Tech4Nature México

Ethical Use of AI Systems for Biodiversity Protection

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Ethical Use of AI systems for Biodiversity Protection: The Case of Tech4Nature Mexico

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EXECUTIVE SUMMARY

The fundamental importance of nature and biodiversity in providing ecosystem services vital to life cannot be underestimated. In this context, the adoption of digital technologies, such as Artificial Intelligence (AI) systems, is presented as a powerful catalyst for making informed decisions for the conservation and understanding of our natural world.

The **Tech4Nature Mexico pilot project**, pioneer in Latin America, serves as an example of this potential. Operating within the Dzilam State Reserve on the Yucatan Peninsula, this initiative combines community-driven methodologies, machine learning techniques, and multi-sector partnerships to strengthen the monitoring, understanding, and protection of biodiversity for informed decision-making.

For this initiative, the responsible and ethical development of advanced technologies was guided by frameworks that proactively mitigate potential social and environmental risks. Collaborative efforts across multiple sectors, a strong commitment to human rights, and the active participation of local communities were essential to achieving this goal.

The Tech4Nature Mexico project achieved important local and international impacts. **Locally**, it has improved understanding of the biodiversity of the Dzilam State Reserve; confirmed the presence of numerous species, and enriched the knowledge of local communities. It has also laid the foundation for secure data sharing between institutions in the region and reduced human threats to wildlife. **On an international level**, the project seeks to contribute to the replicability of AI tools and resources for the protection of biodiversity in Latin America. In addition, it supports the Reserve's inclusion in international standards and is providing recommendations for the ethical use of AI in conservation, facilitating the replication and scalability of conservation efforts throughout the region. Additionally, the project's methodology, successful partnerships, and ethical use of technology have positioned **Tech4Nature Mexico** as an international case study, showing its impact and its compliance with ethical standards.

This report not only presents the methodology and achievements of this initiative, but also the opportunities and strategies to scale and replicate initiatives like these that leverage AI systems for conservation. These include: i) taking advantage of the opportunities offered by cutting-edge technologies for the responsible, inclusive and sustainable protection of biodiversity; ii) identify interested parties and establish a working group dedicated to the development, research and application of emerging technologies for the protection and regeneration of biodiversity; iii) develop and/or strengthen strategies that promote education and the development of technical skills in an inclusive manner, with

the purpose of supporting conservation initiatives through innovation; iv) establish or direct the use of tools and strategies based on emerging technologies to support conservation activities and promote their accelerated adoption; and v) develop a strategy aimed at identifying and mitigating possible adverse effects on the environment caused by the implementation of AI systems in conservation actions.

The partners of this project hope that this report will help other practitioners and people working in the field of biodiversity conservation and regeneration to develop and implement responsible initiatives that harness the power of emerging technologies, multi-sector partnerships and community-centered approaches to carry out more effective and transparent solutions that have the potential to lead the region towards greater resilience and environmental sustainability.

INTRODUCTION

INTRODUCTION

Nature and biodiversity[1], in addition to its intrinsic value[2], play a fundamental role in the provision of ecosystem services essential for life. From regulating the climate and facilitating pollination, ensuring clean water and air, to ensuring food security and air quality, their influence is irrefutable. Its importance transcends the tangible, enriching our lives, as well as our cultural, educational and scientific horizons. Thus, biodiversity conservation emerges as a crucial pillar to ensure the sustainability and well-being of present and future generations.

To address the accelerated loss of biodiversity and the threat of extinction of more than one million species in an unprecedented rate in the last 10 million years[3], it's crucial to accelerate informed, transparent and responsible decision-making. Regions such as Latin America and the Caribbean, which are home to 40% of global biodiversity, 30% of the world's fresh water and nearly half of the planet's tropical forests[4], become priority areas for this purpose.

In this context, digital technologies, particularly Artificial Intelligence (AI) systems, are revealed as tools to transform and streamline effective decision-making for the protection and restoration of biodiversity. These technologies deploy an endless number of possibilities, such as the analysis of large amounts of data to support intelligent management of natural resources[5] or the ability to identify endangered species through the analysis of big data[6] in the form of images and/or audio recordings in an automated manner[7].

Effectively expanding our capabilities in the understanding, monitoring and

[1]Biodiversity is the part of nature that is alive, and includes all living beings on Earth. Nature is all existing systems created at the same time as the Earth, all features, forces and processes, such as climate, sea and mountains. See more:https://www.cbd.int/idb/activities/difference-biodiversity-nature.pdf

[2] The concept of intrinsic value reflects the view that nature has value in its own right, independent of human uses. See more:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5790155/#:~:text=The%20concept%20of%20intrinsic%20value,directly%20or%20indirectly%20benefit%20humans.

[3] This deterioration is manifested in alarming numbers, such as a quarter of mammal species, one in eight bird species, more than 30% of sharks and rays, and 40% of amphibian species, which face risks of disappearance. WWF (2022). Living Planet Report. See more: https://livingplanet.panda.org/es-ES/

[4]Development Bank of Latin America (2020). Ecosystem services and biodiversity in Latin America and the Caribbean. See more: https://scioteca.caf.com/bitstream/handle/123456789/2051/Servicios%20ecosist%C3%A9micos%20y%20biodiversidad%20en%20ALC.pdf?sequence=1&isAllowed=y

[5] United Nations Environment Program (2022). How artificial intelligence is helping tackle environmental challenges. See more: https://www.unep.org/news-and-stories/story/how-artificial-intelligence-helping-tackle-environmental-challenges

[6] Big data refers to data that is so large, fast or complex that it's difficult or impossible to process using traditional methods.

[7] Microsoft (2023). Guacamaya Project: Artificial Intelligence to preserve the Amazon. See more: https://news.microsoft.com/es-xl/proyecto-guacamaya-inteligencia-artificial-para-preservar-la-amazonia/

protection of nature and biodiversity, by fully and responsibly taking advantage of the technological wave, becomes essential to accelerate the fulfillment of global goals such as the Kunming-Montreal Global Biodiversity Framework[8], the Paris Agreement[9] and the Sustainable Development Goals[10]. In addition, **promoting the adoption of emerging technologies according to local needs and contexts, encouraging collaboration between different disciplines and sectors - with a special emphasis on local communities - and ensuring transparent impact measurement strategies to foster investment and financing in this field are fundamental actions towards a sustainable, fair, and effective impact.**

Under this context, the **Tech4Nature Mexico** pilot was forged, a project focused on accelerating monitoring actions to support decision-making for the protection of biodiversity in southern Mexico. By combining the use of AI systems, biodiversity monitoring sensors, multi-sector collaborations and community-focused approaches, this use case stands out as a pioneering initiative in Latin America.

This project, led by C Minds, the Secretariat of Sustainable Development of Yucatán (SDS), the community of the municipalities of Dzilam de Bravo and Dzilam González in Yucatán, the International Union for Conservation of Nature (IUCN) and Huawei, in collaboration with the Polytechnic University of Yucatán (UPY) and Rainforest Connection (RFCx), and with the advice and feedback of expert biologists in feline conservation (more information in Annex 1), combined the knowledge of different institutions and people to create an alliance with environmental and socioeconomic impact, both locally and internationally.

The following report summarizes **the methodology, achievements and learnings of the Tech4Nature Mexico pilot.** Although **it is not intended to be an exhaustive analysis, it provides a guide oriented towards the technical, ethical, social, and environmental aspects, as well as the opportunities for scaling towards the possible replication and expansion of similar initiatives in the region.**

Through this case study, we seek to lay the foundations for the development and implementation of responsible initiatives that, with the power of emerging technologies, have the potential to lead the region towards greater resilience and environmental sustainability.

[8] See more: https://www.cbd.int/doc/c/e6d3/cd1d/daf663719a03902a9b116c34/cop-15-l-25-en.pdf
[9] See more: https://unfccc.int/es/acerca-de-las-ndc/el-acuerdo-de-paris
[10] See more: https://www.undp.org/sustainable-development-goals#:~:text=The%20Sustainable%20Development%20Goals%20

CASE STUDY

TECH4NATURE MEXICO: CASE STUDY

What is Tech4Nature Mexico?

It is a pilot project that, through continuous monitoring of biodiversity, using phototrapping and acoustic monitoring devices, and the use of AI systems, sought to classify and identify priority species, such as the jaguar, that inhabit the Yucatan Peninsula[11], as well as generating a baseline of ecosystem health to strengthen the understanding of the impacts of climate change in the area and the response of species under pressure from external factors to strengthen its protection in the medium and long term. **The main goal was to generate inputs to support and inform transparent and informed decision-making based on data to** drive the conservation and effective regeneration of biodiversity.

Likewise, this project contributed to the generation of capabilities and the preparation of talent in the use of AI systems in the region. Approach that was materialized through the inclusion of the community as main partners and contributors, and the construction of solid multi sector alliances.

With the successful closure of its pilot phase by the end of 2023, Tech4Nature Mexico will take the next step towards expanding its impacts. This project has demonstrated that the combination of efforts and innovative approaches can lay the foundation for the effective conservation and management of biodiversity in a changing environment.

Discover more about our initiative in the documentary Tech4Nature Mexico

Box 1. Dzilam State Reserve in Yucatán

The **Dzilam State Reserve**, in Yucatan, is an area recognized internationally under RAMSAR designations[12] and AICA[13].

This coastal reserve has a large expanse of lowland jungle, mangroves and coastal ecosystems, and is home to key species for conservation.

In addition, it is an integral part of the Mesoamerican Biological Corridor.[14]

[11] Yucatán is the first region in Latin America to be part of the global Tech4Nature project. See more: http://tech4nature.iucngreenlist.org/

[12] Sites of international importance for the conservation and sustainable use of wetlands inhabited by migratory waterfowl.
[13] Important Area for the Conservation of Birds.
[14] Mesoamerican Biological Corridor Project – Mexico. See more: https://www.biodiversidad.gob.mx/region/cbmm

Specific objectives

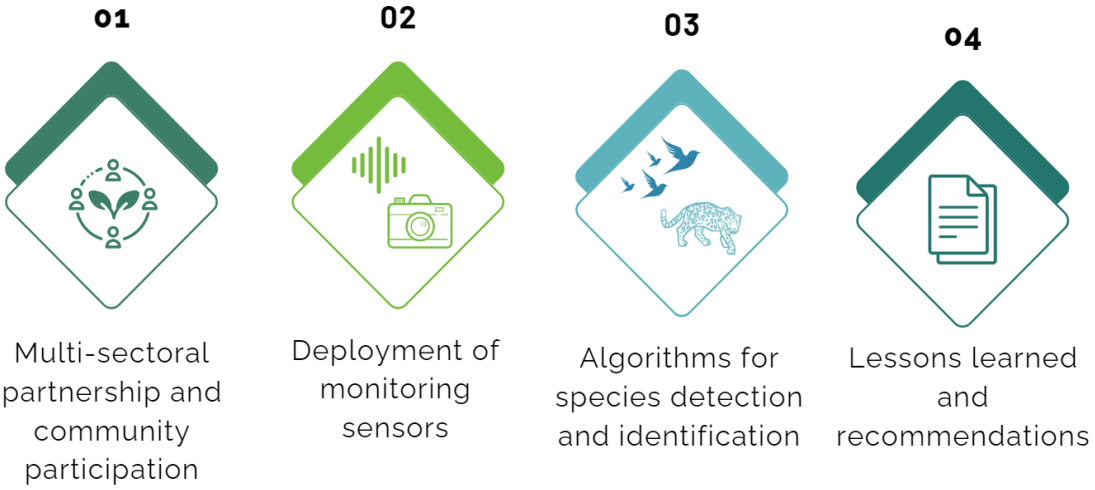
The pilot phase of the Tech4Nature project sought to achieve the following specific objectives:

- Provide sufficient, reliable and timely data to improve the understanding **of the ecosystem and contribute to the generation of information** on other globally threatened species.
- Develop algorithms for the detection and identification of jaguars and other species of interest, taking advantage of artificial intelligence systems to **support decision making and strengthen institutional preparedness** in the use of these technologies.
- Create value for the reserve by achieving conservation success based on the **IUCN Green List** conservation standard. **and transfer knowledge to local communities** for the adoption of technologies.
- Offer a platform **to catalyze collective action** for conservation through the use of AI systems.

Methodology

The pilot follows a comprehensive approach:

Which translates into the following components:



Multi-sector alliance

This project combined the knowledge of different institutions and individuals from the public, private, academic, and social sectors, to create an alliance with environmental and socioeconomic impact, both at the local and international level (Annex 1).

The participation of local leaders was essential from the beginning of the project, as well as its strategic direction. Their ideas and needs were actively incorporated into the project's life cycle.

Deployment of monitoring sensors (phototrapping and eco-acoustic monitoring)

The local team strategically placed camera traps and eco-acoustic monitoring devices (more information in Annex 3) in mangrove and lowland forest habitats with a high probability of detecting wildlife. This deployment effectively captured the biodiversity of the region and generated valuable data for further analysis.

Development and responsible use of algorithms for the detection and identification of species

a. Image recognition models and AI:

The image recognition component, based on Convolutional Neural Networks (CNN)[15], played a fundamental role in the analysis of images captured by the cameras, to advance the automatic detection and identification of individual jaguars, in order to improve the understanding of local populations. For this, machine learning models[16] that can identify jaguars from images captured in the jungle and other places, were developed.

The creation of these models gave rise to the creation of the Bio-Scanner platform, with Huawei cloud-based architecture (Box 2), that seeks to catalyze collective action by providing useful and accurate tools for monitoring jaguars in Mexico and on the continent.

The objectives of this component were:

1. Automatically detect the presence of jaguars in camera trap captured-images , which speeds **up data processing and allows the application of automated approaches in individual processing.**
2. Automatically identify individual jaguars in the region, which improves **the knowledge of local populations.** This approach is of vital importance in conservation as it leverages advanced methods that enable faster and more detailed analysis, taking advantage of object detection, image classification and individual detection methods.

b. Acoustic pattern matching models and AI:

We also conducted passive acoustic monitoring, where recorders are put up and record all sounds in the environment. To analyze the sound data, we used a machine learning pipeline that involved generating training data through Arbimon's Pattern Matching[17] tool and

[15] Convolutional neural networks can have dozens or hundreds of layers, each of which learns to detect different features of an image or sound. See more:https://www.ibm.com/mx-es/topics/convolutional-neural-networks

[16] Machine learning is a form of AI that allows a system to learn from data rather than learning through explicit programming. See more:https://www.ibm.com/mx-es/analytics/machine-learning

[17] Pattern matching (also known as template matching) is an automated sound detection algorithm that uses a single example of a target signal (i.e., the template) to search a larger set of

developing a CNN for species across the region. The CNN will facilitate continuous monitoring of the area, as new data can be run through the model to automate species detection and classification. We also conducted soundscape analyses to holistically compare the acoustic activity across sites and assess how environmental variables influence soundscapes.

These models were used to automatically identify 95 species of conservation interest, with 60 of them integrated into the CNN.

This component achieved the following objectives:

1. **Automatically identify species of conservation interest**, through the generation of pattern matching models, which will allow the model to be used over time to compare impacts in the area, based on behavioral pattern changes.
2. Analyze the soundscape to compare **the presence of species with the diversity of sounds in the environment.**

The data obtained allowed the creation of the project dashboard in Arbimon for collective visualization and analysis, in order to compare the soundscape in the long impact.

recordings for similar signals based on a similarity score.

Generation of inputs for decision making, as well as AI solutions for conservation

In this report, the project translates its learning into opportunities and recommendations to promote innovation, as well as to inform actions to accelerate the responsible use of technologies and the digital transformation, strengthen multi sector alliances and integrate local communities in the protection of biodiversity.

Box 2. Most important digital tools used to train the image recognition model

Huawei cloud[18] was used for the following activities: The dataset generated by the project was securely stored in Huawei's Object Storage Service (OBS) , a diverse collection of images.

In the modeling phase, the team took advantage of Huawei's ExeML, an automated modeling tool for image classification available through Huawei's cloud platform. Thus, Huawei cloud services played a fundamental role in optimizing these key stages of the project.

[18] See more: https://www.huaweicloud.com/intl/es-us/

AI systems

Technological components are a fundamental pillar in the ecosystem of **Tech4Nature Mexico.** During the pilot phase, two main categories of solutions were used:
i) monitoring devices
ii) AI systems

The responsible use of passive biodiversity monitoring devices and AI systems represents a significant advance in how we manage and leverage data to accelerate conservation actions, research and decision-making processes.

Effective measures to protect biodiversity require a solid database and long-term monitoring, which traditionally involve manual methods limited by resources and time. Some of the many benefits of leveraging AI systems are, for example; the optimization **of the entire data lifecycle**[19], greater **transparency in decision-making processes**[20], the potential to expand **and scale the use** of these technologies for solutions that can be adapted and applied to a broader **range of ecosystems and regions, maximizing impact,** among many others. Likewise, the potential to analyze the large amount of data generated by monitoring devices in a short window of time can support active and relevant evidence-based decision making, helping to prioritize conservation and restoration actions more effectively. Likewise, an application of AI systems that is gaining momentum[21] is its use for monitoring changes in biodiversity patterns and detecting their causes.

In the last decade, advances in the field of deep learning[22] and CNNs have transformed the approach to recognize and analyze patterns from complex data such as images and sounds. These techniques have demonstrated an outstanding **ability to extract essential and subtle characteristics from this type of information, allowing unprecedented precision in species identification from distinctive patterns** (such as songs or calls in sounds, and facial or pattern recognition such as spots in images). As was seen in the experience of this project, this allows for a much **deeper approach to individual behavior within wildlife populations, to strengthen data-based conservation actions.**

This multidimensional approach not only enriches biological research and biodiversity conservation, but also provides exciting perspectives for measuring, understanding and protecting our natural environment.

[19]From data collection in the field to subsequent processing and analysis which means faster access to critical information, a reduction in manual work and fewer errors, ultimately saving both time and resources.
[20]Stakeholders can access and view the data that feeds the systems, promoting accountability and trust among partners and communities involved in conservation efforts.

[21]GPAI (2022). Biodiversity & Artificial Intelligence, Opportunities and Recommendations, See more: https://gpai.ai/projects/responsible-ai/environment/biodiversity-and-AI-opportunities-recommendations-for-action.pdf
[22] Deep learning is a machine learning technique that teaches computers to do what comes naturally to humans: learn by example. See more: https://www.mathworks.com/discovery/deep-learning.html#:~:text=Deep%20learning%20is%20a%20machine,a%20pedestrian%20from%20a%20lamppost.

The **Tech4Nature Mexico** project harnesses these models to analyze two types of voluminous data: images and videos from camera traps, as well as audio recordings from eco-acoustic monitoring sensors.

Development and ethical use of AI systems for the protection of biodiversity

The implementation of projects that use AI systems for environmental and social purposes must be guided by ethical principles and the protection of Human Rights. The responsible application of AI systems in conservation is essential to avoid potential social inequalities and environmental damage. As cloud and AI infrastructure advance, the need to prevent bias and misuse of data in these systems becomes evident.

It's essential to adopt **approaches that promote multi-sector partnerships, and the perspectives of local communities and end users.** Collaboration between different sectors, such as academia, industry, civil society, and government institutions and communities, is essential to comprehensively address the challenges and possible risks associated with the use of these technologies and the social implications.

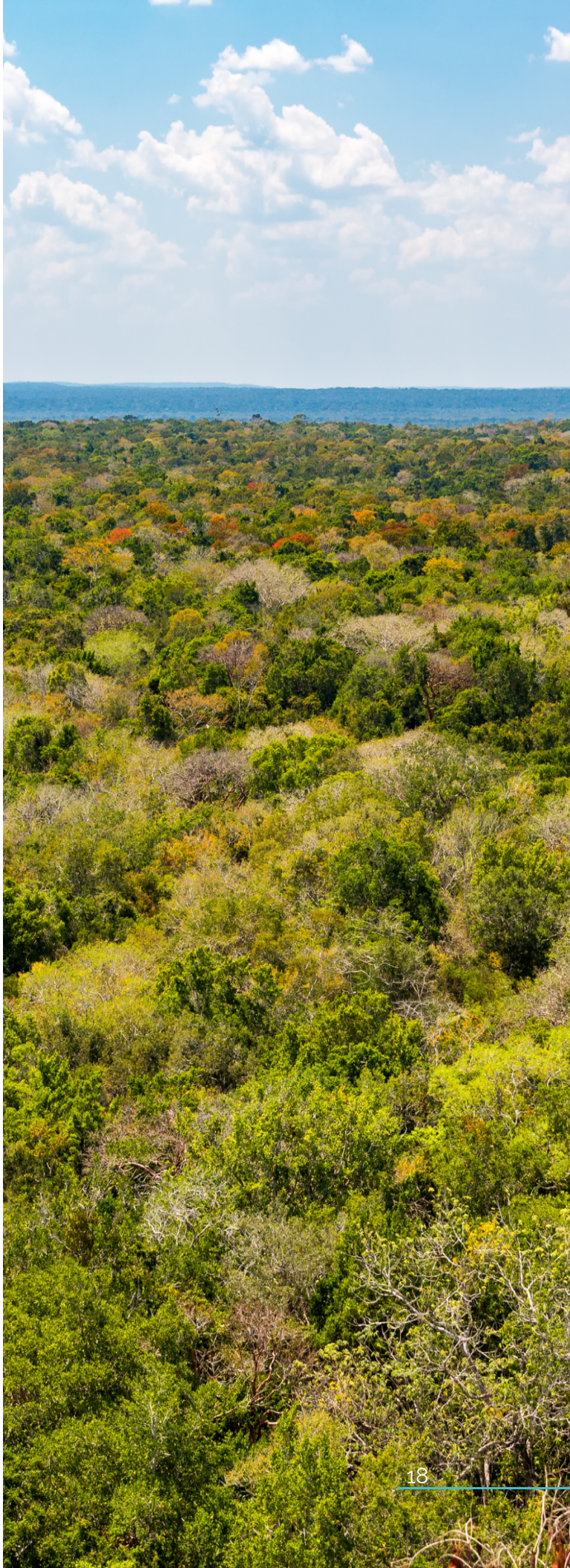
To guide the deployment and ethical adoption of the AI systems developed in this case study, various international guidelines were taken into account, with special emphasis on the global instrument: "Recommendation on the Ethics of Artificial Intelligence" of UNESCO.[23], adopted by 193 UN member countries[24]. This was one of the first instruments to include a chapter dedicated to the ethical use of AI systems for biodiversity. At the same time, the project followed several guides created by the C Minds AI for Good Lab[25] among other global frameworks and standards such as the IUCN Green List.

[23] United Nations Educational, Scientific and Cultural Organization (UNESCO)
[24] United Nations Organization (UN)
[25] https://www.cminds.co/ai-for-good-lab

The coordinators of **Tech4Nature Mexico** took a special interest in following the **AI ethics best practices to understand**, from own experience, **how they become operational and integrated into biodiversity conservation projects in a pragmatic way**, with an emphasis on:

- Evaluation of the environmental impacts of the technologies used.
- Inclusion of gender perspectives, youth and local communities.
- The use of AI systems as a complement to local environmental management strategies.
- Transparency and explainability of the technologies used.
- Responsible data governance.
- Responsible development of algorithms.

Details can be found in Annex 1.



THE IMPACT OF TECH4NATURE MEXICO

The achievements obtained within the framework of **Tech4Nature Mexico** have improved the holistic understanding of the Dzilam State Reserve and its biodiversity in unprecedented ways, redefining conservation and community engagement in the area.

Some of the most notable results of the project are:

- Automatic confirmation of the presence of 146 species, of which 40 of them are under some risk category[26], from **80,000 images and videos**, and more than **600,000 acoustic files** collected.
- Creation of **pioneering algorithms** for the region:
    - Creation of the first CNN for image recognition for the **detection and identification of jaguar individuals in the region open to the public**[27].
    - Creation of the **first audio classification CNN for the region** (60 species).
- Publication of **two dashboards**[28] to catalyze collective action through visualization and data analysis (image and sound).
- **Advancement of the state of the art** for automatic identification of individuals and wildlife monitoring.
- Launching of the **capacity building program pilot** for the management of innovative conservation projects imparted to the Dzilam community.

Local impact

These results not only enrich our understanding of the Reserve's biodiversity, but have also become essential tools for decision-making in the region. The most notable local impacts were:

- **Species identification in a way never before verified.** The development and application of pioneering algorithms for species detection and identification provides a solid foundation to guide conservation efforts and smake data-driven decisions.
- **Generation of mechanisms to reinforce local involvement.** The pilot promoted a deep connection with local communities, who acquired valuable knowledge about the biodiversity of their environment. An incredible example is Juan Castillo's growing leadership in the region (Box 3).
- **Facilitation of mechanisms for secure and transparent data**

[26] According to the IUCN Red List of Threatened Species (https://www.iucnredlist.org/) and NOM-059-SEMARNAT-2010 (https://www.dof.gob.mx/normasOficiales/4254/semarnat/semarnat.htm)
[27] See more:https://github.com/aiforclimate/tech4naturemexico
[28] Image Analysis Dashboard: http://www.bio-scanner.com/ and audio analysis dashboard: https://bio.rfcx.org/tech4nature-mexico

sharing in the region. The development of jaguar detection and identification models was advised and tested by local feline conservation experts. This collaboration allows to lay the foundations for the development of initiatives aimed at protecting and creating biological corridors for the distribution of the jaguar.

- **Reduction of human threats in the area.** According to testimonies from the local community, the **Tech4Nature Mexico** project played a fundamental role in mitigating human threats to the Reserve's wildlife, such as illegal hunting.

- **Local training in the use of these technologies for the protection of nature.** Through comprehensive training initiatives, the project sought to ensure that both the local partners and the local community receive the necessary training to take advantage of frontier technologies for the protection of nature, with initiatives such as the capacity-building workshop "Managing conservation projects with innovation." , taught to the Dzilam community[29].

[29] See more: https://www.cminds.co/post/local-leadership-in-dzilam-de-bravo-environmental-monitoring-for-conservation

Box 3. The heart of the Reserve: Juan Castillo and his commitment to biodiversity

Juan Castillo, current community leader within the Tech4Nature Mexico initiative, has emerged as an international conservation champion, acclaimed for his tireless dedication to this noble cause. His history dates back to before Dzilam State Reserve gained protected natural area designation in January 1989.

He grew up in a family that prospered thanks to hunting, agriculture, and livestock in the Reserve. Juan, like his family, once shared the belief that it was essential to defend livestock from jaguars that invaded his ranch, even if it meant killing the big cats.

It is estimated that the expansion of agriculture into the reserve has caused the displacement of large mammal species, possibly one of the main factors behind the decline in jaguar populations.

As the years went by, Juan came to a deep understanding: he and his family were the ones who invaded the jaguar's natural habitat. He took a bold step by removing his cattle from the reserve and settling in Dzilam González.

Today, as a grandfather, he passes on his love of nature to his grandchildren, instilling in them the understanding that these species have more value alive than dead and that they are crucial to the survival of the forest, its countless inhabitants and, ultimately, to the people.

With his iconic phrase “the day I die I would like to be a jaguar”, Juan Castillo expresses his philosophy and commitment to these big cats. Today, Juan remains steadfast in his decision to donate his land for conservation purposes, even though it is located within the reserve and is legally his property. Together with his friend, Benjamín, they have become distinguished guides, explorers and passionate defenders of the conservation of the jaguar, its prey, the tropical forest and the mangroves. They diligently care for the camera traps and acoustic monitoring devices, ensuring the safety of everyone within the Tech4Nature Mexico project.

International impact

Also, the project's impact extends to international efforts through the identification and documentation of good practices and positioning as a case study of inclusive and innovative methodologies. The most notable impacts with international reach were:

- **The information generated is supporting the process of including the Reserve in the IUCN Green List of Protected and Conserved Areas.**The information generated supports the inclusion of the Reserve in international standards. Data and analysis ensure that conservation strategies are based on concrete evidence.
- **Inputs for the replicability of AI tools and resources for the protection of biodiversity for Latin America were generated.** What was learned at each step and with each partner contributed to strengthening AI tools and methodologies for the protection of biodiversity. Digital resources are now available on the following platforms: Arbimon AI and Bio-scanner
- **Creation of recommendations for good practices in the ethical use of AI for conservation.** This report also provides practical recommendations for the ethical use of artificial intelligence in conservation.
- **Pilot positioning as an international case study.** Furthermore, the methodology, the successful creation of strategic alliances and the ethical use of new technologies have positioned **Tech4Nature Mexico** as a case study at an international level (Box 4). This demonstrates its global impact and its adherence to international ethical standards.

Box 4. Tech4Nature Mexico in high-impact international spaces

- The Global AI Summit (2022)
- The Wired Summit (2022)
- Huawei Cloud Summit (2022)
- The InventIA Forum (2022)
- The Smart Cities Summit (2022)
- COP 15 (2022)
- Green In-Sites (2023)
- Smarter Biodiversity Conservation (2023)
- IUCN Forum Leaders (2023)

OPPORTUNITIES

OPPORTUNITIES FOR TECHNOLOGY-BASED CONSERVATION

Based on the results obtained in the pilot phase of **Tech4Nature Mexico** and, given the relevance of implementing projects of this nature in Latin America, a **series of opportunities and recommendations intended to guide the scalability process is presented.** These opportunities are accompanied by specific lines of action for each case. It should be noted that this approach is based on solid ethical principles, placing emphasis on people and respect for human rights, promoting a connected ecosystem that accelerates effective and transparent conservation actions through the development and use of emerging technologies.

It is crucial to highlight that digital technologies are neither a universal solution nor a panacea to address biodiversity loss. Although they undoubtedly represent essential and transformative tools to carry out these actions, it is necessary that their application be in line with ethical principles and that they be used only when it is demonstrated that they are the most suitable option.

Below are the opportunities identified with their respective lines of action:

1. Taking advantage of the opportunities offered by cutting-edge technologies for the responsible, inclusive, and sustainable protection of biodiversity.

The following lines of action advocate for the responsible use of technology in biodiversity conservation with an emphasis on inclusion, collaboration with government agencies, data protection and the creation of a data exchange platform:

1.1. Guide the responsible use of these technologies, taking into account the needs for the protection and regeneration of biodiversity in different local contexts, as well as their technical, economic, social, and institutional viability.

1.2. Develop implementation and adoption strategies that are inclusive and equitable, reflecting the particularities and needs of local communities, including indigenous populations.

1.3. Guide decision-making and public policies related to technology in a way that benefits both people and the ecosystems and species that inhabit them.

1.4. Collaborate closely with various levels of government, especially with entities in charge of the environment and sustainable development, to strengthen technological exploitation strategies, improve digital and technological skills in an inclusive manner, and establish effective data exchange mechanisms between institutions, among other aspects.

1.5. Provide tools, training and resources to biodiversity conservation projects that have the potential to take advantage of new technologies to expand their impact.

1.6. Promote cybersecurity strategies that guarantee responsible data protection, including the protection of sensitive data such as the geolocation of species at risk due to illegal hunting, with the aim of preventing adverse damage, and reducing hunting and trafficking of these species.

1.7. Create an open dashboard, visualization platform or data lake[30] with an effective governance protocol for catalyzing collective action for the protection and regeneration of biodiversity so that different sectors can contribute their knowledge and data; as well as developing APIs[31] for effective data consumption by interest groups. This in order to encourage the processing of big data, real-time analysis and machine learning for decision making and the generation of new knowledge[32].

1.8. More broadly identify the critical needs of ecosystems and vulnerable populations, where the use of digital technologies has great potential to address environmental challenges and generate market opportunities.

1.9. Promote a people-centered vision that prioritizes well-being, the efficient use of resources, and the implementation of circular processes and regenerative actions.

[30] A data lake is a centralized repository that allows you to store all structured and unstructured data at any scale. See more:https://aws.amazon.com/big-data/datalakes-and-analytics/what-is-a-data-lake/

[31] APIs: Mechanisms that allow two software components to communicate with each other through a set of definitions and protocols. See more: https://aws.amazon.com/es/what-is/api/

[32] Document and give visibility to applied case studies where data was used with clear explanations of the learning and its impact to encourage the use of data for the protection of biodiversity and make the benefits tangible.

2. Identifying interested parties and establishing a working group dedicated to the development, research, and application of emerging technologies for the protection and regeneration of biodiversity.

This area of opportunity recommends creating a diverse coalition involving government, the private sector, academia, and other actors to share knowledge and improve biodiversity conservation policies, as well as to monitor technology performance, identify impacts, and develop an approved roadmap for efficient implementation:

2.1. Form a working group, coalition or multi-sector strategic alliance that includes representatives of the government, private, academic, social, community, media and other relevant institutions. This group must promote the exchange of knowledge, the horizontal transfer of best practices and the strengthening of public policies to guarantee sustainable impacts and promote the diversification of the profiles involved in the projects.

2.2. Monitor and evaluate the performance of technologies used for biodiversity conservation through various tools such as data analysis, surveys, evaluations and simulation models. These activities will help identify potential environmental and social impacts, both positive and negative.

2.3. Develop a roadmap and an established methodology that has the approval of all partners involved, in order to expedite the implementation of cutting-edge technologies. This process must take into account the individual contributions and capabilities of the members of the multi-sector working group.

3. Developing and/or strengthening strategies that promote education and the development of technical skills in an inclusive manner, with the purpose of supporting conservation initiatives through innovation.

The following paragraphs highlight the importance of promoting inclusive education and the development of skills for conservation through innovation, as well as collaborating with indigenous communities; training public officials in digital technologies and improving digital literacy for public participation. Likewise, it highlights the importance of training academics in fields related to technology, and promote practices in projects focused on biodiversity:

3.1. Develop and/or strengthen strategies that promote

education and the development of technical skills in an inclusive manner, with the purpose of supporting conservation initiatives through innovation.

3.2. Collaborate closely with indigenous communities and vulnerable populations affected by the technology-based projects, in order to understand and address their specific needs. It is essential to respect the worldview and self-management capacity of these communities, while providing support to strengthen their knowledge and skills, allowing the diversification of their sources of income.

3.3. Establish a specialized training program aimed at public officials, with a focus on better understanding the potential of leveraging emerging digital technologies from the public sector for conservation initiatives[33].

3.4. Develop educational programs focused on strengthening digital language learning[34], as well as the possible benefits derived from the use of digital technologies, and increasing the participation of the population in public policies and decision-making processes. This will contribute to promoting inclusive strategies and achieving an equitable distribution of costs and benefits.

3.5. Prepare and provide training to academics with skills in technological fields, such as information and communication technologies (ICT), data science, data engineering, embedded systems engineering, among others, who have the necessary potential to contribute to the development of projects aimed at the conservation of nature and biodiversity.

3.6. Encourage participation in professional internship programs in technology companies, both national and international, as well as projects from multiple sectors, government entities and other institutions with a focus on climate action.

[33] Review tool for "Responsible use of AI for public policy: project formulation manual" https://publications.iadb.org/publications/spanish/viewer/Uso-responsable-de-IA-para-politica-publica-manual-de-formulacion-de-proyectos.pdf

[34] Through prioritizing programs for young people that strengthen skills in emerging digital technologies.

4. Establishing or directing the use of tools and strategies based on emerging technologies to support conservation activities and promote their accelerated adoption.

The following action lines recommend boosting the capacity of companies to adopt technology, promote conservation projects with emerging technologies and create inclusive platforms for public participation in policy development and transparency in all sectors:

4.1. Strengthen the institutional capacity of companies to address existing market opportunities, intensify research and development, increase investment and accelerate the adoption of digital technologies in a timely and responsible manner.

4.2. Strengthen the impact mitigation capacity of companies, their stakeholders and their value chains, taking advantage of emerging technologies to implement transparent, effective, replicable and scalable conservation projects. An example of this is the use of the Huawei Cloud for processing data related to species detection and identification.

4.3. Facilitate the creation of collaborative and decentralized spaces that bring all people closer to open access resources, including information, training and tools related to the latest technologies. These spaces will encourage participation in the formulation of public policies, the monitoring of initiatives and the promotion of transparency in the actions of all sectors, in addition to promoting the creation of projects that contribute to conservation.

5. Developing a strategy aimed at identifying and mitigating possible adverse effects on the environment caused by the implementation of AI systems in conservation actions.

The following lines of action focus on developing impact assessments before implementing new technologies for conservation, regulating waste management, transitioning to clean energy for AI, and avoiding biases in the ecological impact of AI:

5.1. Establish impact evaluation procedures before the implementation of new technologies aimed at protecting biodiversity.

5.2. Institute mechanisms that regulate the management of the impacts and waste generated by the use of these technologies throughout their life cycle, and implement programs aimed at the proper

management and disposal of electronic waste, such as camera traps or audiomoths that are no longer functional due to sun exposure or heavy rain events.

5.3. Develop guidelines and offer incentives to promote the transition towards the use of clean, renewable energy sources that are capable of meeting the high energy demand associated with the use of AI systems. In addition, design strategies to offset the carbon footprint, for example, through the generation of carbon or biodiversity credits.

5.4. Formulate impact measurement strategies with the purpose of guaranteeing that AI systems do not reproduce or amplify existing prejudices or negative interpretations in relation to species and ecosystems, thus avoiding any damage to the ecological balance.

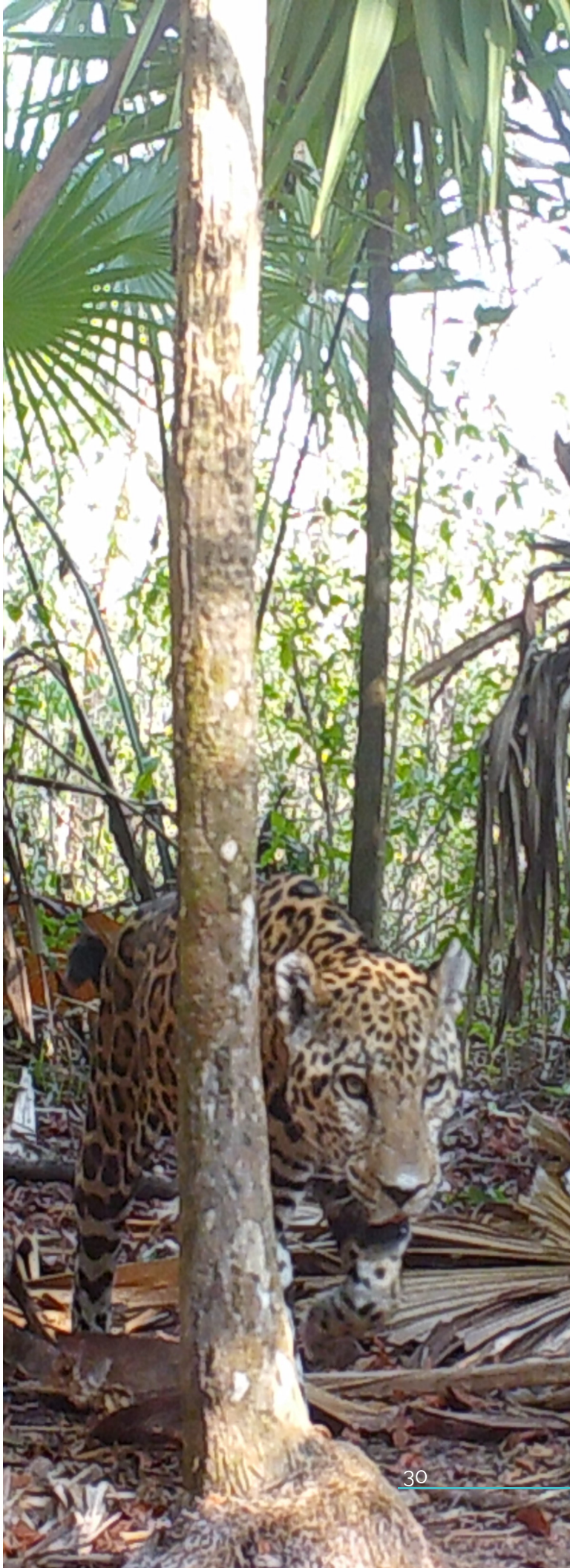
CHALLENGES AND MITIGATION STRATEGIES

Carrying out a project that develops and leverages AI systems to inform decision-making focused on the protection of biodiversity is a notable achievement that deserves recognition of the experience and dedication of all the stakeholders involved.

Likewise, the development of AI systems in lower-middle-income countries has historically been less prominent compared to the global north, a consequence of inequalities in terms of resources, investment in research, access to data and education, and more, so this endeavor has also faced challenges and risks.

Some of the challenges faced during the pilot included limited data availability; difficulties in pattern recognition due to the natural camouflage of the species; longer than expected data collection and labeling times, and the need for a substantial amount of training data, especially for difficult-to-detect species.

In order to share the lessons learned, the project committed to identifying and sharing areas of improvement, which become opportunities for future iterations with greater success and impact (More information in Annex 2).



CONCLUSION

The conservation and restoration of nature and biodiversity has become a fundamental pillar to guarantee the sustainability and well-being of current and future generations, and the use of digital technologies to achieve this objective has the potential to reinforce actions and produce clearer, more transparent, effective, reliable and even faster results.

The use of these systems emerges as one of the fundamental tools that can support the achievement of goals to protect 30% of all terrestrial, marine, coastal and continental ecosystems, as well as to restore damaged ecosystems by 2030 and achieve net zero emissions in 2050. To achieve this, it will be necessary to strengthen collective action mechanisms and renew commitments to use all available tools that will allow the established international objectives to be achieved.

The transformative potential of digital technologies, especially AI systems, to boost the protection and understanding of nature, is highlighted in pilot projects such as **Tech4Nature Mexico**, an example of how multi-sector collaboration, people-centered approaches and ethical implementation of AI systems can accelerate effective biodiversity conservation in a key region like Latin America.

However, at a time when biodiversity loss is accelerating at an alarming rate, it is necessary to act responsibly and transparently. As Latin America and the Caribbean is home to a significant portion of global biodiversity, the responsible use of frontier technologies such as Artificial Intelligence can make a difference in the success of conserving these invaluable natural resources before it is too late.

There is a call to forceful action. The global community, including governments, industry, academia and civil society, must come together to fully harness the potential of technology, including AI systems, in biodiversity conservation. This advancement must be rooted in ethics and human rights, involving local communities, promoting the inclusion of diverse perspectives, ensuring transparency and explainability, and with responsible data governance.

ANNEX

Annex 1. Ethical considerations

The ethical considerations and learnings of this project during its pilot phase are highlighted below, with the purpose of promoting the exchange of knowledge and best practices in the responsible use of AI in conservation, based on UNESCO's Recommendation on AI Ethics:

1. **Evaluation of the environmental impacts of the technologies used**

The development of AI system models often depends on expensive computing processes, which are carried out in data centers that generate CO2 emissions[35]. Using the the ML CO2 Impact[36] tool, it is estimated that the **Tech4Nature Mexico** opportunity, which leverages the Tesla V10-SXM2-32GB processor for approximately 200 hours in Huawei Cloud, has produced around **33.6 kg** of CO_2[37].

These emissions will be mitigated during the following phases of the project. Likewise, the use of AI systems provide quantifiable **evidence of positive environmental impact**, which will greatly enable the potential issuance of carbon and/or biodiversity credits by offering data-based information on conservation efforts.

2. **Inclusion of gender perspectives, youth and local communities**

Historically, the field of AI systems development has excluded many perspectives, including those of women and indigenous communities. This exclusion promotes algorithms to lack diverse contexts and perspectives, producing systematic biases that create potentially inaccurate and dangerous results. Furthermore, projects that are not designed in an inclusive manner can generate an asymmetric knowledge production cycle, in which the communities where the projects are implemented are used as sites for primarily extractive research.

To address these challenges, the **Tech4Nature Mexico** pilot has implemented the following strategies:

- **Inclusion of local communities and indigenous perspectives:** Local leaders were involved from the design stage, giving them responsibility for the characterization and selection of sampling and monitoring sites, sensor deployment, data visualization and communication of results. Their needs and ideas were integrated throughout the project life cycle.
- **Integration of the gender perspective:** 30% of the total team is made up of women, and in the management team, 53% are

[35] Emissions are estimated to range from 25 to 500 metric tons of CO_2 during the training stage, comparable to the emissions of 5 cars during their entire useful life, according to data published in MIT Technology Review:https://www.technologyreview.com/2019/06/06/239031/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/
[36] https://mlco2.github.io/impact/
[37] Equivalent to driving 135 km in an average internal combustion car.

women. However, the main challenge lies in ensuring equitable representation of women in the local community, which is currently non-existent, and in the field of technical development of technologies and algorithmic models, where only 13% are women.

3. Using AI systems as a complement to local environmental management strategies

It is important to recognize that decision making based on AI systems operates on empirical logic. By relying excessively or uncritically on the knowledge generated by AI systems, we could put local, indigenous and non-empirical knowledge at risk. This knowledge, intrinsically valuable and adapted to specific contexts, deserves our respect and protection. Here lies the importance of involving all relevant stakeholders in the decision-making processes, and forming new skills and capabilities that remain installed in the community.

In this way, C Minds, in collaboration with the Secretariat of Sustainable Development, developed and taught a pilot course on conservation project management with technological innovation in the community of Dzilam de Bravo. The program aimed to encourage the development of technical skills, encourage collaboration and promote a united and committed community, with the participation of important allies of C Minds such as UNESCO that provided knowledge about good practices for the ethical use of AI to this type of projects.

4. Transparency and explainability of the technologies used

Transparency and explainability in a project that uses AI systems refers to the ability to understand and communicate in a clear and comprehensible way how the AI models and algorithms work, as well as the processes and decisions they generate. These concepts are crucial to ensuring trust, accountability, and informed decision-making in AI applications.

To ensure that the models are transparent and open to the public, and to encourage responsible iteration and expert feedback from the scientific community, the image recognition component models are hosted in an open GitHub repository.[38] under the Apache 2.0 license, which allows users to use, modify and distribute the codes freely. Likewise, to ensure the explainability of the image analysis platform, it is accompanied by documentation[39] for users with definitions of all the terms, and a detailed explanation of how the models work.

In the case of acoustic models, Rainforest Connection's Arbimon platform has extensive documentation in the form of a glossary of terms and explanation of the generalized pattern matching model.[40]. The results of the **Tech4Nature Mexico**

[38] https://github.com/aiforclimate/tech4naturemexico

[39] https://www.forclimate.ai/_files/ugd/de03fd_5efabdae33ac425088f27b4dcdab23bb.pdf

[40] https://support.rfcx.org/article/93-acoustic-monitoring-terminology

project are available to the public, with special emphasis on the scientific, conservation, and decision-making community.

5. Responsible governance of collected data

Data governance refers to the mechanisms and processes that control how an organization's data is used, managed, accessed, processed, and stored. That is, the way in which an organization's data is managed and administered; with the main objective that the data retains its integrity (including consistency and reliability) and that it is used appropriately. Unlike data obtained by a company to provide or operate a service, data collected and/or provided through government agencies is considered public in nature (in this case, project data is obtained within a reserve of governmental nature). This data is usually difficult to govern as it does not have a unique or clearly identifiable owner and, in some cases, because it is covetable in nature by third parties who seek to speculate with it. Consequently, appropriate mechanisms were implemented within the institutions to achieve multi sector collaborations that comply not only with data protection regulations, but also with ethical and responsible use.

With this purpose in mind, the **Tech4Nature Mexico** project adopted various measures:

- **Collaboration and confidentiality agreements** focused on opening the models to the public were forged..
- Recognizing the sensitivity of certain data, such as the location of monitoring devices and the geolocation of detected jaguars, this information is managed exclusively by the government, C Minds and the local community.
- The data resides on the Huawei Cloud platform, with access restricted to project partners, thus ensuring the data **protection and privacy**.

5. Responsible development of algorithms

Developers must take responsibility for the decisions and consequences generated by the algorithms they create. This involves identifying and addressing potential risks and ethical issues.

For an entire school year, a group of 8 young UPY data engineering students dedicated themselves to the development of image recognition models. Given the possibility that the models presented biases in the recognition of jaguars due to the students' lack of experience in monitoring this species, the group received training and feedback from a biologist specialized in feline conservation in Yucatan. This approach sought to mitigate any potential bias in identification.

Annex 2. Details of the challenges faced and mitigation strategies

Below is a detailed analysis of the challenges faced, mainly during the execution of the technical components of data analysis through the use of AI systems, along with the strategies taken for their mitigation:

1. Data availability for training

A considerable challenge in developing automatic models for detecting and identifying jaguars in images was faced. This task is complicated by the scarcity of available data.

One of the ways to mitigate this challenge was the successful generation of a highly valuable alliance for responsible data exchange mechanism with Pronatura Peninsula de Yucatan A.C, to access databases with previously identified jaguars, which made it possible to test the effectiveness of the developed algorithms and guarantee more accurate and reliable results.

2. Pattern recognition in complex systems

One of the factors that complicates the task of pattern recognition in images that contain relevant species is the natural camouflage that animals have developed throughout evolution to survive in their environment. This natural camouflage ability demands that models be extremely sensitive to subtle details and specific features, posing an additional challenge to ensuring the accuracy of the predictions in this unique context.

To address this complexity, background was removed from the images, allowing only the pixels belonging to the animal of interest to be isolated; the jaguar, in this case, for which the Segment Anything model (SAM) was used.[41].

3. Data collection and labeling time was longer than expected

The collection and labeling of data for training the algorithm took more time than initially planned in the project, due to various factors such as the characteristics of the terrain for the implementation of sensors and the availability of personnel for image classification, among other challenges.

To mitigate this risk in future projects, it is recommended to ensure the availability of data sufficiently in advance before starting the training of the models, based on a risk and ethics analysis of AI systems.

4. Need to have a large amount of training data.

The lack of sufficient sonic training data for some rare species posed a challenge. CNNs tend to require large training

[41] The Segment Anything model (SAM) is an innovative and powerful Artificial Intelligence tool capable of segmenting any object present in an image or video. The highlight of SAM is its ability to accept various input cues, such as landmarks or bounding boxes, to specify which objects should be segmented. In this context, bounding boxes were used as input cues to generate segmentation masks through the SAM model.

datasets to perform well, and compiling these training data can be challenging. However, new AI techniques such as few-shot learning and unsupervised clustering present opportunities for overcoming this challenge. As a result, the detectability of these species may be less reliable and effective compared to more common ones, compromising project objectives and diverting attention to species that are not of primary interest for decision making.

To address this situation, multiple iterations of both acoustic and phototrapping sensor deployment were implemented. This was done with the purpose of ensuring a broader representation of the various climatic seasons and times of presence of different species. Through this approach, we sought to improve the availability of training data and, therefore, increase the reliability and effectiveness of the models, minimizing the risk associated with the lack of sufficient data for less common species. As more data is collected in future, the acoustic CNN can be retrained to include more species and supplement training data for rarer species so that the model performs better for these.

Annex 3. Biodiversity monitoring devices

Monitoring systems

With the objective of generating holistic knowledge of the health status of the ecosystems and species in the Reserve, the project takes advantage of two of the most outstanding monitoring methods that allow a deeper analysis of the ecosystems and the species that inhabit them without disturbing the ecological patterns of the area.

1. **Camera trapping**: also known as the use of camera traps. This approach involves placing discreet cameras in natural areas to capture images of wildlife in their habitat. These images provide information on the presence and/or absence of species, behaviors and movement patterns, which contributes to more effective management of protected areas.

2. **Passive acoustic monitoring**: Autonomous audio recorders that are deployed in a site to record all sound within the environment (the soundscape). This includes animal sounds (biophony) such as calls from birds, amphibians, mammals, fish, and insects. The soundscape also includes geophony (rain, wind) and anthrophony (man-made noises such as chainsaws, gunshots and vehicles). This technology has been used to automate the identification of thousands of species and cover much larger areas in great detail compared to the spatial limitations of using camera traps. Through this approach, it is possible to identify how changes in the environment, climatic variations or human influence affect the vocalization and behavior patterns of the species present.

One of the most relevant applications of AI systems for biodiversity is the identification of species in images captured by camera traps and echo-acoustic monitoring devices.

Browning camera trap

Audiomoth (photo credits to RFCx)

Annex 4. Partners and key actors of Tech4Nature Mexico

The table below provides more information on the key partners and actors involved in the .**Tech4Nature Mexico** pilot project

C Minds	C Minds is a women-led organization that promotes the exploration, development and responsible use of technologies border for the benefit of Latin America, **Role:** Co-leadership of the initiative, coordinator and main implementer of the program.
Secretary of Sustainable Development (SDS)	Government entity that participates in the development, implementation and evaluation of public policies and actions that generate balanced development in environmental, social and economic terms to promote sustainability in the State, in a transversal, innovative and equitable manner, with absolute adherence to the law and through the efficient use of resources. **Role:** Co-leadership of the initiative, coordinator of sensor deployment, data collection and decision-making strategies.
International Union for Conservation of Nature (IUCN)	The International Union for Conservation of Nature (IUCN) is a membership Union uniquely composed of government and civil society organizations. By harnessing the experience, resources and reach of its more than 1,400 member organizations and the contribution of some 15,000 experts, IUCN is the global authority on the state of the natural world and the measures needed to protect it. **Role:** Green List Standard Advisor, Solution Evaluator
Huawei	Huawei is an industry-leading global provider of information and communications technology (ICT) solutions. **Role:** Image Processing Cloud Solution Provider
Polytechnic University of Yucatan (UPY)	Public university that contributes to the comprehensive training of higher-level students with excellent innovative and cultural preparation of international level specialized in the field of ICT. **Role:** Development of image recognition models
Rainforest Connection (RFCx)	A nature tech non-profit organization that combines the power of sound and AI to monitor biodiversity, detect threats, and protect threatened ecosystems at scale. RFCx's team of experts works with

partners across the world to translate ecoacoustic data into ecological insights and conservation action.

Role: Development of acoustic analysis pipeline, including pattern matching, soundscape analyses, and CNN training, deployment, and validation.