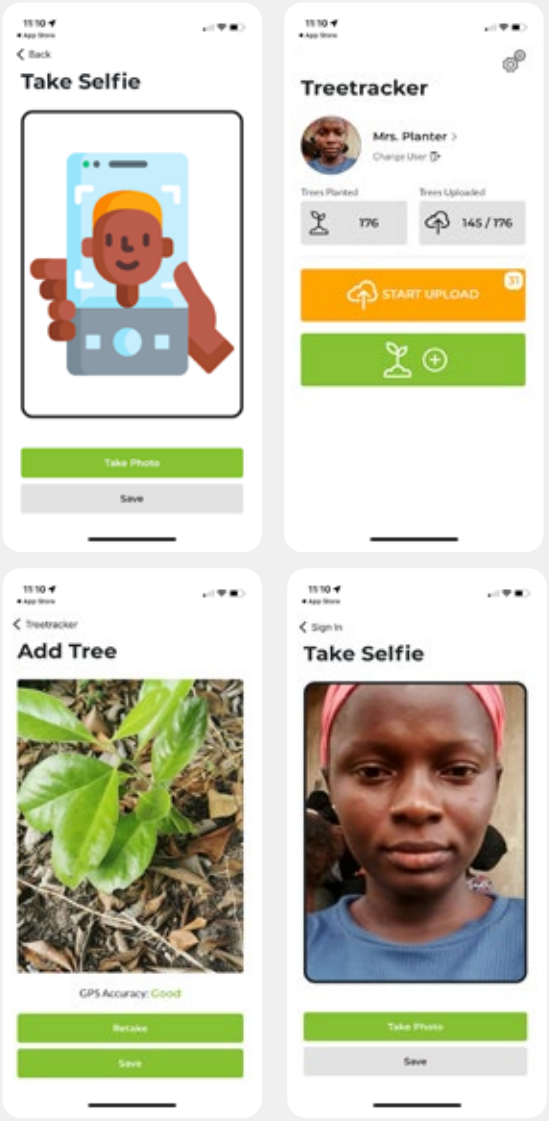
The people of Sub-Saharan Africa have a higher reliance on natural resources for their income than in other regions of the world.[48] However, returns from natural resources are often restricted for local communities due to existing power inequalities and weak environmental regulation systems. People from affluent backgrounds, private sector companies and governments are more likely to enjoy the economic benefits over local community members. There is need for a system that distributes the returns of NRM among those who put the work into rehabilitating and preserving these resources.

Payments for ecosystem services (PES) schemes provide income for individuals or communities (such as farmers or landowners) who have agreed to take certain actions to manage land or natural resources to provide an ecological service.[49] While PES is rapidly becoming a worldwide practice, these schemes are often difficult to deliver and most projects have failed to achieve scale.[50]

Against this backdrop, Fairtree, an organisation active across communities in East Africa, has developed and implemented a 'pay-to-grow' system of reforestation which incentivises local communities and individuals to plant and maintain trees in return for direct payments.

48 Brookings (2018). 7 surprising findings about resource-rich sub-Saharan Africa
49 https://www.iied.org/markets-payments-for-environmental-services
50 GSMA (2020). Digital Dividends in Natural Resource Management

Pay-to-grow using the Treetracker mobile app



Example user journey

Download the app on a mobile device

- Change the language if needed
- Choose the ‘Track’ option

Create a profile

- Enter a phone number or email address
- Take a selfie

Choose profile

- If multiple users have profiles on the same phone, choose your profile
- Click on ‘Wallet’

Track a tree

- Capture a picture of a tree
  - Stand close to the tree
  - Take a picture
  - Add the species name in the ‘Notes’ field
  - Choose the ‘i’ button for instructions
- Upload the picture
  - Find a good internet connection
  - Open the app
  - Wait for the ‘Sync Successful’ message to appear on the screen

Get paid

- Wait for the tree to be verified by Fairtree
- Get direct payment to mobile phone

Fairtree uses the Treetracker app, an open-source platform developed by their partner Greenstand, to help users plant and track trees through geo-tagged pictures. Once a grower uploads a batch of photos, these are reviewed and verified before being published on openly available maps.

Treetracker uses data points from the pictures (such as location and timestamps) to verify the tree’s progress. Fairtree works with each project to develop a pay-to-grow plan that sets tree prices based on various factors such as tree type, wage labour required to keep the tree alive, and the prevailing market rates. Once the price is estimated, Fairtree sends batch payments using existing mobile payment systems provided by mobile network operators, such as MTN in Uganda, Safaricom in Kenya, and Vodacom in Tanzania.

Each tree is tracked for the first two years of its growth. Growers receive payment every time they submit updated photos of their trees. Payments are sent out corresponding to a project-specific tracking schedule set by Fairtree. At planting, after one month, after three months and so on.

Fairtree developed a sophisticated tool for determining the price per tree and the frequency of tracking. The complexity and adaptability of this tool helps set Fairtree apart from other tree growing organisations. In any given project there may be 30-50 variables that factor into the price, including local wage rates and time expenditures on various aspects of the process.

For example, projects that rely on assisted regeneration of existing trees (usually from stumps or shrubs) require less frequent tracking (only three to four times, per two-year period) because the trees do not require frequent watering or care and have a near 100 per cent survival rate. More traditional reforestation projects with planted seedlings require frequent tracking because the planted seedlings need extra water and care in an exposed environment.

Once each grower goes through a vetting and approval process, they are eligible to receive payments and earn ongoing income from planting trees. Fairtree seeks to ensure fair and timely payments, with at least 75 per cent going directly into the hands of growers, with the remaining 25 per cent covering operational and transaction costs. To date, in Kenya, Tanzania, and Uganda, Fairtree has helped growers plant 250,000 trees.

Key Treetracker stakeholders

The Treetracker app was developed through the vision and implementation of several key stakeholders.

Key stakeholders

Users

Potential growers can be any individual with smartphone access. Sometimes, groups of individuals use the same phone to access their Treetracker accounts. As such, individuals may not have a phone but they can still set up a profile on a communal phone.

Design and implementation

The Treetracker app was built and managed by Greenstand,[51] an open-sourced community of web developers, tree planting organisations and international development professionals, dedicated to improving the transparency and effectiveness of reforestation projects. Fairtree uses Greenstand's verification to review each individual photo uploaded and leads on implementation and uptake in key communities.

Funding

Fairtree primarily relies on donors and awards for funding. For example, the organisation recently received a grant from the African Forest Landscape Restoration Initiative (AFR100)[52] which funds the top 100 tree-planting projects in Africa.

Collaborators

Fairtree partners with experts to train the community on tree growing.

They have also worked with a smartphone recycling company called Newaya to improve penetration and access to these handsets in some communities.

Disseminators

Fairtree recruits and trains new growers remotely through a network of community-based change agents. This allows pay-to-grow to be used in areas that are typically difficult for most non-profits to reach.

51 https://greenstand.org
52 https://afr100.org

Barriers to local impact

While the simplicity of the approach lends itself to rapid scaling for new communities, interviews with Fairtree highlighted some of the challenges faced in maximising uptake of the pay-to-grow system, particularly among harder-to-reach users.

Social barriers

Engaging diverse users

Fairtree tries to make specific efforts towards diverse users—particularly recruiting women—but they are often the least likely to have access to a smartphone. In addition, in some locations, women have less mobility, which is required for planting and visiting the trees.

Structural barriers

Smartphone penetration

Low smartphone penetration is a key barrier in some locations and when trying to scale up Treetracker to new communities, concentrating its current use to those with more access to technology.

Time constraints of grant funding

The value of the pay-to-grow system through the Treetracker app has been recognised and supported through grants offered by external funders such as AFR100 and individual donations. However, to achieve ongoing scale and sustainability, Fairtree highlighted that the current business model must evolve to ensure it can continue through other sources of longer-term investment.

Unpredictable transaction charges

Fairtree strives to ensure fair and timely payments, with at least 75 per cent going directly into the hands of growers. However, when bringing the technology to additional contexts, new payment systems are needed and associated transaction charges can be unpredictable and inconsistent. This is an additional cost borne by Fairtree.

Motivational barriers

Understanding financial impact

When it comes to measuring impact on livelihoods, growers can be reluctant to share personal financial information such as their income outside of Fairtree or what they spend their earnings from Fairtree on. Furthermore, pushing for answers on these topics may erode trust in the programme. This makes it more difficult to form a baseline to measure impact against changes in livelihoods.

Exploring incentives for uptake

As a digital solution that has been adapted and scaled across three countries, Fairtree shared some of the factors that helped improve the uptake and impact of the Treetracker app.

Financial incentives for action

Financial incentives are often the biggest motivator for local communities to invest time and energy in engaging with a new tech solution.

The the pay-to-grow system is simple, transparent and directly tied to the welfare of the tree at different periods of time.

As the rewards of reforestation are not immediately seen, Fairtree circumvents potential loss of engagement among end users by providing up-front financial incentives. This is further helped by timely payments delivered at consistent intervals.

To date, the carbon credits market[53] only rewards those who plant trees within designated project areas. However, with pay-to-grow through the Treetracker app, growers can plant trees in areas familiar and close to them and be rewarded for it, making it a more inclusive way for end users to benefit from the management of their local resources.

Local ownership

Fairtree's involvement is almost entirely remote, including planning, management, and monitoring. As such, the success of their solution relies on community members with existing local connections, called crew leaders, to manage groups of growers. Crew leaders recruit within their communities and provide on the ground support, helping to navigate the many challenges associated with the power dynamics within tightly-knit communities.

Communities are given training on how to plant trees and keep them alive and how to use the app to upload pictures of the trees they plant. Through this, the technology helps to mobilise communities in remote areas and gives them the autonomy to plan out and execute their own tree-growing projects.

Fairtree builds on the knowledge base of the communities, drawing from horticultural and historical nuances to direct which trees to grow. It is underpinned by the view that communities know how to manage their resources best.

53 Trading systems in which carbon credits are sold and bought. A tradable carbon credit equals one tonne of carbon dioxide or the equivalent amount of a different greenhouse gas reduced, sequestered or avoided.

Low tech, bottom-up

The Treetracker app is intuitive and easy to use. Growers simply take pictures of their trees and post it against their profile.

Moreover, Fairtree focuses on the growth of indigenous species of trees to be grown. Local communities have the know-how required to plant and care for these trees, ensuring that community-specific knowledge is utilised.

Focusing on the reforestation and maintenance of indigenous species of trees offers biodiversity benefits such as habitat creation, ecosystem restoration, preservation of genetic diversity, and the provision of ecological services in each area.

Leveraging systems and technology the community already knows

Fairtree's pathway is through existing systems and resources: community networks, smartphones and payment systems already in use. Treetracker uses mobile money payment systems offered by established mobile network operators to make digital payments to growers, increasing the ease of use and trust in the pay-to-grow system. Vice versa, as growers already use their local mobile money provider, Fairtree is better able to vet new growers.

Creating a scalable solution

The pay-to-grow app is relatively easy to replicate and adapt to new regions or languages, as the Treetracker technology can be used in any context. Fairtree can continue to use established, easy and direct payments in any context as well.

Reforestation projects often struggle to achieve sustainability due to the requirement for long-term engagement and investment. The challenge of maintaining ongoing commitments is further compounded in low-income households in East Africa, where livelihood pressures can take priority over the sustainable management of natural resources. However, Fairtree has made notable progress in overcoming these challenges through its innovative pay-to-grow system through the Treetracker app, which drives tree growth, supports local biodiversity regeneration, and secures long-term engagement from communities. One key factor in the success of Fairtree is the use of regular and salient financial incentives, which not only drives action but also supports economic stability. The Treetracker app's integration within existing systems and promotion through community members has been crucial in ensuring Fairtree's continued success. Fairtree's solution has the potential to thrive beyond its current grants-based income business model, and they are actively exploring how to scale it up. By addressing the challenges of long-term engagement and investment in reforestation, Fairtree's approach provides a valuable model for sustainable natural resource management.

Further information about Fairtree can be found here.

Case study 3:

Protecting forests and wildlife through acoustic monitoring in Sumatra

Context

Sumatra, an island in Indonesia, is home to some of the richest and most diverse tropical forests in the world. However, in the past two decades, about 50 per cent of the rainforest in Sumatra has been felled and cleared.[54] This has negatively impacted a variety of animals native to the island's rainforests, driving Sumatran tigers, elephants, rhinos, and other animals towards extinction.[55] Millions of hectares of the rainforest are protected and should be free from logging activities but highly organised illegal logging operations exist that threaten these areas.

Illegal hunting and trading of wildlife in Sumatra is driven by a high demand for wildlife products, such as ivory, tiger bones, rhino horns, and pangolin scales, which are used in traditional medicine and/or as status symbols. The loss of habitat due to deforestation and human encroachment on wildlife habitats has also contributed to the decline of many species, making them more vulnerable to poaching as they become more sought after.

Efforts have been made to combat poaching and illegal logging in Sumatra, including strengthening law enforcement, increasing community-based initiatives, and promoting sustainable livelihoods. However, ongoing illegal activities remain a serious threat to the wildlife on the island, and more action is needed to protect these endangered species and the island's rich biodiversity.

Rainforest Connection (RFCx) is a non-profit that has monitoring projects in Indonesia (and 34 other countries) which uses their acoustic devices and technology empowered by artificial intelligence models. These devices are designed to monitor biodiversity around the world to inform conservation efforts and detect threats to protect ecosystems from illegal logging and poaching.[56] This has been rolled out in West Sumatra, where RFCx uses their 'Guardian' System to help Village Forest Guards forest rangers to more accurately and efficiently identify and respond to the risks of illegal logging and poaching.

54 WWF | Sumatra
55 WWF | Sumatra
56 https://rfcx.org

The technology: AI-backed deforestation prevention

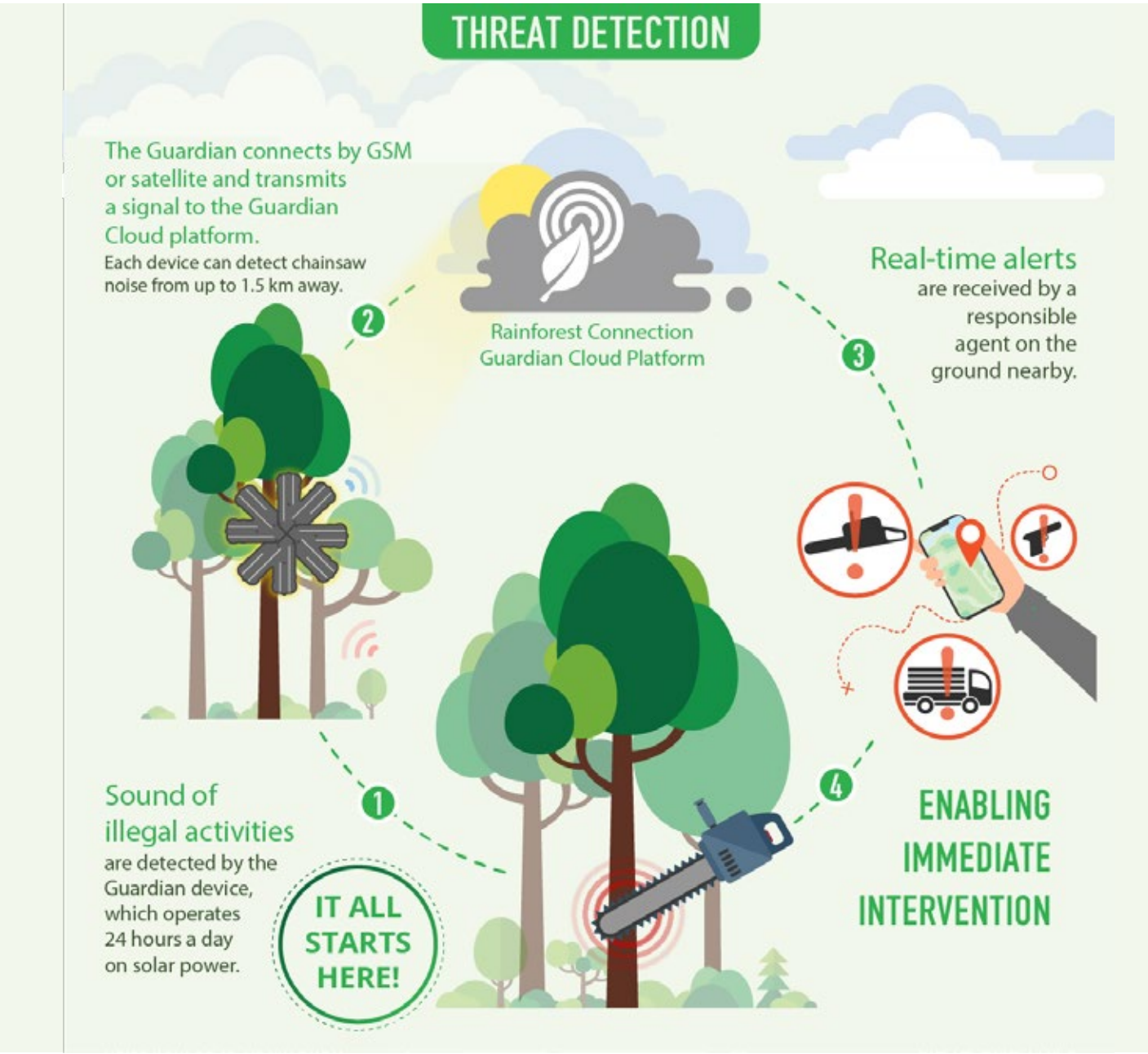
AI is a way to build models that mimic intelligent human behaviour and decision-making capabilities.

RFCx's models are based upon machine learning: using rule-based algorithms on bioacoustics data to enable systems to learn how to recognise patterns and make predictions through experience.[57]

One way to address illegal logging and poaching in West Sumatra is to send the local village forest guards (VFG) to patrol the land, which can be difficult given the expansive land to cover, as well as dangerous for the individuals involved.

In place of people going through the collected audio recordings manually to identify specific sounds, RFCx trains and employs AI models to quickly analyse the large amounts of audio collected by their bioacoustics monitoring devices. This allows RFCx's devices to establish a baseline for the soundscape of Sumatra's rainforests and quickly identify sounds associated with illegal logging and deforestation.

Guardian device: How it works



57 Brown, S. (2021). Machine learning, explained MIT Management Sloan School

Image: Guardian device

The tool: Guardian

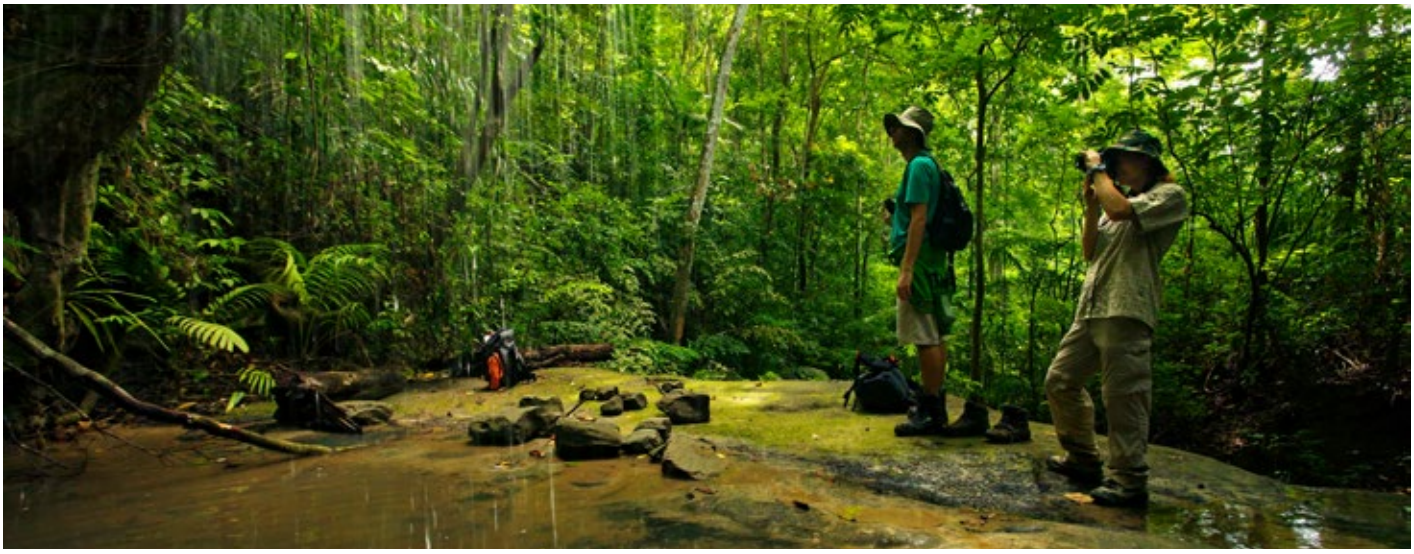
For Sumatra, detecting the sounds of logging and human activity is equally as important as tracking animals. Up to 61 per cent of all Indonesian lumber results from illegal forestry, costing the government around two billion USD a year from corruption, uncollected taxes and general poor resource management. This deforestation also has dire consequences for Sumatra's native species, which rely on the cover of the rainforest to survive. In the last two decades, deforestation has removed 12 million hectares of rainforest from Sumatra – a loss of almost 50 per cent.[58]

This challenge has been addressed with RFCx's in-house real-time acoustics monitoring device, called 'the Guardian'. The Guardian's primary purpose is to constantly gather data on the surrounding environment. The platform delivers rapid insight into what is happening in the forest ecosystem across Sumatra and other project sites, identifying potentially harmful behaviour, and helps village forest guards pinpoint and stop damaging activities as they occur.

When connected via the Global System for Mobile Communications (GSM),[59] the Guardian device uploads a continuous recording of the surrounding environment's soundscape, transmitting the audio in real-time to the cloud for instant analysis. Once the sensors detect such sounds, they transmit real-time alerts to a team of local rangers on the island, who can then quickly respond and intervene to stop the illegal logging. The Guardian device has been deployed in several areas across the island, including the Leuser Ecosystem, one of the largest remaining rainforests in Southeast Asia. In Sumatra, as of 2021, RFCx has introduced 27 Guardian devices in nine villages alongside local partners.[60]

A key aspect of RFCx's approach is building and maintaining strong local partnerships with conservation organisations on the ground to champion the use of Guardians among the community. In Sumatra, this organisation is KKI Warsi – a key player in conserving with the community living in the Kerinci Seblat National Park area.[61] Their approach is to ensure that the community is integrated in the management of forest areas across Indonesia, including in Sumatra.

58 Newton, M. (2019). The conservationists and rangers of Sumatra's diverse rainforests have gained an AI ally in their fight against illegal logging. Reset
59 GSM is a standard for digital cellular communication that is widely used for mobile phones and other wireless devices.
60 Hitachi Vantara (2021). Hitachi Vantara and Rainforest Connection expand partnership to protect rainforests through data and AI
61 https://warsi.or.id



Key stakeholders

Interviewed RFCx staff shared their experiences of implementing the Guardian tool in Sumatra. They emphasised that simply introducing the technology itself is not enough and the importance of aligning with trusted partners such as KKI Warsi to implement the technology and work through complications.

End-users

In Sumatra, the end users of the Guardians are largely village forest guards (VFG), as they are the ones that act on threat detection alerts. The VFGs also collaborate with the Forest Management Unit (FMU) and the Forest Police who are sent reports prepared by KKI Warsi. These are based on field reports given by the VFGs. In other contexts where Guardians have been introduced, end users include indigenous or local leaders. For example, Rainforest Connection has worked closely with the Tembé Indigenous community in Brazil to prevent illegal encroachment and logging on the Tembé reserve as they are best placed to put this data into use.

Funders

RFCx receives funding from partners, family foundations, and private grant-making organisations of varying sizes. To date, some of their funding partners include USAID, Change Happens Foundation, and McGovern Foundation.

Corporate partners

RFCx aids corporations with their corporate social responsibility initiatives, and receives direct support for projects on the ground and support with technology development. Some of their recent corporate partnerships include Google, Huawei, Hitachi, Infineon, Rolex, Salesforce, and Sonos.

Implementation partners

In Sumatra, RFCx works with local implementation partners KKI Warsi to install the Guardians, increase buy-in of the end users, and provide context-specific knowledge and understanding. This component of working alongside local partners is carried across every RFCx project.

Barriers to local impact

Interviews with RFCx highlighted challenges faced in maximising their impact in Sumatra, both in terms of technical challenges as well as some initial pushback from the local community.

Technical barriers

Installation of Guardian devices

Being able to monitor sounds in a wide radius can be difficult and RFCx faced challenges installing the Guardians in Sumatra. The devices need adequate access to sunlight and connectivity to work effectively, which requires climbing 100 metres vertically into the canopy of the rainforest.

Making hardware work consistently

It can be challenging to ensure hardware performs consistently in remote parts of the Sumatran rainforest with varying extreme weather conditions, and still be able to extract data from the Guardians in real-time.

Social barriers

Local nuances

Threat detection is different in every single location RFCx works in due to local nuances. This includes differences in how much the government supports the efforts, how much jurisdiction and agency the end users have in terms of acting on the threats, and how organised the logging/poaching enterprises are. Such nuances affect the overall impact of the threat detection technology. In Sumatra, RFCx faced the challenge of trying to empower forest communities to protect their land against the government's agenda of relocating people who historically live in the Kerinci Seblat National Park areas. Consistent governmental support is needed to offset resistance, which impacts the reach of the technology.

Power dynamics

In Indonesia, hierarchy plays a crucial role in relationships. As a result, the RFCx team partnered with the reputable and trusted local organisation, KKI Warsi, to facilitate the implementation of the Guardian technology solution.

It is important to note that in some cases, illegal loggers may come from neighbouring villages, outskirts of the village forests, or even the same village forests. Due to existing relationships, conversations with these loggers can be uncomfortable.

Furthermore, there is a general mistrust of international organisations as they are often seen as outsiders who come and go. KKI Warsi is highly effective in addressing this issue, as they are a local NGO and experts in community building. They have been working closely with these village forests for years and are widely trusted.

Motivational barriers

Shifting priorities at the local level

At the start of the project, the potential end-users showed significant interest in the Guardian system. However, their enthusiasm diminished over time due to changes in priorities and a lack of direct, personal incentives to use the threat detection software.

To address this, RFCx collaborated with KKI Warsi to develop concrete milestones that encouraged end-users to continue using the technology after installation. This approach allowed for increased engagement and ensures that the Guardian device is used to its full potential.

Exploring incentives for uptake

RFCx explained that they employed the following strategies to maximise their local on-ground impact in Sumatra.

Strong local partnerships

Partnerships with local organisations are central to the Guardian's impact and growth. As such, RFCx invests time and resources identifying partners best placed to successfully introduce the technology. In Sumatra, RFCx works with Indonesian conservation NGO, KKI Warsi. RFCx provided KKI Warsi with in-depth training on the Guardian system, enabling them to teach the VFGs effectively. KKI Warsi holds monthly meetings and makes regular visits to village forests to provide status updates. In addition, the RFCx team and KKI Warsi meet monthly to review the response status and address any issues that VFGs may face while in the field.

Localisation

RFCx utilises local knowledge and understanding of their implementation partners to augment their strategy on the ground. For example, in Sumatra they plan sessions around religious holidays and prayer times. They also made sure to translate the language so VFGs could easily use the technology.

Working closely with end users

RFCx works closely with their end users to ensure buy-in and adoption of their technology. They installed Guardians alongside KKI Warsi and end users to make sure they became familiar with the technology. They also designed workshops to educate village forest guards on the technology and the various benefits of their threat-detection solutions. To further support the VFGs, the RFCx team provides them with equipment such as mobile phones and allowance support for village meetings, as well as on-demand technical support. The programme's success has been underpinned by strong accountability and effective communication, which KKI Warsi and RFCx consistently maintain to keep the VFGs engaged with the program.

Agile approach

RFCx produces Guardians in small batches. They work iteratively to continuously better their devices and ensure they remain up-to-date solutions to threat detection.

The Guardian's success can be attributed to several key factors. Firstly, RFCx benefits from robust funding, which has enabled them to scale their operations and impact significantly. Secondly, RFCx has forged strong and relevant partnerships across the multiple countries in which they operate. This approach of creating and fostering partnerships with local implementation partners has been a crucial factor in their success, as it helps to tailor the introduction and ongoing use of the Guardian devices to the specific context.

Thirdly, while RFCx has encountered some technological challenges that are typical of organisations operating at their scale, they have placed a strong emphasis on continuous reiteration of their platforms. This approach ensures that their solution for threat detection and biodiversity monitoring is well-suited to the needs of end-users and the environmental context in which it is being used. Through these steps, RFCx has been able to maintain its position as a leader in forest conservation and protection.

Further information about Rainforest Connection's missions, projects and solutions can be found here.

Barriers to digital NRM solutions

Evidence from the desk review and case study interviews highlights that when organisations face issues of low uptake, or failure to scale or maintain sustained use in their digital NRM solution, there are often multiple factors at play. As outlined in the case studies, each of these barriers can manifest in different ways in communities. For example, inability to access an internet connection may be due to a lack of wireless infrastructure or because certain groups within a community are restricted from using the internet due to social norms. As such, it is important to understand whether a barrier is at a **structural, technical, social** or **motivational level** (or a combination) so that it can be contextually addressed through targeted interventions.

Structural barriers

Structural barriers result from existing institutional, environmental and governmental structures. For example, low smartphone penetration is a key barrier for Fairtree when trying to scale up Treetracker to new communities. As such, when considering new potential communities for their work, smartphone penetration is a key factor in feasibility.

Technical barriers

Technical barriers result from the limitations of the technology or digital solution itself. For example, Rainforest Connection must periodically service and maintain their Guardian tools to ensure they work well, because rainforests are difficult terrain to traverse and internet connectivity is low in these areas. Technical issues faced across the case studies can pose problems for the tool's performance and perceived value among users. If the user deems the technology to be overly complex or confusing, they are unlikely to maintain interest in the digital solution. Building capacity of expertise on the ground helps to ensure that technical problems can be swiftly addressed.

Social barriers

Social barriers result from how communities interact among themselves and prevalent social norms. CLART initially faced pushback as communities saw common land as unproductive 'waste' land and did not immediately see the relevance of the tool to their lives. Changing social perceptions around the value of the land contributed to CLART's success. Existing power dynamics can also pose challenges to inclusive impact at both governmental and community levels, which is why existing dynamics must be carefully considered with the design of any new tech solution.

Motivational barriers

Motivational barriers are a result of human tendencies to behave in certain ways. Fairtree's system of direct payments plays on people's preferences for immediate rewards. At the individual level, people are more likely to consistently engage with the 'pay-to-grow' mobile application when they receive regular payments with quick turnaround times.

The level at which a consideration is present in a community is indicative of if and how a barrier can be addressed through technological intervention, alongside ways it can be leveraged to ensure the success of the digital solution. The categories provide a useful framework for understanding the complex interactions between individuals, their social environments, and the broader ecological systems that shape human behaviour and affect outcomes related to technology uptake.

By considering these different levels of influence on an individual's behaviour, projects can develop targeted interventions to address the specific factors that inhibit the desired NRM outcomes and identify the most effective strategies for promoting technology adoption. For instance, interventions focused on reducing individual and social barriers should be behavioural in nature, taking into account interpersonal factors such as social norms, peer influence and power dynamics within the community. On the other hand, to solve technical barriers, interventions must focus on making technology more accessible and easier to use by iterating the digital solution. Finally, structural challenges can be addressed by building partnerships with stakeholders at various levels to create the infrastructure or environment conducive to technology adoption. The success factors that help to overcome such barriers are outlined in the following chapter.

Best practices for designing digital NRM solutions

Drawing from the desk research, stakeholder consultations and lessons learned from the three case studies in Asia and Africa, this chapter presents best practices to support the development and uptake of digital solutions within NRM.

Co-create solutions

Above all else, interviews with organisations and experts underlined the importance of understanding the NRM problem as it relates to the IP&LCs that own, protect or depend on the resource for income. If organisations do not understand the problem from the perspective of end users, it is likely that the solution developed will not be best suited to address the problem and face push-back from the community.

To make sure all facets of a problem are understood, it is essential to co-create solutions. This means talking to end users, getting feedback from developers and consulting NRM practitioners. This approach ensures community buy-in, which will help sustain the use of the technology where organisations may face barriers due to funding or technology breakdown. IO achieved this by conducting extensive user and stakeholder research across communities in India to fully explore the challenges of managing soil and water resources, taking into account specific geographic, structural and governmental considerations, and shaping the CLART tool to directly address these pain points.

Co-creation is only possible once strong and trusted working relationships have been developed among key stakeholders. Communities may have had negative experiences in the past with organisations and be reticent to engage with new projects. For this reason, the importance of establishing mutual trust to lay the best foundation for co-creating solutions cannot be underestimated.

Co-defining problems and creating solutions

The GEO Indigenous Alliance hosts regular hackathons in which communities co-design digital solutions. In 2020, a COVID-19 hackathon was held. This co-design process gave way to a digital solution called the Namunyak app. The application allows the Sambura community in Northern Kenya to design and develop their own maps to document their land's natural resources and important locations. The map has symbols and words that are contextually relevant to the community, which helps to bypass issues of communication and understanding. Developing an application like this without the community co-design aspect would have limited its reach and functionality – demonstrating the importance of co-design and co-creation taking place during the inception stage.

> "If end users are a part of the process, they feel invested, and the solution is culturally relevant."
>
> Diana Mastracci, GEO Indigenous Alliance

Localise the design and application of the digital solution

It is vital to design both the solution and implementation strategy based on a thorough understanding of the local context and existing NRM practices. IO prioritised localisation when designing and later scaling the CLART app, ensuring it could be used in local dialects and adapting the app for offline use in response to connectivity issues in some locations. Similarly, when introducing the Guardian tool to communities in Sumatra, Rainforest Connection worked closely with on the ground implementation partners KKI Warsi to integrate local language options, as well as build roll out strategies around key community events and holidays among village forest guards.

Provide clear and direct rewards for using the solution

Offering tangible rewards for end users helps drive engagement and perceived value in the digital solution, whether benefits are monetary or focus on other advantages. Fairtree's Treetracker app offers the clearest example of this, providing direct mobile money payments to IP&LCs to grow and maintain trees. Paying growers in intervals helps to maintain longer-term engagement and support local livelihoods. For projects which offer non-monetary incentives, it is important to make the benefits salient. With IO, the benefit of using CLART in India is that the potential of natural resources is maximised, which can benefit the whole community in terms of access to resources, planning how to use them, and securing future government funding for their area. With Rainforest Connection in Sumatra, the incentive of using the Guardian is that village forest guards are better equipped to do their jobs in protecting the forest from illegal activity. When the incentives are more result-based (i.e. only after using the technology does one see the benefit) it can be helpful to make these benefits more visible, for example through providing real-life examples during training or capacity building efforts of other people using and benefiting from the technologies to help end users better understand what value engaging with the solution will bring to their lives.

Prioritise simple and intuitive user interfaces

Digital solutions in NRM need to focus on creating a simple and engaging user interface to ensure the product is easy to navigate, particularly when targeting end users with low levels of literacy. With digital solutions that are more complex and rely on natural resource data, such as IO's CLART, this can be difficult. However, IO overcame this challenge by using local terms and intuitive colour schemes to simplify the information presented. User interfaces can be refined when piloting the solution. Gathering early feedback from community members who will be interacting with the solution helps to ensure the product is easily understood and navigated by the target user. Gamification can also incentivise sustained IP&LC engagement in digital solutions and influence positive behaviours aligned with NRM outcomes.

Foster strong local partnerships for longer-term impact

Across all three case studies, maintaining strong local partnerships and disseminating the technology through trusted individuals in the community was critical to success, facilitating faster and more sustainable buy-in. In the case of IO's CLART technology, giving some community members more responsibility and involving them in training and dissemination improved uptake outcomes. Fairtree crew leaders are trusted community members with a wide network. This makes it easier to hire potential growers, reduces user hesitancy and increases trust around the payment aspect of the pay-to-grow system. KKI Warsi offered significant value in helping introduce and embed the Guardian tool in Sumatra as a recognised grassroots organisation in Indonesia. For communities that may have had previous negative experiences with external organisations, working with local partners can help to offset concerns and ensure IP&LC perspectives are prioritised.

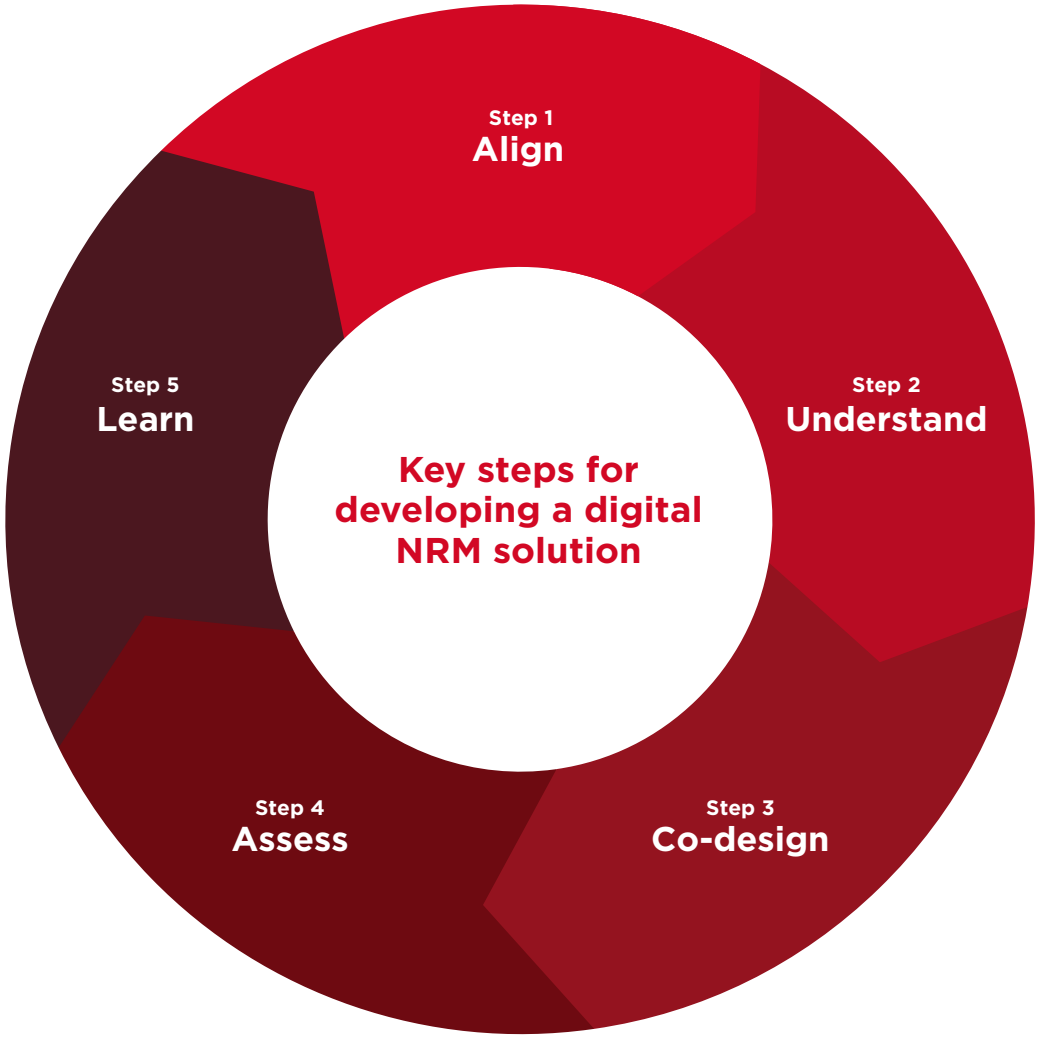
Work within an established system by making use of existing frameworks and/or technologies as pathways to users

When it comes to dissemination and scaling, working within an established framework can greatly improve uptake outcomes. IO was able to do this by embedding CLART into existing government programmes. This resulted in users perceiving the technology as trustworthy and reliable, and more familiar as they work with similar implementation partners to other existing government programme interventions. Meanwhile, Fairtree used established frameworks for existing mobile payment systems that helped set up payment systems quickly and came with a level of trust in the community.

Recommended steps for developing a digital NRM solution

In this chapter, we lay out key steps for creating a digital solution for NRM from scratch, based on insights gathered from the research. This can also be used by organisations who have already developed products. The framework will help ensure that organisations embed end users in their development, the digital solution emerges from participatory design, and it addresses, rather than reinforces, existing power dynamics within the community.

Given the iterative nature of designing digital solutions, previous stages may benefit from being revisited to deliver the strongest end product. This ensures the solution takes a user-centred approach through continuous testing and refinement of the product based on user feedback.[62]



Source: GSMA ClimateTech

62 Example toolkits to support co-designing solutions and human-centered design can be found from UNICEF Human-Centred Design resources, frog and Stanford d.school.

Step 1:
Align and build trust

Ensure all relevant stakeholders are on the same page. End users, funders, developers and partners should be aligned in the expectations and goals of the project. When those who make key decisions do not have the same vision from the start, it can lead to issues with sustained usage and community buy-in down the line. Build trust.

Checklist

- Make a list of key decision-making stakeholders (e.g., end users, local government, community activists, funders, etc.).
- Set a clear agenda for the discussion (e.g., to discuss the key challenge end users are facing and the overall goal of the digital solution).
- Coordinate in-person or virtual meetings.
- End with a clear consensus.
- Define next steps.

Step 2:
Understand

Talk to end users and other stakeholders. This could include both informal and formal figures of authority in the community, or other organisations or individuals working in the space. When designing community-level engagements, it is important to factor in the power dynamics at play and carefully consider who is consulted. For example, avoid asking local leaders to speak on behalf of diverse groups as this could present a skewed understanding of what solution would best serve the target end users. Instead, explore ways that vulnerable or marginalised social groups—defined through intersecting modalities such as gender, class or ethnicity—can be consulted to understand how they use and derive benefits from the resource in question. This will help to clarify their abilities to engage with and benefit from a digital solution, as well what might change if such a solution was to be introduced.[63]

Ask questions about the NRM problem you are trying to solve, the relationship between the local community and the resource, and the existing power dynamics and structures that exist in the target population. It is also useful to establish shared understanding of key terms related to the activities, such as what restoration or conservation means and looks like in the context. At the end of this step, you should be able to clearly define the central NRM problem and its implications on various stakeholders. This will help to avoid duplication of efforts and fruitless solutions, ground the technology in the local context, and ensure local participation.

Checklist

- Review existing solutions from other contexts to understand what has worked and lessons to build upon.
- Make a list of members from the end user community who guide decision-making (e.g., religious leaders).
- Carefully consider the existing power dynamics and how the research could best understand and work around this. Try to ensure marginalised groups within the community are consulted so that their unique perspectives and experiences are captured. This can help to avoid inadvertently reinforcing existing inequalities and/or capture the experiences of those with more resources and social capital.
- Decide the most appropriate way to speak to end users (e.g. focus groups, key informant interviews, community observations). Choose approaches that fit with the availability and resources of under-represented groups. This could include having discussions with women led by female researchers, meeting end users in locations where they work, or ensuring seasonal workers are also consulted.
- Draft interview guides that will allow you to understand:
  - The NRM problem from the perspective of the community;
  - The relationship the community has with the resource;
  - The organisational problem (e.g., low uptake) from the perspective of end users; and
  - Explore potential barriers and enablers in the context of your problem.
- Where possible, try to classify potential barriers and enablers based on the existing interviews.
- Use this understanding of the context in the design phase to ensure solution prototypes consider potential barriers and leverage enablers.

63 REDAA ESRC Scoping Paper (2022). Intersectional inequalities.

Step 3:
Co-design

Develop locally relevant solutions to tackle the identified problem(s), which can be done through co-design workshops. Leverage what is known and break free of existing, ineffective solutions. You will ideally have an understanding of what has not worked after the 'Understand' phase. This does not mean the technology has to be out of the box or 'high tech'. The primary goal is to ensure the end product is locally relevant and effective.

After the workshop, you will have co-created ways to address the NRM problem you are trying to solve. Take time to synthesise your findings. If you have more than one solution by the end of the co-design workshop, you can use the following vetting framework to narrow down on one solution.

Vetting framework

For each potential solution, assess on a scale of 1 (lowest) through 5 (highest), according to the degree to which you agree with the following:

Impact	The solution will directly lead to the targeted outcome among end users.
Ease	The solution will not require a lot of resources from the end user (time, money, etc.).
Cost	Implementing the solution is a cost-effective use of organisation and community resources.
Fit	Implementing the solution makes sense for the community's existing social and cultural practices.

Vetting can be a group activity to review and rate the ideas based on these criteria. At the end of the vetting exercise, you will be able to judge which of your solutions are the most feasible and impactful.

Prototyping

The solutions that have the highest total overall score on the vetting sheet should be chosen for prototyping. Prototypes are low-fidelity, initial representations of solutions that will help gather feedback on the viability of your digital NRM idea. Prototypes can take many forms, such as:

- Product mock ups;
- Sketches/diagrams; or
- Wireframe of an app.

Once you have created prototypes for your solution, it is advisable to gather feedback from different stakeholders. This is called participatory ideation and can be done by sharing the prototypes and inviting feedback either as a group or from individuals. Having visual representations and example user journeys will help key stakeholders engage with the practicalities of the solution and provide more concrete suggestions for how to strengthen the design. Some questions to consider asking are: How would you improve the design? Are there any parts you would remove from the design? From your perspective, how will this help or hinder NRM efforts?

When you receive feedback from stakeholders with different perspectives of the same problem, you will be able to choose which prototypes to move forward with and tweak aspects of the chosen prototypes that will likely improve the effectiveness of the intervention.

Gaining input from different perspectives at this early stage helps to strengthen the overall design and foster buy-in from key stakeholders, which facilitates a strong foundation for the remaining steps.

Checklist

- Coordinate a co-design workshop including end users as key stakeholders.
- Focus on the most impactful barriers and enablers through structured discussion.
- Invite design ideas to address chosen barriers and leverage enablers.
- End your workshop with clear takeaways.
- Vet your solutions from the workshop (score them on Impact, Ease, Cost, Fit).
- Select the solutions that are most feasible and impactful (i.e.: the solutions that score highest during vetting).
- Create prototypes of your chosen solutions.
- Gather feedback on prototypes.
- Ensure consensus on the chosen prototype.

Step 4:
Assess

Use a pilot rollout of the solution to measure the uptake and impact of the technology among end users. It is important to remember that impact can mean different things for different solutions. Clearly define what you mean by impact before you measure it; for example, if you are considering the perspective of the natural resource itself, or the users' empowerment to participate in NRM decisions. Use this step to iterate and optimise your approach. As outlined in earlier sections of the report, many well-meaning digital NRM solutions fail or falter in new contexts. Use this as an opportunity to learn more about your solution and adapt accordingly. If the solution has failed to achieve the desired level of uptake and impact, revisit steps one to three.

Checklist

- Clearly define your target population.
- Decide the most feasible research design to test your solution (e.g., experimental, observational etc.).
- Analyse results.
- Identify shortcomings of your solution.
- Choose aspects of the solution to further iterate and change.

Step 5:
Learn

The final stage considers the implementation of the digital solution, monitoring its performance over time. This includes identifying which key performance indicators (KPIs) will be tracked and how data will be gathered and managed. Regular assessment of KPIs and user feedback ensures necessary updates can be made to respond to evolving contextual needs and challenges.

When you have a co-created and contextualised digital NRM solution, make sure to share your learning. Creating meaningful, shareable insights for others to learn from and apply in different contexts can help create impact beyond your own end users and strengthen NRM efforts elsewhere.

Checklist

- Agree KPIs to monitor the digital solution's contribution to intended outcomes.
- Design data management framework and processes.
- Identify the key learnings from your participatory approach to designing a digital solution for NRM.
- Choose an appropriate channel to share your learnings.
- Disseminate your learnings to strengthen the evidence base and support others creating digital solutions for NRM activities.

In conclusion, the steps outlined offer a structure for creating a digital solution for NRM that incorporates participatory design and puts IP&LCs at the centre of decisions. Although the stages are presented sequentially, they should be approached iteratively, with a focus on continuous testing and refinement based on community feedback to maintain a user-centred approach. Critical components of the framework include engaging all relevant stakeholders, gaining a community perspective on the NRM problem, building trust, and developing locally relevant solutions. By following these steps, organisations can increase the likelihood of impact, efficiency and sustained usage of the digital solution beyond the timeframe of a project's funding.

Appendix:
NRM projects reviewed

Name	Region	NRM activities	Technologies
ABALOBI	Sub-Saharan Africa	Sustainable Fishing Practices	Mobile Handsets and Data Management
Arribada Initiative	Various	Various (Wildlife Tracking, Plastic Waste Monitoring)	Sensors, Thermal Imaging
Baotree	Sub-Saharan Africa	Community Engagement for Participatory NRM	Data Management Software, Mobile Application
Cadasta	Various	Securing Land Rights	GIS Mapping
Ceres Tag	Sub-Saharan Africa	Wildlife Tracking	GPS Tracking
ChimpFace	Various	Anti-Trafficking	Facial Recognition
CLART	South Asia	Soil and Water Conservation	GIS Mapping
ClimDev Africa Special Fund	Sub-Saharan Africa	Crop Protection	Supercomputer
Connected Conservation Foundation	Sub-Saharan Africa	Wildlife Tracking	Sensors, Satellite Imagery, Artificial Intelligence, Drones
Cool Earth	Various	Forest Monitoring	Satellite Imagery
Coorest OÜ + PLCNetwork	Sub-Saharan Africa	Wildlife Tracking	NFTs
Crop Water Budgeting	South Asia	Ground Water Management	Data Management Software
Digital Earth Africa	Sub-Saharan Africa	Grassland Conservation	Satellite Imagery
DSAIL - Dedan Kimathi University of Technology Conservancy	Sub-Saharan Africa	Wildlife Tracking	Sensors
Fauna and Flora International	Southeast Asia	Sustainable Fishing Practices and Anti-Poaching	Drones, GPS Technology
Fin Finder	Southeast Asia	Wildlife Trafficking	Machine Learning, Artificial Intelligence
Forest Atlases	Various	Forest Management	Data Visualisation
Forest Mind (Catapult)	Various	Forest Management	Artificial Intelligence, Sensors
Forest-PLUS 2.0	South Asia	Forest Management	Digital Inventory Management Tools

Name	Region	NRM activities	Technologies
Giraffe Conservation Foundation - Twiga Tracker	Sub-Saharan Africa	Anti-Poaching and Wildlife Conservation	GPS Tracking, Satellite Imagery
Husma Dena Thuru	South Asia	Forest Management	Digital Inventory Management Tool
IFMT (Integrated Forest Management Toolbox)	South Asia	Forest Management	GIS Mapping, Sensors
Innovating for Clean Air (Catapult)	South Asia	Air Pollution Monitoring	Satellite Imagery
Liwonde National Park x Smart Parks	Sub-Saharan Africa	Anti-Poaching	IoT Infrastructure, Sensors, GPS Tracking
Luwire Wildlife Conservancy x Smart Parks	Sub-Saharan Africa	Anti-Poaching	IoT Infrastructure, Sensors
Mara Elephant Project	Sub-Saharan Africa	Anti-Poaching	Sensors, Mobile Devices
Ocean Watch	Various	Ocean Management	Data Visualisation
PIN Early Warning System	Southeast Asia	Building Resilience to Climate Change	Sensors
Rainforest Connection	Southeast Asia	Forest Management	Sensors, Artificial Intelligence
RangerEdge	Sub-Saharan Africa	Anti-Poaching and Wildlife Conservation	GPS Tracking, Handheld Communications Devices
Save Vietnam's Wildlife x Wildlife Drones	Southeast Asia	Wildlife Tracking	Drones
SMART Patrolling - Royal Manas National Park	South Asia, Global	Anti-Poaching	IoT Infrastructure, Sensors
Stellenbosch University - Cape Floristic Region Project	Sub-Saharan Africa	Forest Management	Satellite Imagery
The Satellite-Based Water Monitoring and Flow Forecasting System (SATH-NBA)	Sub-Saharan Africa	Water Resource Management	Satellite Imagery
Using IoT and Machine Learning to Help Protect Kenya's Rivers	Sub-Saharan Africa	Water Catchment Management	IoT Infrastructure, Sensors, Data Visualisation
Virtual Nation Builders/ Black Rock Rhino	Sub-Saharan Africa	Anti-Poaching	NFTs
Water Management System in Brunei	Southeast Asia	Marine Habitat Protection and Restoration	IoT Infrastructure, Sensors

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