

FUNDECOR: Visualizing Reforestation

San Jose, Costa Rica 2024

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Abstract:

Global deforestation is a prevalent problem that disrupts natural biodiversity and affects the planet's climate. FUNDECOR works toward reforesting Costa Rica by supporting small farmers, and their potential BIOTA biodiversity credit system would generate funding for these small farms. Our project goal is to showcase the positive impact that FUNDECOR has had on sustainable farming in the environment and economy of Sarapiquí. We did this through analysis of existing farm data and individual case studies on five small farms. The result of our project is five individual profiles for each farm that display the personal testimonies of the owners published on the BIOTA website, aiming to increase community involvement and raise awareness about protecting biodiversity.

**Interactive Qualifying Project
WORCESTER POLYTECHNIC INSTITUTE**



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Meet the Team



Melina Iannacchione is a third-year Aerospace Engineering major with a concentration on astronautical engineering and pursuing a minor in Spanish, with 14 years of elementary school/middle school/high school/college Spanish and proficient communication skills. Melina is from Worcester, Massachusetts, and enjoys playing guitar, crocheting, going to the gym, and watching basketball in her free time.

Team contributions: led team meetings, communicated with sponsors and advisors, organized tasks, conducted interviews on-site, transcribed and translated interview audio files, wrote farm descriptions, wrote and formatted the executive summary, and created and edited report content



Brianna Romero is third year Psychology major with a concentration in biology/biotech on the pre-health track, with 8 years of elementary/middle school Spanish experience with proficient communication skills. Brianna is from Carmel, New York and enjoys playing the piano, volleyball, and hiking with her friends.

Team contributions: conducted interviews on-site, translated interview audio files, and created and edited report content



Liv Santurri is a third-year Biology/Biotechnology major with a focus in genetics and cellular engineering. She has 6 years of middle school/high school Spanish experience with basic to intermediate communication skills. Liv is from Cranston, Rhode Island and enjoys staying active through sports and going to the gym, reading, being outdoors, and spending time with friends and family.

Team contributions: Curated agendas and recorded meeting minutes during team meetings, collected video and photographic content at each farm, formulated profile mockups, submitted IRB application, and created and edited report content



Cameron Robbins is a third-year Computer Science major with a focus in Data Science. He has 8 years of elementary school/middle school/high school Spanish experience with intermediate communication skills. Cameron is from Londonderry, New Hampshire, and enjoys exercising, playing soccer and football, writing code, and spending time outside in his free time.

Team contributions: Created, edited, and formatted final booklet, created and edited report content, collected video and photographic content at each farm, recorded interviews, wrote recommendations, created charts and visual content

“Con Hambre, No Hay Conservación”

“With Hunger, There is No Conservation”

Deforestation hurts Earth’s ecosystem in many ways such as disrupting natural biodiversity and preventing the forests’ natural carbon sequestration process¹. These effects have major impacts on local temperature change and the global climate crisis. However, deforesting land for mining, urbanization, and agricultural expansion is profitable. Converting forests to fields that produce a large amount of one product, as shown in Figure 1, can benefit that farm owner or family economically, but monocropping destroys biodiversity and the environment in the bigger picture. Global initiatives to reforest the Earth and rebuild biodiversity benefit the environment significantly, but without examining the economic aspect by providing alternative income sources for landowners, these policies and programs become less effective².



Figure 1: A large pineapple field in Sarapiquí, Costa Rica.

Proper financial resources and training on sustainable farming practices provide the foundation for successfully integrated reforestation initiatives³. This is especially important for families living on small farms. While larger scale projects and forestry management initiatives usually benefit from government funding, smaller scale farms are at a disadvantage due to not qualifying for this assistance. Ensuring the sustainability of small farms adds up to

big environmental impact, as half of the world’s habitable land is used for agriculture⁴. Sustainable farming practices, if broadly implemented, can help prevent issues like soil destruction and further forest deterioration⁵.

The Foundation for the Development of the Central Volcanic Mountain Range (FUNDECOR), a Costa Rican non-profit and non-government organization, is on a mission to enhance both natural sustainability and economic development through land management. One of their slogans that defines this goal is “con hambre, no hay conservación,” which translates to “with hunger, there is no conservation,” communicating that without proper economic support to put food on the table, people will be less interested in choosing more sustainable, at times less profitable, farming practices. FUNDECOR has been involved in many projects such as their Biodiversity Conservation Mechanism using Blockchain (BIOTA) program, which has been working toward addressing the needs of local landowners in the Sarapiquí region of Costa Rica. The program plans to accomplish this goal by aiding in the fundraising for conservation of agricultural farms for which government support is insufficient. Highlighting the potential for programs like BIOTA can help raise public awareness about sustainability. The BIOTA program’s geospatial tools already provide a map of large tracts of forest in the Sarapiquí region, with data included in each location. The visual nature of this database makes it easily understandable for the public. However, the database does not include small farms, whose personal testimonies would help raise public awareness about the importance of sustainable farming practices, encourage other farmers to join the program, and promote donations by large corporations using the new BIOTA program. Adding individual case studies on small farms to the BIOTA website would provide more widespread benefit.

The purpose of this project is to showcase the positive impact that FUNDECOR’s BIOTA program has had on sustainable farming in the environment and economy of Sarapiquí through analysis of existing farm profiles and individual case studies on farms, aiming to increase funding for the farms and families as well as promote this program to other potential beneficiaries.

History and Analysis of Costa Rica's Land Development and Protection

We begin this chapter with an overview of the detrimental impacts of deforestation on a global scale. Next, we examine the history of sustainability in Costa Rica, outlining its humble beginnings to becoming one of the most sustainable countries in the world. We then consider the economy of Costa Rica, looking at economic trends surrounding its main exports as well as specifically examining the economic situation of farmers in the country. We introduce our sponsor, FUNDECOR, and how they have successfully worked toward sustainability. We will dive deeper into their BIOTA program, explain their Geospatial Tool feature on their website, and provide context to the data that they possess in the form of farm profiles. Finally, we explain how our project aims to raise public awareness while encouraging companies to invest in the environment.

Global Deforestation

Deforestation is the clearing of forests for mining, urbanization, or agricultural expansion. There are occurrences where deforestation occurs due to natural disasters such as fires, but deforestation also commonly occurs for industry purposes. Deforestation is a major problem because it disrupts natural biodiversity and has detrimental impacts on the Earth's ecosystem which negatively affects the climate both locally and globally. Forests help absorb carbon dioxide from the air, but when people clear away trees, it inhibits the forests' natural carbon sequestration process¹. Carbon dioxide levels then rise, contributing to alteration of local temperatures and broader climate patterns like global warming.



From Deforestation to Sustainability in Costa Rica

Today, Costa Rica is regarded as one of the most sustainable and biodiverse countries in the world, but its history is not so clean. In 1943, 77% of Costa Rica was covered by forests, but forest cover rapidly declined in the following forty years to just 44% in 1986⁶, as shown in Figure 2. Profit for various industries motivated this deforestation. For the agricultural

industry's benefit, crop production and cattle grazing boomed, causing mass conversion of forests into fields. Urbanization also boomed during this time, with the development of buildings and expansion of the road system in Costa Rica converting forests into cities. In other words, improving the economy motivated the people of Costa Rica to convert 'unproductive' land into 'productive' land⁷.

This might have been economically productive, but there are negative consequences to these decisions, and these negative factors led to the people of Costa Rica making changes. Costa Rica depends on hydropower

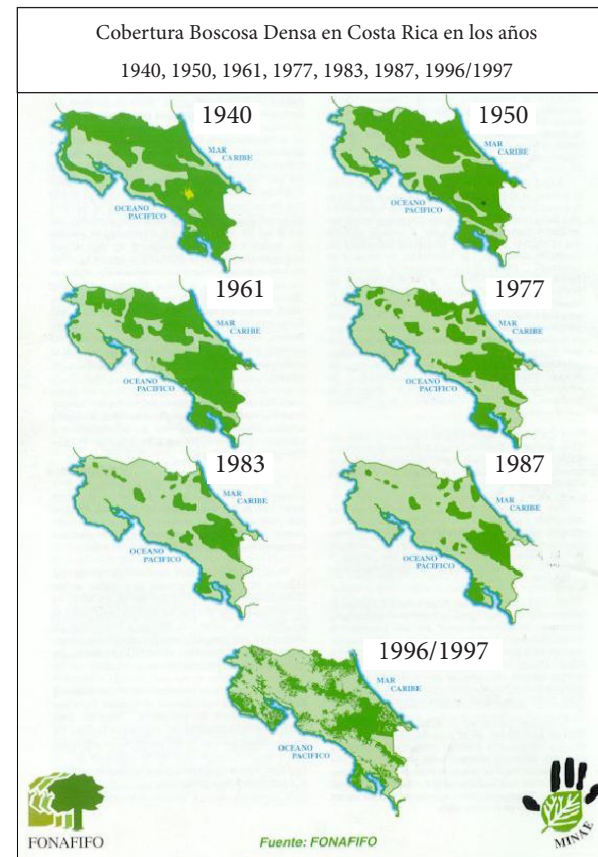


Figure 2: Map of tree cover loss and gain in Costa Rica between 1940 and 1997⁸

reservoirs to provide about 75% of the nation's electricity⁶, and an unforeseen environmental consequence of deforestation that threatened to backfire on the economy was soil erosion. Removing trees from forests at this rapid rate and introducing the cultivation of a mass amount of only a few types of crops eroded the land's ability to retain soil and water, which can cause the weakened land to slide and ripple⁵, as shown in Figure 3. People were worried that this land could clog the reservoirs and maim the country's electricity supply, thus disrupting the economy and day to day life of Costa Ricans.



Figure 3: Landslides due to deforestation and monocropping⁹

Once the people of Costa Rica realized the negative effects that deforestation was having on the country, they took action and sparked the beginning of the green transition. Costa Rica has implemented important sustainability policies that foster the establishment of new national parks, promote ecotourism, preserve the natural environment, and promote a greener economy for the future. In 1996 the Forestry Law made it illegal to chop down forests without approval from the authorities, restricted

importation of forest products, and banned exportation of unprocessed timber¹⁰. A program called Payment for Environmental Services (PES) was enacted in 1997 which pays farmers to protect their watersheds and plant more trees that would absorb carbon dioxide¹¹. One year later, government officials implemented the National Biodiversity Strategy and Action Plan (NBSAP). This comprehensive plan provided the framework for conservation and sustainability, integrating Costa Rica's rich biodiversity¹⁰. Today, rainforests cover about 60% of Costa Rican land again¹².

Costa Rica's impressive turnaround has set it apart from other Central American countries. The Future Policy Gold Award was awarded to Costa Rica in 2010¹³. In 2019, the United Nations Environment Programme (UNEP) awarded the country one of the highest environmental honors called the Champions of the Earth award for their role in protecting nature and their commitment to combating climate change¹⁴. Costa Rica also was awarded the Earthshot Prize in 2021, which has attracted significant global media coverage, celebrating the country as a 'green leader'¹⁵. Costa Rica continues to be a leader in driving the global environmental agenda.

Costa Rica's Economy

Costa Rica's exports have improved its economy over the years. In 2022, Costa Rica shipped an estimated 15.3 billion USD worth of products around the globe¹⁶, up from 11.3 billion USD in 2018. Costa Rica's main exports include optical, technical, medical apparatus and food products such as fruit, nuts, vegetables, coffee, tea, and spices.

The rich landscapes that produce these products are also ripe with opportunities for eco-tourism, a type of tourism that immerses participants in natural areas. However, while Costa Rican hotels, for example, can profit from the appeal of their beautiful surroundings, the owners of the lands they overlook do not see the same benefits. They are often affected by poverty, lack of educational opportunities, and marginalization¹⁷. Landowners and farmers are exploited this way, and to put food on the table for their families, conservation and sustainable farming practices are often the last priority.

FUNDECOR

FUNDECOR, also known as the Fundación para el Desarrollo de la Cordillera Volcánica Central (Foundation for the Development of the Central Volcanic Range), is a non-governmental organization (NGO) and aims to help farmers reprioritize conservation and sustainability. The Costa Rican government in conjunction with the United States Agency for International Development (USAID) created FUNDECOR in 1991 as an indirect result of the 1980's debt crisis which promoted the formation of agricultural land and disregarded its effect on biodiversity and the environment. FUNDECOR's founding was set in motion to help manage a 7.5-million USD project called FOR-ESTA. This program's main objective was to economically support the conservation and development of the Cordillera Volcánica Central (Central Volcanic Region) of Costa Rica. FUNDECOR later integrated this mission into their formal goals and objectives¹⁸.

Today, FUNDECOR's goals and values remain stably committed to promoting reforestation efforts and protecting biodiversity in Costa Rica. FUNDECOR's mission as stated on their website is to "contribute to the generation of innovative solutions for comprehensive landscape management through inclusive initiatives that enhance the benefits of nature for people and inclusive and resilient development."²⁰.

This organization focuses on financial assistance to poorer landowners to rebuild forestland from agricultural farms. This appeal helps to boost both the economy of poorer communities and increase biodiversity in the region, like the Sarapiquí region, which houses one of FUNDECOR's offices. FUNDECOR works on many different programs with numerous organizations and landowners, as shown in Figure 4. FUNDECOR



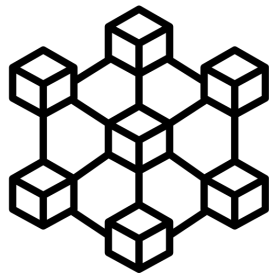
Figure 4: FUNDECOR employee Carla Solis consulting with a landowner.¹⁹

has partnered with the International Analog Forestry Network (IANF) to host workshops for landowners interested in improving biodiversity and addressing environmental concerns on their farms. These workshops have already benefited forty-five families²¹, which is just one of the ways FUNDECOR is helping the environment and social structure in the Sarapiquí region.

The BIOTA Program and Blockchain

FUNDECOR has also been at the center of the development of the Biodiversity Conservation Mechanism using Blockchain (BIOTA) program, which aims to redefine the way people conduct conservation financially. The BIOTA program would allow donors to purchase what FUNDECOR calls “biodiversity credits” with their own currency. The proceeds from these biodiversity credits would then be allocated to specific sections of land. For small farms that only receive minimal government assistance, the BIOTA program would be integral in maintaining their sustainability. BIOTA would create personalized plans to help landowners create solutions that will work best for the farmers and the region’s ecosystem. BIOTA aims to increase the funding of the small farms from 65 USD per hectare to 1600 USD per hectare. This can be done through blockchain technology, hoping to delegate resources towards biodiversity initiatives to benefit the economy, the environment, and greater society²².

Blockchain is useful as a decentralized tool that utilizes linking blocks and coding to store vast amounts of information, most notably to store financial transactions as a sort of ledger. Utilizing blockchain and its innovative methods, BIOTA aims to continue to create ethical and transparent contracts based on the experiences with landowners from the past 25 years that are smart and trackable²¹. By having larger companies invest in BIOTA’s credits, not only will they be contributing to the preservation and conservation of the farms, but they will also be supporting the livelihood of the farmers and their families.



BIOTA’s Geospatial Tools

In the BIOTA program, geospatial tools are essential for mapping and analyzing Costa Rica's diverse landscapes and ecosystems, particularly in the context of reforestation and biodiversity conservation. These tools integrate detailed satellite imagery and various environmental data layers, providing a comprehensive view of land use dynamics and ecological shifts. A typical profile within this system, such as that of a nature reserve or a specific ecosystem, encapsulates a wealth of information crucial for understanding and managing these natural areas. Figure 5 shows an example of one of these profiles, the Tirimbina Biological Reserve, covering 347.43 hectares²³.

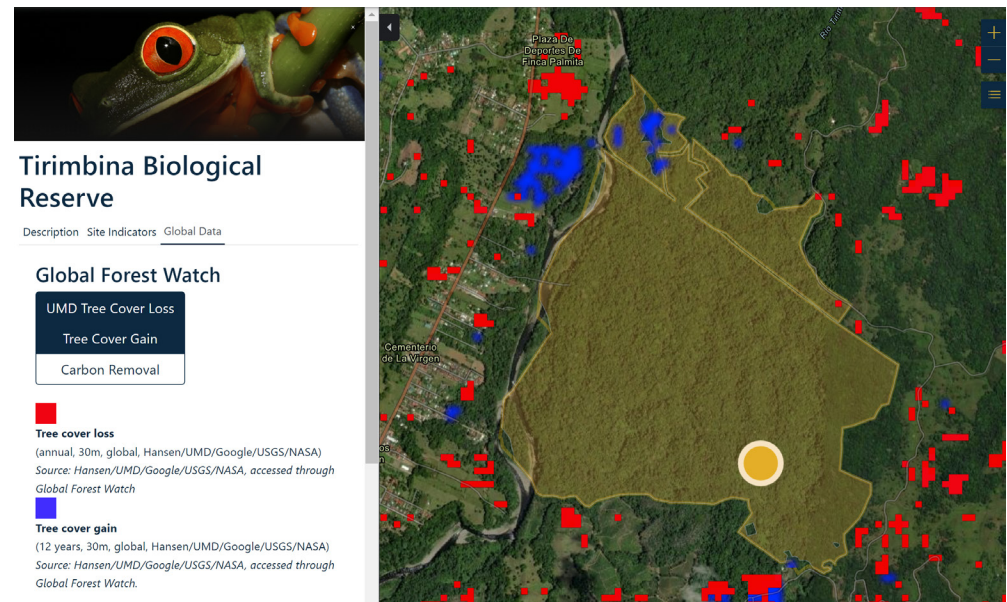


Figure 5: Screenshot of the Tirimbina Biological Reserve as it appears on BIOTA’s geospatial tools. Map of the area shows global data on the tree cover loss (red) and tree cover gain (blue)²³

Each profile includes critical data such as area size, land use classifications, and ecological characteristics, ranging from vegetation types to forest extents and water bodies. These profiles also emphasize biodiversity, detailing species variety with a focus on flora and fauna. Under the "Site

Indicators" tab, it tracks 8 essential indicators of biodiversity status. These are the social development index, conservation gaps, wild protected areas, the National Registry of Wetlands, essential areas for biodiversity support, biological corridors, water priority, and prediction of tree cover loss (2021 - 2025). Each indicator provides key insights into the area's ecological health and conservation status. Coupled with bird sightings and carbon removal data, these indicators offer a comprehensive characterization of an area's ecological significance.

Additionally, a typical profile delves deeper into the significance and management of the area. It usually outlines the ecological importance of the location, shedding light on its role in broader ecological networks, such as its contribution to biodiversity corridors or its significance as a habitat for threatened species. This section often includes information about current conservation efforts, such as reforestation initiatives, habitat restoration, and wildlife protection programs. It also touches on the area's challenges, like threats from deforestation, climate change, or human encroachment, providing a full picture of the area's ecological dynamics and conservation needs.

By presenting a comprehensive and detailed view of each location, these profiles not only support the protection and management of Costa Rica's natural landscapes, but also underscore the importance of each area within the broader context of ecological conservation. This approach highlights the country's commitment to preserving natural ecosystems, reflecting a proactive strategy in addressing global environmental challenges.

On a broader scale, the BIOTA program's geospatial tools integrate extensive global datasets, providing vital environmental insights. This includes data on tree cover loss and gain, which is crucial for monitoring deforestation and reforestation efforts. These metrics, derived from the collaborative efforts of organizations such as the University of Maryland (UMD), Google, the U.S. Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), and the Hansen research group, are accessed through the Global Forest Watch platform²³. This comprehensive data helps identify areas most affected by deforestation, enabling targeted

reforestation and conservation strategies. It also assists in understanding the long-term impacts of land-use changes on ecosystems, which is essential for planning sustainable environmental policies.



Figure 6: Two black-cheeked woodpeckers spotted on a banana tree at the Finca Oasis in La Fortuna, Costa Rica.

Additionally, the project utilizes data from the Global Biodiversity Information Facility (GBIF), focusing on bird sightings, as shown in Figure 6, to evaluate biodiversity health. GBIF often considers bird populations to be key indicators of ecological well-being due to their sensitivity to environmental changes. By monitoring bird species diversity and abundance, the BIOTA project can gauge the health of ecosystems and the effectiveness of conservation efforts. This information is critical in areas undergoing reforestation, as it provides tangible evidence of ecological recovery and biodiversity enrichment.

In this context, the integration of these diverse data sets is invaluable. It enables a more nuanced understanding of environmental changes, guiding effective conservation practices. Using advanced geospatial tools to analyze these data underscores the BIOTA program's commitment to leveraging technology for ecological stewardship, aligning Costa Rica's local conservation efforts with broader global environmental trends.

In the context of the BIOTA project, the blockchain-enabled platform includes a global open market for biodiversity credits, linking the geospatial data directly with conservation financing²². This unique integration directly connects changes in land use, forest cover, and biodiversity, as recorded and analyzed by the geospatial tools, to the issuance and trading of biodiversity credits. These credits are only for sale to donors if land is found to have met certain goals of improvement in a set period, using metrics such as species richness, ecological integrity, and water quality²⁴. Biodiversity credits provide financial incentives for conservation efforts, making the geospatial tools' data informative and actionable.

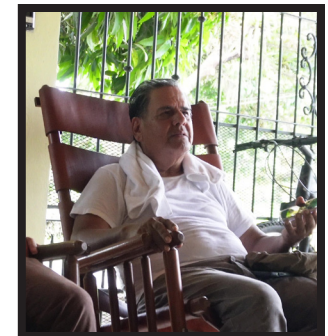
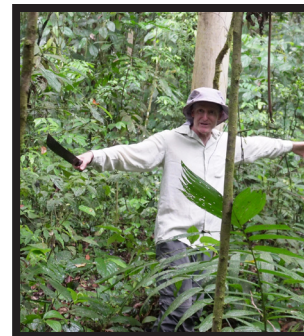
Public Awareness Through a Personal Perspective

Seeing real people's perspectives of sustainability and conservation would impact the public too. A successful pesticide reduction campaign beginning in 2003 in Costa Rica has reduced the ozone-depleting pesticide methyl bromide use by 52%²⁵. Supporting materials for the campaign included a video of local farmers explaining the issues, a campaign logo designed by a local painter, and the development of presentations for different meetings and audiences. FUNDECOR could adopt this strategy and compile personal interviews and testimonies of the results of their reforestation efforts for the public to read, spreading environmental awareness about natural resource conservation and global sustainability.

Using these profiles will hopefully also lead to more investments from big companies interested in becoming more involved with corporate public responsibility. When companies choose to invest in biodiversity credits, they

are not only investing in carbon offsets, but also in helping to fund solutions for worldly issues or the less fortunate. This looks good to the consumer base and boosts marketing campaigns, intending to incentivize people to buy their product over the competition. This kind of system is exactly what FUNDECOR is looking to create. These investors can fund a small farm so the farmers can maintain their land and increase their biodiversity and environmental benefits, so the company can reap the benefits of protecting the planet through investing in these smaller farms and their farmers; it is a win-win situation.

Our project aims to add profiles for smaller farms on to the BIOTA geospatial tools database that will supplement their environmental data with personal testimonies of how FUNDECOR's BIOTA program could impact their livelihoods as well as the sustainability of their farms, with the primary goal of appealing to potential beneficiaries and showing them what FUNDECOR can do to help them as well as increase potential funding for the small farms.



Developing Farm Profiles

The 5 farms the team studied were those of Elicinio Flores Porras, Ingrid Mabel Quirós Vargas, David Reuland, Pedro Garcia Rueda, and Isaias Arguedas Arce. The main project goal was to create profiles for these 5 small properties to add to the Geospatial Tools tab on the BIOTA website. To accomplish this goal, we broke down our approach into four objectives, as shown in Figure 7.

Objective 1 was to learn more about the indicators that FUNDECOR's BIOTA program has developed for biodiversity. We researched their 8 indicators of biodiversity and viewed existing data for the 5 farms pertaining to whether they qualify for these indicators. Objective 2 was to gain valuable expert opinions and knowledge about the BIOTA program by talking to our sponsors about their perspectives on the potential program. Objective 3 was to research how the 5 farms would be integrated into the map on the BIOTA website's Geospatial Tools tab and to gain insight into the technical capabilities of the website. We accomplished this goal by analyzing land use maps for each of the 5 farms and working closely with the administrator of the BIOTA website. Last but certainly not least, Objective 4 was to learn more about the small farms in the Sarapiquí region from the owners of 5 small farms by collecting their testimonies and photographing their properties.

All the information and knowledge obtained through the pursuit of these 4 objectives were used to create profiles that tell the story of the environmental and economic impact that FUNDECOR's support has had on families and farms in Sarapiquí. Once the outlines of the 5 farms were uploaded onto the website with these profiles, the global satellite data could be used to analyze the environmental sustainability of each property.

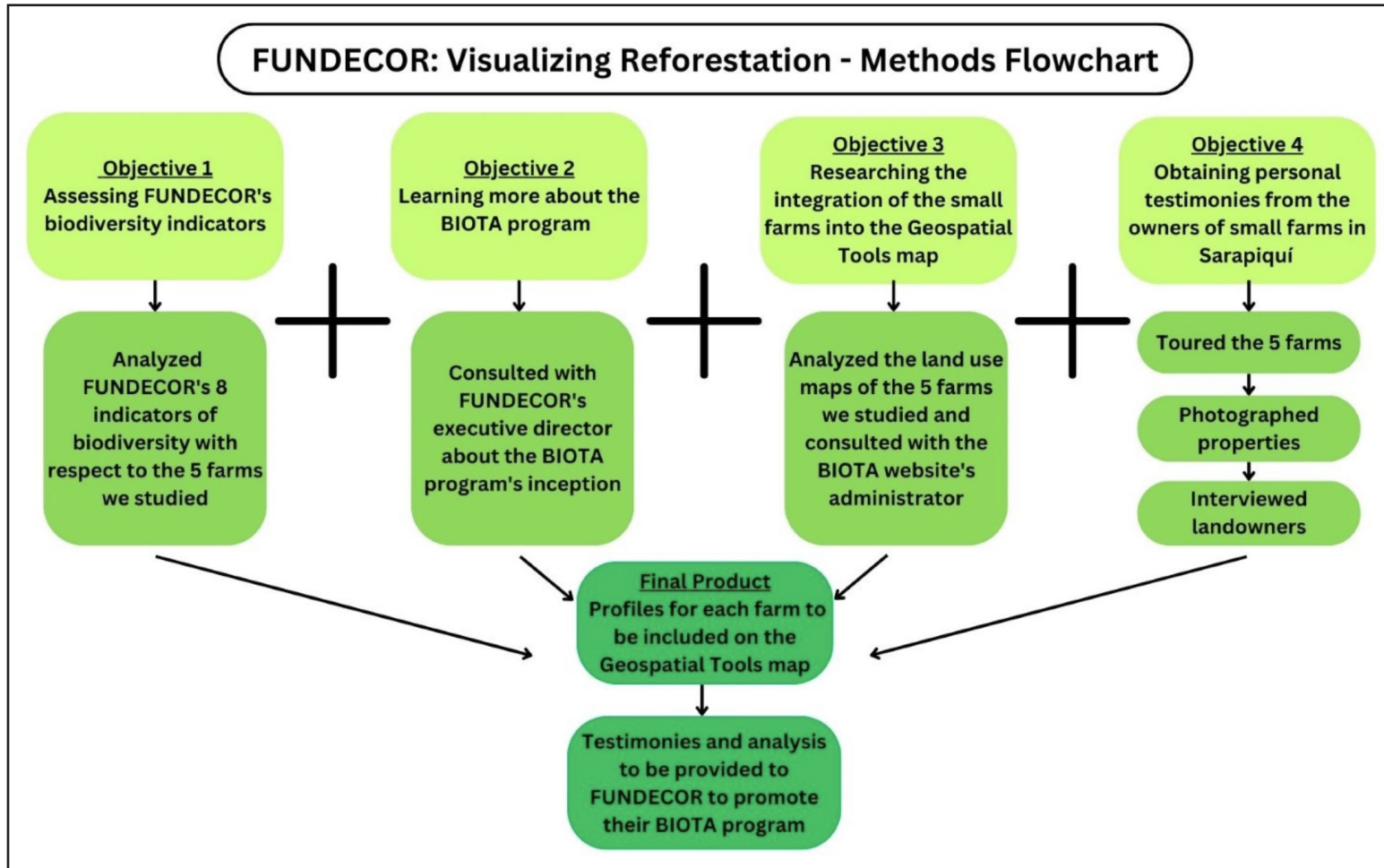


Figure 7: Methods flowchart for our project.

Assessing FUNDECOR's Biodiversity Indicators

Our team conducted in-depth research and analysis of the 8 biodiversity indicators of FUNDECOR's BIOTA program, which helped us to make broader conclusions about FUNDECOR's biodiversity initiative. Our FUNDECOR sponsors provided our team with a supervisor, Danny Cordoba. Cordoba is a forest engineer with over 20 years of experience at FUNDECOR, who used to visit the farms in Sarapiquí every day. He provided our team with an Excel sheet that marked whether the 5 properties qualified for each of the eight indicators shown in Table 1, and we were able to analyze each of the farms through this lens. A 1 indicates the farm receives that indicator while a 0 means they do not qualify. Once the outlines of the 5 farms were uploaded onto the website with these profiles, the global satellite data could be used to analyze the environmental sustainability of each property.

FUNDECOR's Eight Indicators for Measuring Biodiversity

FUNDECOR's BIOTA program utilizes eight site indicators – biodiversity, biological corridor, conservation gap, loss of tree coverage, protected wilderness areas, Social Development Index (SDI), water priority, and wetlands – to help assess and monitor a variety of aspects related to environmental sustainability and agricultural practices. The 8 indicators were developed by Cordoba; the FUNDECOR executive director, Mario Piedra; and the chief executive officer and administrator for the BIOTA website, Alejandro Solis, and approved by the Costa Rican government. If a property has 30% or more of the specific criteria, it gets tagged on the website with the indicator²².

Biodiversity preservation is addressed through the identification of farms located within areas cataloged as essential for maintaining biodiversity in

Table 1: The 8 Biodiversity Indicators for the 5 Farms

Farm	Protected Wilderness Areas	Biological Corridor	Water Priority	Wetlands	Low SDI	Biodiversity	Prediction of Tree Loss	Conservation Gaps
Elicinio Flores Porras	0	0	1	0	0	0	1	0
Isaías Arguedas Arce	1	0	1	0	0	1	0	0
Juan José Umaña Molina (Ingrid Mabel Quirós Vargas)	0	1	1	0	0	0	0	0
Pedro García Rueda	0	1	1	0	0	1	0	0
Proyectos Oasis Reforestación S.A.	0	0	1	0	0	0	0	0

Costa Rica. This classification is determined by the United Nations Development Program (UNDP) methodology, which is implemented by the Ministry of Environment and Energy (MINAE) and Laboratory Programa de Investigaciones Aerotransportadas y Sensores Remotos (PRIAS), providing a framework for preserving, restoring, and managing specific areas. In the methodology, there are 6 areas important for maintaining biodiversity conservation: protected areas (PAs), access and benefit sharing (ABS), agrobiodiversity, mainstreaming biodiversity, wildlife and conservation area management, and invasive alien species (IAS)²⁶. According to Cordoba's Excel sheet, Rueda's, and Arce's properties both qualify for this indicator.

Biological corridors, established by the National System of Conservation Areas (SINAC), are important for biological connectivity between protected wild areas. These corridors help address the problem of habitat fragmentation, which is caused by industrial activities such as agriculture, industrial reforestation, and urbanization, and they serve as a buffer zone for parks. Farms within these corridors contribute to the goal of maintaining ecological balance and promoting biodiversity through the migration and spread of fauna and flora²⁷. Vargas's and Rueda's properties qualify for this indicator.

While the purpose of the **conservation gap** indicator is not officially stated in the BIOTA geospatial tools, it does identify farms located in areas deemed important for conservation. This highlights the importance of preserving ecologically valuable regions. None of the 5 farms that we studied qualify for this indicator.

The **loss of tree coverage** indicator uses machine learning modeling based on global data from satellites to assess farms located in areas with a medium to high probability of tree cover loss. Various variables were used for the model including land use, SDI, elevation, capacity, slope, and proximity to infrastructure. The indicator aims to identify areas where tree cover loss is likely due to either natural or human causes. Predicting these kinds of areas provides an understanding of potential threats to the forest's ecosystem²². Porras's property is the only one that qualifies for this indicator.

Farms within *protected wilderness areas* are classified by various management categories such as Forest Reserves, National Parks, Wildlife Refuges, and more. This indicator integrates different levels of protection while stressing the significance of preserving these areas for the overall well-being of Costa Rica's biodiversity and ecosystems²². Arce's property is the only one that qualifies for this indicator.

The **Social Development Index (SDI)** identifies farms located within districts characterized by a very low index of less than 47. A low index may

indicate limited human development or economic activity leaving the forest relatively untouched due to lower levels of industrialization or traditional yet sustainable practices. However, this indicator can signify both benefits and detriments, as a low index may lead to unsustainable practices such as illegal logging or limit the capacity for conservation efforts. An area's SDI is determined by factors such as life expectancy, income, access to resources such as education, healthcare, and clean water as developed by the Ministry of National Planning and Economic Policy in Costa Rica (MIDEPLAN). Using this index, MIDEPLAN plans to use the data collected to review and carry out public interventions to help regions in Costa Rica with a low SDI. The indicator is used by the National Forestry Financing Fund in Costa Rica (FONAFIFO) for its PES program²⁸. None of the 5 farms that we studied qualify for this indicator.

Water resources and their conservation are assessed through the **water priority** indicator. This involves identifying farms within areas of water importance as outlined by the PES program, which aims to also protect water systems that protect a variety of fauna and flora, especially endangered species, areas facing water scarcity for several reasons, and safeguarding sources important for consumption. This indicator is also used by FONAFIFO for its PES program to prioritize conservation efforts related to water resources²⁹. Porras, Vargas, Reuland, Rueda, and Arce all have properties that qualify for this indicator, making it the most common among the 5 farms we studied.

For the **wetland** indicator, farms are assessed based on their proximity to a national wetland. This indicator, derived from the National Wetland Inventory (NWI) of Costa Rica and continually updated by SINAC's wetland program, helps with the identification and protection of these ecologically significant areas. Based on the NWI of Costa Rica, wetlands are classified into 5 different types – fluvial, estuary, marine, lacustrine, or palustrine³⁰. None of the 5 farms that we studied qualify for this indicator.

Learning More About the BIOTA Program

We interviewed employees at the FUNDECOR office, specifically our sponsors Cristian Zuñiga and Mario Piedra. Piedra is the executive director of FUNDECOR, and we obtained a lot of information about the BIOTA program through conversations with him. We asked questions about the biodiversity credit system, incentives for investing from the investor's perspective, the process of investing, and how this money would be used. We familiarized ourselves with details of the BIOTA program and its potential impact on both investors and beneficiaries.

Limitations of the PES system

Piedra explained the limitations of the PES system that led the creators of BIOTA to consider an alternative. Most, if not all, of the PES money comes from taxes on goods that typically hurt the environment, such as gasoline, plastic bags, take-out containers, and other single-use plastics. The PES system is one part of Costa Rica's plan to help protect the environment while also providing its people with goods that they want and need. The money from these taxes that the PES system provides to landowners creates a balance in the world where individuals can still get the products they want while simultaneously funding conservation efforts. The PES system aims to heal the damage caused by using environmentally harmful products.

Unfortunately, this system is not able to keep up with the current lifestyle of people in Costa Rica. In 2020 when the COVID-19 pandemic began, people stayed home and drove significantly less, which caused the money being funneled into the PES program to diminish greatly. Eventually, this money ran out in 2021. The lack of funding combined with people's efforts to be more eco-friendly, like using less plastic and the rise of electric cars, means that new methods of funding need to be proposed to provide money for landowners to maintain their land and preserve the forest and ecosystems.

The current PES system provides landowners with only 65 USD per hectare per year, however, this is insufficient for landowners to maintain their land and sustain themselves. To support these landowners and their land, new sources of revenue need to be created.

The BIOTA Program

The goal of the BIOTA program is strongly connected to the idea of public goods. Public goods are things that all of humanity benefits from, such as good air quality, water quality, and carbon sequestration, and these goods are naturally provided by forests. FUNDECOR consulted RAMSAR, the Convention on Wetlands, who evaluated forest land and provided a monetary amount reflecting the value of the public goods that the land provides. While it is challenging to put a price on nature, the value RAMSAR applied to the land was about 1600 USD per hectare per year³¹, about 25x the amount currently supplied by the PES. The BIOTA program aims to provide landowners with more sufficient income that more accurately reflects the value of the environmental services provided by their lands.

According to Piedra, the BIOTA program provides a new way to gather funding through a different source: corporate investments. BIOTA aims to target larger corporations and organizations and show that forest land is worth investing in with the BIOTA biodiversity credit system. The BIOTA biodiversity credit system uses blockchain technology to create smart, non-fungible contracts in which big companies or individual patrons can pay by card completely online and receive a certificate. This certificate serves as the biodiversity credit, where 1 credit equals 1 hectare. The certificate also includes all information about the land and its owners. The credits bought by companies can help provide landowners with increased funding to continue protecting their land, and the company-landowner relationship can also benefit the investing company. Piedra explains the incentives of the program are philanthropy campaigns, Environmental, Social, and Governance (ESG) investing, corporate public responsibility, corporate compensation for emissions, and carbon footprint offset for companies. According to the 2022 PwC report, ESG investments are predicted to

increase 84% by 2026 to a total of 33.9 trillion USD globally³² demonstrating that this concept could have real potential for success. FUNDECOR is at the forefront of using new blockchain technology to help promote sustainability in Costa Rica, and hopefully soon expanding to other parts of the world with BIOTA NEXUS, an initiative that plans to take this concept global.

While discussions about using blockchain technology and a biodiversity credit system to invest in sustainability have begun circulating in recent years, little movement or action has occurred to turn this idea into a reality. Currently, BIOTA is only in the proof-of-concept phase, but by its creators continuing to market the program, they aim to move to the next level. As part of their marketing strategy, the creators of FUNDECOR'S BIOTA program would like to develop personalized profiles of the farms to attract potential investors. From a large company's perspective, providing income for these small farms can make the company look better to the consumer, which in turn can increase their business, profits, and company image in the long term. BIOTA's concept is a win-win situation for all, including the investors, the recipients, and the environment.

Researching the Integration of the 5 farms into the Geospatial Tools Map

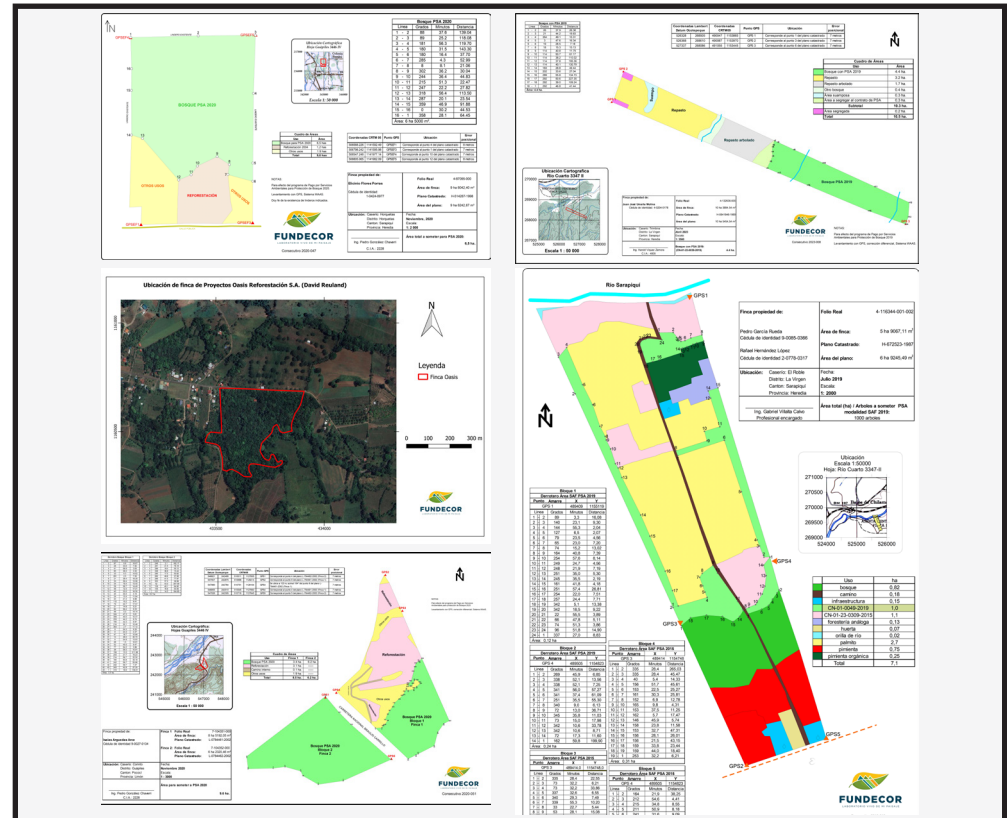
Cordoba provided detailed maps of each land plot we visited except the Finca Oasis. These maps give a visual representation of the spatial distribution of various land uses within each farm, enhancing our understanding of the land management strategies employed by the landowners. Additionally, Keyhole Markup Language (KML) files outlining the property borders of each plot were also provided to complement the maps.

To seamlessly integrate content into the BIOTA website and gain understanding about website development on a technical level, the team consulted with Solis, who guided us specifically on the Geospatial Tools tab of the BIOTA website. We met with him to learn more about how the website is run, how the layers of data work, the sources of the data, and to

put the KML outlines of the 5 farms we visited onto the map in the same way that the large forests are present.

Analysis of Land Use Maps

In analyzing sustainable land use and reforestation efforts across different farms, it is vital to consider the various approaches to land management and conservation practices undertaken by landowners. The maps of the five properties each showcase a unique commitment to environmental preservation, agricultural productivity, and biodiversity enhancement. The green areas on each map represent the lands for which the owners receive money from the PES system.



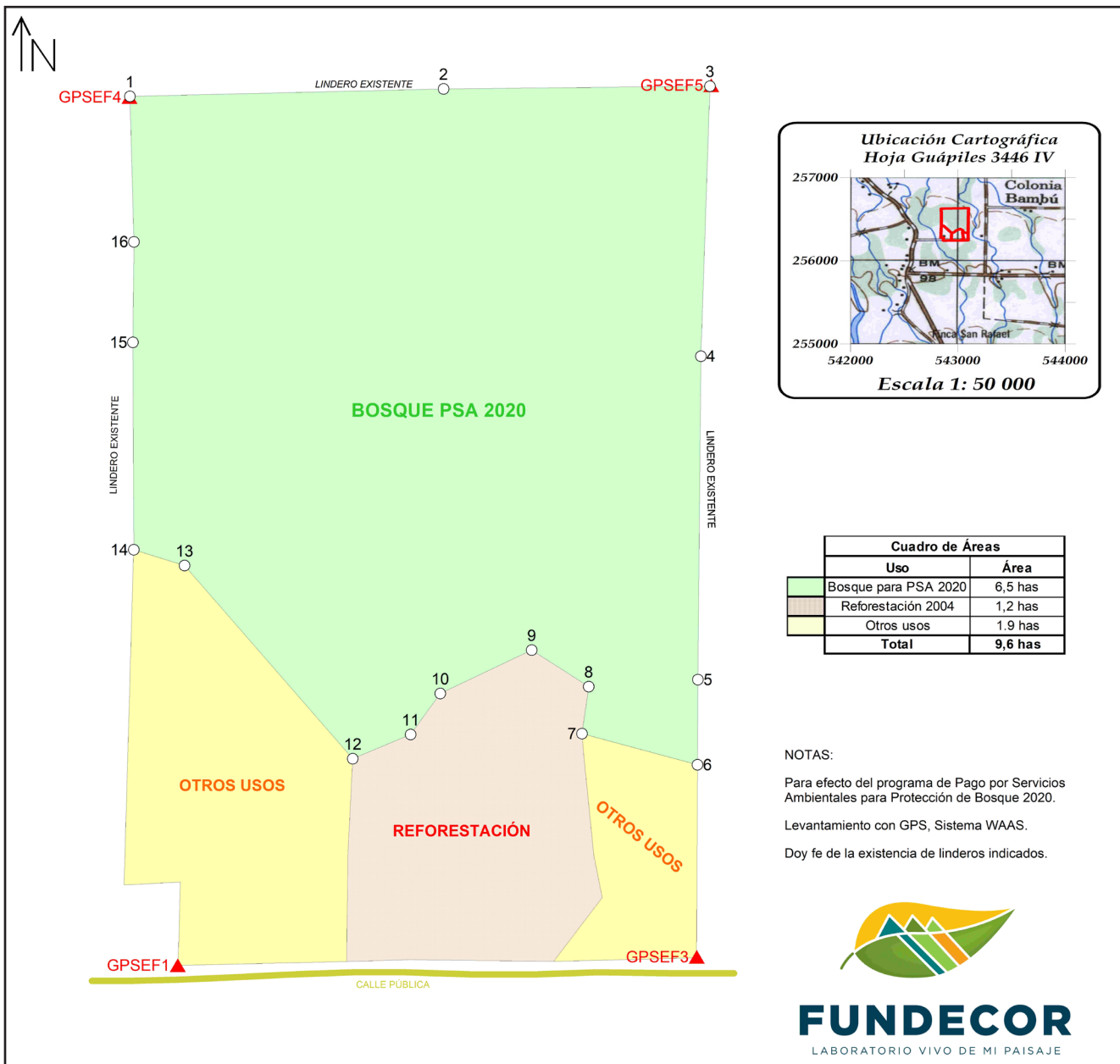


Figure 8: Map of Elicinio Flores Porras' Land

Elicinio Flores Porras

Porras oversees a 9.6-hectare farm primarily focused on forest conservation through PES, alongside dedicated areas for reforestation and other unspecified uses. A 6.5-hectare section of the land earned PES money in 2020. This property is primarily focused on forest conservation, aiming to address the threat of the tree cover loss indicator placed on his property. Porras's property is also surrounded by rivers as shown in the cartographic map, which is one reason that his property qualifies for the water priority indicator.

Table 2: Data from Elicinio Flores Porras' Land

Land Use	Area (ha)
Forest with PES 2020	6.5
Reforestation 2004	1.2
Other Uses	1.9
Total	9.6

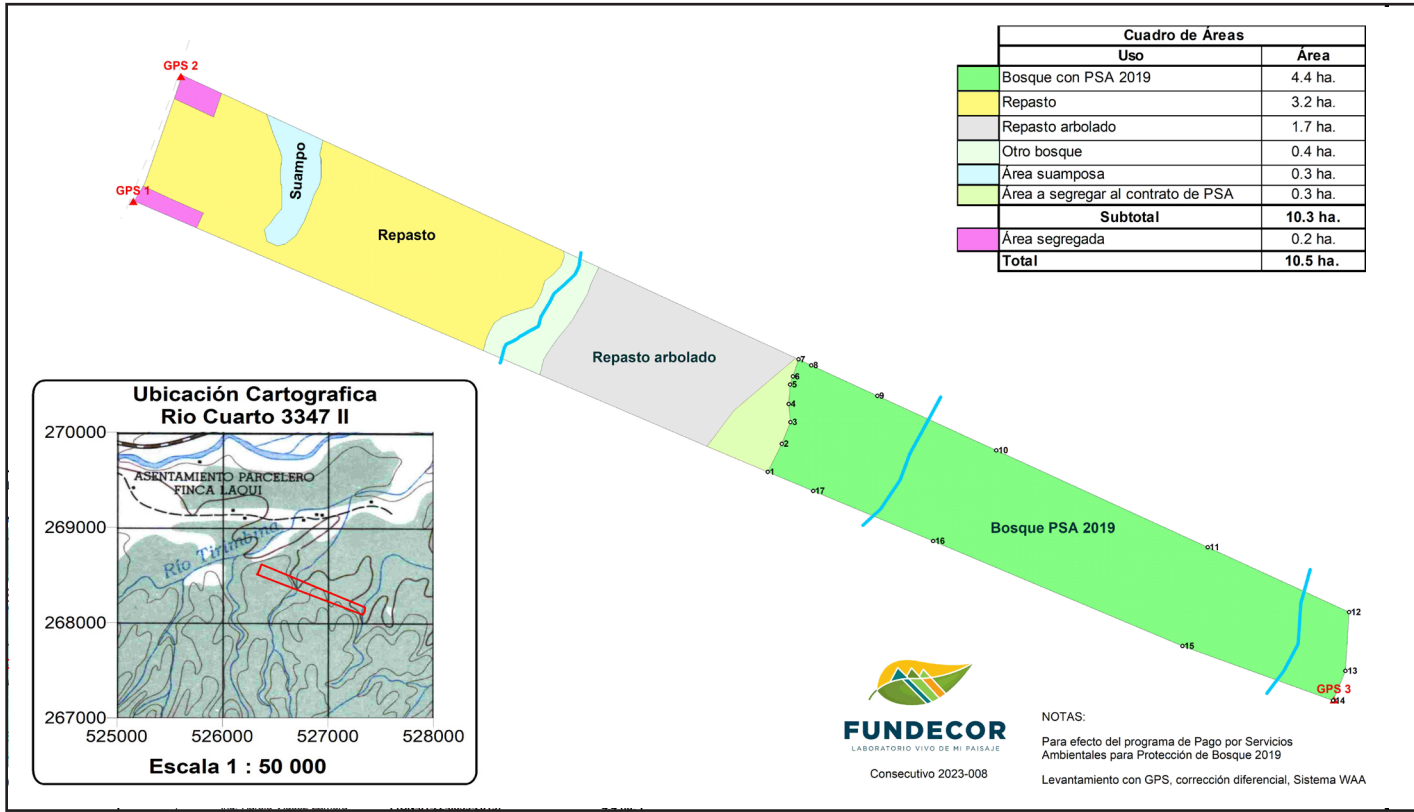


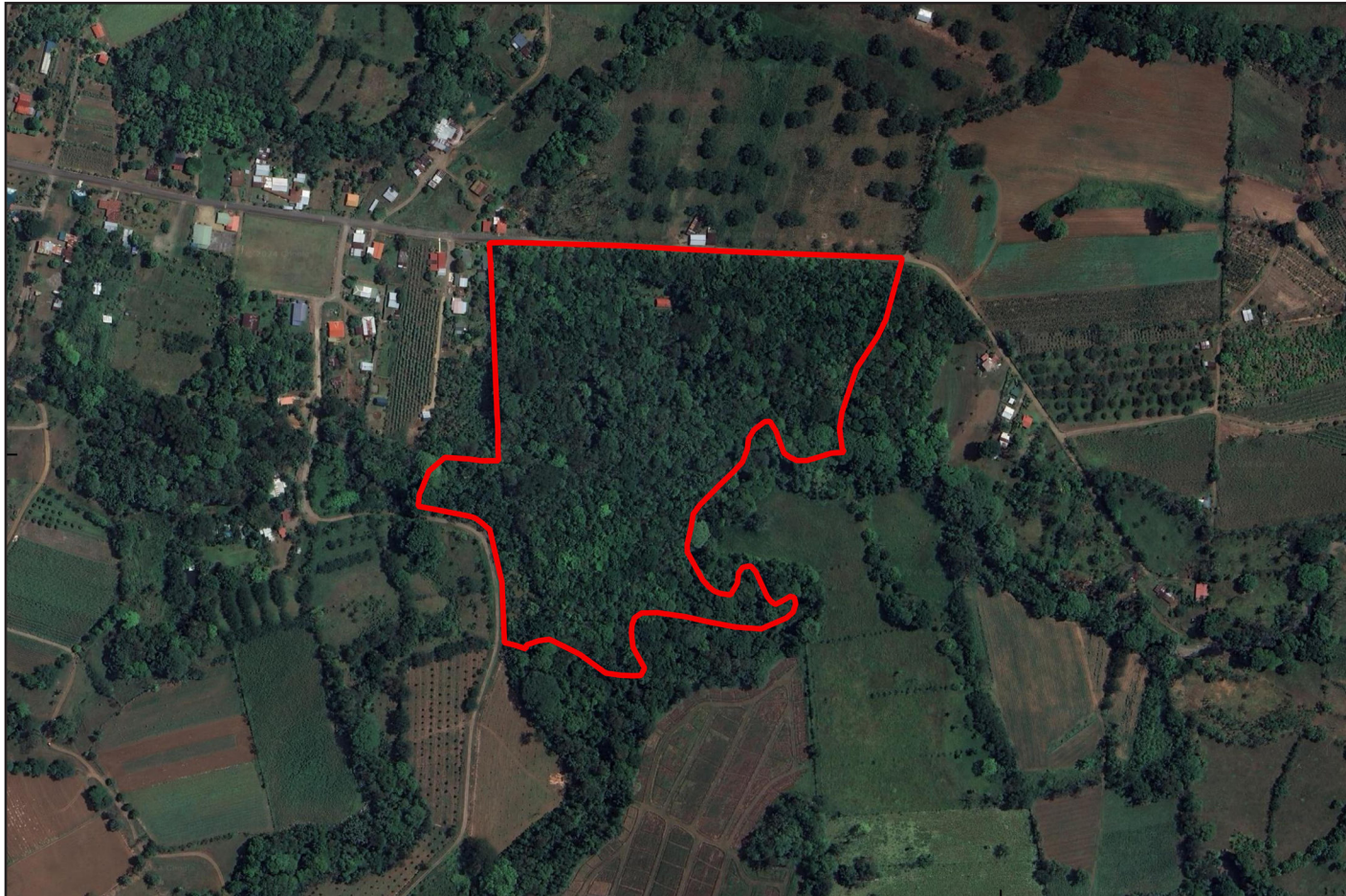
Figure 9: Map of Ingrid Mabel Quirós Vargas's Land

Table 3: Data from Ingrid Mabel Quirós Vargas's Land

Land Use	Area (ha)
Forest with PSA 2019	4.4
Pasture	3.2
Wooded Pasture	1.7
Other Forest	0.4
Swamp Area	0.3
Area to be segregated from PSA contract	0.3
Subtotal	10.3
Segregated Area	0.2
Total	10.5

Ingrid Mabel Quirós Vargas

Vargas's 10.5-hectare farm features a diversified land use pattern, significantly emphasizing forest conservation ("Forest with PES 2019"), pasture, and wooded pasture lands. This blend of uses indicates a strategic approach to combining forest conservation with agriculture, aiming to sustain biodiversity alongside livestock productivity. Vargas reports many animal species migrating through her property, hence her land qualifying for the biological corridor indicator. Other forest areas and a swamp further diversify the habitat, contributing to the ecological complexity of the plot, as well as the reason for the water priority indicator being placed on her property.

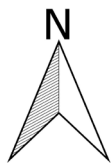


David Reuland - Finca Oasis

A detailed land use breakdown was not provided for Reuland's Finca Oasis. A small portion of the 11 hectares is dedicated to agricultural land for Reuland's personal use and lodging. Much of the land consists of rainforest regenerated over the past 20+ years through dedicated reforestation efforts.

The project began in 2002 with the idea of restoring highly deforested land that was previously used for agriculture and grazing to a functional tropical forest ecosystem. Throughout Reuland's reforestation efforts, more than twelve thousand trees, palms, vines, orchids, and bromeliads have been planted. All species were selected and planted by hand. This process has helped to change the microclimate and facilitate natural healing and the return of native flora and fauna.

The property now supports over 350 native species of trees and palms and about 100 endangered species of flora and fauna from the IUCN Red List³³ including several endangered palm species. The project has encouraged natural regeneration, supported by the proximity to Arenal National Park and large streams, which make his property qualify for the water priority indicator.



Leyenda

 Finca Oasis

0 100 200 300 m

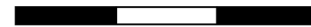


Figure 9: Map of Ingrid Mabel Quirós Vargas's Land

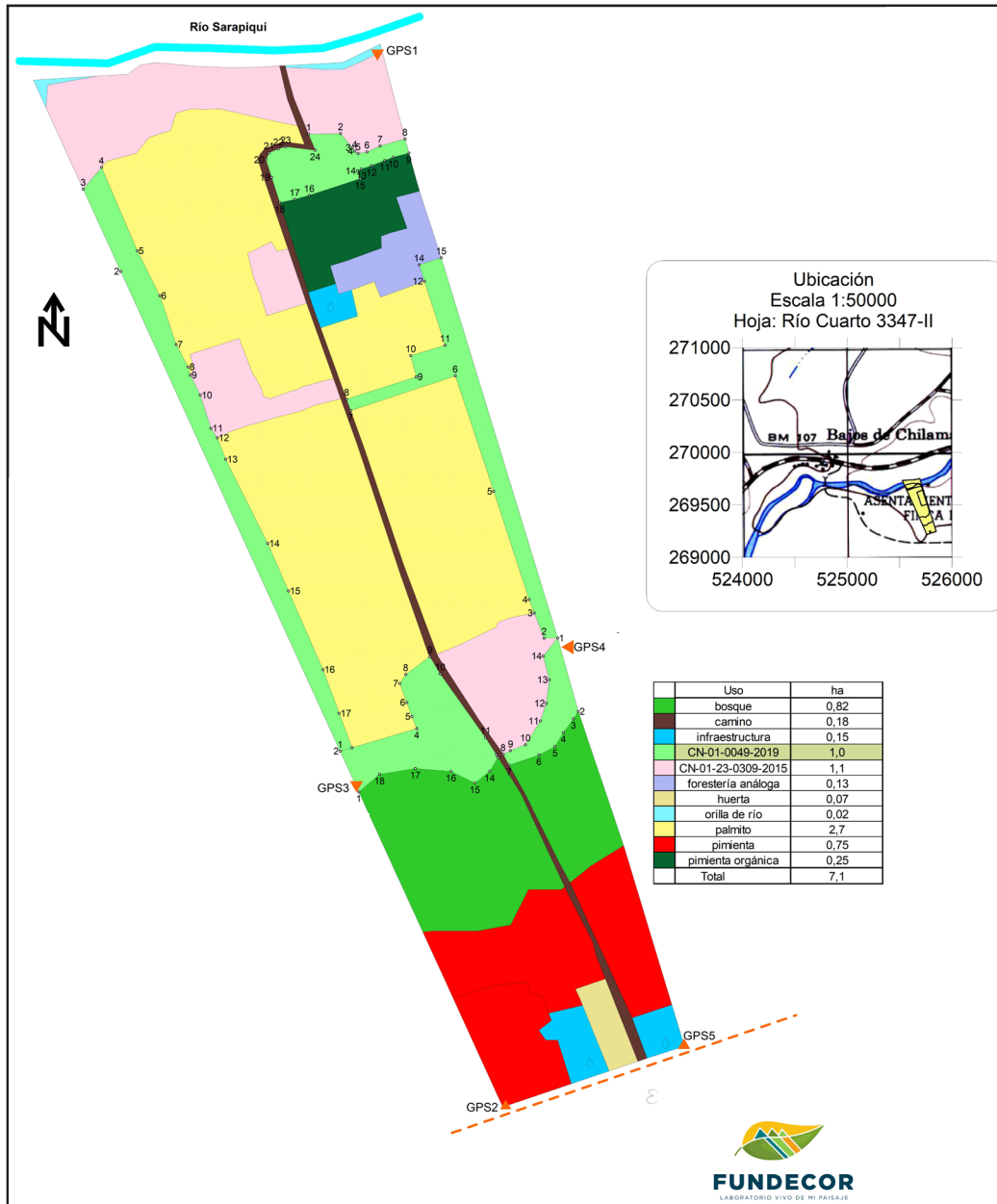


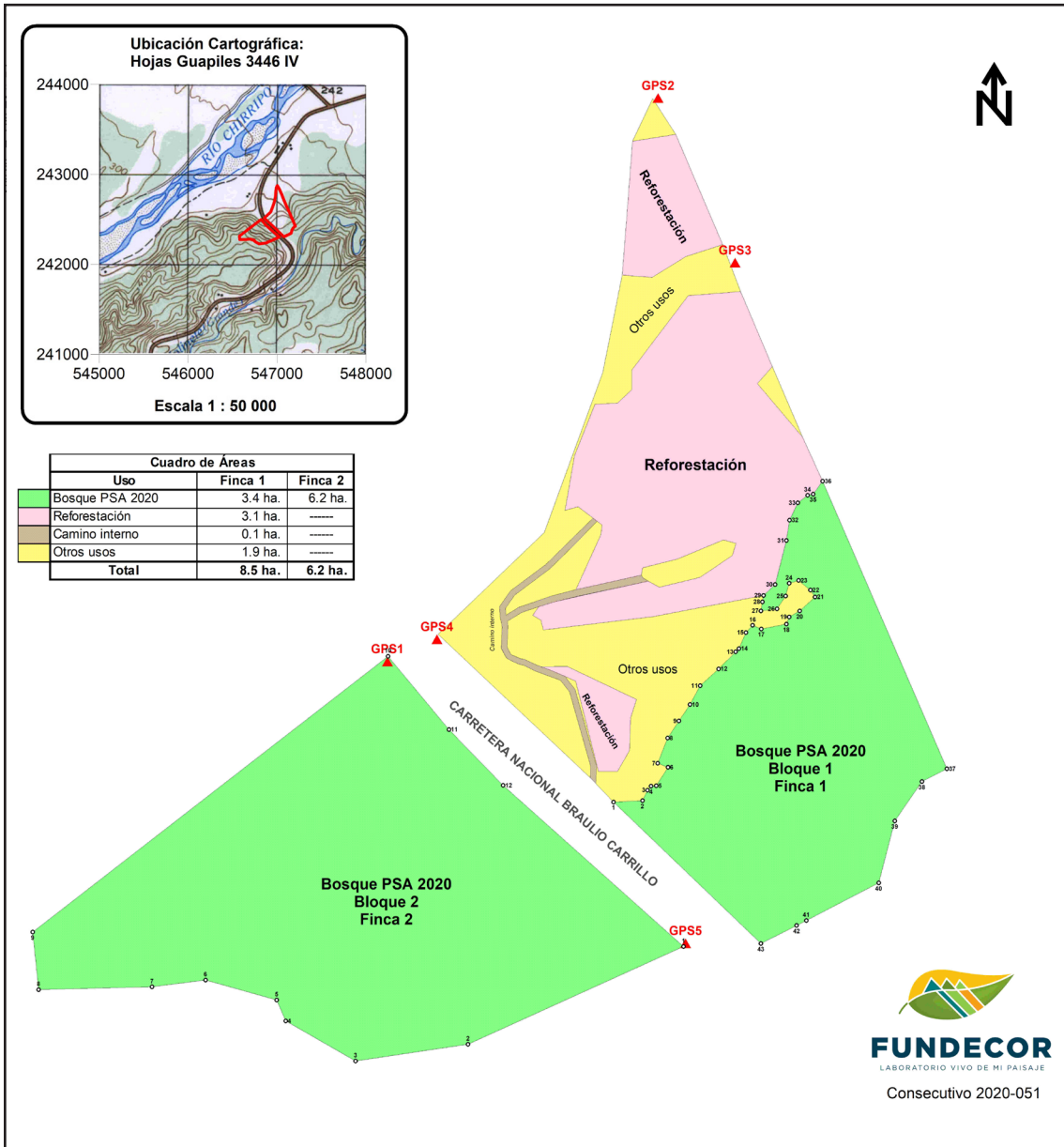
Figure 11: Map of Pedro Garcia Rueda's Land

Table 4: Data from Pedro Garcia Rueda's Land

Land Use	Area (ha)
Forest	0.82
Road	0.18
Infrastructure	0.15
Forest with PES 2019	1.0
Forest with PES 2015	1.1
Analog Forestry	0.13
Garden	0.07
Riverbank	0.02
Palm	2.7
Pepper	0.75
Organic Pepper	0.25
Total	7.1

Pedro Garcia Rueda

Rueda's 7.1-hectare farm presents a diversified land-use approach, integrating forest preservation with agricultural activities, similar to Vargas's property. As previously stated, both Vargas and Rueda qualify for the biological corridor indicator due to reports of many animal species migrating through their respective properties. The farm is segmented into various blocks dedicated to forest conservation under the PES program for different years, alongside areas allocated for cocoa, analog forestry, garden cultivation, and significant palm and pepper production portions. This distribution shows a balanced integration of sustainable agriculture with environmental stewardship, showing the farm's role in promoting biodiversity while ensuring agricultural productivity. The successful promotion of biodiversity earned Rueda's property the biodiversity indicator, and his property's close vicinity to the Sarapiquí river also makes it qualify for the water priority indicator.



Isaias Arguedas Arce

Arce's property, encompassing 8.5 hectares, dedicates a substantial portion to forest conservation, with "Forest PSA 2020 Block 2" and "Block 1" making up most of the land. An additional 3.1 hectares are earmarked for reforestation efforts. As shown in the cartographic map, the left side of Arce's property is especially steep, and with the freeway running in between the two halves, preventing soil erosion and landslides is very important for the safety of the area, which is one reason the property may qualify for the protected wildlife areas indicator. The steepness of that left side also makes it very inaccessible for human endeavors, which could benefit the biodiversity of the property, qualifying it for the biodiversity indicator. Rivers running around the property also qualify it for the water priority indicator.

Table 5: Data from Isaias Arguedas Arce's Land

Land Use	Area (ha)
Forest PSA 2020 Block 1	3.4
Forest PSA 2020 Block 2	6.2
Reforestation	3.1
Internal Road	0.1
Other Uses	1.9
Total	8.5

Figure 12: Map of Isaias Arguedas Arce's Land

Obtaining Personal Testimonies from the Owners of Small Farms in Sarapiquí

Our team visited Sarapiquí for one week to collect firsthand information about the farms for which we were to create profiles. During that week, we visited one farm per morning from Monday to Friday, for 5 farms in total. Throughout the week, we were guided by Cordoba, Zuñiga, Piedra, Randy Herrera Miranda, a technical assistant of ecosystem management, and Carla Solis Escobedo, an economic expert who works closely with the landowners that FUNDECOR oversees. Once back at the FUNDECOR office in Sarapiquí each afternoon, we organized our collected data with guidance from the employees.

FUNDECOR supports over 300 farms in the Sarapiquí region and Costa Rica as a whole, and these farms all have profiles that FUNDECOR oversees. Prior to this fieldwork, our sponsors narrowed down the 5 farms from this extensive list. The farms are small, family-owned, and chosen by how willing the farmers and their families were to be interviewed and interact with us. Variety between these 5 farms was important to see a broader range of perspectives, so farms that are spread out in the Sarapiquí region were chosen so that we could see the differences in their flora and fauna and the families' living situations.

Interviews with the families that run each farm were critical to the information collection process. Conversations with Zuniga helped us further refine our interview questions for the farmers so we could get all the necessary information we were looking for pertaining to the use of their land for farming and/or forest conservation. The informed consent form that was distributed to all interview participants includes all our finalized interview questions listed (*See Supplementary Materials, B*). The interviews included specific questions about the crops the farmers grow,

common animal and plant species in the region, perceived changes in biodiversity, challenges of farming in the region, the farmers' perspective on sustainability and sustainable practices, and the impact that investments through the BIOTA program could have on their families' livelihoods. By spending a day at each farm, the research team gathered the owners' unique narratives. The team took detailed notes, and audio was recorded to ensure no information was lost. These notes and audio recordings were transcribed, translated, and used to develop their profile descriptions, adding qualitative depth to their testimonies. This ensures a thorough understanding of sustainable farming from both technical and human perspectives, highlighting these small-scale farmers' individual challenges and triumphs. Also, each farm was extensively photographed to capture the physical representation of sustainability and biodiversity, such as birds, mammals, plant species, and the landowners themselves.

The Landowner's Personal Perspectives

After visiting the 5 small properties in the Sarapiquí regions of Costa Rica, the landowners' unique experiences and perspectives both stood in comparison to one another, as well as shared some commonalities. All their properties include both conserved forest areas as well as areas where they farm crops or raise livestock either for their own personal consumption, as in the cases of Porras and Reuland, or for sale as a source of income, as in the cases of Vargas, Rueda, and Arce. Common crops that they grow include yuca, heart of palm, bananas, potatoes, corn, pineapples, beans, tiquisque, and coconuts. Reuland and Rueda do not raise livestock, while Porras, Vargas, and Arce all raise chickens. Vargas also raises cattle. In their forests, common animal species include sloths, monkeys, armadillos, frogs, deer, bats, big cats, churingas, and many species of birds. Common tree species in their forests include Gavilan, Manu, oak, walking palm, Laurel, and Poro.



Pedro Garcia Rueda

Figure 13: Photo collage from Rueda's farm

All landowners noted observations of changes in biodiversity and environmental patterns due to climate change. Vargas and Arce noted shifts in bird migration, and Vargas and Rueda have noted uncommon species use their properties as biological corridors and have cited climate change as the contributor to this phenomenon. Porras and Reuland both noted their forests' regeneration, either naturally, as in Porras's case, or through planting trees, as in Reuland's case.



Ingrid Mabel Quirós Vargas

Figure 14: Photo collage from Vargas's farm

While each landowner expressed unique needs, economic challenges were a common theme in the interviews, with concerns about profitability and income generation from their land. All landowners receive payments through the PES system, and for Porras, Reuland, and Arce, these payments are some of their only sources of income. Vargas uses the additional income provided by the PES system to help cover municipal taxes, while Rueda saved up his PES income to help build a clean drinking water system on his farm. From the interviews and farm tours, all landowners also express a common desire for self-sufficiency in various aspects, such as growing their own crops and providing for their families. Some have unique initiatives like marketing organic plant fertilizer (Vargas), selling products from their farms (Vargas and Rueda), or engaging in ecotourism (Rueda). Despite economic challenges, all landowners have access to clean water, health services, and educational resources.

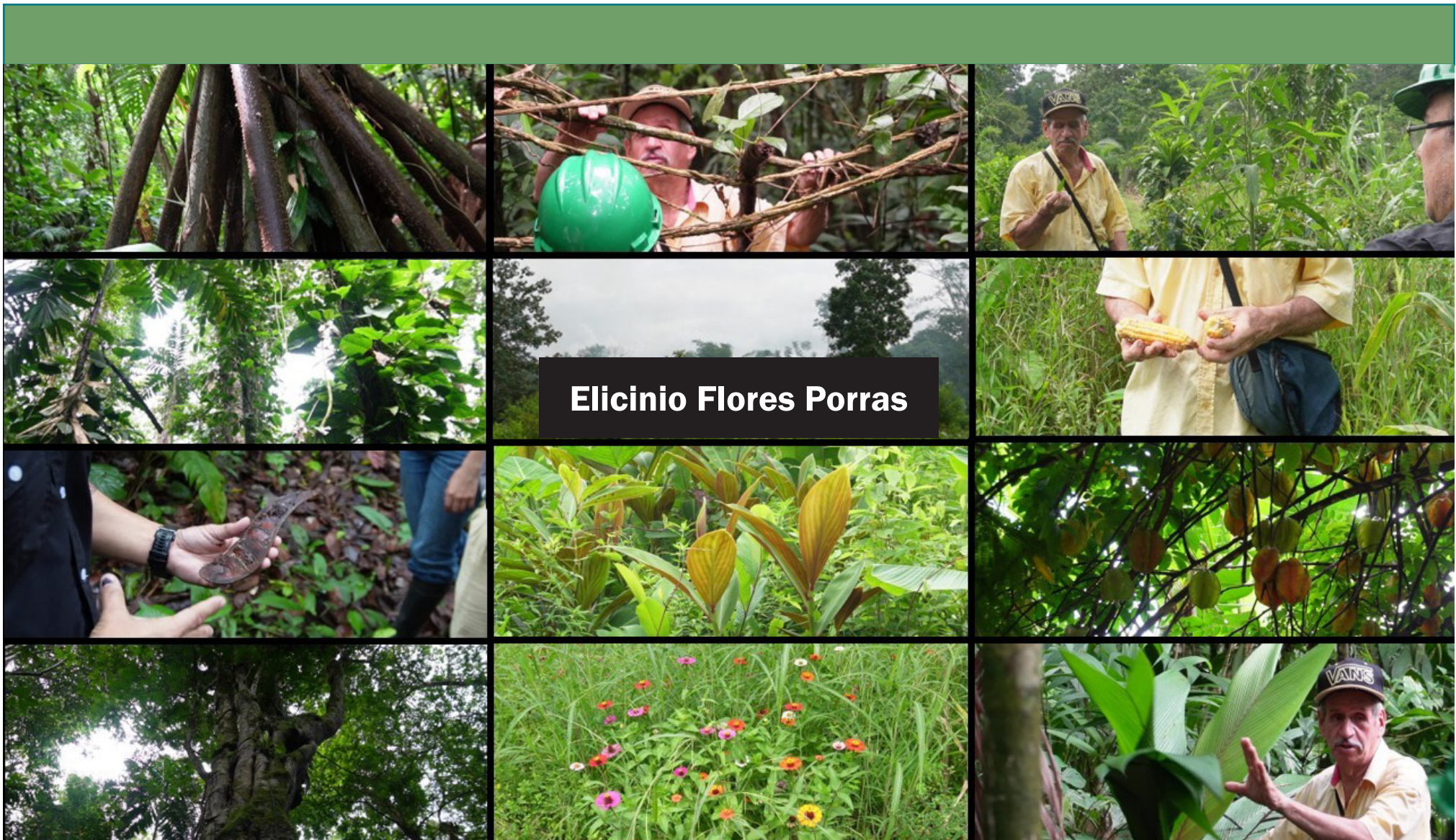
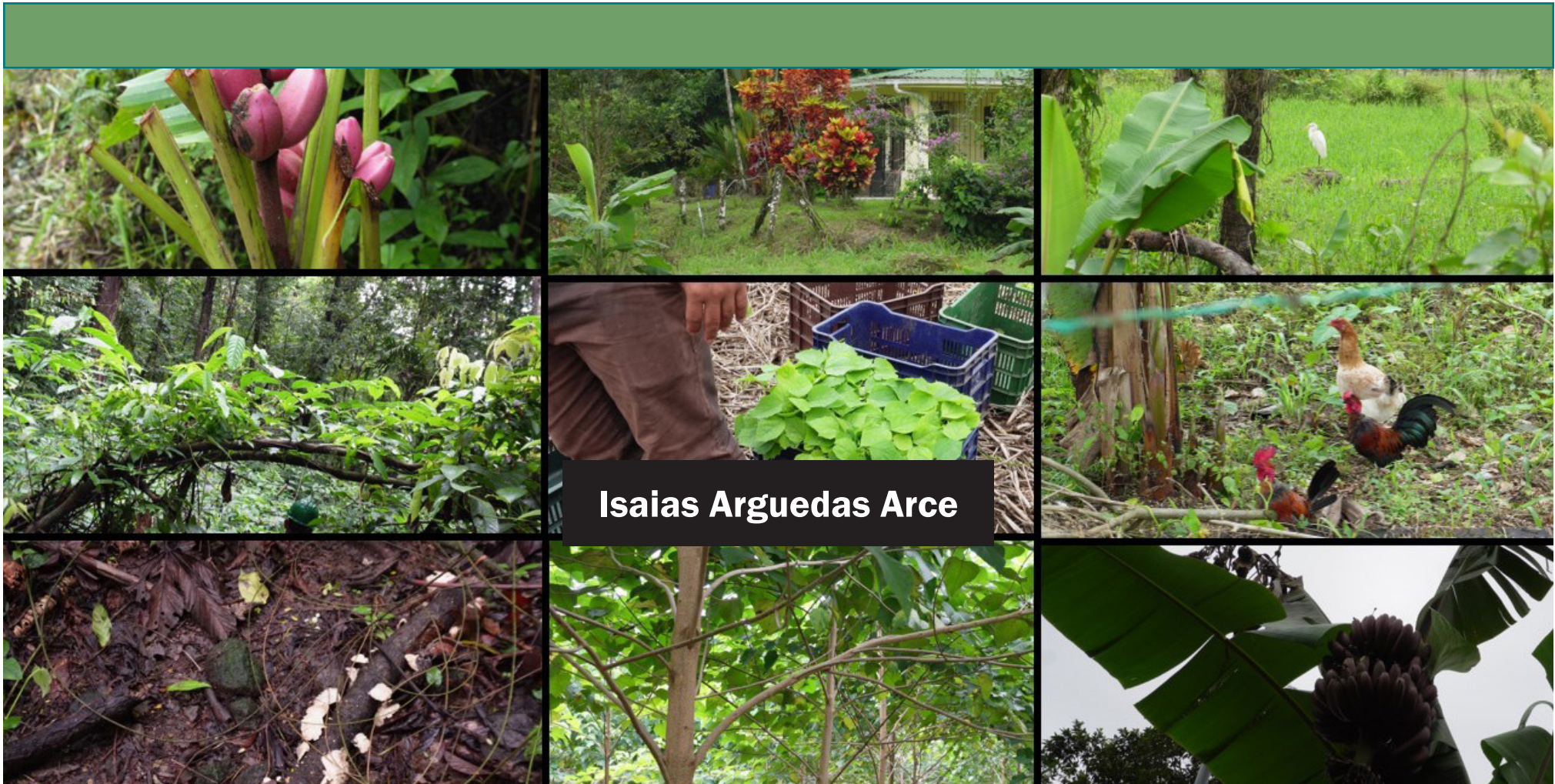


Figure 15: Photo collage from Porras's farm

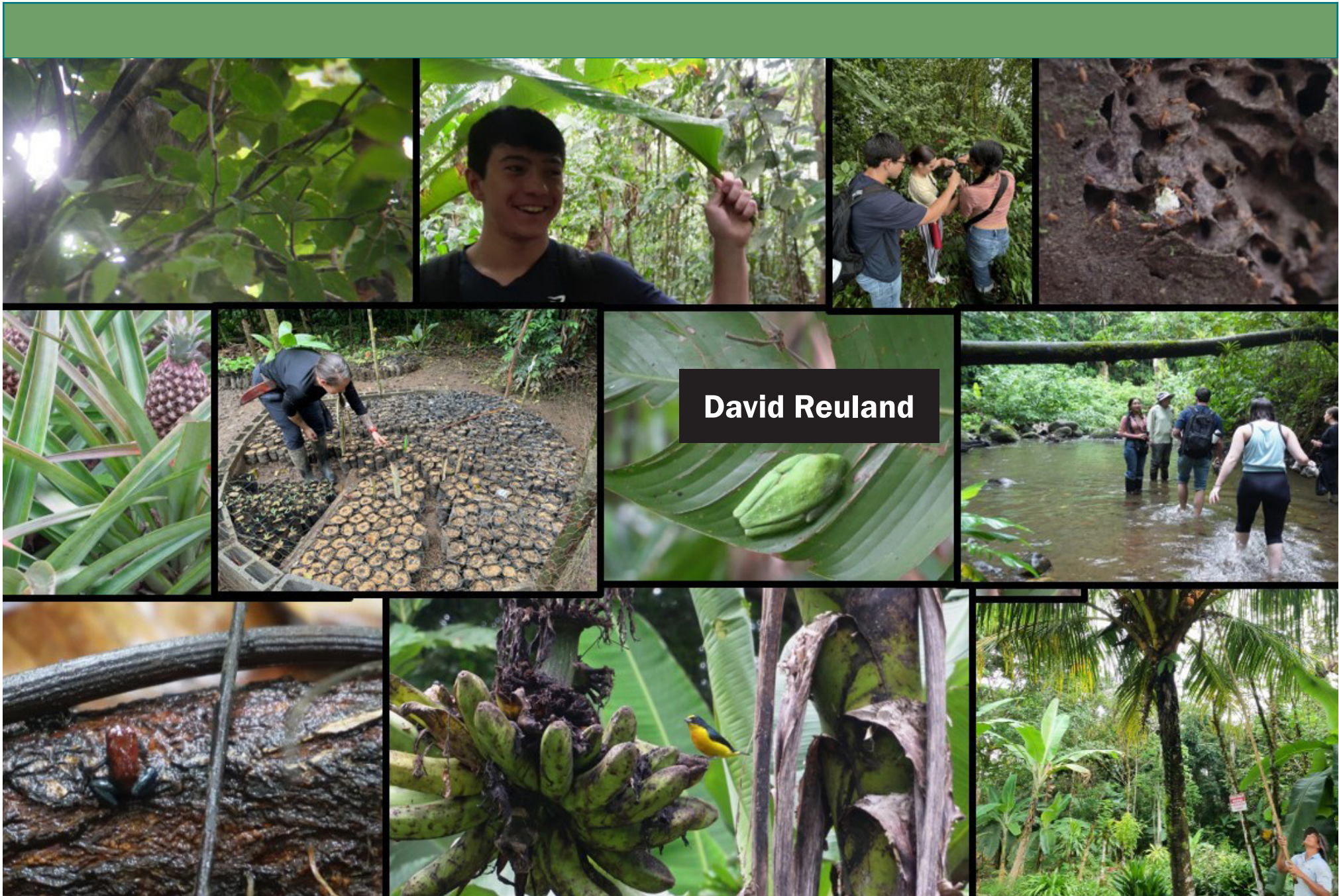
There is a shared commitment to protecting the environment and a recognition of the urgency to address issues like climate change and pollution. Deforestation caused by large plantations is highlighted as a significant problem affecting the health of the planet, and all landowners incorporate environmental sustainability into their lifestyles. All landowners engage in sustainable farming practices, such as conserving their forests, as in the case of Porras; reforestation, in the cases of Reuland and Arce; organic farming, manual weed removal, and the use of recycled fertilizers, as in Vargas's case; or in the case of Rueda, use their farms for environmental education, hosting students and participating in reforestation projects to raise awareness and contribute to conservation efforts.



Isaias Arguedas Arce

Figure 16: Photo collage from Arce's farm

All landowners described their relationship to FUNDECOR in a positive way. FUNDECOR plays a crucial role in supporting them through technical assistance and training. FUNDECOR has also educated them on the balance between conservation and economic support with the PES program. While appreciating PES payments, there is a common sentiment that the payments may be insufficient for the size of their land and the efforts put into conservation and reforestation. When asked about what they would put an increased amount of income towards, each landowner had a unique answer. Porras would use an increased income for his children's education. Vargas would buy a processor for her organic fertilizer. Reuland would invest in more land to reforest. Rueda would continue to develop his plant nursery. Arce would improve the fences and other infrastructure on his property. All their goals are different, but there is a shared interest in programs like BIOTA that aim to increase financial support for environmental services. While their specific circumstances and challenges vary, these individuals collectively represent a diverse group of landowners working towards sustainable practices and environmental conservation in the Sarapiquí region.



David Reuland

Figure 17: Photo collage from Reuland's farm

The Final Product – Adding the Small Farm Profiles to the BIOTA Website

After compiling all images and interview responses, we created a mockup of how the profiles were to look on the website. We also wrote descriptions for each farm to be included in the profiles. The visualization of the impact that FUNDECOR has had on farmer communities in Sarapiquí who struggle economically aims to bring awareness to their challenges and demonstrate the importance of this initiative to the public and potential investors.

All pictures, videos, audio files, transcriptions, translations, descriptions, Excel sheets, and KML outline files were provided to Solis, which were used to meticulously compile 5 individual, in-depth profiles of each farm. These comprehensive profiles were integrated into a new section of the BIOTA Geospatial Tools website, enriching it with valuable, ground-level insights into the region's agricultural landscape. The profiles provide an immersive and detailed view of each farm, contributing significantly to the understanding and documentation of sustainable agricultural practices in the region.

The outlines of each farm were added onto the BIOTA website with their respective profiles, and we analyzed the Geospatial Tool's global satellite data on tree forest cover and loss, carbon removal, and bird sightings for each property in tandem with the data from the farm profile maps to draw conclusions about FUNDECOR's environmental impact.

Final Design and Mockups of Farm Profiles

As shown in Figure 18, the mockup exactly mirrors the current look of the BIOTA Geospatial Tools website, as seen in Figure 5, with blank spaces to put images from the small forest and farms and images of the landowners. We also have a spot left open for a description of the farm based on the

information we gathered on the tours of the forest and the interviews. The personal testimonies explaining the unique perspectives and living situations of the farmers display the important social and economic aspects of the BIOTA program. Included in these descriptions is information about the lives of the forest owners and their families, the typical flora and fauna they see on their property, how the money they receive from PES has helped support them, how further funding could improve their forests and livelihood, as well as their relationship with FUNDECOR.

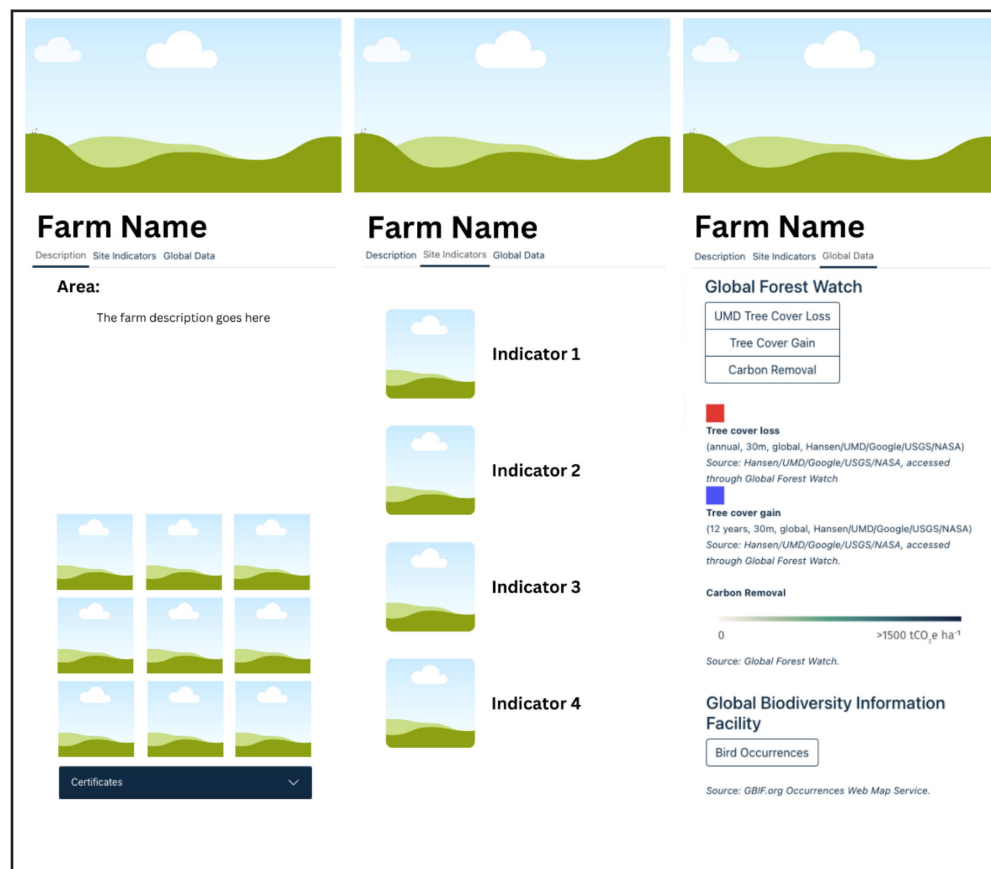


Figure 18: Mockups mirroring the current look of the website

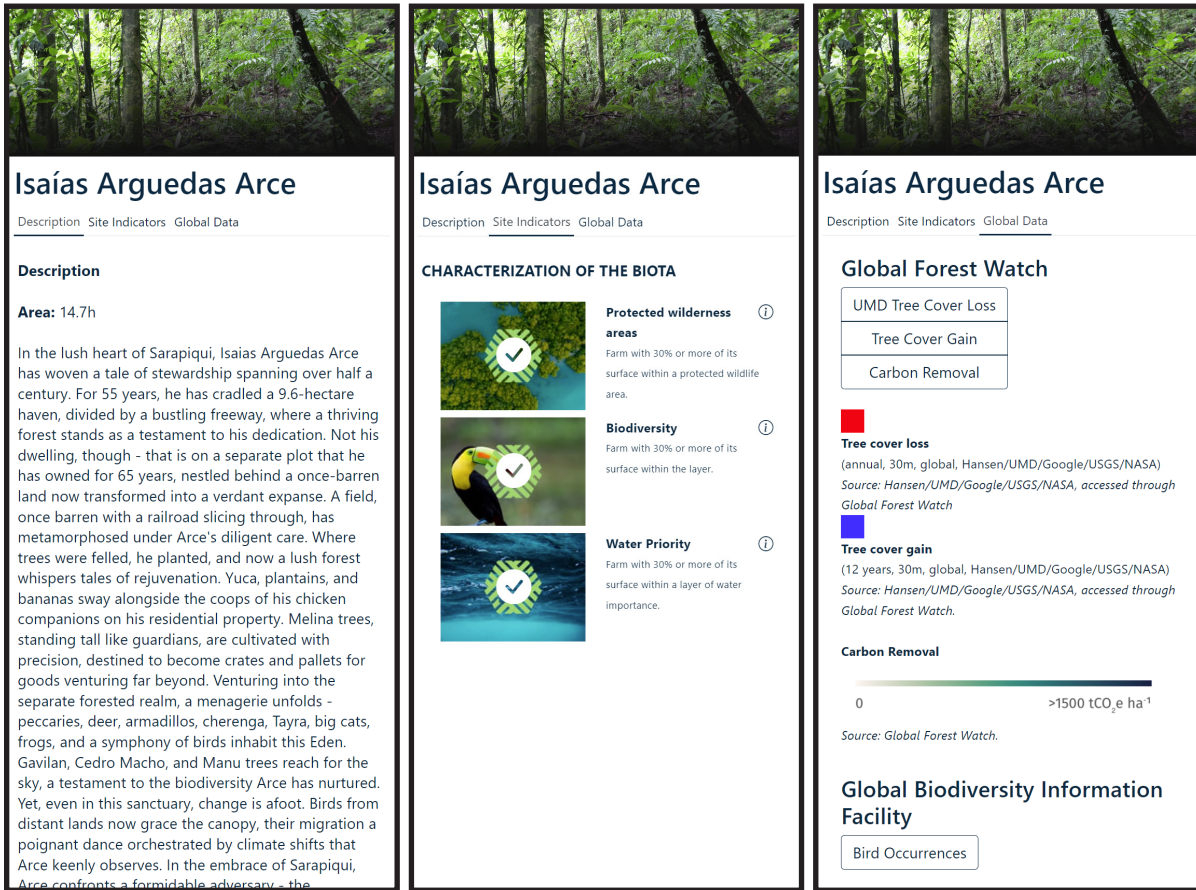


Figure 19: The farm profile for Isaiás Arguedas Arce's property as it appears on the BIOTA website²³

The global satellite data layers show tree cover loss in red, tree cover gain in blue, carbon removal on a scale of very light green for less removal to very dark green for more removal, and bird occurrences with shades of yellow, orange, and red signifying the frequency of the sightings. Small red areas of tree cover loss are seen on each property on the satellite imagery. Areas of blue are not seen on the satellite imagery of any of the properties, meaning that tree cover gain was not observed. All properties have a thin green film over them in the satellite imagery, meaning that low, but not insignificant, amounts of carbon removal were observed. The bird occurrences layer is a bit more nuanced, as it is not really

a reflection of the actual bird population in the area, but a reflection of how many have been reported by humans. Most of the properties only have one or two bird occurrences reported in close proximity to freeways; it is not that the bird population is higher around freeways, but since human activity is higher on freeways, freeways are where they are seen by humans the most. Rueda's property is the only exception as shown in Figure 20, with quite a few bird occurrences observed, but as he hosts many visitors on his property, there are more people there to report the bird sightings.



Figure 20: Satellite image of Rueda's land as it appears on the BIOTA website²³

Conclusion

The 8 indicators – biodiversity, biological corridor, conservation gap, loss of tree coverage, protected wilderness areas, Social Development Index, water priority, and wetlands – allow FUNDECOR'S BIOTA program to assess the biodiversity of each of the 300+ farms that the organization oversees. The BIOTA biodiversity credit system recognizes the gap between the small amount of funding that the PES system provides, and the much larger value that forest land in Costa Rica provides through vital public goods and life-sustaining properties such as air and water quality and carbon sequestration. The BIOTA program has the potential to generate funding that could be a viable solution for landowners who seek increased income and support for their land. Each property of land that FUNDECOR oversees is vastly different, and their landowners all have different goals for the use of their land, but all of them unite over their shared commitment to sustainable practices and environmental conservation. FUNDECOR and the small landowners of Sarapiquí that are participants in the PES system have a very unique and important relationship when it comes to sustainability and protecting the forest land of Costa Rica, and the challenges and successes of these landowners are now rightfully recognized on the Geospatial Tool's tab of the BIOTA website to continue to promote environmental conservation.

Recommendations for FUNDECOR

To aid FUNDECOR's efforts in showcasing sustainable farming, it is vital to go beyond these five farms and keep **developing in-depth profiles for all of the farms** tracked by FUNDECOR. We suggest that the profiles, tailored to captivate both potential investors and future landowner participants, should highlight the direct benefits and significant returns on investments through focused communication strategies and the power of testimonials to gain trust and attract contributions. Similarly, by spotlighting the practical advantages and success stories from current participants in FUNDECOR-led education and conservation efforts, and leveraging local networks and educational initiatives, these narratives will illuminate the opportunities provided by the potential BIOTA program.

Our group recommends **expanding the storytelling toolkit to include videos and interactive online platforms** to boost the profiles' emotional impact and informative value. Social media campaigns can also be utilized to spread FUNDECOR's message. We also recommend **establishing mechanisms for receiving feedback from the farmers**, the FUNDECOR team, and the broader community on the BIOTA website where the profiles and testimonies are published. The feedback received can be used to refine and improve future storytelling efforts. This approach not only aims to broaden the program's visibility and support, but also ensures the continuity and expansion of FUNDECOR's mission with BIOTA NEXUS.

As the BIOTA program evolves, **monitoring the impact of the farm profiles over time** becomes essential. This involves tracking how effectively the profiles engage investors and beneficiaries, assessing changes in support levels, and evaluating the program's success in expansion efforts. By analyzing these trends, FUNDECOR can refine its strategies, ensuring that the storytelling continues to engage readers and drive the program's goals forward. This constant expansion and evolution of strategies is the key to maximizing the effectiveness and overall impact of the potential BIOTA program.

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Executive Summary

Deforestation poses significant threats to Earth's ecosystem, disrupting biodiversity and hindering natural carbon sequestration¹. Despite its profitability for activities like mining and agriculture, the environmental consequences, such as climate change, are severe. Global reforestation initiatives, though crucial, often neglect the economic aspect for landowners, rendering these efforts less effective².

Proper financial resources and training on sustainable farming practices provide the foundation for successfully integrated reforestation initiatives³. This is especially important for families living on small farms. While larger scale projects and forestry management initiatives usually benefit from government funding, smaller scale farms are at a disadvantage due to not qualifying for this assistance. Ensuring the sustainability of small farms adds up to big environmental impact, as half of the world's habitable land is used for agriculture⁴. Sustainable farming practices, if broadly implemented, can help prevent issues like soil destruction and further forest deterioration⁵.

The Foundation for the Development of the Central Volcanic Mountain Range (FUNDECOR), a Costa Rican non-profit and non-government organization, is on a mission to enhance both natural sustainability and economic development through land management. One of their slogans that defines this goal is “con hambre, no hay conservación,” which translates to “with hunger, there is no conservation,” communicating that without proper economic support to put food on the table, people will be less interested in choosing more sustainable, at times less profitable, farming practices. To address this, initiatives like FUNDECOR's Biodiversity Conservation Mechanism using Blockchain (BIOTA) program focus on both environmental sustainability and economic development. However, the current database lacks representation of small farms, hindering public awareness.



Our project highlights BIOTA's potential impact in Sarapiquí by creating profiles for five small farms. We focused on four objectives:

1. Assessing BIOTA's biodiversity indicators by conducting research with respect to the five farms we studied
2. Learning more about the BIOTA program by consulting with FUNDECOR's executive director
3. Researching the integration of the small farms onto the Geospatial Tools map by analyzing the land use maps of the five farms and by consulting the BIOTA website's administrator
4. Obtaining personal testimonies from the owners of small farms in Sarapiquí by touring the five farms, photographing their properties, and interviewing the landowners

The resulting farm profiles, added to the Geospatial Tools tab on the BIOTA website, illustrate the environmental and economic successes of the farms that FUNDECOR oversees. By highlighting the real-world impact on these properties, our project aims to attract funding, encourage participation, and promote BIOTA to a wider audience.

BIOTA's Biodiversity Indicators

The eight BIOTA indicators—biodiversity, biological corridor, conservation gap, loss of tree coverage, protected wilderness areas, Social Development Index (SDI), water priority, and wetlands—were developed collaboratively by FUNDECOR staff. The indicators, approved by the Costa Rican government, aim to assess environmental sustainability and agricultural practices⁶. The

biodiversity indicator identifies farms essential for maintaining Costa Rica's biodiversity, following the UNDP methodology implemented by MINAE and PRIAS⁷. Biological corridors, established by SINAC, connect protected wild areas, addressing habitat fragmentation caused by industrial activities⁸. The conservation gap indicator identifies farms in crucial conservation areas. The loss of tree coverage indicator employs machine learning to predict tree cover loss⁶. Protected wilderness areas include Forest Reserves, National Parks, and Wildlife Refuges⁶. The Social Development Index (SDI) identifies farms in districts with a very low index, reflecting limited human development⁹. The water priority indicator assesses farms in areas crucial for water conservation¹⁰. The wetland indicator assesses farms based on proximity to national wetlands¹¹. As shown in the table below, our analysis revealed varying levels of qualification across the eight indicators, providing valuable insights into FUNDECOR's biodiversity initiative. A 1 indicates the farm receives that indicator while a 0 means they do not qualify.

The 8 Biodiversity Indicators for the 5 Farms

Farm	Protected Wilderness Areas	Biological Corridor	Water Priority	Wetlands	Low SDI	Biodiversity	Prediction of Tree Loss	Conservation Gaps
Elicinio Flores Porras	0	0	1	0	0	0	1	0
Isaías Arguedas Arce	1	0	1	0	0	1	0	0
Juan José Umaña Molina (Ingrid Mabel Quirós Vargas)	0	1	1	0	0	0	0	0
Pedro García Rueda	0	1	1	0	0	1	0	0
Proyectos Oasis Reforestación S.A.	0	0	1	0	0	0	0	0

The BIOTA Program

Changing lifestyles and eco-friendly practices demand alternative funding methods for land preservation. The BIOTA program addresses this gap, valuing public goods provided by forests. RAMSAR assessed forest land, assigning a value 25 times higher than the Payment for Environmental Services (PES) amount¹². BIOTA aims to provide landowners with fairer compensation through a biodiversity credit system. Piedra emphasized BIOTA's unique funding approach, targeting large corporations through blockchain-based biodiversity credits. These smart contracts, purchased online, represent land in hectares, providing companies with certificates and detailed land information. The program aligns with corporate incentives such as philanthropy, ESG investing, and carbon offsetting. The growing trend of ESG investments globally supports the program's potential success¹³. Though currently in the proof-of-concept phase, ongoing marketing efforts aim to attract investors by creating personalized farm profiles. BIOTA's win-win model benefits investors, recipients, and the environment, offering a more sustainable alternative to the PES system's insufficient 65 USD per hectare annual funding for landowners.

Analysis of Land Use Maps

Analyzing sustainable land use, each property showcases unique commitments to environmental preservation. Porras's 9.6-hectare farm prioritizes forest conservation and is surrounded by rivers, addressing the tree cover loss indicator and water priority indicator. Vargas's 10.5-hectare farm blends forest conservation with agriculture, fostering biodiversity, and earning the biological corridor and water priority indicators. Reuland's Finca Oasis, an 11-hectare property, emphasizes rainforest regeneration over 20+ years, supporting over 350 native species, and qualifies for the water priority indicator. Rueda's 7.1-hectare farm, like Vargas's, integrates forest preservation with agriculture, earning the biodiversity, biological corridor, and water priority indicators. Arce's 8.5-hectare property dedicates a significant portion to forest conservation and reforestation, and its steep left side facing the freeway and rivers qualify it for protected wildlife areas, biodiversity, and water priority indicators.

The Landowner's Personal Perspectives

The farms displayed commonalities and distinctions. All integrated conserved forest areas with crops or livestock farming. Common crops include yuca, heart of palm, bananas, potatoes, corn, pineapples, beans, tiquisque, and coconuts. Livestock varied, with some solely for personal use. Forests harbored diverse species, with observations of climate-induced changes. Economic challenges were a recurring theme, addressed partly through PES payments. Clean water, health services, and education were accessible to all landowners. Despite challenges, a shared commitment to environmental protection emerged. Landowners engaged in sustainable practices, supported by FUNDECOR. Economic concerns were evident, and increased income would be directed towards their children's education, infrastructure, or farming improvements. While facing distinct challenges, these landowners collectively represent a diverse group committed to sustainable practices and environmental conservation in Sarapiquí.

Descriptions for each farm, enriched with multimedia content, were integrated into a new section of the BIOTA website. These comprehensive profiles offer detailed insights into sustainable agricultural practices in Sarapiquí, showcasing FUNDECOR's impact. The website mirrors the mockup. Each farm profile includes personal testimonies, highlighting social and economic aspects, with data layers indicating tree cover loss, carbon removal, and bird occurrences.

The 8 indicators in FUNDECOR's BIOTA program assess biodiversity, conservation, tree coverage, and more across 300+ farms. Addressing the gap in PES funding, BIOTA's credit system values vital public goods from Costa Rican forest land, offering a potential income solution for landowners committed to sustainability. Despite diverse land goals, FUNDECOR and Sarapiquí landowners, united in environmental conservation, are spotlighted on the BIOTA website's Geospatial Tool tab, showcasing their unique relationship and contributions to forest protection.

Based on our findings, we recommend that FUNDECOR:

1. Go beyond these five farms and keep developing in-depth profiles for all the farms tracked by FUNDECOR
2. Expand the storytelling toolkit to include videos and interactive online platforms, such as social media
3. Establish mechanisms for receiving feedback from the farmers, the FUNDECOR team, and the broader community on the BIOTA website where the profiles and testimonies are published
4. Monitor the impact of the farm profiles over time

List of acronyms:

- UNDP - United Nations Development Program
MINAE - Ministry of Environment and Energy
PRIAS - Laboratorio Programa de Investigaciones Aerotransportadas y Sensores Remotos
SINAC - National System of Conservation Areas

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Elicinio Flores Porras

In the heart of the Sarapiquí region in Costa Rica, Elicinio Flores Porras, a retired Ministry of Environment and Energy employee, tends to his cherished property with a rich history dating back to the days when the land had no owner. Some 70-80 years ago, the Costa Rican government allocated vast stretches of land to banana companies, reserving the best for cultivation, and returning the rest for governmental management. The Rural Development Institute, born in 1961, distributed this reclaimed land to families, and Porras became the proud steward of 6.5 hectares in 1976. Porras' land tells a tale of resilience and natural regeneration. Within its boundaries, 5 hectares stand tall with the wisdom of centuries in the form of primary forest, while 1.5 hectares boast the vibrant energy of 30-year-old secondary forest, a testament to the enduring cycles of nature. The ancient canopy above the primary forest continues its age-old dance, absorbing the summer sun and embracing carbon dioxide as it has done for generations.

This haven of biodiversity is not just a home for Porras and his family; it is a thriving ecosystem where monkeys, squirrels, deer, sloths, iguanas, birds, and bats coexist among the towering trees like Gavilán, Laurel, Guácimo, Pilón, oak, and the mystical walking palm. In this green sanctuary, Porras cultivates a variety of crops for his family's sustenance—corn, yuca, sweet potato, heart of palm, peanuts, coffee, sugar cane, and star fruit, complemented by the cheerful presence of chickens. His property, a treasure trove of indigenous knowledge, whispers tales of vines turned into baskets and leaves transformed into roofing, echoing the traditions of those who once walked these lands. The natural symphony is accompanied by abundant water sources, and the occasional heavy storm serves as a reminder of the land's natural temperament.

However, Porras faces a challenge familiar to those who embrace self-sufficiency—maintaining it. Despite the convenience of purchasing pre-made corn tortillas, Porras takes pride in grinding his own corn, crafting tortillas from scratch, a testament to his unwavering belief in the natural way.



When it comes to environmental conservation, Porras stands as a staunch advocate, describing it as "medicine for the planet." Gratitude fills his voice as he acknowledges the payments from the Payment for Environmental Services (PSA) system that reward him for leaving the forest untouched, channeling the income towards his children's education. While he once rented out portions of his land to fellow farmers, Porras now relies solely on pensions and the PSA system for his livelihood.

In the ongoing story of Porras' connection to the land, FUNDECOR plays a pivotal role. His relationship with the organization is marked by camaraderie and support. Regular check-ins from FUNDECOR employees ensure the well-being of his land, and opportunities to deepen his understanding of sustainable land management have strengthened his bond with the organization. As Porras looks toward the future, he envisions potential prosperity through FUNDECOR's BIOTA initiative. With increased income, he dreams of supporting not only himself but also his family, weaving a brighter, sustainable chapter into the ongoing narrative of his life and land.

Ingrid Mabel Quirós Vargas

Ingrid Mabel Quirós Vargas, a former high school biology instructor, shares her life nestled near the El Roble area of Sarapiquí with her husband, Juan José Umaña Molina, a landowner and naturalist. Together, they cultivate a vibrant 10.5-hectare haven named Finca Ecogar. Their days are filled with the joyful chaos of raising pigs, chickens, and dairy cattle, tending to flourishing crops like Saragundi, bananas, papayas, and lemons. The couple is eagerly awaiting the day they can extend their green fingers to lettuce, tomatoes, string beans, and coriander in a promising new plant nursery. In a heartfelt effort to make their farm sustainable, Vargas envisions producing organic plant fertilizer from the wholesome excrement of their cherished cows.

The very land she cultivates extends into a magical forest, where a tapestry of wild species, from tostão to Manú, Poro to Guarumo, thrives in harmony with white-faced monkeys, coyotes, Grisons, and a myriad of birds—around 200 of which have found a special place in the hearts of Ingrid and Juan. However, amidst the beauty, Vargas has become a keen observer of change. The biodiversity of their sanctuary is evolving, with bird migrations delayed and numbers dwindling—a poignant dance she attributes to the looming specter of climate change and rising temperatures. The forest, once a seamless tapestry of life, now witnesses unconventional species navigating its labyrinth as they adapt to the shifting patterns dictated by a changing climate.

While Vargas cherishes the natural bounty of her farm, she faces an economic challenge peculiar to her principled choices. Refusing to deforest or engage in large-scale crop plantations, her income does not match the profits reaped by those who exploit the land more aggressively. Despite the financial strains, she staunchly opposes the environmental devastation caused by industries like pineapple farming and remains unwavering in her commitment to sustainable practices.

Vargas is driven by a profound sense of responsibility to protect her forest sanctuary, understanding that the world is running out of time to address issues like polluted water and climate change. In her pursuit of environmentally conscious farming, she opts for manual weed removal over invasive



herbicides and employs recycled organic fertilizer to nurture her crops. Her sources of income include the sale of chicken, pork, and beef produced on their property, complemented by her husband's salary. Over the past two years, the payments from the Payment for Environmental Services (PSA) system have provided additional support, covering municipal taxes. Still, Vargas acknowledges its limitations, yearning for more substantial income to fortify her dreams.

Enter FUNDECOR, a beacon of support in Vargas's journey. The organization has not only assisted in educating Vargas on the PSA system but also provided invaluable technical guidance. FUNDECOR's BIOTA program emerges as a lifeline, promising to fill the financial gaps left by the modest PSA funds. As the story unfolds, Ingrid Mabel Quirós Vargas remains a steward of the land, determined to strike a harmonious balance between economic viability and environmental preservation. With her dreams of a greenhouse, an expanding organic garden, improved fencing, and a state-of-the-art processor for her fertilizer project, Vargas exemplifies resilience and dedication to a sustainable, greener future.

David Reuland - Finca Oasis

In the lush heart of La Fortuna, a retired engineer named David Reuland tends to his earthly haven, the Finca Oasis. This sprawling 10-hectare testament to environmental stewardship stands as a living legacy to Reuland's unwavering commitment to conservation. When Reuland first acquired the land, it was a desolate expanse, scarred by past plantations and cattle pastures. Undeterred by the barren fields that greeted him, he embarked on a visionary reforestation project that would transform the landscape. Over 22 years, Reuland breathed life back into the soil, turning it into a thriving rainforest, a vibrant green tapestry.

Within the protective embrace of the Oasis, four garden circles surround Reuland's dwelling. Here, he cultivates a bounty of sustenance for his own consumption – yucca, tiquisque, taro, tropical roots, rice, corn, okra, *Gastonia*, fruta de pan, beans, coconuts, pineapples, and an array of herbs. Beyond these cultivated plots lies the untamed rainforest, a haven for a diverse array of mammals. Jaguars, sloths, churingas, tepezcuintles, otters, armadillos, and a symphony of 50 bat species coexist in harmony with 350 species of plants, trees, palms, and vines.

Reuland, however, was not a seasoned forester when he first took up this ecological challenge. Armed with determination, he delved into technical books, scoured the Internet, sought counsel from local landowners, and gleaned insights from those associated with FUNDECOR. The journey, he attests, was a learning curve well worth the climb.

For Reuland, the environment is not an abstract cause but a deeply personal commitment. His philosophy of "putting his money where his mouth is" echoes through the vast expanse of the Oasis. He invested not just finances, but time and energy, drawing from the earnings of his engineering career in the United States. Though not entirely reliant on it, he also receives payments from the Payment for Environmental Services (PSA) system. The pandemic dealt a blow, causing a two-year loss of this income stream, but he has weath-



ered the storm and is receiving it again. Yet, he voices concerns about the disproportionately modest payments considering the vastness of his land.

Reuland briefly ventured into ecotourism, hoping to share the splendors of his forest refuge. However, the experience soured, leading him to prefer the tranquility of leaving the forest undisturbed. With dreams of expanding his conservation efforts, he envisions investing further in land acquisition and sustaining his reforestation initiative if given more financial support.

In the tapestry of his conservation journey, Reuland's connection with FUNDECOR is woven with personal and informal threads. While he does not rely on technical assistance, his bonds with FUNDECOR employees have proven invaluable. His eyes sparkled with interest when discussing the BIOTA program, an initiative poised to amplify the \$65 per hectare per year payments from PSA, a potentially momentous change in the quest to preserve the verdant legacy of the Finca Oasis.

Pedro Garcia Rueda

In the heart of the El Roble region, where the Sarapiquí river weaves its course, Pedro Garcia Rueda is not just a farmer but a steward of nature. The story of Finca Integral Jicaro unfolds like a tapestry, intricately woven with indigenous wisdom and a deep-rooted connection to the land. In 2015, Rueda embarked on a journey with FUNDECOR, birthing a vision that harmonizes the forest and the fields. His 7.1-hectare haven, a bridge across the Sarapiquí, resonates with the pulse of nature. Descendant of indigenous heritage, Rueda's affinity for the forest extends beyond the ordinary – his intimate knowledge of plant life paints a canvas that blends cultivation and conservation.

Rows of Porro trees stand sentinel, not just as guardians of the land but as partners in growth. Unlike vanilla vines in commercial landscapes, Rueda's vanilla finds sanctuary, climbing the trunks of Porro trees, shielded from the sun's harsh gaze. Amidst this verdant tapestry, an orchestra of crops flourishes – heart of palm, pepper, cocoa, bananas, and an array of root vegetables compose a symphony of abundance. Beyond the cultivated expanse, the wild forest breathes with life – howler monkeys, pizotes, raccoons, and a kaleidoscope of bird species. Tree deities like Almendro Amarillo and Sota Caballo, their names whispered in reverence, grace the land. Jicaro Montana, the namesake of Finca Integral Jicaro, stands tall, a symbol of the symbiosis Rueda strives to nurture. The forest serves as a biological corridor, linking river and wilderness, witnessing the ebb and flow of nature's patterns. Yet, the winds of change blow through – big cats traverse the land, seeking passage. Rueda, a vigilant observer, attributes this to the fingerprint of climate change, disrupting the dance of wild species.

Climate change, however, is a formidable adversary. Temperatures dip, rainfall becomes erratic, and drought casts its shadow. Pineapples, peppers, and bananas shiver in the cold, while corn and beans thirst for moisture. Rueda faces the challenge head-on, enlisting FUNDECOR's aid in planting a protective barrier, a shield against nature's capricious moods.

Rueda's commitment extends beyond his crops; it is a sacred oath to safeguard the forest. He believes in humanity's power not only to protect but to



enhance the environment. Education, he insists, is the key. University students become custodians, volunteering on his farm, cultivating a nursery that births 2000 new trees – gifts to communities yearning for reforestation. The forest echoes with the laughter of student volunteers, hands immersed in soil, planting hope. Rueda, a beacon of conservation, receives payments from the Payment for Ecosystem Services (PSA) system, using the funds to gift his farm with clean water. In this haven, where ecotourism is the rhythm of life, 80% of Rueda's income springs from guided tours through his farm and forest.

Rueda's relationship with FUNDECOR is not just transactional; it is a kinship. Workshops and training courses, a nurturing hand in the design of his farm, and the guidance he receives are threads binding them together. FUNDECOR's BIOTA program, a beacon of hope, promises a future where income for farmers like Rueda burgeons beyond the constraints of PSA. In the whispers of the forest and the rustle of Porro leaves, Pedro Garcia Rueda stands as a guardian, a cultivator, and a storyteller – his tale interwoven with the land he tends, the creatures he shelters, and the dreams he plants.

Isaias Arguedas Arce

In the lush heart of Sarapiquí, Isaias Arguedas Arce has woven a tale of stewardship spanning over half a century. For 55 years, he has cradled a 9.6-hectare haven, divided by a bustling freeway, where a thriving forest stands as a testament to his dedication. Not his dwelling, though - that is on a separate plot that he has owned for 65 years, nestled behind a once-barren land now transformed into a verdant expanse. A field, once barren with a railroad slicing through, has metamorphosed under Arce's diligent care. Where trees were felled, he planted, and now a lush forest whispers tales of rejuvenation.

Yuca, plantains, and bananas sway alongside the coops of his chicken companions on his residential property. Melina trees, standing tall like guardians, are cultivated with precision, destined to become crates and pallets for goods venturing far beyond. Venturing into the separate forested realm, a menagerie unfolds - peccaries, deer, armadillos, chereña, Tayra, big cats, frogs, and a symphony of birds inhabit this Eden. Gavilan, Cedro Macho, and Manu trees reach for the sky, a testament to the biodiversity Arce has nurtured. Yet, even in this sanctuary, change is afoot. Birds from distant lands now grace the canopy, their migration a poignant dance orchestrated by climate shifts that Arce keenly observes.

In the embrace of Sarapiquí, Arce confronts a formidable adversary - the encroaching deforestation, a consequence of expansive pineapple and banana plantations. A silent battle rages for the health of the soil and the well-being of the planet itself. Arce, however, stands as a bulwark, safeguarding his forest not just for profit but as a testament to his belief in environmental conservation. His goal is not merely the cultivation of trees for timber but the harmonious coexistence where trees perpetually renew themselves. Melina trees, with their natural self-seeding prowess, find a sanctuary in Arce's small nursery, a testament to his commitment to nature's perpetual cycle.

Beyond the fertile grounds and towering trees, Arce weaves his sustenance



through diverse threads - renting properties, a chapter of entrepreneurship with a local clothing and shoe business, and the steady rhythm of pensions and payments from the Payment for Environmental Services (PSA) system. Yet, the melody falls short, the payments meager against the symphony of expenses.

In this narrative, FUNDECOR emerges as an ally, a guardian of Arce's haven. They monitor the forest, guide him through the PSA process, and become partners in the pursuit of sustainable living. As the modest \$65 per hectare per year proves insufficient, Arce looks toward FUNDECOR's BIOTA initiative, a beacon promising a more substantial income to fortify his sanctuary. In the dance of stewardship and survival, Isaias Arguedas Arce's story unfolds - a tapestry woven with the threads of nature, resilience, and an unwavering commitment to the earth beneath his feet.