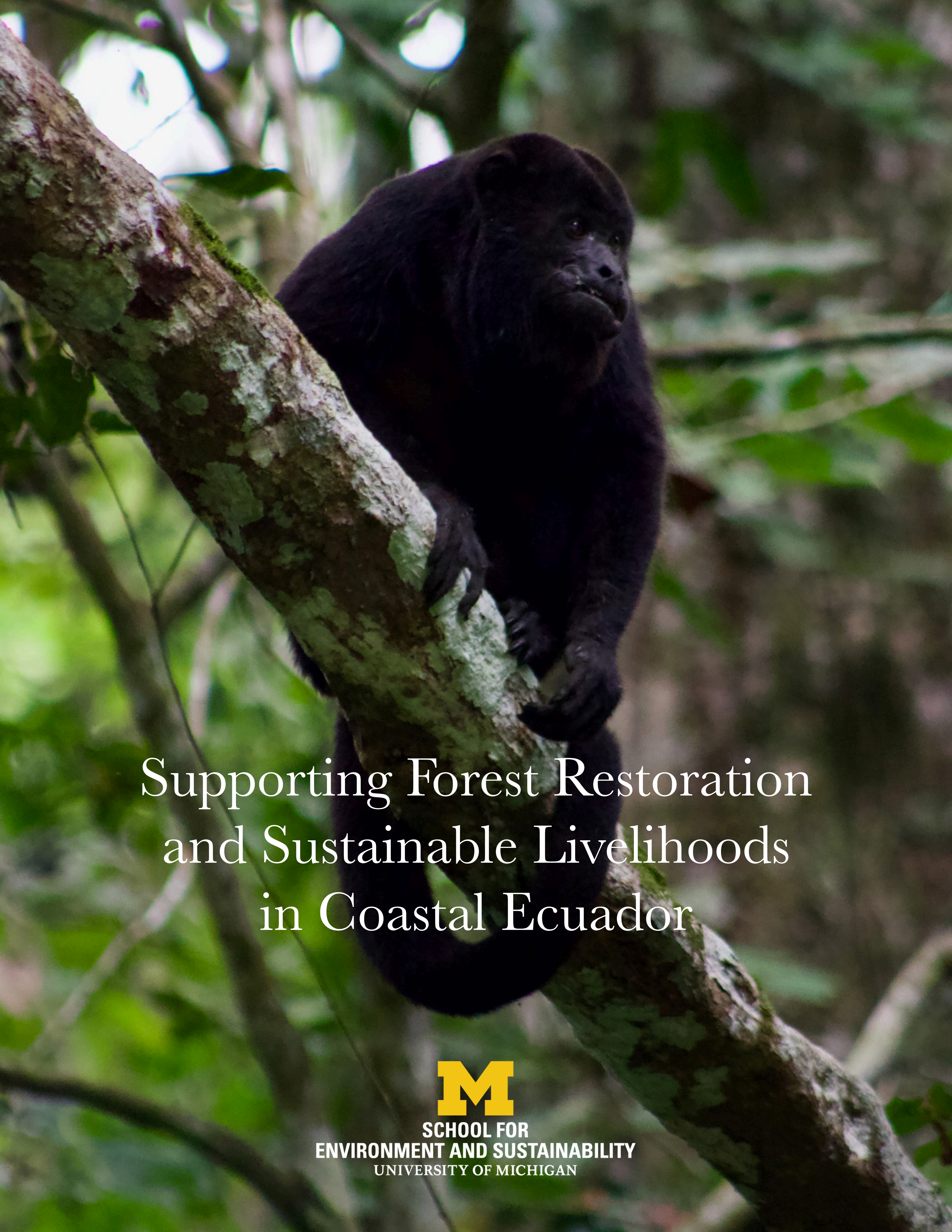

Supporting Forest Restoration and Sustainable Livelihoods in Coastal Ecuador

SCHOOL FOR
ENVIRONMENT AND SUSTAINABILITY
UNIVERSITY OF MICHIGAN

Supporting Forest Restoration and Sustainable Livelihoods in Coastal Ecuador

UM SEAS Master's Project

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Executive Summary

The tropical dry forests of Ecuador are a critical source of biodiversity, carbon sequestration, and ecosystem services, and they provide important ecological and health benefits for local communities. Ecuador has one of the highest rates of deforestation in South America, so these ecosystem services are under threat. Our client, the Ceiba Foundation for Tropical Conservation (the "Ceiba Foundation") is a conservation NGO that aims to address these threats in northwestern Manabí province. Through the creation of the Sustainable Use and Conservation Area (ACUS), spanning 4 cantons of Manabí, the Ceiba Foundation aims to conserve water sources, forest connectivity, and biodiversity. Ideally, this area will promote sustainable livelihoods and food security through eco-entrepreneurship, ecotourism, agrotourism, restoration of degraded ecosystems, and sustainable production.

However, two key challenges threaten to undermine the success of the ACUS. First, resources for implementation of conservation efforts within the ACUS are limited. While restoration in particular shows promise as a solution for addressing fragmentation and biodiversity loss, it is also time- and labor-intensive. Thus, a framework for identifying the lands that are most critical for conservation or restoration is essential to continuing to drive impact at scale.

Second, conservation initiatives such as the ACUS often struggle to bridge the gap between the long-term, community-wide benefits of conservation and the short-term economic drivers of deforestation. Furthermore, while many smallholder farmers practice forms of agriculture that integrate high levels of planned and associated biodiversity, these farmers face significant economic and environmental challenges to the continued viability of their more sustainable modes of production.

We addressed these challenges through 4 main deliverables:

1. The creation of criteria for prioritization of restoration efforts and a map based on these criteria highlighting different levels of restoration priority within the ACUS.
2. An assessment of the motivations of "eco-entrepreneurs" who persist in sustainable modes of production despite significant challenges to this way of life, analysis of the challenges they face, and recommendations for support that the Ceiba Foundation and other stakeholders can provide.
3. Qualitative and quantitative data and analy-

sis on the benefits of a particular form of eco-entrepreneurship—sustainable agroforestry practices—both from a larger geographic perspective and specific to the ACUS region so that these benefits can be shared and promoted.

4. The development of a systematic approach to ecotourism farm tour assessment on small agroforestry farms and application of this approach for farm tours associated with ASOPROCOFFEE, a multi-farm coffee cooperative located in Manabí.

Together, these analyses and deliverables strategically inform the efforts of the Ceiba Foundation and initiatives in the ACUS. They also make a valuable contribution to the larger theory and practice of conservation and restoration, especially in dry tropical forests.

Prioritization Areas for Restoration and Reforestation Within the ACUS Using a Multicriteria Map

We used a GIS and multi-criteria decision analysis to identify different levels of priority areas for restoration and reforestation within the boundaries of the ACUS. Our Final Map prioritizes feasible restoration sites that improve water quality, connectivity, and probability of restoration success. We used both existing data layers and ground truthing through field surveys to assemble layers and weightings that will help the Ceiba Foundation in their restoration goals and make it easier for local stakeholders to maintain restored species, thus saving time and resources. Our final map uses fourteen spatial variables that when combined, show areas of low, medium, and high restoration priority for the entire ACUS. We recommend the Ceiba Foundation to use our final deliverables in the following ways:

- Use the map to assess potential restoration sites
- Refine the map to inform species-specific restoration
- Update data sources over time
- Incorporate social factors, such as landowner willingness
- Continue improving the accuracy and value of the map

Eco-entrepreneurship in the ACUS region: what is the potential and what is missing?

We aimed to assess regionally-specific opportunities for, and barriers to, effective eco-entrepreneurship efforts in Manabí Province to elucidate the support that potential and active eco-entrepreneurs require. In order to make this assessment, we reviewed the literature, gathered information about Manabí, and gained the direct perspective and ideas of local eco-entrepreneurs through on-site interviews and focus groups. The potential benefit to eco-entrepreneurship in this region is enhanced quality of the agroecological matrix, leading to reconciled livelihoods and biodiversity conservation, but there are also potential challenges such as economic barriers, environmental degradation, urban development, and climate change. Interviews revealed that motivating factors for current eco-entrepreneurs include familial connections, the desire for healthier lands and communities, and the desire to fight against marginalization. The challenges they report experiencing are systematically low prices and undervalued products, competition against global industrial production, lack of collaboration, and difficulty attracting tourists to Manabí. Our findings, especially the challenges, suggest that attempting to catalyze transformative change by encouraging greater exposure to global markets presents significant risks to eco-entrepreneurs. Based on our analysis, we recommend that the Ceiba Foundation take the following actions to aid eco-entrepreneurs in this region:

- Focus on supporting efforts toward a locally-owned certification
- Emphasize low-effort ecotourism adaptations

- Communicate the benefits of the ACUS
- Provide forums for collaboration between entrepreneurs

Benefits of Agroforestry for Biodiversity and People

In order to identify ecological and socioeconomic benefits of site-relevant sustainable agroforestry practices in tropical dry forests, we reviewed the published literature on Latin American tropical agroforestry systems and collected interview and field data across a range of agricultural practices in Manabí province. Both the literature and interviews confirm that the crop diversification, structural complexity, and associated biodiversity of agroforestry systems provide numerous benefits, including improved ecosystems services and functions, higher longevity and sustainable yield compared to intensive systems, and income diversification. Based on local field surveys, agroforestry sites showed increased bird, pollinator, and bioindicator abundance and diversity compared to monoculture sites. Overall, agroforestry allowed for economic benefit through reduced inputs and increased resilience. Based on our findings we recommend the following:

- Share and promote the benefits of agroforestry, using the deliverables provided
- Expand field surveys, especially in a way that engages the community and celebrates the benefits of agroforestry
- Market wildlife viewing opportunities on agroforestry farms
- Value agroforestry as much as reforestation in landscape-scale restoration planning
- Aid community transition to agroforestry in a way that supports current values and identities

Improving Agroforestry Ecotourism: Farm Tour Assessment and Case Study of ASOPROCOFFEE

Eco-entrepreneurs often face difficulties in efficiently and effectively improving their operations due to regional and local variations in context, lack of information exchange, and lack of shared assessment frameworks. We addressed this gap by developing systematic Farm Tour Assessment Criteria (FTAC) in order to assess ecotourism on small agroforestry farms. We then applied this approach to an in-depth case study of a multi-farm cooperative in Manabí called ASOPROCOFFEE (ASOPRO). From the development of this framework and the case study, we recommend the following for ASOPRO and the Ceiba Foundation:

- Charge a higher price for ASOPRO farm tours
- Apply specific recommendations in this report to improve existing ASOPRO farm tours
- Apply the FTAC assessment framework to other farm tours in ASOPRO
- Ceiba Foundation should focus on connecting more tourists to ASOPRO and its farms
- Ceiba Foundation should use geospatial data collected on ASOPRO land in conjunction with additional data to be collected to develop a user-friendly map for ecotourists
- ASOPRO should place low effort into improving farm tours given current lack of local ecotourism demand; it should increase effort as and when farm tour demand increases

Photo credit: Mike Kelly

Chapter 1: Introduction

Supporting Forest Restoration and Sustainable Livelihoods in Coastal Ecuador

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Tropical dry forests within Ecuador are a critical source of biodiversity as well as ecosystem services such as carbon sequestration and water filtration, which have significant benefits for both local communities and global conservation efforts (Portillo-Quintero et al., 2015). Yet despite its valuable biodiversity and function, tropical dry forests are also among the most threatened ecosystems on Earth: 86% of Ecuador's tropical dry forests are classified as highly threatened. In the Pacific corridor of Ecuador, including Manabí province, land clearing for production of cash crops and legal and illegal logging have contributed significantly to habitat loss, deforestation, and forest fragmentation (Rivas et al., 2021). In coastal areas, chemical contamination from shrimp farming has caused further forest degradation according to J. Meisel (personal communication, March 7, 2022). These forces are also leading to forest fragmentation and high levels of biodiversity loss (Rivas et al., 2021). The confluence of socioeconomic drivers of deforestation and the high ecological and long-term economic importance of these forests creates an urgent imperative for more research and conservation of tropical dry forests in Manabí.

We worked with the *Ceiba Foundation for Tropical Conservation* (the "Ceiba Foundation") to inform their efforts to support restoration and sustainable livelihoods in Manabí, and specifically within the Sustainable Use and Conservation Area of Manabí (*Area de Conservación y Uso Sostenible*, or "ACUS"). Founded in 1997, the Ceiba Foundation is one of the key conservation actors in Manabí province, and driving the creation of the ACUS—which designates conservation and sustainable production incentives within a continuous landscape—is one of their signature achievements. The ACUS represents a significant step forward for conservation in Manabí, providing a legal and institutional framework to protect the invaluable tropical dry forests of the region and preserve vital ecosystem services.

However, there are two principal challenges to translating the legal and institutional success of the ACUS into positive conservation and sustainable livelihoods outcomes. First, a lack of effective messaging and outreach around the value and process of the ACUS undermines efforts to effectively scale local community participation in the ACUS. More broadly, conservation initiatives—in Manabí and elsewhere—often fail to address the gap between the long-term, community-wide benefits of conservation and the economic drivers of deforestation.

One solution to this disjunct between the benefits of conservation and the drivers of deforestation is to integrate sustainable production and conservation through *eco-entrepreneurship*. We follow (Mars & Lounsbury, 2009) in defining eco-entrepreneurship as an approach to environmental issues grounded in "supposedly competing activist and market logics," (p. 5). Eco-entrepreneurship practices would provide for smallholders' livelihoods while also allowing them to care for the natural environment by centering sustainable land use and production in high quality agroecological systems. For example, several farms in Manabí practice shade-grown coffee cultivation, a practice that contributes to conservation at the landscape level while supporting livelihoods (Perfecto & Vandermeer, 2015). Researching strategies to add value to these sustainable practices could help ensure the long-term viability of these forms of sustainable production, even in the face of significant economic and environmental pressures.

Figure 1.1 A shade coffee farm practicing "eco-entrepreneurship"

A second challenge is that resources for implementation of conservation efforts within the ACUS are limited. While restoration in particular shows promise as a solution for addressing fragmentation and biodiversity loss, it is also time- and labor-intensive. This means that a framework for identifying the lands that are most critical for conservation or restoration is essential to continuing to drive impact at scale. Designing a framework for identifying areas that are most valuable for ecosystem connectivity or have the highest conservation value would allow the Ceiba Foundation to prioritize these areas and more efficiently use its time and resources to design effective programming for the landowners of high-priority lands. Additionally, a method for assessing the willingness of land-holders to engage with the Ceiba Foundation and to participate in restoration of high-priority lands is needed to identify restoration projects with an increased likelihood of success.

We set out to work with the Ceiba Foundation and local stakeholders in Manabí to better understand these challenges, identify solutions to them, and provide resources to support those solutions to the extent possible. Our team reviewed relevant literature on these issues (see below) and then spent six weeks on-site within the ACUS in Manabí province, stationed at the Lalo Loor Dry Forest Reserve where the Ceiba Foundation staff operate locally. This report aims to provide guidance to the Ceiba Foundation and other stakeholders in Manabí, as well as inform the work of practitioners and academics who are pursuing similar work where there are real or perceived tradeoffs between conservation and livelihoods.

Structure of this Report

Chapter 2: Prioritization Areas for Restoration and Reforestation Within the ACUS Using a Multicriteria Map ("Chapter 2"), explores the need for an ecologically- and socially informed landscape-level map of the ACUS that provides the Ceiba Foundation with a visual guide to where it can most impactfully devote resources to reforestation and forest restoration. To create this map, we used multicriteria evaluation for prioritization and consulted a variety of stakeholders and experts to provide input on the variables and layers that can best contribute to an ecologically- and socially informed prioritization map. The resulting prioritization map uses variables on geographic and ecological factors — such as but not limited to, proximity to standing forests, proximity to roads and buildings,

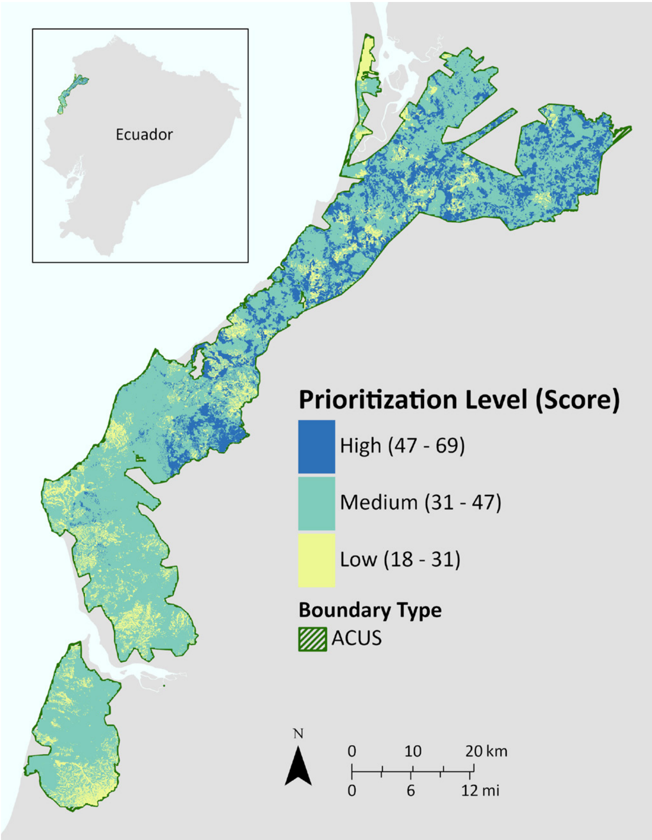

Figure 1.2 Restoration prioritization map from Chapter 2

and distance from rivers — to determine the relative importance and feasibility of reforestation and forest restoration of any point within the external boundaries of the ACUS. Chapter 2 also details the methodology underpinning both data collection in the field and the creation of the prioritization map, such that either the Ceiba Foundation staff or other GIS practitioners could recreate this map or undertake similar work with Chapter 2 as a guide. While the primary audiences for Chapter 2 are the Ceiba Foundation and GIS practitioners who may wish to pursue similar work in other contexts, the methodology in this chapter is also aimed at non-experts who are interested in learning more about prioritization for restoration.

While reforestation and forest restoration are an important aspect of reversing deforestation within the ACUS, significant amounts of land within the ACUS belong to smallholder farmers whose operations include high levels of on-farm biodiversity. These farmers—who produce coffee, cacao, fruit, and other goods—can play a key role in sustaining a high-quality agroecological matrix within the ACUS, but they also face significant economic and ecological pressures on their lands in the form of high opportunity costs for their lands, degraded ecosystem services and climate shocks, and volatile market prices for their goods. *Chapter 3: Eco-Entrepreneurship in the ACUS Region: What Is the Potential and What Is Missing?* ("Chapter 3") explores how eco-entrepreneurship can reconcile the need to support local smallholders' livelihoods with forms of production with high levels of planned and associated biodiversity. Chapter 3 details our review of the literature on eco-entrepreneurship, drawing also on relevant literature from peasant studies and agroecology, before turning to an analysis of interviews conducted with eco-entrepreneurs in Manabí. These interviews illuminate both the challenges that eco-entrepreneurs face as well as their motivations for persisting with this mode of production. We then turn to a set of recommendations that are grounded in our discussion of eco-entrepreneurs' motivations and discussions.

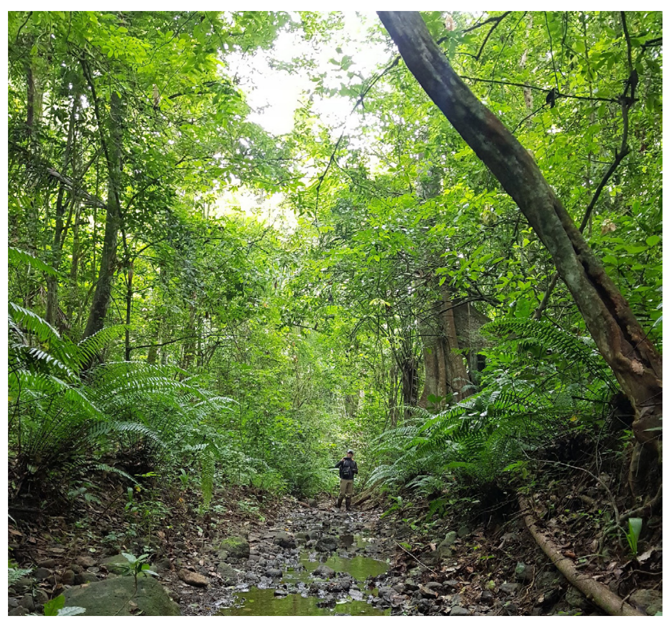

Figure 1.2 Remant tropical dry forest in the Lalo Loor Forest Reserve

Chapter 4: Benefits of Agroforestry for Biodiversity and People ("Chapter 4") explores the ecological benefits of the agroforestry practices employed by many eco-entrepreneurs and smallholder farmers in Manabí. Chapter 4 reviews the relevant literature on this subject before sharing results of ecological surveys the project team carried out near the Lalo Loor Dry Forest Reserve. These ecosurveys compared species richness and abundance of biondicator species of birds and pollinators between agro-forestry plots, primary forests, and monoculture plots. The ecosurveys broadly suggested similar levels of richness and abundance of bioindicator species between primary forests and agro-ecological plots, and higher levels on agro-ecological and primary forests than in monoculture plots. There were also certain species for which our ecological surveys suggested that agro-ecological plots provided a better habitat than primary forests, for instance with pollinator species. Together, these results point to the role that high levels of planned biodiversity play in constituting a high-quality agro-ecological matrix, and thus to providing for the attendant ecological and socio-economic benefits of a high-quality matrix.

Figure 1.3 Touring a shade coffee farm in the ACUS

Given the ecological and social benefits of agroforestry practices, as well as the livelihood (Rivas et al., 2021) challenges associated with them in Manabí, ecotourism has been identified as a possible strategy for advancing eco-entrepreneurship. While Chapter 3 discusses some of the challenges associated with an ecotourism strategy, *Chapter 5: Assessing Agroforestry Ecotourism: Farm Tour Analysis and Case Study of ASOPROCOFFEE* ("Chapter 5") provides a real-world case study that documents both the opportunities and challenges associated with specific ecotourism strategies in Manabí. Eco-entrepreneurs often face difficulties in efficiently and effectively improving their operations due to regional and local variations in context, lack of information exchange, and lack of shared assessment frameworks. We addressed this gap by developing systematic Farm Tour Assessment Criteria to assess ecotourism on small agroforestry farms. We used the literature, interviews, and our in-team experience to develop the following six criteria to assess farm tours:

1. Showcase farm's best assets
2. Demonstrate sustainable coffee farming practices
3. Highlight regional benefits of sustainable agriculture
4. Share story and histories of the farm & lands
5. Provide opportunities for hands-on interaction and learning
6. Provide complete view of process (farm-to-table understanding)

Chapter 5 uses the above Farm Tour Assessment Criteria framework to provide recommendations about the specific strengths of the ASOPRO farm tours, as well as opportunities for improvements that would not require financial investment from the farmers. The chapter concludes with the important recommendation to pursue only low-effort farm tour improvements given the current low level of local ecotourism demand in Manabí and to scale up these efforts only as and when ecotourism demand in the region increases.

Significance and Scope of this Report

This report aims to inform the ongoing work of the Ceiba Foundation, local stakeholders, and the larger theory and practice of conservation and restoration. Notably, not every chapter has the same intended purpose and audience. Chapter 2 is aimed principally at GIS practitioners, for instance, while Chapter 3 is aimed more broadly at practitioners, social scientists, and civil society stakeholders with an interest in eco-entrepreneurship. We encourage readers to identify the chapters which are of greatest interest and relevance to their work.

The two overarching aspects of this project—informing the prioritization of restoration efforts and informing support to eco-entrepreneurs within the ACUS—will benefit both local livelihoods and biodiversity. As a small conservation organization looking to make a disproportionate and positive impact on the 206,000 hectares of the ACUS, the Ceiba Foundation will benefit from efficient use of resources to maximize the impact of restoration efforts. The creation of a prioritization framework for restoration efforts will aid the Ceiba Foundation in identifying where to focus restoration activities. The prioritization framework will emphasize restoration for improving water quality and forest connectivity, both of which improve community health outcomes and increase biodiversity.

The chapters of this report that focus on eco-entrepreneurship and on farm biodiversity should also inform efforts to support eco-entrepreneurs. The Ceiba Foundation drove the creation of the ACUS in Manabí to implement and promote conservation action within the local community. By generating and sharing data on both the opportunities and risks facing eco-entrepreneurs in the ACUS, the Ceiba Foundation will better be able to support sustainable use practices and provide targeted and locally-grounded support for eco-entrepreneurship initiatives within Manabí. Furthermore, success at engendering community participation in restoration and sustainable livelihood efforts at the local level will increase awareness of the ACUS and help regional governments, landowners, and local NGOs such as the Ceiba Foundation refine and expand outreach efforts using the ACUS structure. The Ceiba Foundation has identified such outreach as a potential tool for future work in the policy realm. The benefits of the project may therefore be seen in ongoing conservation work beyond the ACUS.

The lessons learned from this site could also be synthesized to more generally inform the theory and practice of tropical conservation. Tropical deforestation and fragmentation have repercussions for efforts to address climate change and biodiversity loss at a global scale. In many places, these issues are driven by the same or similar socioeconomic drivers and knowledge gaps that are present in the ACUS in Manabí. Larger lessons drawn from this locally-specific work may therefore be adopted by governments, conservation organizations, and local communities to help address tropical livelihoods and conservation efforts.

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Chapter 2: Prioritization Areas for Restoration and Reforestation within the ACUS Using a Multicriteria Map

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1 Purpose and Audience

Deforestation is a global issue that threatens ecosystem services and functions as well as local human communities. The tropical dry forests of Manabí province, one of the main agricultural regions of Ecuador, are particularly threatened. Land clearing for production of cash crops and both legal and illegal logging have left a fragmented forest landscape, reducing both biodiversity and the ecosystem services, such as water quality, that are critical to local communities. Efforts have been made to restore and protect the area's unique biodiversity, while still empowering its inhabitants to use forest resources sustainably. One of these, initiated by our client, the Ceiba Foundation for Tropical Conservation (the "Ceiba Foundation"), is the Area of Conservation and Sustainable Use (Area de Conservacion y Usos Sustentables, the "ACUS"), which provides a legal and institutional framework to protect the tropical dry forests of the region. Within the ACUS, there is an urgency to reverse the damage of deforestation through forest restoration. However, restoration efforts are expensive and require a significant input of time and effort. Creating a prioritization model can aid in highlighting areas most suitable for restoration, thus helping organizations most effectively use their time, funding, energy, and other valuable resources.

We aimed to meet the critical need for an informed and spatially based prioritization tool within the ACUS. Using multicriteria decision analysis, we developed a map that highlights prioritization areas for restoration and reforestation within the ACUS based on multiple variables, especially toward the goals of improving connectivity and water quality. The information present in this chapter will aid the Ceiba Foundation and others to identify where to allocate the appropriate resources for their restoration and reforestation efforts. We have also provided sufficient context to our objective, study site, data sources, rationale, and methodology so that other GIS researchers, whether affiliated with the Ceiba Foundation or not, can build off of our work or use it as inspiration for their own research.

2 Deforestation and the Need for a Prioritized Response

2.1 Deforestation: A Global Problem

Deforestation is the conversion of forest, often for agriculture or extraction (Erbaugh & Oldekop, 2018), that reduces the original canopy cover by 70-90% (van der Werf et al., 2009), resulting in a loss of ecosystem services and function. The ecological consequences of deforestation include the reduction of carbon stores, biodiversity, soil quality, and watershed quality, all of which contribute to major land degradation (Naegeli de Torres et al., 2019). Deforestation is the second leading anthropogenic source of carbon emissions behind fossil fuel combustion (van der Werf et al., 2009) with tropical deforestation releasing 0.81-1.14 billion mg of carbon into the atmosphere annually (Smith et al., 2020). Forest fragmentation is a byproduct of deforestation in which one continuous stretch of forest is split into several smaller, non-continuous, patches. The accompanying fragmentation of populations and inefficient movement between patches correlates with decreased habitat quality and biodiversity loss (Wade et al., 2003).

Not only does deforestation affect the ecology of forests, but also the human communities that depend on them. Forests provide 86 million “green” jobs for local communities (FAO, 2020). In addition to livelihoods and income generation, local communities heavily depend on diverse forest ecosystems for food, fodder, shelter, energy, and medicine (FAO, 2020). When forests are cut down, these socio-ecological relationships are also disrupted.

2.2 Deforestation Trends & Causes in South America

While the continents of Asia and Europe have sustained a positive annual net change in forest area due to afforestation or reforestation efforts, South America’s net change remains negative with 2.6 million ha of forest loss annually (Figure 2.1; FAO, 2020). South America contains around 21% of the world’s tropical forests, and tropical forests are most vulnerable to deforestation (Valente et al., 2021). In order to understand why South America is so prone to tropical deforestation; it is important to review the continent’s complex history.

Although records exist of the Incas harvesting natural resources from tropical forests, mismanaged deforestation likely began after Europeans colonized South America in the 1500s (Chepstow-lusty & Winfield, 2000). The industrial revolution in the 1800s was a catalyst for rampant deforestation efforts since

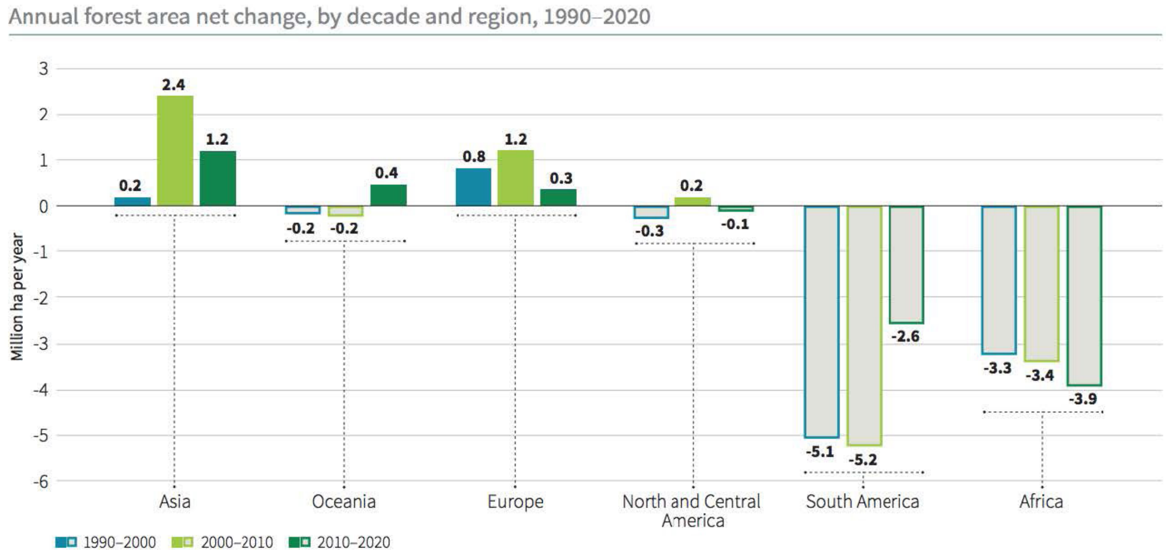

Figure 2.1. Annual Forest Area Net change (FAO, 2020)

advancements in tools enabled the clearing of land at unprecedented rates (Houghton, 2005). After WWII, South America saw an economic boost as a result of lend-lease agreements with the United States. This opened opportunities for rapid development in many countries and led to urbanization and increased infrastructure. Roads aided in connecting many South American countries and establishing official trade routes, thus improving access to the continent's remote natural resources. This inevitably led to the exploitation of these resources with timber being at the forefront (Minkel et al., 2021).

In addition to the continent's dark history with colonialism, the well-studied correlation between low-income countries and high rates of forest loss adds to the instability of South America's forest ecosystems. Deforestation in the form of logging provides basic needs for local communities in low-income countries, most importantly fuelwood, and the industry provides livelihoods for citizens and migrants who desire stable wages (Mills Busa, 2013). While high-income countries can import resources while preserving their own forests, low-income countries' lack of financial opportunities pressures them to demand and exploit their ecosystems to supply the accelerating foreign demand (Mills Busa, 2013). Combating deforestation in these countries must be handled with the utmost care to ensure citizens are still able to receive their basic needs and make a livable wage.

Agricultural intensification and expansion further accelerate deforestation in South America. Agriculture remains one of the most important economic activities in South America, and the continent's leading exports include produce and other food commodities like sugar, bananas, cocoa, coffee, tobacco, beef, corn, and wheat (Appleby et al., 2008). In countries like Brazil, around 23% of the population (43 million people) works in agriculture, and they are the world's second-largest producer of beef, which is vital to the nation's economy (Ferraz & Felício, 2010). This complicates the issue of deforestation in South America because much of the country's economic infrastructure and development revolves around the need for deforested land. In order to truly make a difference in the status of South America's forests, some form of systemic change within the agricultural practices must occur alongside any conservation efforts (see *Chapter 3: Eco-entrepreneurship in the ACUS Region: What is the Potential and What is Missing?*).

2.3 Deforestation in Ecuador

Ecuador has one of the highest rates of deforestation in South America with its root causes mirroring other regions of the continent. Much of Ecuador's primary, old-growth forests were logged in the 1970s for timber production, and much of this land was later converted to pasture for cattle grazing (Jolley, 2013). Ecuador's current top exports - bananas, shrimp, processed fish, and cut flowers - all require some form of natural resource exploitation (OEC, 2021).

The remnant forests of Ecuador are some of the most biodiverse and threatened areas on earth (Aguirre et al., 2011). A prime example is located on Ecuador's western coast. This area is home to six different types of tropical forests: Chocó lowland rainforest, Chocó premontane cloud forest, moist/seasonal evergreen forest, semi-deciduous forest, tropical dry forest, and mangrove forest (Toth, 2021). This diversity of habitats supports a wide range of endemic plant and animal species. One example includes the dry forest region, which is part of the Tumbes-Chocó-Magdalena hotspot, is home to 900 different bird species, with 110 being endemic (Conservation International, 2011). Because of deforestation, less than 1% of the original primary dry forest remains, and the associated habitat loss is putting several of these endemic species at high risk for extinction (Jolley, 2013).

2.4 Government and Non-Government Responses in Ecuador

Recognizing the biodiversity and ecosystem value of their forests, the Ecuadorian government has initiated efforts to conserve remaining forest patches through the establishment of protected areas. In 2008, the Socio Bosque program began which provides monetary incentives to landowners that pledge to maintain the native ecosystem of their land. With the help of this program and others like it, around 20% of Ecuador's land is under protection (Cuesta et al., 2017). However, the conservation struggle in Ecuador is far from over, with the country's main conservation plan "Plan Nacional del Buen Vivir" or "The national plan for good living" stating that in order to preserve the nation's biodiversity, the country must protect a total of 32% of land (Cuesta et al., 2017). Several non-profit organizations now exist to promote these conservation initiatives.

One of these non-profit organizations includes our primary client for this research project: the Ceiba Foundation for Tropical Conservation (the "Ceiba Foundation"). The Ceiba Foundation is a U.S. 501(c)(3) non-profit organization founded in 1997. Their mission is to "[c]onnect tropical nature and sustainable livelihoods through habitat conservation and environmental education" (Ceiba Foundation for Tropical Conservation, n.d.-a). The Ceiba Foundation is an educational organization with an extensive study abroad program and a long history of advising student research. With more than two decades of work in Manabí, Ecuador, the Ceiba Foundation has developed deep relationships with local communities and significant expertise in the ecology of the area.

One of the Ceiba Foundation's signature accomplishments was driving the creation of the Area of Conservation and Sustainable Use (Area de Conservacion y Usos Sustentables, the "ACUS"; Figure 2.2) of northwestern Manabí, Ecuador. The ACUS designates conservation and sustainable production incentives across the cantons (or counties) of Jama, Pedernales, San Vicente, and Sucre. This establishment provides a legal and institutional framework to protect the invaluable tropical dry forests of the region and preserve vital ecosystem services (Ceiba Foundation for Tropical Conservation, n.d.-b). The existing tropical dry forest within the ACUS has felt the effects of deforestation, evidenced by its fragmentation. Therefore, one of the Ceiba Foundation's main objectives is to reverse the damage of deforestation through forest restoration. Restoration aims to restore

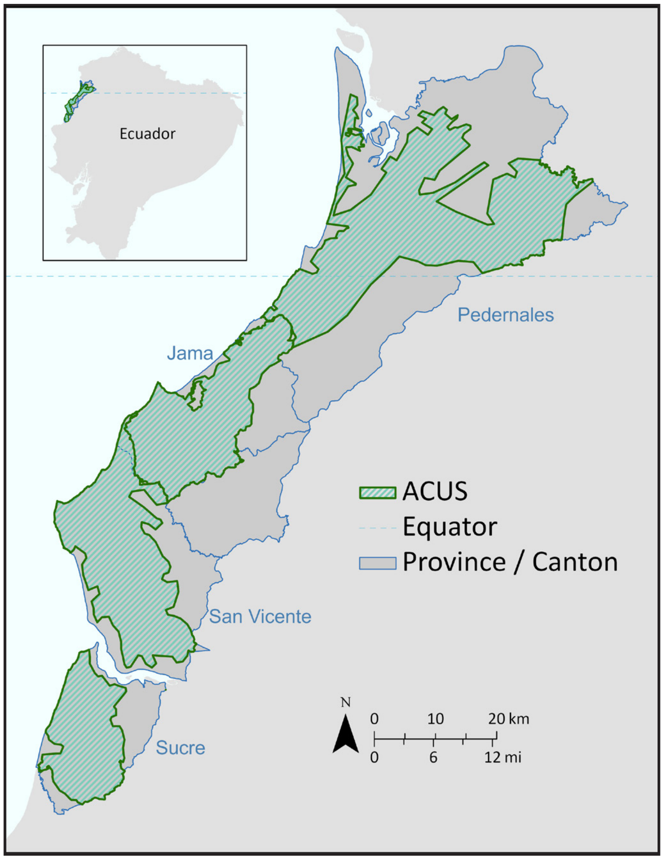

Figure 2.2. Map of the ACUS. This Map shows where the ACUS is within Manabí, Ecuador

native species composition and structure with an emphasis on natural regeneration methods (Stanturf et al., 2014). The idea of reforestation is similar, but often relies on human effort to maintain the health of planted vegetation and does not solely use native species. By working closely with the local communities of the ACUS, the Ceiba Foundation hopes to restore and protect the area's unique biodiversity while still empowering its inhabitants to use forest resources sustainably.

2.5 The Need for Prioritization for Reforestation and Restoration

Forest landscape restoration ("FLR") is an example of restoration that specifically aims to address the human component of restoration, while still attempting to improve the ecological components of a landscape (César et al., 2021; Erbaugh & Oldekop, 2018). This approach highlights the fact that local communities still heavily rely on forest ecosystems for livelihoods, goods, and services and thus prioritizes restoration efforts that benefit these communities as well as the ecological landscape (César et al., 2021). As an example, FLR includes sustainable land use efforts such as agroforestry, in contrast to conventional monoculture farming practices, in order to empower self-sustaining local communities in or near restoration areas (César et al., 2021). This example perfectly aligns with the impact that the Ceiba Foundation is aiming to produce within the ACUS. With the FLR method, both the landscape's ecology and its surrounding community's benefit.

While FLR represents a well-rounded method in theory, restoration efforts are expensive and require a significant input of time and effort. Therefore, prioritizing areas for restoration ensures an efficient process with maximum benefits but minimum time and energy spent. Creating a prioritization model can aid in highlighting areas most suitable for restoration, thus helping organizations most effectively use their time, funding energy, and other valuable resources. The effectiveness of restoration also greatly depends on factors that account for differences in landscape structure and restoration objectives. Therefore, defining these factors as criteria of a landscape can assist in achieving the intended goal of restoration (Vettorazzi & Valente, 2016). A prioritization model, also known as a suitability model, weights locations relative to each other based on given criteria with the aim to develop a prioritization map (i.e., the output of the prioritization model). The map is then used to determine where restoration efforts will produce maximum benefits for the ecology and human inhabitants of the landscape while minimizing costs and labor-intensive work in finding these areas.

2.6 Multicriteria Evaluation for Prioritization

A common method of identifying priority areas for restoration is using Multicriteria Decision Analysis ("MCDA"), also known as Multicriteria Evaluation (MCE), with Geographical Information Systems ("GIS") (Naegeli de Torres et al., 2019; Uribe et al., 2014; Valente et al., 2021). Similar to a raster suitability analysis, this involves choosing and then layering multiple spatial landscape variables, or "criteria", that affect how feasible or necessary restoration activities are within a certain location (Figure 2.3).

Within the MCDA, certain spatial variables are considered more important to the overall goal and indicated by a higher number in an analysis calculation, i.e., a weight. The larger the weight assigned to the spatial variable, the more it will influence the outcome of the calculation (Esri Inc., n.d.-c). For example, in remote areas, issues of accessibility or capacity (for instance, lack of time, energy, or supplies to reach areas far from roadways) may limit restoration efforts. Therefore, a model using MCDA could include a "proximity to roads" criteria, labeling areas within a certain distance to roads as "high priority" and areas beyond the pre-defined distance threshold as "low priority". Typically, the model's builder employs the assistance of experts and stakeholders in choosing the criteria for their model and weighing those criteria to reflect relative importance to the specific landscape/ prioritization map (Valente et al., 2021). While the resulting map is unique to the landscape in which the variables originate from, small adjustments can allow for the application of the model in similar landscapes.

By using MCDA in conjunction with FLR, common outcomes of restoration derived from a prioritization model can include both ecological and socioeconomic benefits. These benefits include biodiversity conservation, climate change mitigation, soil retention, improvement of watershed quality, and improvement of ecosystem services (César et al., 2021). The less obvious benefits that stem from forest restoration are socioeconomic, especially since non-FLR models often exclude the human aspect. These benefits include an increase in human well-being, social and human capital, institutional capital, and economic diversity (César et al., 2021). By incorporating these two methodologies together, the prioritization map created is personal to the specific landscape of study and is, therefore, a valuable and powerful tool for conservation entities to create healthier ecosystems and stronger communities alike.

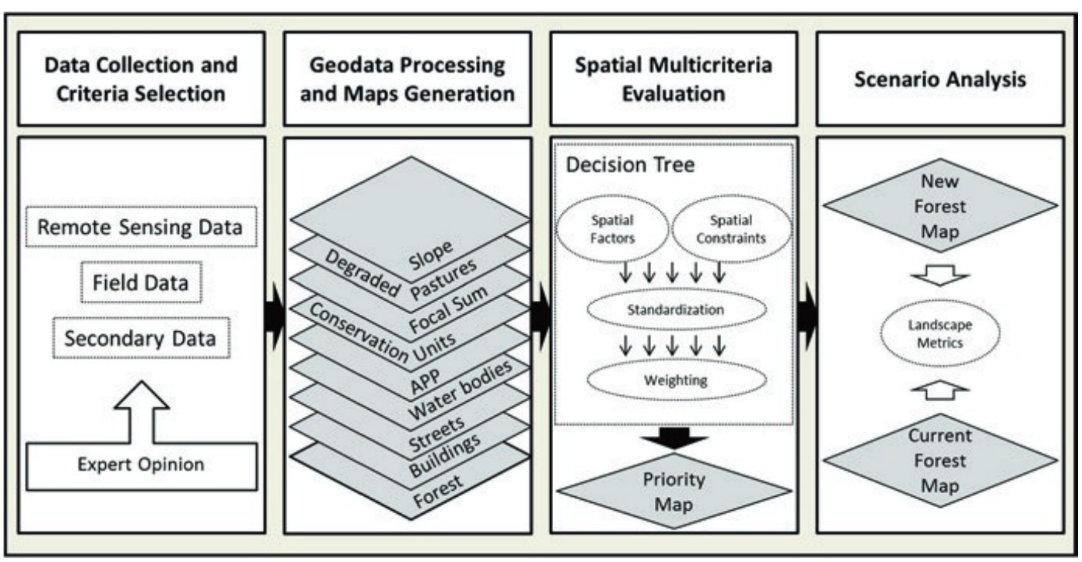

Figure 2.3. Multicriteria Decision Analysis General Scheme (Naegeli de Torres et al., 2019)

3 Prioritization Map Development

What was the overall scheme and methods used to create the Prioritization Model and corresponding Prioritization Map?

3.1 Goal of Research and Methods Used

The goal of our research project is to offer our client, the Ceiba Foundation, a GIS-based approach to identify high-priority areas for restoration and reforestation within the external boundaries of the ACUS. Major concerns for the area were identified by our client as 1) protecting water quality, 2) increasing connectivity, and 3) making restoration feasible and successful. We used these overarching goals to guide our efforts to design a prioritization model that integrates knowledge from a variety of sources, is multi-metric, and considers both ecological and social factors. Using our MCDA method, we collect, process, and analyze existing spatial layers that prioritize which areas within the ACUS will provide both the greatest benefit for forest connectivity and most successful restoration for the local communities in this area. Figure 2.4 represents a visualization of our overall applied methods and research design for the development of our Final Prioritization Map ("FPM").

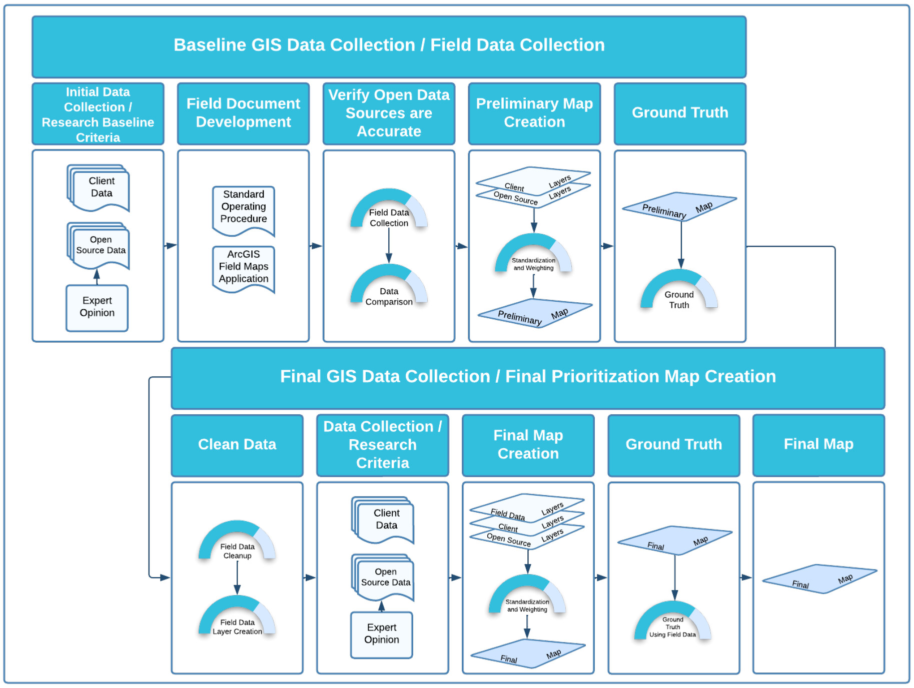

Figure 2.4. Map Creation FlowChart. This flow chart represents the applied methods and research design for the development of Prioritization Areas for Restoration and Reforestation within the ACUS using a Multicriteria Map

3.2 The Study Area

The ACUS comprises approximately 206,000 hectares. Based on available maps of land cover, we estimate the ACUS consists of 36% rangeland, 47% forest, and 3% cropland (Figure 2.5). Due to fragmentation, forests in this area consist of discrete patches, with the largest patch (59,324 ha) located in the northern region of ACUS. There are a few, small urban settlements within external boundaries of the ACUS, notably the cities of Perdenales, Jama, and Canoa. In total, the ACUS has a population of 138,380 (Ceiba Foundation for Tropical Conservation, 2020).

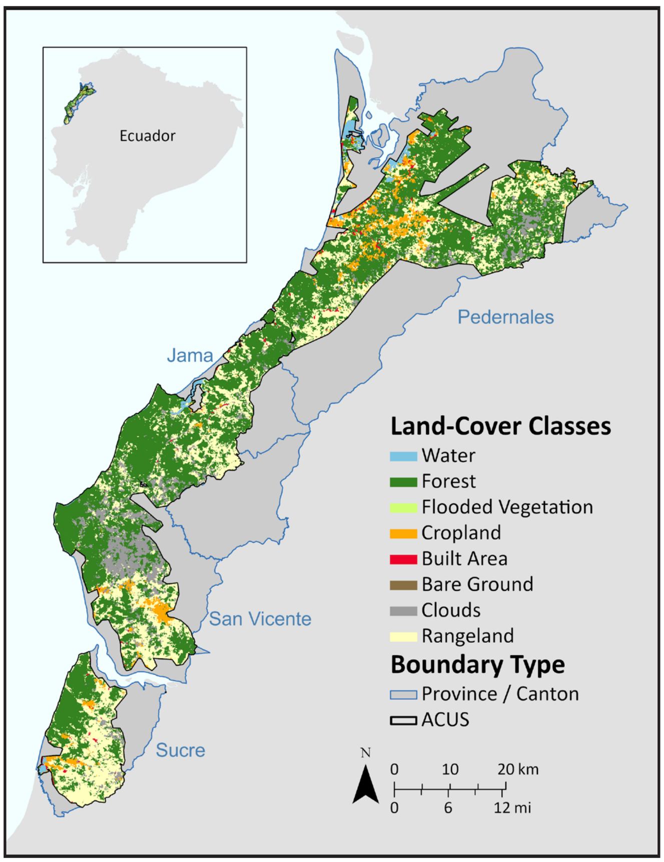

Figure 2.5. Map of Landcover within the ACUS. This visualization shows different land-cover classes within the ACUS. For reference, the ACUS is overlaid on the Province / Cantones of the area

3.3 GIS Data Collection

We had three different data collection periods during the development of our FPM: (1) baseline GIS data collection; (2) field data collection, and (3) final GIS data collection. Our baseline and final GIS data collection involved similar methods. However, our baseline GIS data were used to create our Preliminary Prioritization Map ("PPM"), while the final GIS data were used to create our FPM. We collected field data in order to verify the accuracy of the spatial layers we collected during both GIS data collection periods.

The layers we collected during our GIS data collection periods involved the use of client-provided data and expert opinion driven research. Expert opinions included input from our client, resources available through the University of Michigan ("U-M"), and comparable MCDA studies mentioned in Section 2.6. Based on expert opinions, we focused our GIS data collection efforts on finding datasets containing spatial data related to environmental and social variables.

1. *Environmental* - Environmental variables consist of all the factors outside an organism that influence it—both physical and chemical (abiotic) and other organisms (biotic) (Berry, 2011).

2. *Social* - Social variables consist of human factors that can influence environmental variables (Fang et al., 2021; Scott et al., 2018; Serra et al., 2008).

Additionally, for the development of the Prioritization Maps we identified key factors and constraints for each spatial variable.

1. *Factors* - A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. It is, therefore, measured on a continuous scale. For example, a forestry company may determine that there is a positive association between the cost of

wood and the steepness of a mountains' slope. As a result, more economic areas for logging would be those on shallow slopes - the flatter, the better (Eastman et al., 1995).

2. *Constraints* - A constraint serves to limit the alternatives under consideration. A good example of a constraint would be the exclusion of development within areas designated as wildlife reserves. Another might be the stipulation that no development can proceed on slopes exceeding a 30 percent gradient (Eastman et al., 1995).

We started our GIS data collection by conducting internet and database searches for areas within Ecuador, the ACUS, and our study area, focusing on datasets available through local and federal organizations in Ecuador. However, aside from the datasets provided by our client, we found a limited number of downloadable datasets through local and federal organizations near our study area. So, we focused our research on using open and federal data source providers in the United States and other regions of the world. Please refer to *Appendix A: Prioritization Map Development Process* for the list of data sources we searched through.

Open source databases are not always reliable, and the quality of data can be inaccurate. Because the accuracy of open source databases varies widely, the correctness of the information needs to be assessed before it can be used reliably (Arias de Reyna & Simoes, 2016). One way to verify that open source data are accurate, is to perform ground truthing through field data collection. Ground truthing is the accuracy of remotely sensed or mathematically calculated data based on data actually measured in the field (Esri Support GIS Dictionary, n.d.).

3.4 Field Data Collection

Our project team spent six (6) weeks collecting field data in Manabí, Ecuador in order to verify the accuracy of the database sources we found. Our field data collection and ground truthing efforts consisted of taking samples on public and private sites (combined as "sample sites") located within the external boundaries of the ACUS, primarily the cantons (or counties) of Jama and Pedernales (our "study area"). The selection of our sample sites was based on (1) adaptive sampling methods, (2) our Preliminary Prioritization Map (PPM), and (3) the Ceiba Foundation's knowledge, connections, and work currently being conducted in the ACUS (Figure 2.6).

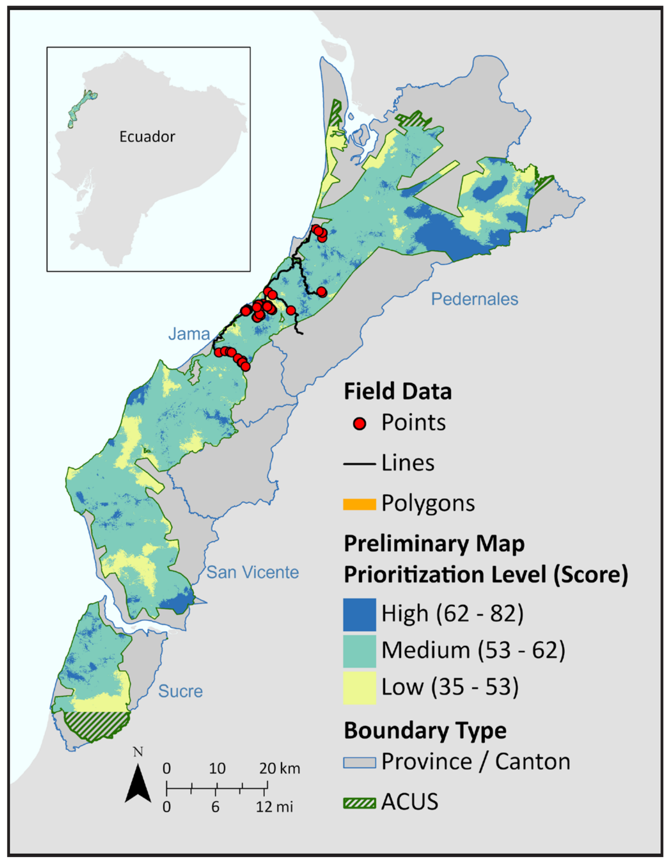

Figure 2.6. Map of Sample Sites. This visualization shows locations where we collected our field data (Points, Lines, and Polygons) within the Cantones of Jama and Pedernales, overlaid on the Preliminary Prioritization Map (PPM) showing Areas for Restoration and Reforestation within the ACUS – low priority in yellow; medium priority in cyan; and high priority in blue. For reference, the ACUS is overlaid on the Province / Cantones of the region

The Ceiba Foundation played an integral role in the field data collection phase of our research project, including organizing community member participation. Community member participation included, but was not limited to, helping us travel to and from the Lalo Loor Reserve (location where we stayed while in Ecuador) to different sample sites, and landowners allowing us access to their private sites.

All field data samples were conducted between May 23 and July 1, 2022, during Manabí's dry season. Some of the field data collected were also used to assess other site variables that are described in *Chapter 4: Benefits of Agroforestry for Biodiversity and People.* Prior to any fieldwork activities being conducted, we created our PPM, developed a Field Data Collection Standard Operating Procedure ("SOP"; see *Appendix B: Standard Operating Procedures for Ecological Field Data Collection*), and set up a platform for data collection (hereafter "Field App") using ESRI's ArcGIS Field Maps web application prior to any fieldwork activities being conducted (Esri Inc., n.d.-b).

We created our PPM to be used in our adaptive sampling approach; using our PPM to select some of our sample sites. We did not use any mathematical calculations in the determination of data source reliability prior to the development of the PPM. Instead, we used visual interpretation in the accuracy verification process of the open source data providers. Visual interpretation of map for accuracy is a commonly used practice when validating a map's layer's accuracy (Bolstad, 2019; Huisman, 2009). The output of the PPM did not show prioritization areas within the entire external boundaries of the ACUS (refer to the PPM within Figure 2.6). This was due to one of the data layers not covering the entire extent of the ACUS. However, the PPM did show prioritization areas within our study area of the Jama and Pedernales, allowing us to collect ground truth data.

We determined that an adaptive sampling design was going to be the most efficient and cost effective approach to collect field data while in Ecuador. An adaptive sampling approach performs better than other sampling methods when considering sampling costs, particularly distance traveled (Morrison et al., 2008), and greater amounts of small scale variation or less amounts of homogeneous areas in sampling locations (Bolstad, 2019). In a situation where we have additional information (maps) about the area, adaptive sampling ensures specific selection within all strata, so more samples can be selected where there is more variation or greater area (Bergen, 2021b). The use of an adaptive sampling method allowed us to select sample locations based on variations observed in the field, not having to rely on calculations performed in the office. This allowed for flexibility in field data collection as long as everyone used the Field App and followed protocols outlined in our SOP.

ArcGIS Field Maps is a mobile solution that allows you to streamline field workflows and take maps anywhere. Maps are configured in the Field Maps web app and used in the field with the Field Maps mobile app (combined as "Field Maps Apps"). The ArcGIS Field Maps web app and corresponding mobile app for our research project was developed in ESRI ArcGIS Pro ("ArcGIS Pro") 2.9.3 by utilizing methods provided in (Brines, 2022; Esri Inc., n.d.-a). All project team members used the SOP and Field App to collect field data, ensuring consistency of methods and protocols.

The two main reasons for the use of ArcGIS Field Maps for our data collection were (1) the data created in ArcGIS Field Maps can be easily downloaded into ArcGIS Pro for map creation and data exportation for analysis and (2) the ability for us to download and use the Field App for use offline. After collecting data offline and regaining internet connection, we synced our data and uploaded it to the ArcGIS Online hosted feature layer for later use in ArcGIS Pro (Esri Inc., n.d.-a). The ability to download and upload the most recent data optimized our processes and streamlined our field data collection.

The development of the Field Maps App was an ongoing process. As developments came up and new information became known, we needed to update the Field Maps Apps. Table 2.1 shows the consistently collected attribute fields created for each feature class used in the development of the Prioritization Maps.

We prioritized sample collection to variables that would help in verifying the accuracy of our FPM. The variables included, but were not limited to, elevation data, river and stream locations, forest cover locations, road locations, and building locations. Please refer to *Appendix B: Standard Operating Procedures for Ecological Field Data Collection* for the list of variables that were selected based on conversations with the Ceiba Foundation, other expert opinion driven research, and databases we found during our baseline GIS data collection.

Table 2.1. Field Maps Application Attributes

Attribute Field	Description
Surveyors Name	Full name of the team member who performed the survey point, line, or polygon
Site Name	The name of the site and location where the Point / Line / Polygon was taken.
Date and Time Created	Date and time the point, line, or polygon was created.
Notes	Any information deemed necessary about the visited site that is not covered in the other attribute fields. This could include, but is not limited to, restricted accessibility, geographical features, or notable, climate-related conditions.
Attachments	Attachments can include photos, videos, or audio recordings. Attaching photos to the specific features enables us to conduct further data analysis, such as FPM ground truthing (discussed in Section 4.1), and data visualizations.
GPS/GNSS Metadata	Location and Metadata, including horizontal accuracy for the collecting device, were collected automatically. This information will help conduct the FPM ground truthing. Storing metadata can be valuable for assessing data quality and ensuring data collection standards have been maintained (Shaner, n.d.).

We used an adaptive sampling approach to select our ground truth sample locations within the PPM. To use our data collection time effectively, we selected our sampling locations based on category/colors of the PPM (refer to the PPM within Figure 2.6), proximity to the Lalo Loor Reserve, and accessibility to a roadway. We focused our efforts on collecting ground truth points in each category/color of the model: high (blue), medium (cyan), low (yellow). Our process for choosing ground truth sampling sites involved using the Field App and GPS/GNSS. We displayed our location overlaid on the PPM and traveled to the different categories/colors. Once we reached the desired site category/color, we took samples using methods outlined in our SOP (see *Appendix B: Standard Operating Procedures for Ecological Field Data Collection*). Using a proximity factor allowed us ample time to return to the Lalo Loor Reserve before the working day was done. Using an accessibility to a roadway factor allows us to drive to different locations faster and generally meant we would not go into private properties. This cost effective approach ensured we collected samples in low, medium, and high priority locations within our study area. The points, lines, and polygons shown in Figure 2.6, represent our sample locations within the ACUS.

3.5 Map Layers: Rationale and Process

Our FPM integrates design elements that take into account common restoration practices outlined in our introduction, easy access to restoration sites, and factors that may limit the need for continuous stakeholder involvement (e.g., watering plants). We used sources we found during our data collection periods to develop layers that will help the Ceiba Foundation in their restoration goals and make it more feasible for local stakeholders to maintain newly planted species without needing to use too much of their valuable time and resources.

We used ArcMap 10.8 software (Esri Inc., 2020) and ArcGIS Pro 3.0.2 software (Esri Inc., 2022) to conduct our geoprocessing for our MCDA. Our data sources include layers containing points, lines, polygons, and raster datasets. In order to conduct the MCDA, we first had to convert all the spatial variables into a common raster format (see Table 2.2). Please refer to *Appendix A: Prioritization Map Development Process* for the full development process for each spatial variable used in the FPM.

Table 2.2. Common Format Used for Spatial Variables

Parameter	Common Format	Reasoning
Projected Coordinate System	WGS 1984 UTM Zone 17S	Includes our study area (Klokan Technologies GmbH, n.d.) and the Ceiba Foundation uses them in their geoprocessing workflows.
Projection	Transverse Mercator	
Geographic Coordinate System	WGS 1984	
Datum	D WGS 1984	
Data Type	Raster	Workflow requirement (Esri Inc., n.d.-c; Moeinaddini et al., 2010)
Measurement Unit	Meter	Standard in GIS computing and standard measurement unit in Ecuador
Final Layer Extent	ACUS	Client request
Scale (Cell Value)	0 - 100	Workflow requirement (Esri Inc., n.d.-c; Moeinaddini et al., 2010)
Resolution (Cell Size)	10 meters	*Workflow requirements; Field observations; Cosmetic

*A cell resolution of 10 meters was chosen for three (3) reasons: (1) workflow requirements, (2) to account for field observations, and (3) FPM cosmetic aesthetics. A MCDA workflow requires raster data as input variables. After the analysis is completed, the output data are resampled to the largest cell size of the input variables (Esri Inc., n.d.-c; Moeinaddini et al., 2010). Three of our input variables were not raster, Locations of Active Fires in 2021, Proximity to Buildings and Proximity to Rivers or Streams. They were points and lines. During our field work, we observed both dirt roads leading to sample sites as well as various stream sample points measuring less than 10 meters wide. These two field observations were our minimum mapping unit in our output map. So, we resampled all resolutions to an output cell size of 10 meters. This made the FPM output have smoother transitions from cell to cell. Additionally, the resampling of all data sources do not increase the accuracy of the different layers, it only helps in workflow requirements.

Once we developed the selected layers, we relied on the Ceiba Foundation to recommend the weights for each spatial variable. The MCDA requires the total sum of the spatial variables relative weights be equal to 1 (i.e., 100%) in order for the calculations to work properly. Using these assigned weights, we used ArcGIS Pro's Weighted Sum (Image Analyst) tool to combine all the spatial variables we created (Esri Inc., n.d.-d). The general equation used in this tool is as follows:

([Spatial\ Variable\ #1] × [Relative Weight #1]) + ([Spatial Variable #2] × [Relative Weight #2]) + ... + ([Spatial Variable #14] × [Relative Weight #14]) = FPM

General information, including assigned weights, for the spatial variables we used in our FPM is provided in Table 2.3. In the following sections we provide development summaries and use justification for each of the spatial variables used in development of the FPM.

Table 2.3. Summary of Spatial Variables Used in Final Prioritization Map

Ref*	Spatial Variable (Layer)	Data Year	Original Resolution	Source Citation	Factor / Constraint	Relative Weight (%)**
3.5.1	ACUS	2020	Polygon	(Ceiba Foundation for Tropical Conservation, 2020)	Boundary	-
3.5.2	Proximity to Surface Rivers or Streams	2020	30 meter	(Kelly, 2022; NASA JPL, 2020)	Closer = Higher Priority	15
3.5.3	Slope (0–8%)	2020	30 meter	(NASA JPL, 2020)	Low Priority within slope range	2
3.5.3	Slope (8-16%)	2020	30 meter	(NASA JPL, 2020)	High Priority within slope range	10
3.5.3	Slope (>16%)	2020	30 meter	(NASA JPL, 2020)	Low Priority within slope range	2
3.5.4	Proximity to Roads	2022	Line	(OpenStreetMap, n.d.)	Closer = Higher Priority	5
3.5.5	Proximity to Buildings	2022	30 meter	(Facebook CIESIN - Columbia University, 2016)	Closer = Low Priority	4
3.5.6	Proximity to Forests	2018	25 meter	(Shimada et al., 2014)	Closer = Higher Priority	14
3.5.6	Forest Connectivity	2020	10 meter	(Karra et al., 2021)	Varying Priority Levels	15
3.5.7	Locations of Active Fires in 2021	2021	Point	(Earth Science Data Systems, 2016)	Closer = Lower Priority	5
3.5.7	Forest Loss Due to Fire 2001-2021	2001-2021	30 meter	(Tyukavina et al., 2022)	Closer = Lower Priority	5
3.5.8	Average Precipitation from Years 1970-2000	1970-2000	30 seconds (~1 km2)	(Fick & Hijmans, 2017)	Higher = Higher Priority	7
3.5.9	Flood Risk	2018	Polygon	(Ministerio de Agricultura et al., 2018)	Higher = Lower Priority	4
3.5.10	Ownership	2010	Polygon	(Censo Ecuador, n.d.)	Higher = Higher Priority	6
3.5.11	Population Density	2010	Polygon	(Censo Ecuador, n.d.)	Lower = Higher Priority	6

*Ref = Reference section of this document where variable rationale and process is discussed.

** Weights assigned based on our expert opinion driven research and input from the Ceiba Foundation.

3.5.1 ACUS

This vector layer was provided by the Ceiba Foundation. We used this layer to clip all of the following layers to its boundary.

3.5.2 Proximity to Surface Rivers or Streams

The Ceiba Foundation ranks protecting rivers and streams as one of their highest priorities in their restoration activities. To support the goal of protecting regional water quality, it is necessary to prioritize restoration in river and streams' riparian zones. For example, if restoration occurs in these areas, the resulting forests have the potential to improve hydrologic function and wildlife habitat (Jolley, 2013). Also, if riparian soils are free from excessive human disturbance, they provide an excellent environment for the growth of endemic or native species which aids in the restoration process (Mikkelsen & Vesho, 2000). We found it important to include a Proximity to Rivers or Streams layer in our model due to the plethora of ecosystem functions and services that will be provided by restoring forests in riparian zones.

The Ceiba Foundation provided the rivers and streams layer used in the analysis. The layer was developed using a digital elevation model ("DEM"), ArcGIS Pro 2.9.3, and ground truthing in Ecuador (Kelly, 2022). DEMs are computer data files that give land-surface elevations at grid points (Dingman, 2015). The grid points were used to delineate the flow accumulation layers used in our FPM. We used a Euclidean distance calculation in order to calculate the proximity to each cell within the flow accumulation layers. The output raster highlights areas closer to rivers and streams as higher priority areas and cells further away as lower priority.

3.5.3 Slope

The Ceiba Foundation's main goals and priorities for restoration includes having restoration sites be accessible for individuals to reach. However, landowners are not always willing to allow restoration efforts to be conducted on flat areas of their land. To control for these variables, we must include the slope of the landscape in our prioritization model.

The slope of a landscape plays an important role in accelerated soil erosion and water quality of a given area. Generally, steeper slopes are more likely to shed surface water as surface runoff. This surface runoff leads to non-point source contamination, including sediment buildup, in watersheds. By increasing the sediment trapping efficacy within sloped areas along riparian zones, the Ceiba Foundation can target areas where soil erosion and watershed contamination is or will be occurring (Dingman, 2015; Liu et al., 2008; Wall et al., 2012).

We created our slope layers using the same DEM used in the creation of the Proximity to Rivers or Streams layer. Using raster calculations, we split the Slope layer into three (3) steepness / grade categories: (1) 0–8%, (2) 8–16%, and (3) less than >16%. These categories were based on Ecuador soil classifications outlined in (de Koning et al., 1998). In our FPM, areas classified as Categories 1 and 3 were considered constraints due to landowner willingness and accessibility, respectively. While areas classified as Category 2 were given higher priority scores. By classifying Category 2 as a higher priority sloped areas, we capture the optimum 9% slope for riparian zones and sediment trapping efficacy outlined in (Liu et al., 2008). The 9% optimum slope is based on a number of factors including but not limited to location, vegetation, and soil makeup. By having a wider range, we account for varying soil types within Ecuador as well as areas not within the riparian zones.

3.5.4 Proximity to Roads

As previously mentioned, much of the ACUS is very remote and it is important that potential restoration areas are accessible for the Ceiba Foundation's team, relating back to their goal of feasibility. This layer acts as a sort of "friction", or impedance to movement, equivalent since accurate land-based travel friction data are difficult to find for this region. Therefore, we processed our Proximity to Road layer to have a lower priority value the further you get from a road in an effort to prevent higher priority zones from being too inaccessible. This was done by using a Euclidean distance calculation from the location where the roads were located.

3.5.5 Proximity to Buildings

Buildings represent a spatial constraint in our model as it is impossible to perform restoration activities in their precise location (Naegeli de Torres et al., 2019). We implemented a Euclidean distance calculation from buildings in order to acknowledge that restoration activities will likely be ineffective in close proximity to human settlements.

3.5.6 Forest Connectivity and Proximity to Forests

With deforestation in this region happening at an alarming rate, fragmentation is occurring throughout the area, and this is leading to high values of biodiversity loss (Rivas et al., 2021). In order to combat this, one of the Ceiba Foundation's goals involves improving and maintaining forest connectivity. Forest connectivity is a critical component that maintains biodiversity and ecological functions of a landscape. This is mainly due to the adequate animal dispersal that a connected landscape provides, in contrast to a highly fragmented landscape (Pascual-Hortal & Saura, 2006). Therefore, we performed a connectivity analysis of our study area in order to highlight forest fragments that were most crucial to the overall connectivity of the tropical dry forest ecosystem. Restoration efforts should take place in areas near these highlighted fragments in order to maintain and improve forest connectivity.

We chose a graph theory method, using Conefor 2.6 open-source software (Saura, S. & J. Torné. 2009) in order to perform our analysis. This software analyzes the nodes (forest patches) and links (distance between patches) of a forest. It then produces a value for each node that indicates how important that particular forest patch is for maintaining overall forest connectivity. Although the Conefor software can run analysis using multiple different indices, we chose to use the integral index of connectivity (IIC) as it is sensitive to multiple types of landscape change and shows more prioritization skill relative to other indices (Pascual-Hortal & Saura, 2006). We entered into the software a distance threshold of 1,000 m in order to represent the max dispersal distance of multiple species of taxa found in a tropical forest ecosystem (Coates, 2018).

3.5.7 Locations of Active Fires in 2021 and Forest Loss Due to Fire 2001-2021

Fire is a natural occurrence in dry forests, but where fire frequency increases so that trees cannot regenerate, forest cover will decline (Miles et al., 2006). Studies show that fire disturbances in combination with logging (i.e., deforestation), increases the fire frequency in the area where the fire disturbance occurred. In contrast, fire frequency in these disturbed areas can be decreased by increasing regeneration efforts (i.e., restoration and reforestation), thereby helping in the recovery process of these ecosystems. However, during this regeneration period, young stands are more susceptible to being killed due to recurring forest fires. It is not until they are larger that they become more fire resistant (de Andrade et al., 2020; Lindenmayer et al., 2011; Miranda et al., 2016; Standish et al., 2014). This is why it is essential to not only restore these areas, but protect them during their regeneration periods as well.

In order to determine areas where forest fire disturbances have occurred, while highlighting the most recent disturbance locations, we incorporate two (2) different fire disturbance layers within our model:

1. *Active Fires in 2021* represents hotspot/fire locations detected for the entire year of 2021. These locations were created using Visible Infrared Imaging Radiometer Suite (VIIRS) S-NPP hotspot detection (Tyukavina et al., 2022).

2. *Forest Loss Due to Fire for Years 2001-2021* is defined as natural or human-ignited fires, resulting in direct loss of tree canopy cover exceeding 5 meters in height (Tyukavina et al., 2022).

According to the Ceiba Foundation, most fires in the study area occur due to people. This being the case, this layer will be considered a constraint due to the social risk of restoring species in these areas. We used a Euclidean distance calculation from these fire disturbance locations, in order to represent lower priority levels, the closer you are to the given locations.

3.5.8 Average Precipitation from Years 1970-2000

Precipitation and rainfall represent a practical criterion that environmental restoration requires (Rahman et al., 2014). Without an ample level of annual precipitation, replanted species for restoration are unlikely to survive naturally and will require an input of human effort for their reliance on water. This directly contradicts the natural regeneration aspect of FLR so therefore, it is important that these species are planted in areas that receive enough precipitation to sustain them.

Many native species that the Ceiba Foundation uses for restoration have specific edaphic requirements, including precipitation, in which to grow and prosper. For example, the Guayacan (Tabebuia chrysantha), a tree species native to Ecuador, has a specific precipitation tolerance of 1000-2500 mm (Palma Rodriguez, 2018). Therefore, restoration efforts using this species should take place in prioritized areas with these precipitation characteristics.

The Average Precipitation from Years 1970-2000 dataset includes twelve (12) rasters representing the average precipitation in Ecuador for the years 1970-2000 for the months of January through December (i.e., raster layer 1 = the average precipitation recorded for all January months in 1970-2000) (Fick & Hijmans, 2017). We merged all twelve (12) layers together to get an output cell value that represents the average rainfall for the year. This was done because plant species need water year-round, not just specific months.

3.5.9 Flood Risk

How a landscape reacts to a flooding event depends on the health of its landscape. A healthy landscape with a diverse ecosystem can withstand a large flood event by using its complex interconnected systems to filter and disperse the flow of the water. However, if the landscape has an unhealthy ecosystem, the flooding event can be recognized as a hazard and may cause widespread damages including soil erosion, forest destruction, and even large scale habitat loss (Naiman et al., 2005; Standish et al., 2014).

While flooding often has a strong association with destruction, it can actually cause many beneficial ecosystem functions to riparian restoration areas. Flooding can increase microbial populations within the riparian soils, providing a hospitable environment for soil bacteria, fungi, and cellulose decomposers (Molles et al., 1998). These microbes play critical roles in the ecosystem's nutrient cycles and can further improve soil conditions, thus making natural flood plains quality environments for restoration activities.

The Flood Risk layer contains information about the flood hazard for second-level administrative areas within Ecuador (Ministerio de Agricultura et al., 2018). Using the scores presented, we run an equalization calculation on the data source and generate a flood risk score for the Cantones (or counties) of Jama, Pedernales, San Vicente, and Sucre. With the Ceiba Foundations input, the final layer represents areas with higher flood risk having lower priority levels.

3.5.10 Ownership

The Ceiba Foundation works with local stakeholders, including landowners, when conducting restoration efforts in the ACUS. Some of these landowners allow the Ceiba Foundation to utilize sections of their properties for restoration purposes. With limited resources themselves, the local landowners do not always have the time or means to continuously maintain newly planted species in these restoration areas. The species then go unattended to and die. This results in an unsuccessful restoration effort for the Ceiba Foundation. Therefore, it is important to add in criteria related to how willing a given landowner is to participate in restoration activities on his or her property.

We created this layer as a placeholder for a future, more precise, layer consisting of data from our landowner willingness survey (see *Appendix C: Landowner Willingness Survey*). The current layer prioritizes census blocks with high percentages in landownership. Since the Ceiba Foundation mainly performs restoration activities on private land (with landowners' permission) it is more likely that these activities will take place in census blocks with a higher percentage of ownership. While the spatial resolution of this criteria is fairly substantial, a future, improved layer will consist of individual landowner properties.

3.5.11 Population Density

When considering ecosystem conservation and restoration, it is important to consider humans' relationship to their environment (Berry, 2011; Schmitz, 2007). Humans are part of the environment and everything they do affects it in some way shape or form. Additionally, any factor that affects an ecosystem's functions, including deforestation and fragmentation, will in turn, affect humans as well. This is why we considered social variables as an important factor in the development of our Prioritization Maps. However, the Ecuador census has not been conducted since the 2010 census. So we created this layer as a placeholder for a future layer consisting of data from a more up to date census of the ACUS. The layer represents areas with lower population density as higher priority.

4 Results

What were the results of the Final Prioritization Map?

4.1 Determining Data Source Reliability Analyses

We use mathematical calculations, data we collected in the field, and elements of visual interpretation to determine the accuracy of the open source data we use in the development of our FPM (Lillesand et al., 2015). We used (Esri Inc. et al., 2023) World Imagery ("EWI") when conducting visual interpretations. The open source data providers we looked through during our GIS data collection resulted in eleven (11) open data source layers viable for use in the development of the fourteen (14) layers used in the FPM (refer to Table 2.3 in Section 3.5). We discuss the reliability of the different FPM data source layers in the following sections. The layers we verify for levels of accuracy include: (1) DEM, (2) Road Locations, (3) Building Locations, (4) Forest Locations, (5) Forest Connectivity, (6) Locations of Active Fires in 2021, and (7) Forest Loss Due to Fire 2001-2021. We did not verify the accuracy of the following layers: (1) Average Precipitation, (2) Flood Risk, (3) Ownership, and (4) Population. However, the layers were created by credible data source providers and therefore assumed to be of good quality for the development of the FPM. Based on our analysis, as well as our expert opinion driven research, we updated three (3) of the four (4) open source data providers from the development of our PPM to the development of our FPM. The layers we updated include: (1) DEM, (2) Building Locations, and (3) Forest Locations. We used the same Road Locations in both the PPM and FPM.

4.1.1 DEM - Slope Reliability

Vertical accuracy from any GPS/GNSS receiver can be challenging to measure and is nearly always worse than the horizontal accuracy at that same location. This is due to a number of factors including but not limited to geoid height, horizontal datum, data source resolution, and the type of GPS/GNSS receiver used in data collection. Typically, high accuracy survey points with precise vertical and horizontal measurements are used as control points in order to calculate the root mean square error ("RMSE") of a given dataset (Bolstad, 2019; Brines, 2022). However, we were unable to find publicly available control points for our study area. With the absence of control points, we used our field data in order to calculate the RMSE for the DEM used in the creation of the Proximity to Surface Rivers or Streams and Slope layers.

Throughout our study area we took field samples using the Field App and a Bad Elf GPS Pro+ ("BEP+"). According to BEP+ documentation, under ideal conditions, the device can observe horizontal accuracies of up to ~2.5 meters. Vertical accuracy is typically 1.5x to 2x horizontal accuracy (Bad Elf, n.d.). Our project team used different phone types (e.g., Samsung and iPhone) to collect Field App data. We also collected data samples while driving and walking. In order to stay consistent, to calculate the RMSE for the DEM, we only used elevation data from sample areas where: (a) we used our BEP+ and (b) we walked (Figure 2.7). We took BEP+ samples at six (6) different locations where we walked approximately 8,907 meters and collected approximately 74,492 samples. Using this data, we calculate the RMSE for the DEM (Table 2.4; Bolstad, 2019; Brines, 2022).

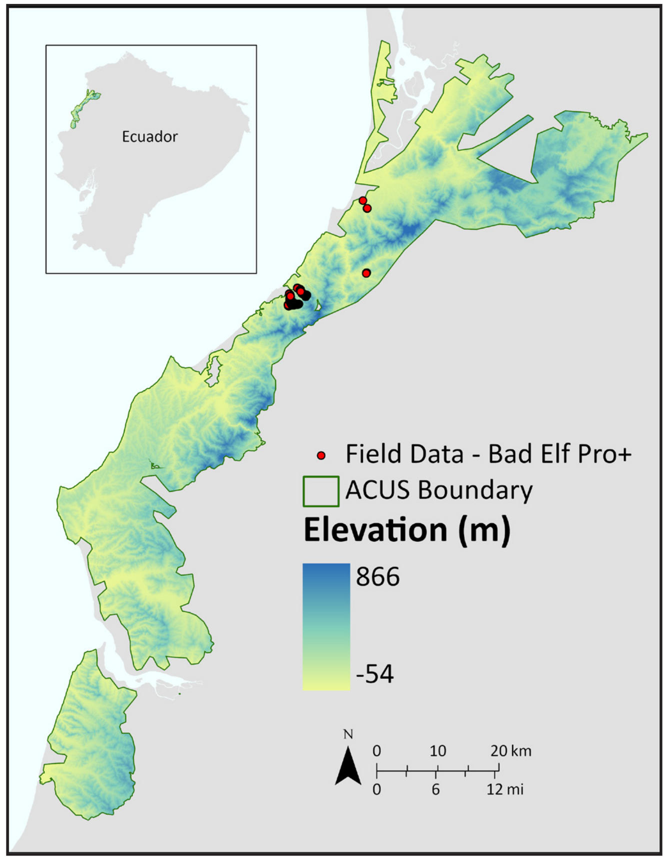

Figure 2.7. BEP+ Sample Locations and DEM. This visualization shows the locations where we conducted field samples while walking and using a BEP+ overlaid on the DEM of the ACUS used in the FPM. We used these sample locations to conduct our RMSE scores. The DEM is visualized by a yellow to cyan to blue gradient, with blue areas deemed higher elevation than cyan and yellow, respectively

Table 2.4. DEM RMSE

Location	BEP+ Sample Count at Location	Meters Walked	Average Elevation for DEM	Average Elevation for Sample	RMSE*
1	11,837	766	55.82	51.79	8.70
2	27,366	4,490	150.49	141.77	19.14
3	33,852	3,376	113.79	106.05	12.42
4	363	160	30.78	26.05	5.04
5	654	105	44.42	35.40	9.39
6	420	10	28	23.06	4.98
Total	74,492	8,907	116.57	109.07	14.76

* $RMSE = \sqrt{((\sum_{i=1}^{n} \times (z - z^{i})^{2})/n)}$

A reasonable expectation for a reliable DEM data source, is to have a total RMSE score to be less than 10 (Bergen, 2022). With an overall RMSE score of 14.76, the DEM may not be the most reliable data source for the FPM. This high RMSE score may be due to the DEM being developed for the entire world, not specifically Ecuador. This being said, there are areas within the study area that scored below 10 RMSE (Locations 1, 4, 5, and 6). So, we did go forward with using the DEM in the model. We calculated our PPM slope layer using a 3 by 3 cell moving window within the Geoprocessing: Focal Statistics ArcGIS Pro Toolbox (Bergen, 2021a; Esri Inc., 2022). When this Slope layer was combined in the PPM, the PPM did not account for the drastic change in elevation (Figure 2.8). To account for this change in elevation in our FPM, we used the Geoprocessing: Surface Parameters ArcGIS Pro Toolbox (Esri Inc., 2022; Minár et al., 2020). We then split the Slope layer into three (3) categories, as outlined in Section 3.5.3. When these Slope layers were combined in the FPM, the FPM did account for the drastic change in elevation (Figure 2.9).

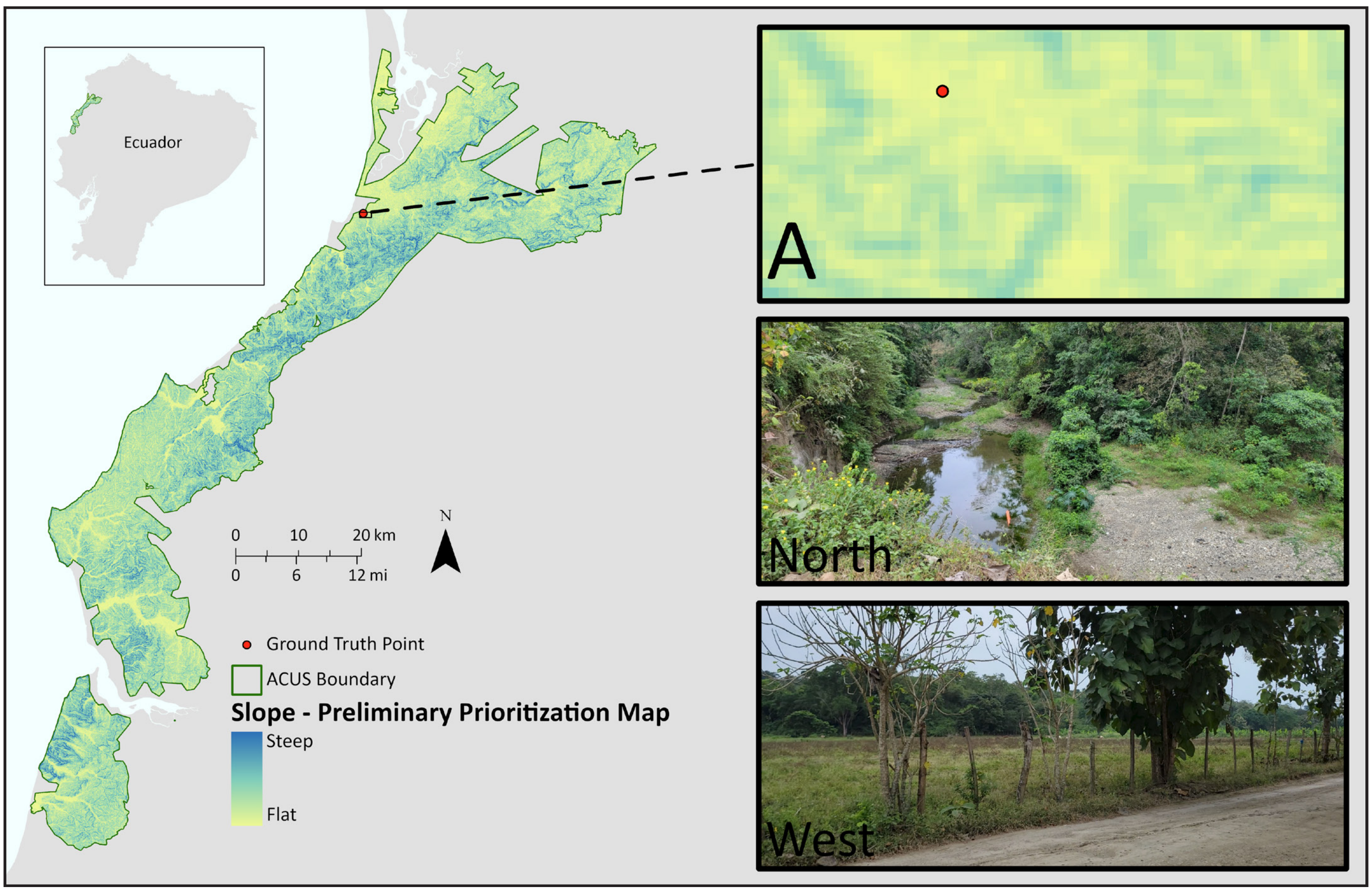

Figure 2.8. PPM Slope Accuracy. This visualization shows a location where we conducted ground truthing (red point) overlaid on the DEM of the ACUS used in the PPM. The DEM is visualized by a yellow to cyan to blue gradient, with blue areas deemed higher elevation than cyan and yellow, respectively. (A) Map inset showing slope data layer accuracy at ground truth point above a cliff to the north. Slope does not account for the large drop in slope; (North) Photo taken facing north towards cliff; (West) Photo taken facing west away from cliff. Photo credit: Antonio Morsette, 2022

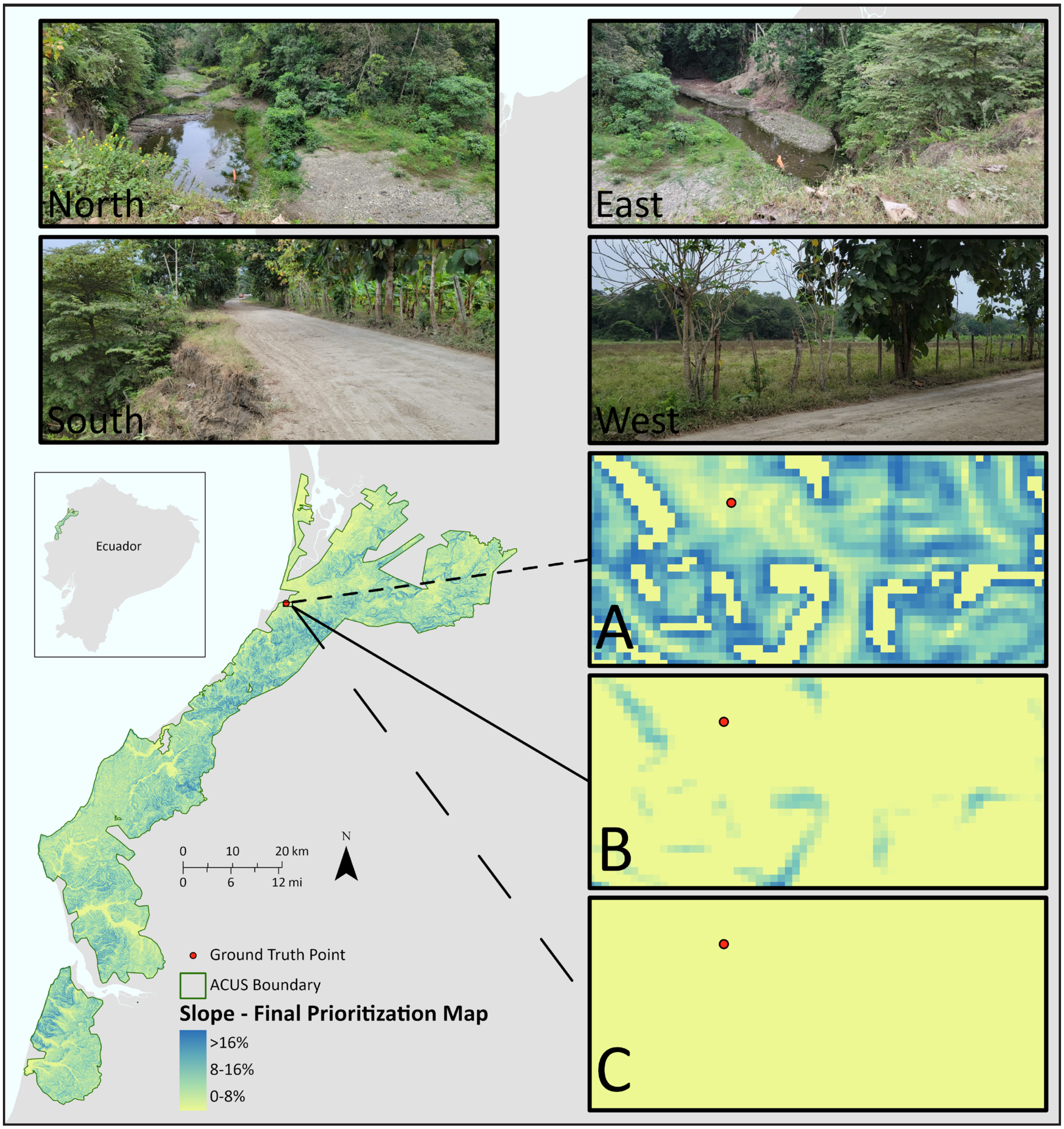

Figure 2.9. FPM Slope Accuracy. This visualization shows a location where we conducted ground truthing (red point) overlaid on the DEM of the ACUS used in the FPM. The DEM is visualized by a yellow to cyan to blue gradient, with blue areas deemed higher elevation than cyan and yellow, respectively. (A) Map inset showing FPM Slope Category 1 data layer accuracy at ground truth point above a cliff to the north. FPM Slope Category 1 does account for the large drop in slope; (B) Map inset showing FPM Slope Category 2 data layer accuracy at ground truth point above a cliff to the north. FPM Slope Category 2 shows elevation changes in the south and west; (C) Map inset showing FPM Slope Category 3 data layer accuracy at ground truth point above a cliff to the north. FPM Slope Category 3 does not show steep elevation changes in the area; (North) Photo taken facing north towards cliff from Ground Truth Point; (East) Photo taken facing east towards cliff from Ground Truth Point; (South) Photo taken facing south away from cliff from Ground Truth Point; (West) Photo taken facing west away from cliff from Ground Truth Point. Photo credit: Antonio Morsette, 2022

4.1.2 DEM - Proximity to Water

Figure 2.10 shows Surface Rivers or Streams from two different sources: (1) yellow data were collected in the field by our project team, and (2) cyan data were developed by (Kelly, 2022). The (Kelly, 2022) Surface Rivers or Streams ("KSRS") layer is fairly accurate due the Ceiba Foundation spending time developing the map and ground truthing the waterways. The KSRS layer accounts for most of the stream location data we collected in the field. However, it does not account for intermittent streams that only flow during the wet season (Figure 2.10(C)). The nearest water source from where we sampled the dried stream is approximately 770 meters away (Figure 2.10(C)). This is not a problem for the purposes of this study as water being available year round is more important to species restoration in this area.

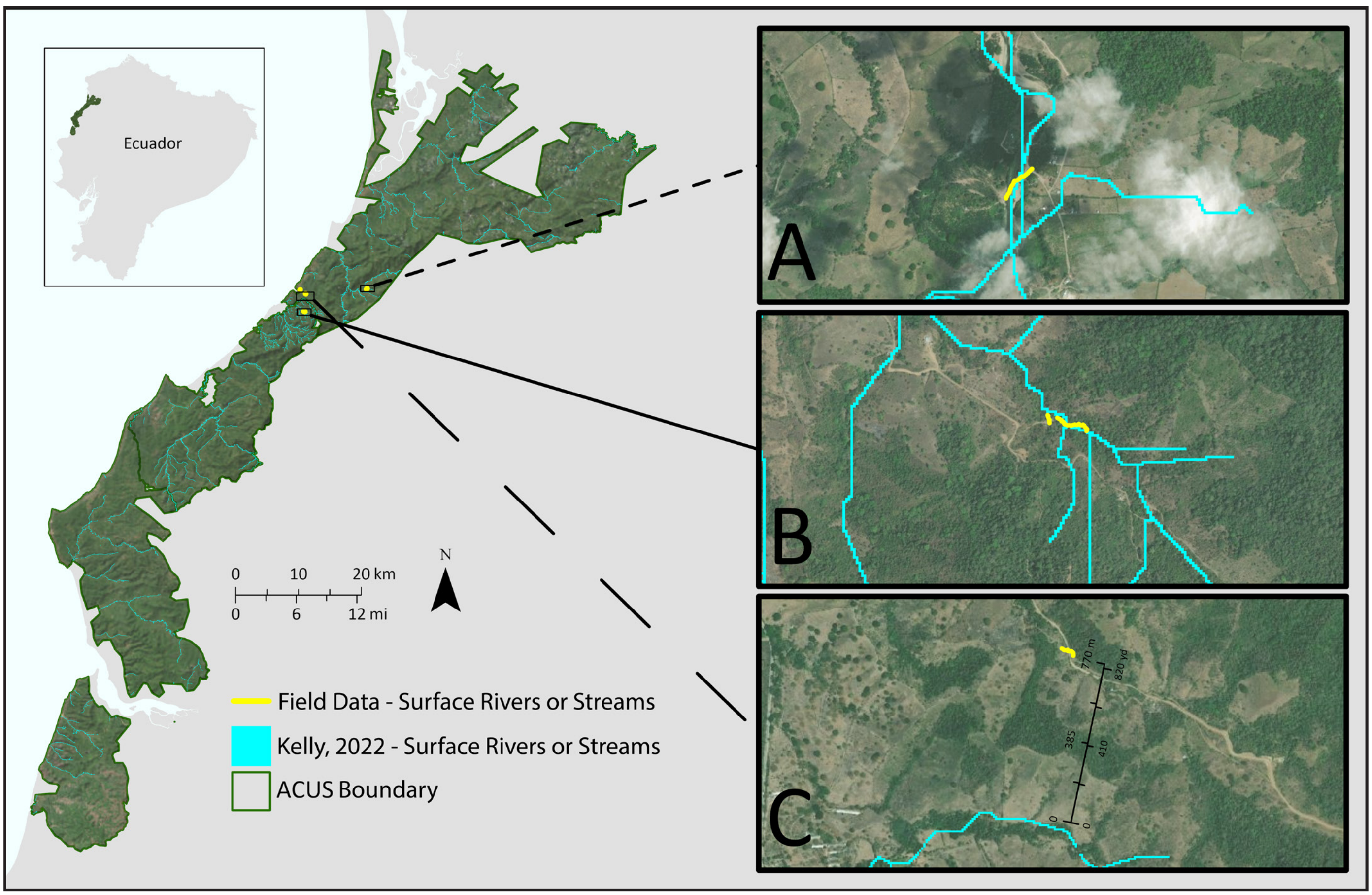

Figure 2.10. Surface Rivers or Streams Data Layer Reliability. This map shows a comparison of ground truthed locations in yellow and DEM derived stream water layer in cyan. The location is within the external boundaries of the ACUS. (A) Field data taken at a stream that runs through the Finca properties shows the layer accounts for stream data; (B) Field data taken at a river shows the layer accounts for river data; and (C) Field data taken at a dried stream shows the layer does not account for intermittent streams in the ACUS

4.1.3 Proximity to Roads

We use elements of visual interpretation to determine the accuracy of the (OpenStreetMap, n.d.) roads data ("OSM") layer, including comparing the layer to GPS/GNSS data we collected in the field (Figure 2.11). We individually compare the OSM layer with our GPS/GNSS data and EWI, Figure 2.11(A, B, and C) respectively. The results indicate that the OSM layer accounts for main roads but is missing data when compared to some dirt roads (Figure 2.11(C)). However, this missing data are minimal. Additionally, there are areas around the edge of the ACUS that are far away from any roads (e.g., the northeast section of the ACUS). This does affect the Euclidean distance calculation (e.g., some areas do not have a calculated score), but the effects are minimal and only happen around the edge of the ACUS. With this level of accuracy throughout the study area, we can be confident that the OSM roads layer is a good fit for our model.

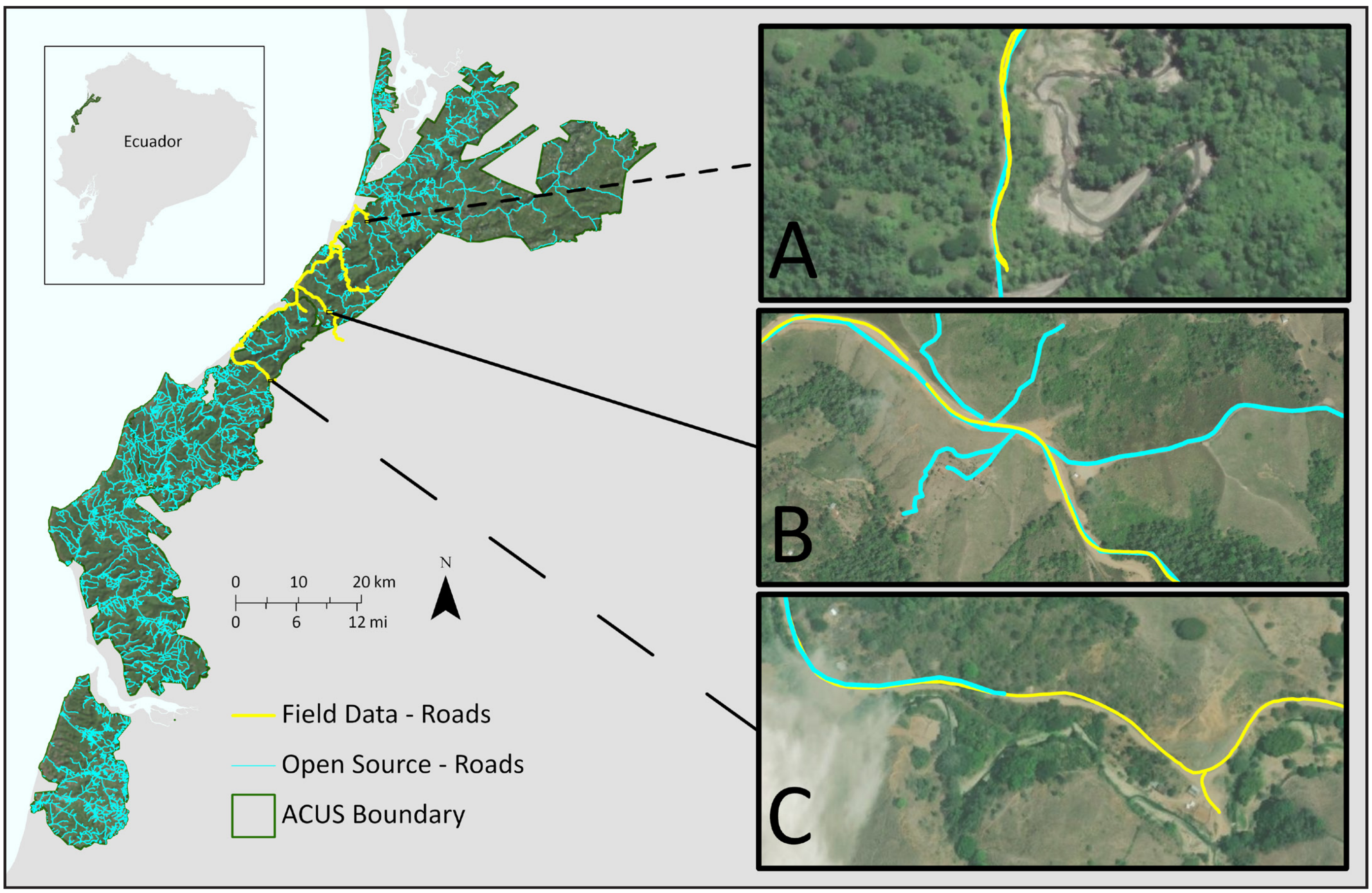

Figure 2.11. Road Data Layer Reliability. This map shows a comparison of ground truthed locations in yellow and open source data in cyan. The location is within the external boundaries of the ACUS. (A) Field data taken on a dirt road shows the OSM layer accounts for dirt roads; (B) Field data taken on a dirt road shows the OSM layer accounts for dirt roads beyond what where we visited; and (C) Field data taken on a dirt road shows the OSM layer does not account for all dirt roads' locations

4.1.4 Location of Buildings

According to the developers of the Proximity to Buildings data source layer, building identification has an average precision and recall of 0.95 and 0.91, respectively (Tiecke et al., 2017). Figure 2.12 shows a comparison of open source data in cyan overlaid on EWI. With a pixel size of 30 meters, the Location of Buildings open source layer completely masks the buildings in the EWI (Figure 2.12(B)). The open source data accounts for smaller single housing settlements (Figure 2.12(A and B)) and larger settlements (Figure 2.12(C and D)). There are some inaccuracies within the dataset, but they do seem to be minimal. With this level of accuracy throughout the study area, we can be confident that the Location of Buildings layer is a good fit for our model.

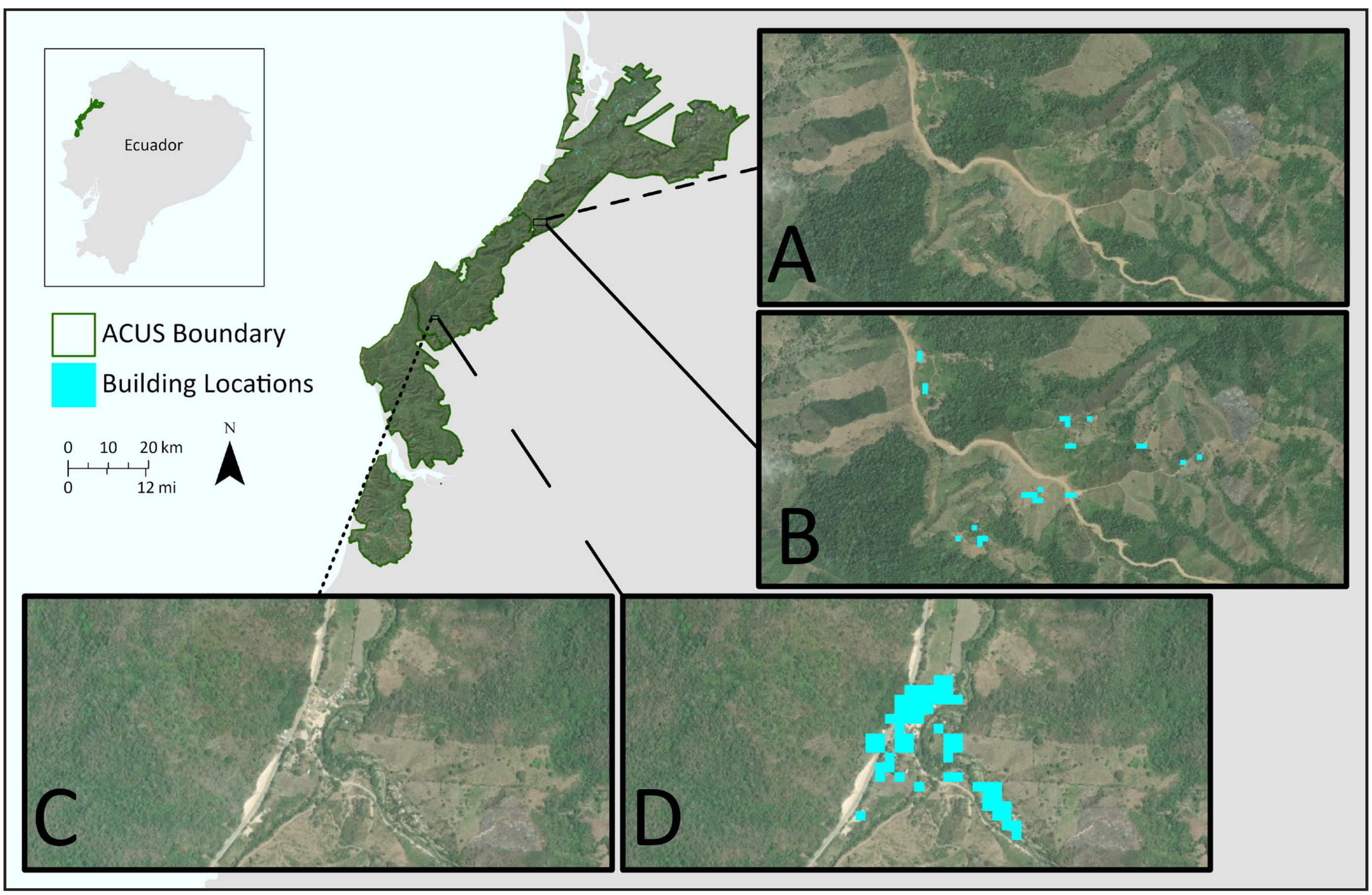

Figure 2.12. Building Data Layer Reliability. This map shows a comparison of open source data in cyan overlaid on EWI. The location is within the external boundaries of the ACUS. (A) Remote area where a low number of housing developments are located; (B) Showing reliability of open source data identifying housing developments in location A; (C) Larger settlement area where a higher number of housing developments are located; and (D) Showing reliability of open source data identifying housing developments in location C

4.1.5 Forest Locations

When we conduct a visual interpretation of the Forest Location data source compared against EWI, we observe that its level of accuracy varies throughout the ACUS landscape (Figure 2.13). These findings are consistent with (Shimada et al., 2014); where levels of accuracy vary from 82%-94.81% depending on the data source it is compared against. With this level of accuracy throughout the study area, we can be confident that the Forest Location source is a good fit for use in our model.

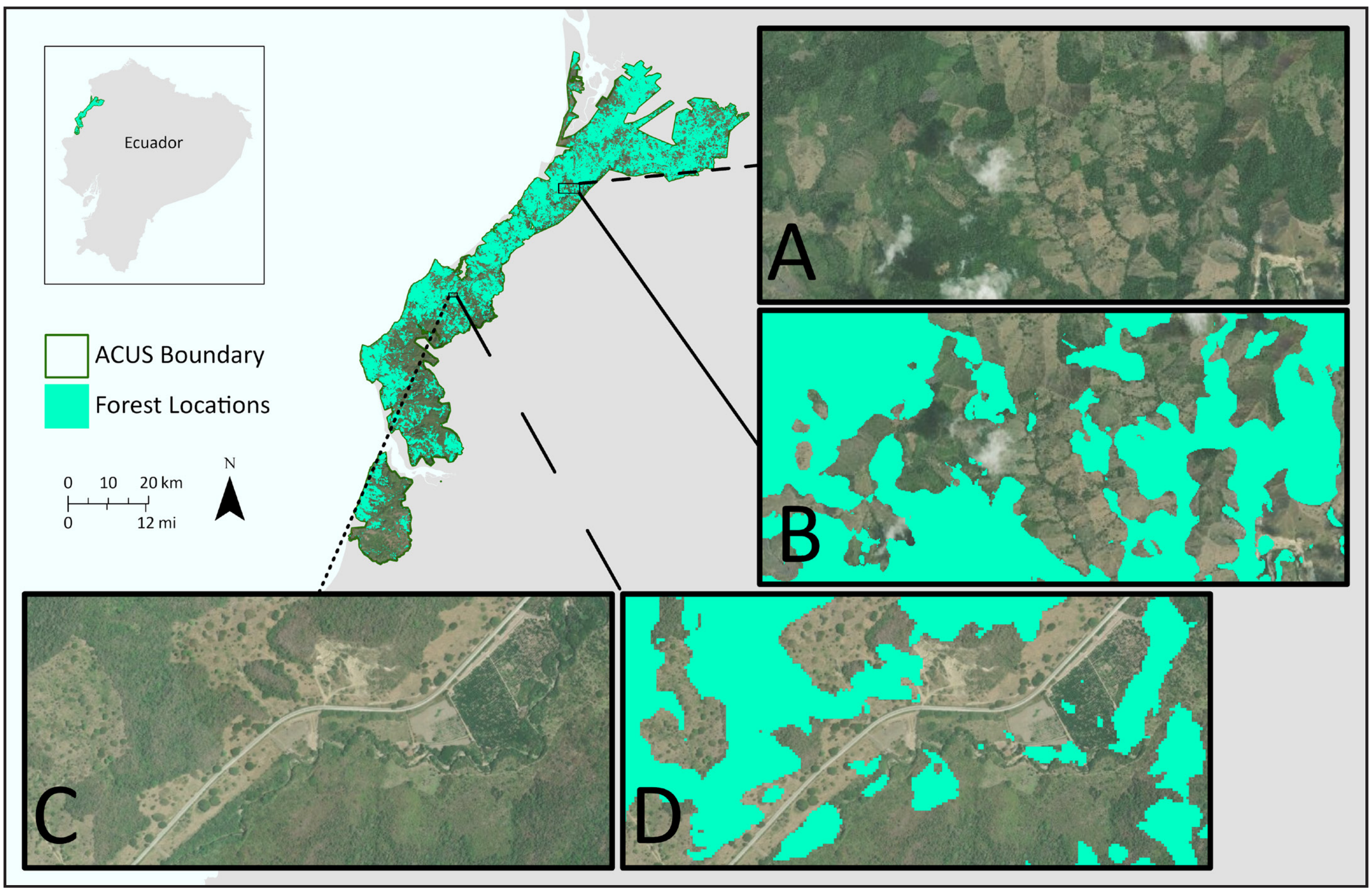

Figure 2.13. Forest Location Data Source Reliability. This map shows a comparison of open source data in cyan overlaid on EWI. The location is within the external boundaries of the ACUS. (A) Remote area where a high number of forests are located; (B) Showing reliability of open source data identifying and differentiating between forested and not forested areas within location A; (C) Area where a large area appears to be made up of primarily open fields; and (D) Showing reliability of open source data identifying and differentiating between forested and not forested areas within location D

4.1.6 Forest Connectivity

The Conefor software provided information that helped assess the overall connectivity dynamics of the ACUS. Using this information, we could prioritize restoration areas that have the potential to maintain or improve overall connectivity of the forest landscape.

Conefor calculated the overall connectivity index of EC(IIC) as 67243.63 which interprets to be the size of a single forest patch (m^2) that would provide the same value of the IIC metric as the actual forest landscape pattern as the ACUS. This indicates that the forest of the ACUS has the same relative connectivity of a continuous patch of forest the size of 6.724363 ha.

"Nodes" refer to the forest patches themselves. For this analysis, we used a minimum node size of 10 ha by request of the client which led to the identification of 225 forest nodes within the ACUS. The Conefor software also calculated the importance of each node as a value that represents the decrease in overall connectivity caused by the removal of that node from the landscape (Figure 2.14).

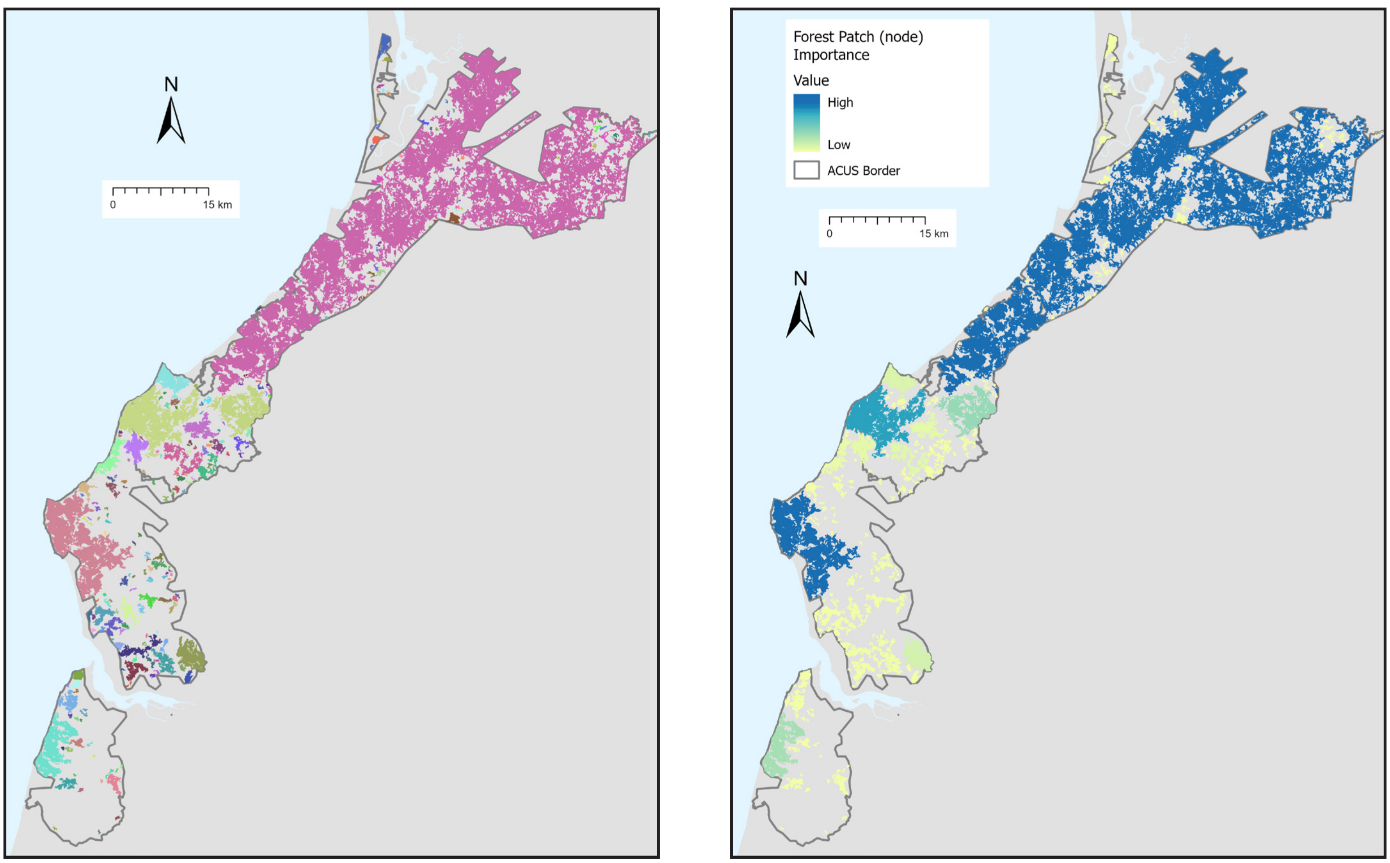

Figure 2.14. Forest Patches. The left map shows the ACUS with each individual forest patch (or node) larger than 10 ha displayed with a unique color. The largest node by far is the pink patch covering much of the upper ACUS (59324 ha) and therefore it has the largest index score of 62.53765. The right map displays each patch with its corresponding index score assigned by the connectivity analysis (high scores: dark blue, low scores: yellow)

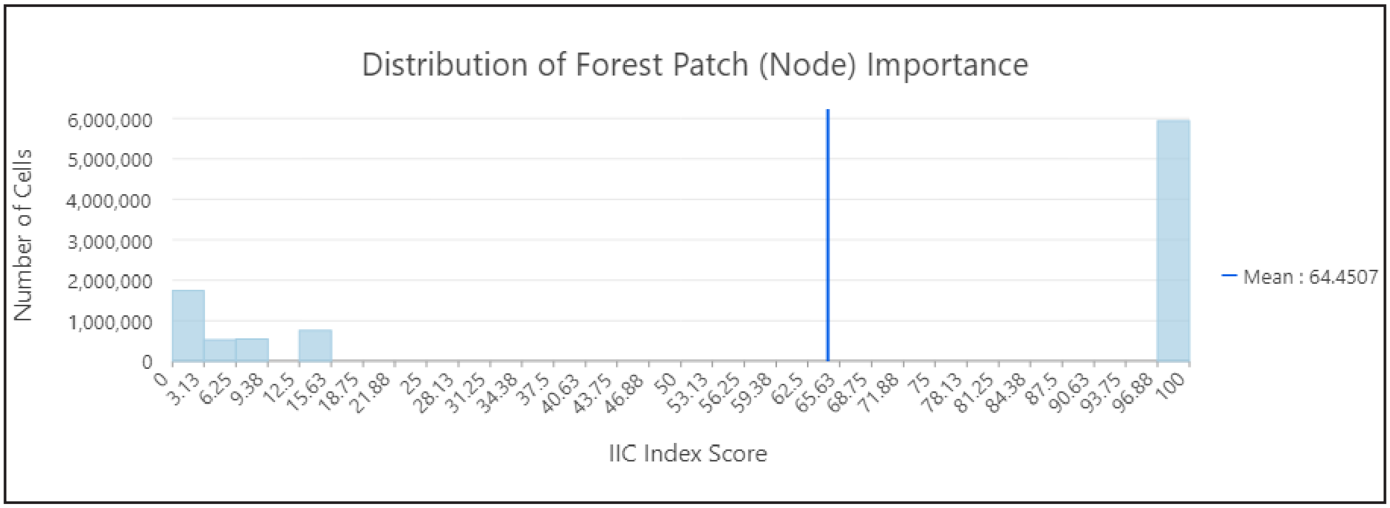

Figure 2.15. Node Importance. Distribution of node importance scores (rescaled to 0-100). These scores have an extremely odd distribution with a wide gap in between lower scored patches and higher scored patches

Using the node importance values, we were able to assign those values to the cells surrounding each corresponding forest patch (Figure 2.15). We then created a layer that took into account distance from forest patches as well, and when we combined these two layers, the result was a layer that prioritized restoration activities to occur close to forest patches with high node importance values (Figure 2.16).

"Links" refer to a pair of patches that are currently connected in the landscape. Since we were not focusing on restoration for a single species, we implemented a distance threshold of 1000 meters in order to account for the potential dispersal distance of multiple taxa within this ecosystem (Saura, 2006). Therefore, in our specific analysis, links represent two patches that are within 1000 meters of each other. When using this distance threshold, our study area had a total of 399 links which account for 18.1905 points to the overall IIC index.

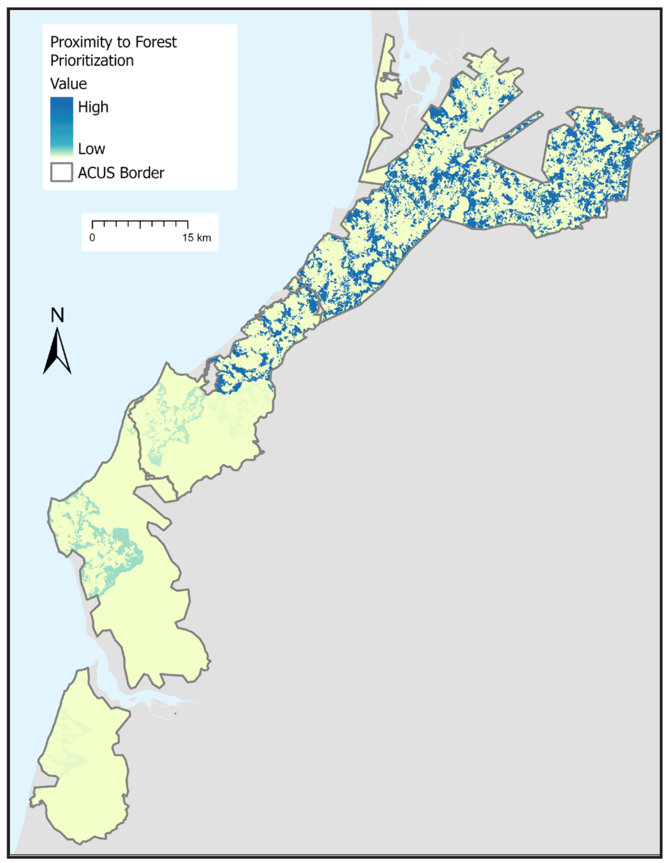

Figure 2.16. Proximity to Forest. Layer created using node importance values from the connectivity analysis. The layer is visualized using a yellow to cyan to blue gradient, with blue areas deemed higher prioritization than cyan and yellow, respectively

The Conefor software we used also had the ability to calculate "link improvements". This part of the analysis highlighted connections between patches (that were not currently links or less than 1,000m distance) that could lead to overall connectivity improved if restored. Some of these connections passed through areas outside of the ACUS, and therefore they were deleted. We also deleted connections that were greater than 10,000m as restoring connections above this distance would be an unrealistic task. This left us with 21 connections that have the potential to increase the connectivity index by 36.6 points (almost twice than if all existing links were removed) (Figure 2.17).

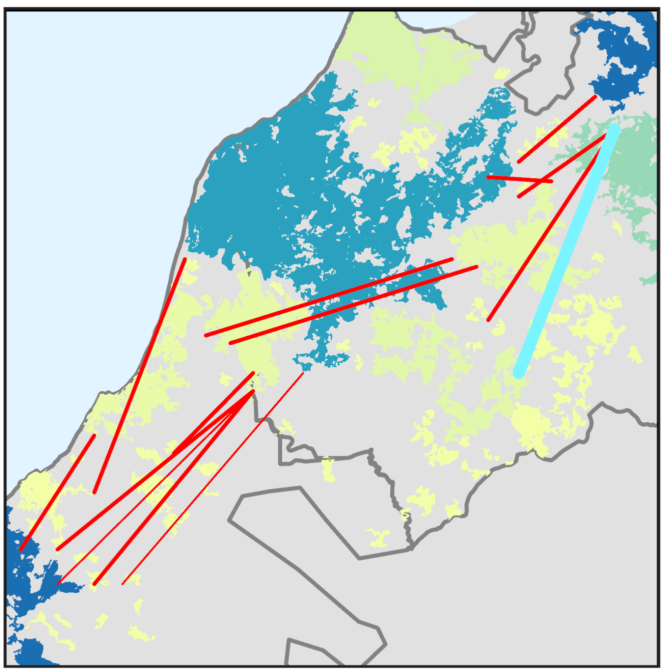

Figure 2.17. Connectivity Improvement Lines. The red lines in this visualization show potential link improvement connections. The connection (i.e., the line) highlighted in cyan represents the connection with the highest improvement potential if restored with a score of 3.007

Using the improvement scores of each of these connections, we were able to assign those scores to the matrix (or unforested) cells, both in and around these connections. We again created a layer that took into account distance from connection lines, and when we combined these two layers, the result was a layer that prioritized restoration activities to occur between patches that showed potential improvement to the overall connectivity of the landscape if further connected via restoration (Figure 2.18).

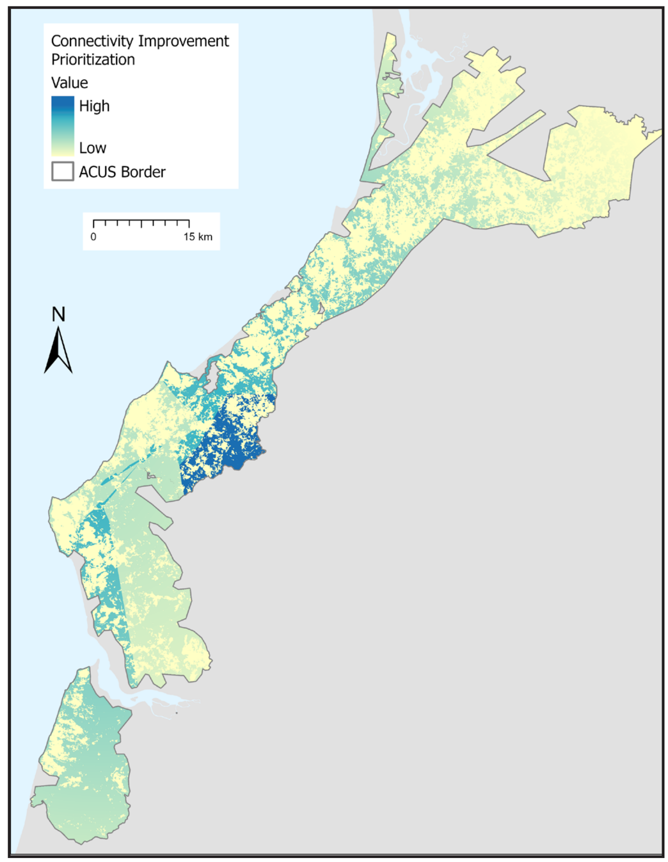

Figure 2.18. Connectivity Improvement Map. "Connectivity" layer created using connection lines and their corresponding link improvement scores generated during the analysis. The layer is visualized using a yellow to cyan to blue gradient, with blue areas deemed higher prioritization than cyan and yellow, respectively

4.1.7 Locations of Active Fires in 2021 and Forest Loss Due to Fire 2001-2021

In order to get the most accurate representation of fires in our study area, we did the following to the two forest layers:

1. Active Fires in 2021 - We filter low confidence data out of our layer in order to remove potential false positive hotspot/fire pixels (Earth Science Data Systems, 2016).
2. Forest Loss Due to Fire for Years 2001-2021 - We filter the data source in order to represent a medium to high certainty that the forest loss was due to fires (Tyukavina et al., 2022).

If we compare the results of the two Fire layers to a deforestation layer created from (Hansen et al., 2013), we find that fire locations do not occur in every deforested area of the map (Figure 2.19). This gives us confidence that we can use these layers in our FPM in order to represent forest fire locations.

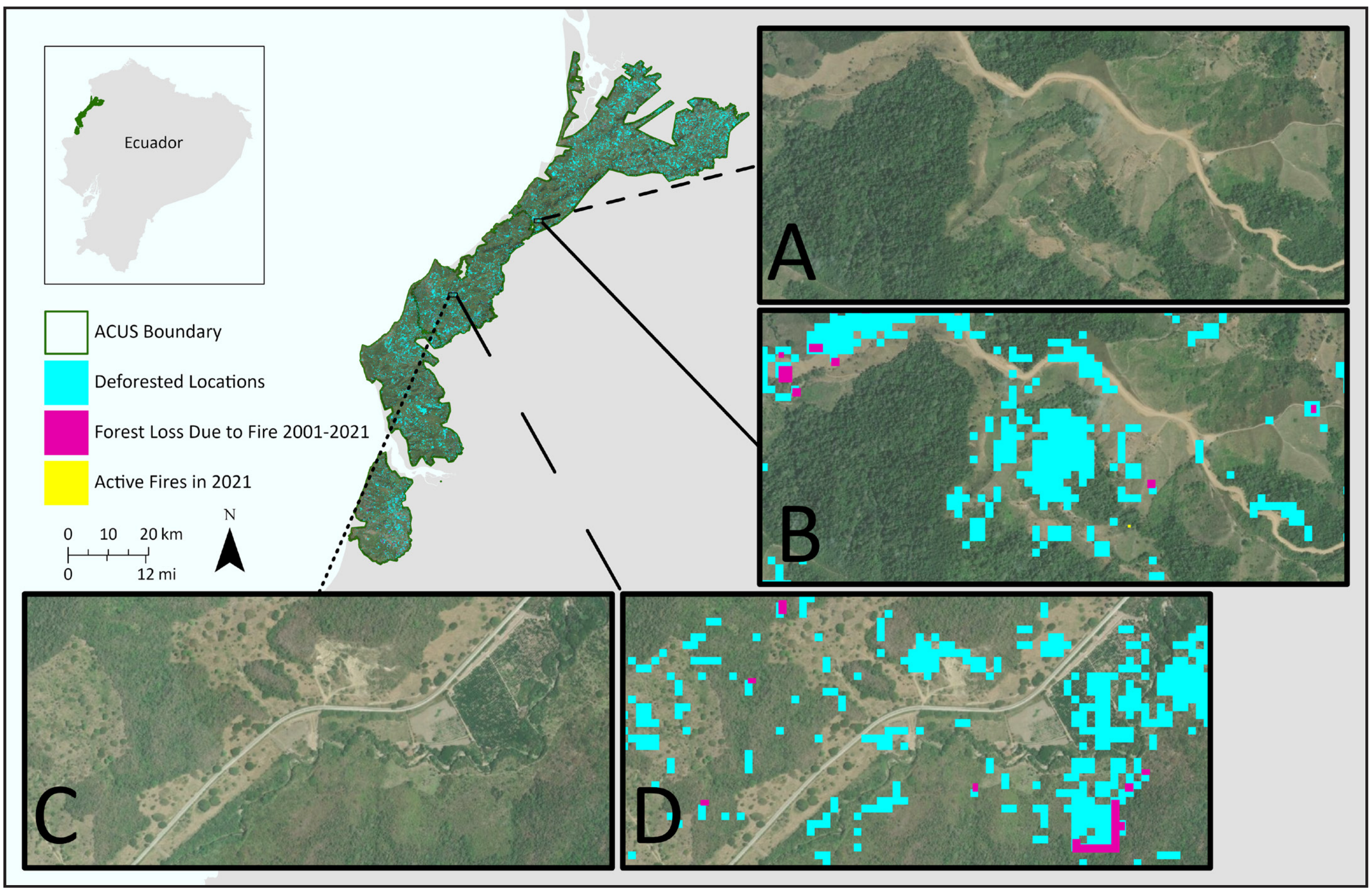

Figure 2.19. Fire Data Layers Reliability. This map shows a comparison of Forest Loss Due to Fire 2001-2021 in Pink, Locations of Active Fires in 2021 in yellow, and Deforested Locations in cyan overlaid on EWI. The location is within the external boundaries of the ACUS. (A) Remote area where a large area is made up of forest; (B) Showing reliability of open source data identifying deforested locations and differentiating among it and the two fire land cover classes within location A; (C) Area where a large area appears to be made up of primarily open fields; and (D) Showing reliability of open source data identifying deforested locations and differentiating among it and the two fire land cover classes within location C

4.2 Final Map

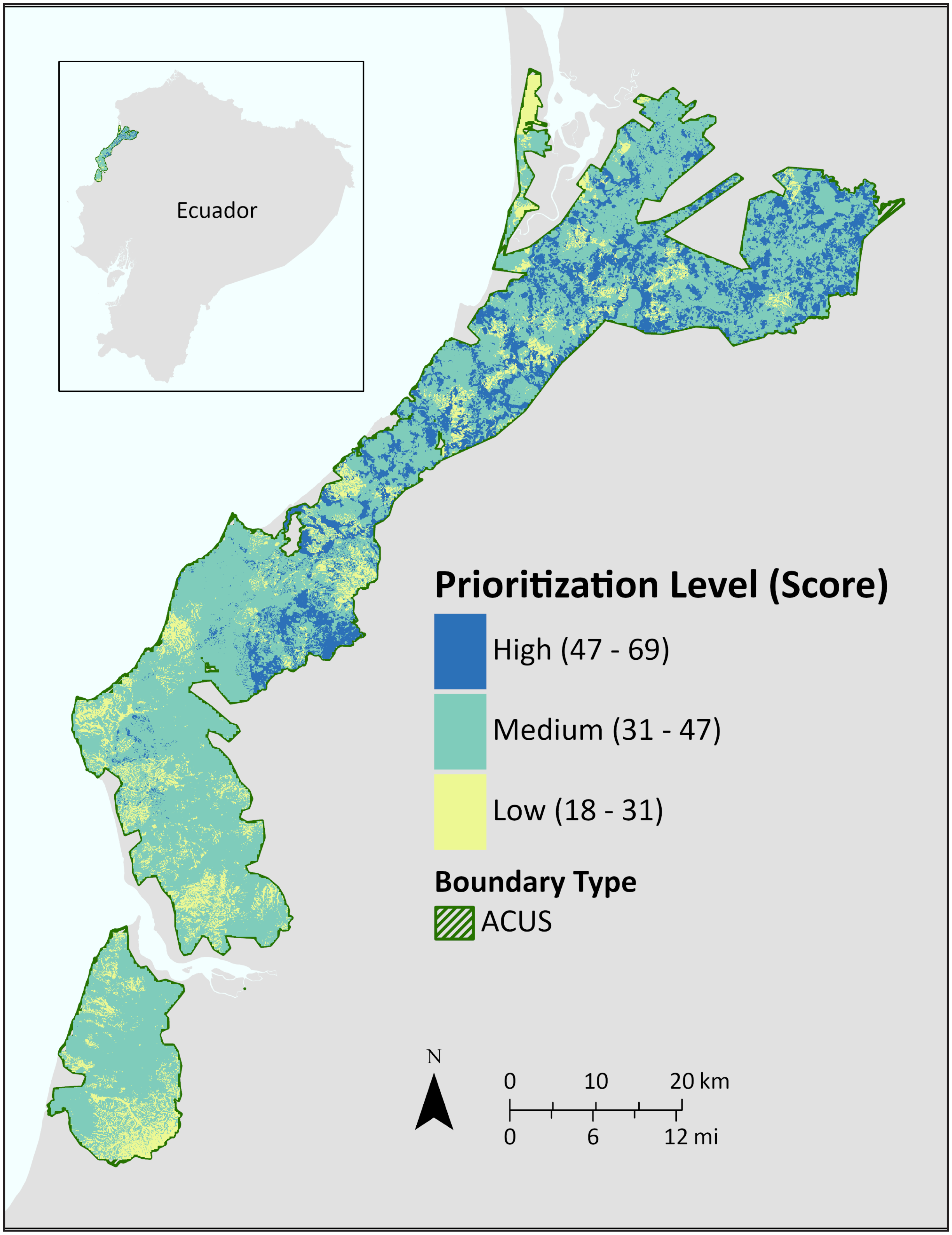

Figure 2.20. Final Prioritization and Restoration Map. This visualization shows a map of the Final Prioritization Areas for Restoration and Reforestation within the ACUS

The FPM depicts prioritization areas highlighted on a scale from highest restoration priority in blue, to medium restoration priority in cyan, to lowest restoration priority in yellow (Figure 2.20). Restoration priority level categories are based on the standard deviation from the mean for the distribution of pixels/ cells' values within the FPM (Figure 2.21). The FPM does have areas around the edge of the ACUS that do not have a prioritization level score. This is due to data accuracy / availability in the area (see previous Section 4.1 for more information).

Table 2.5. Distribution of FPM

Priority	Min	Max	Count	Hectares	Percent
Low	18	31	2,363,108	24,720	12%
Medium	31	47	14,145,192	144,200	70%
High	47	69	3,653,345	37,080	18%
	Total		*20,161,645*	*206,000*	*100%*

By examining the histogram of the FPM cell values, we have a general idea of the distribution of prioritization areas within the ACUS. This in turn is an indicator of the relative amount of prioritization areas in which the Ceiba Foundation should focus their restoration and reforestation efforts. Based on the FPM, the Ceiba Foundation has approximately 37,080 hectares (18%) of the ACUS (206,000 hectares) that are labeled high priority areas for restoration and reforestation (Table 2.5).

We developed our FPM with design elements that will help the Ceiba Foundation and future GIS researchers read and understand our geographic visualization more easily. In order to do this, we include a color blind friendly palette, legible fonts, and we organize the FPM in such a way that there is a hierarchical balance to the piece. The color blind friendly palette was chosen in order to be as inclusive as possible to the visually challenged (Harrower & Brewer, 2003; Silva et al., 2011). By incorporating this simple design, the FPM is easily replicable and will continue to help the Ceiba Foundation in their restoration and reforestation efforts.

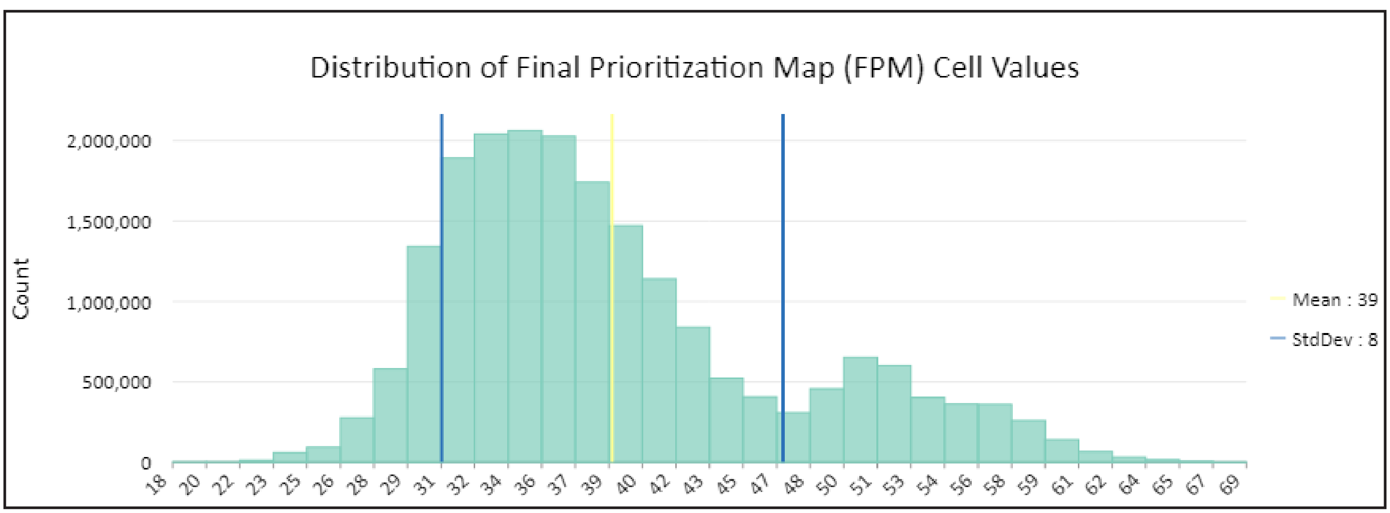

Figure 2.21. Distribution of FPM. This visualization shows the distribution of cell pixels/cells' values within the FPM. The mean is displayed in yellow while the standard deviation is displayed in dark blue

5 Recommendations

5.1 Use the Map to Assess Potential Restoration Sites

The FPM can be used by the Ceiba Foundation as a tool to help identify possible restoration sites within the ACUS. By overlaying potential restoration sites on the FPM, the Ceiba Foundation can use the map to generate a score for sites based on the FPM output cells (Figure 2.22). We have provided a Python script at the end of *Appendix A: Prioritization Map Development Process* to help in generating this score.

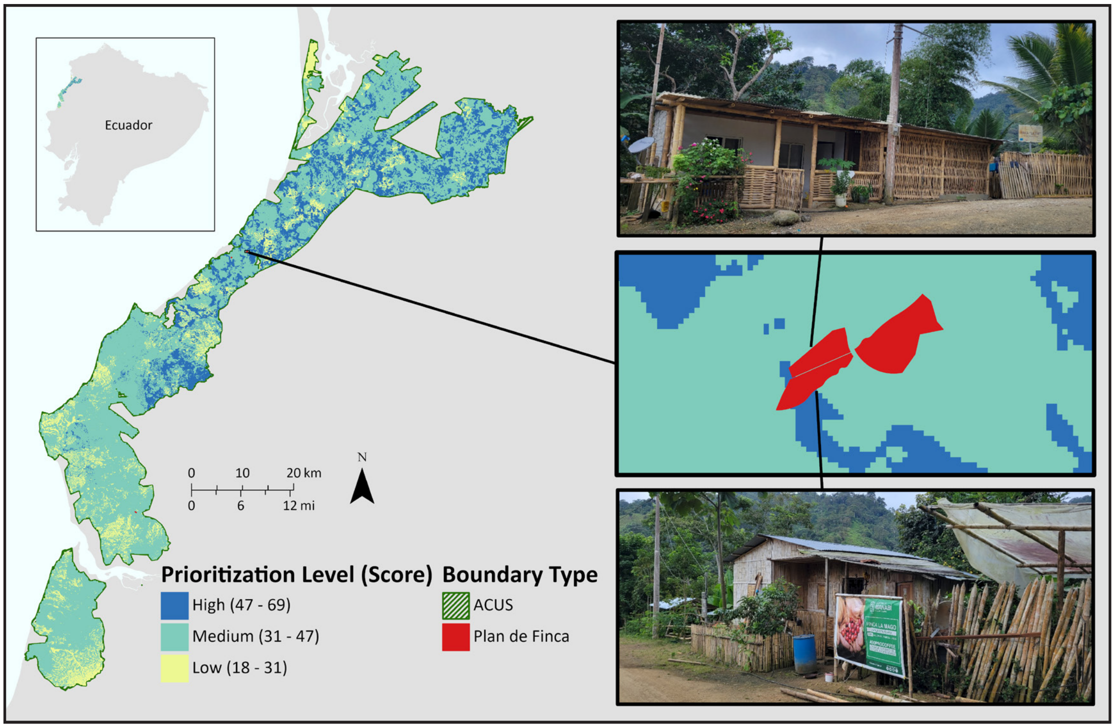

Figure 2.22. Property Prioritization Level. This visualization shows two properties the Ceiba Foundation currently works with overlaid on the FPM to show the potential use of the FPM. Photo credit: Antonio Morsette, 2022

5.2 Refine the Map to Inform Species-Specific Restoration

Our FPM helps in assessing the viability of a restoration site by incorporating restoration criteria from open source layers as inputs. The inputs incorporate criteria specific to Ecuador (e.g., slope), but are not specific to any one species. This being said, our FPM should be used as a generalized tool and not for specific species restoration. If the Ceiba Foundation would like the FPM to be more specific to a given species, we would recommend updating the data sources to fit the species parameters. By identifying more specific species parameters, the Ceiba Foundation can improve the success of their restoration efforts for a given species. These parameters may include but are not limited to: water intake, ideal soil conditions (e.g., soil acidity/alkalinity), fire resistance, and predators.

5.3 Update Data Sources Over Time

The FPM is meant to be a living document that changes as new information becomes known and or new data layer sources become available. Most of the data we used in the development of our FPM is updated by their respective data source providers on an annual basis. This constant updating from the data source providers affords the Ceiba Foundation with an opportunity to update our FPM with the most current information on at least an annual basis. We provide web links for where each data source may be downloaded as well as the full development process for each spatial variable within *Appendix A: Prioritization Map Development Process*.

Our FPM uses data from a variety of sources and therefore has a variety of accuracy levels for each corresponding layer (refer to Section 4.1). To increase these levels of accuracy, we recommend the Ceiba Foundation: (1) update the existing data source layers with ground truth data, (2) create new data source layers to be used in place of or with the FPM, and or (3) find new data source layers to be incorporated into FPM. Table 2.6 represents the specific data source layer recommendations based on our expert opinion driven research and results from our accuracy assessments outlined in Section 4.1

Table 2.6. Data Source Layer Recommendations

Source / Layer	Recommendation
DEM	Updating will help in creating slope layers and water river and stream layers. Once updated, DEM will rarely need to be updated again as the geography of an area doesn't change much through time.
Soil	Find / create a soil layer to make the slope layer more accurate. Once developed, additional layers may be developed (e.g., soil stability). If a specific species is selected for restoration, constrain soil input to the species' ideal soil conditions.
Land Cover	Replace all layers incorporating land cover maps with land cover map currently being developed. Using a map developed specifically for the ACUS will increase overall accuracy.
Precipitation	If a specific species is selected for restoration, edit the precipitation layer to only contain values within the species edaphoclimatic range in order to promote natural survival.
Roads	Create / update existing OSM layer with more dirt roads. This will increase the accuracy and will fill in some of the missing data for the boundary of the ACUS
Buildings	Quantify constraints for buildings and towns in the area. For example: select anything smaller than 60 meters2 and include it as a factor, not a constraint. This will increase the accuracy by helping to identity farm locations - properties the Ceiba Foundation wishes to work with
Ownership	Replace current ownership layer with layer created with data from the landowner willingness survey
Population	Replace with updated census data

5.4 Incorporate Social Factors: Landowner Willingness

Attitudes and perceived behavioral control (individuals' confidence in the impact of their actions), have been found to be significant predictors of intentions among farmers to engage in restoration or conservation actions, however, these indicators measure intentions and not behavioral outcome (Fielding et al., 2008). Lack of technical knowledge about restoration practice and process is a common barrier to landowner participation (Cortés-Capano et al., 2021; Ota et al., 2020; Powlen & Jones, 2019). As a first step to engaging with landowners about potential restoration feasibility, the assessment in *Appendix C: Landowner Willingness Survey* may detect landowners' motivations for restoration, as well as perceived barriers to restoration that align with Ceiba Foundation's expertise and service offerings. Demographic factors have not been shown to affect willingness in the literature. However, this may be different in non-Western societies and local expertise from Ceiba's practitioners should inform inclusion of such variables.

5.5 Continue Improving the Accuracy and Value of the Map

We are confident that our FPM provides the Ceiba Foundation with a reliable tool to help them identify possible restoration sites within the ACUS. However, we still recommend that the Ceiba Foundation perform additional ground truthing throughout the ACUS to determine not only the overall accuracy of the FPM, but the accuracy of each data source layer as well. The Ceiba Foundation can adapt the protocols outlined in our SOP in order to help streamline their ground truthing efforts.

We were able to address some technical challenges in map development as they arose with the support of U-M resources and the Ceiba Foundation, but our capacity to further develop the prioritization map was limited by some other factors. We were able to spend only six weeks on site, working remotely the rest of the time. In the field, our access to vehicles, internet, and electricity were limited to working hours (8am-4pm). Our abilities were also somewhat restricted by our limited knowledge of the area and ability for all team members to speak Spanish. These limitations just confirm the value of future field researchers to continue map development and refine this useful prioritization tool so that it can further contribute to the protection of the unique tropical dry forests of Ecuador.

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Chapter 3: Eco-entrepreneurship in the ACUS Region: What is the Potential and What is Missing?

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1 Purpose and Audience

While the tropical dry forests of Ecuador are a critical source of ecosystem services for local communities, they are also among the most threatened ecosystems on earth. Conservation efforts have sought to protect the invaluable landscapes and biodiversity of Ecuador's forests through the creation of protected areas and "areas of conservation and sustainable use," through which easements and other incentives are granted to local landholders who engage in conservation activity. Efforts like these provide a legal and institutional framework to protect the landscapes and biodiversity of the local tropical dry forests. However, persistent poverty and high opportunity costs for conserving land contribute to pressures to develop or extract resources from these lands in ways that may run counter to local landholders' values.

One possible solution to address the disjunct between the community-wide benefits of conservation and the short-term economic pressures that cause deforestation is eco-entrepreneurship, a term that encompasses a variety of livelihoods practices from wild-harvested or sustainably-grown products to ecotourism. For smallholder farmers or landowners for whom preserving or conserving the natural environment is a key value, eco-entrepreneurship represents an opportunity for individuals to utilize the market economy in ways that align with their values, and to opt out where there is a value mis alignment. Eco-entrepreneurs provide for their own livelihoods while caring for the natural environment by centering sustainable land use and production.

This chapter examines how eco-entrepreneurship can address environmental and livelihood challenges in Manabí, a province of coastal Ecuador rich in both biodiversity and food culture. To understand how eco-entrepreneurship may offer a way forward for sustainable livelihoods and biodiversity conservation in Manabí, we first define and explore the benefits of eco-entrepreneurship. We then address two specific questions:

1. *What are the potential opportunities for and challenges of implementing eco-entrepreneurship in Manabí?*
2. *What are the actual perspectives and experiences of landowners currently utilizing an eco-entrepreneurship approach in Manabí?*

We address the first question through an analysis of the situation for eco-entrepreneurs in Manabí; and we address the second by drawing from interviews we conducted with local eco-entrepreneurs on-site in Manabí.

We provide this analysis of regionally-specific opportunities for, and barriers to, effective eco-entrepreneurship efforts in this region to elucidate the support that potential and active eco-entrepreneurs require specifically to inform the following key audiences:

1. The Ceiba Foundation for Tropical Conservation (the "Ceiba Foundation"). The Ceiba Foundation is an NGO with more than 20 years of experience in conservation and programming with local communities in Manabí. They are also the client organization for this project (see Chapter 1 - Introduction: Supporting Forest Restoration and Sustainable Livelihoods in Coastal Ecuador).
2. Farmers and food producers in Manabí, who may benefit from exposure to new or adapted strategies to support their livelihoods that adhere to a value system that guides them (see Section 4.2).
3. Scholars or practitioners interested in the nexus of sustainability and livelihoods in a tropical dry forest context (e.g., other conservation organizations looking for strategies to support community livelihoods and biodiversity).

While the information provided in this chapter is designed specifically with these three audiences in mind, themes from our analyses and findings are relevant to broader efforts toward supporting sustainable livelihoods in tropical settings.

Figure 3.1. Coffee-drying process in raised beds at processing facilities of local coffee cooperative ASOPROCOFFEE

2 What is Eco-entrepreneurship, and Can it Address Deforestation in Manabí?

2.1 The Problem of Deforestation in Manabí

The tropical dry forests of Ecuador are a critical source of biodiversity, carbon sequestration, and ecosystem services such as water purification, and they provide important ecological and health benefits for local communities (Quijas et al., 2019). Despite these benefits, tropical dry forests are among the most threatened ecosystems on Earth, with 86 percent of Ecuador's tropical dry forests classified as highly threatened (Rivas et al., 2021). Logging, land clearing for agro-industrial production, and contamination from shrimp farming are all causing significant habitat loss and fragmentation in Manabí's tropical dry forests (Rivas et al., 2021).

International and local conservation efforts have sought to protect Manabí's tropical dry forests through the creation of protected areas and the provision of incentives for local landholders (including farmers, ranchers, reserve owners, and developers). An example of these efforts is the Sustainable Use and Conservation Area of Manabí (in Spanish, the Area de Conservación y Uso Sostenible, or "ACUS" — the development of which is explained in *Chapter 1: Introduction*). The ACUS designates conservation and sustainable production incentives within a continuous landscape, across four coastal counties in Ecuador. The ACUS provides a legal and institutional framework to protect the invaluable tropical dry forests of the region and preserve vital ecosystem services while supporting eco-entrepreneurs engaged in conservation efforts.

However, while efforts in the region provide a legal and institutional framework to protect local tropical dry forests, poverty and opportunity costs create sustained pressure to develop or extract resources from these lands. The intensive developmental pressures placed on these lands are powerful and not easily remedied. Thus, despite current conservation efforts, tropical dry forests in Manabí remain at high risk for deforestation. The implementation of eco-entrepreneurship strategies is a potential solution to reconcile local landholders' values, biodiversity conservation, and viable livelihoods practices. Here we clarify what it encompasses, and what its known benefits are.

2.2 What is Eco-entrepreneurship?

The concept of eco-entrepreneurship is central to this chapter and project overall, because it provides a conceptual framework to bridge the goals of sustainable agricultural productivity and environmental protection. While the term eco-entrepreneurship is variably defined in the agroecology and conservation literatures (Table 3.1), we follow Mars & Lounsbury (2009) in defining eco-entrepreneurship as an approach to environmentalissues grounded in "supposedly competing activist andmarket logics (p.8). This definition underscores the critical role that values play in structuring how eco-entrepreneurs engage strategically with markets where such engagement aligns with their values, but use alternative practices such as subsistence farming where income maximization as a value and strategy would undermine more salient values held by eco-entrepreneurs. Eco-entrepreneurship strategies thus both exist within and work outside market economies.

Eco-entrepreneurship strategies can also differ within a landscape. Within the Manabí ACUS, approaches to eco-entrepreneurship span a range of agricultural and business practices that includes sales of wild-harvested or sustainably-grown products and various forms of ecotourism, but specific approaches to these strategies can differ significantly. Eco-entrepreneurs within the ACUS often, though not always, combine sustainable production with high-value-added products, that is, products where outputs have been modified to have some sort of higher value (for instance fruit jam or spirits instead of raw fruit, roasted coffee rather than harvested coffee cherries, or chocolate as opposed to cacao). These practices echo van der Ploeg's (2018) analysis of the role that added value plays in sustaining peasant economies, and enabling smallholder farmers to retain livelihoods practices and value systems that exist outside the framework of profit maximization.

2.3 Eco-entrepreneurship Improves the Agroecosystem Quality of the Matrix

The literature on tropical dry forests is underdeveloped relative to their importance to global biodiversity conservation efforts and climate change mitigation (Schröder et al., 2021). However, there is some evidence that eco-entrepreneurship grounded in agroforestry (Montes-Londoño, 2017) or silvopastoral systems (Sánchez-Romero et al., 2021) can balance food production and biodiversity conservation in a tropical dry forest context. Eco-entrepreneurial activities with high levels of planned and associated biodiversity (planned biodiversity being the species a farmer chooses to introduce, and associated biodiversity being the unplanned flora and fauna that then inhabit the resulting agroecosystem) introduce a number of ecosystem benefits beyond the site of the farm.

One potential benefit of agroecosystems is that they can enhance the quality of the agroecological matrix, or patchwork of agricultural and forested land across the landscape, meaning that species are better able to migrate across food-producing plots and repopulate forest patches (Perfecto et al., 2009). This high connectivity across the landscape is particularly prevalent in agroecosystems with high levels of planned biodiversity, relatively low levels of agricultural intensification, and nearby patches of unperturbed forest habitat. For instance, research indicates that shade-grown coffee farms with a variety of native tree species that provide canopy for smaller coffee trees can contribute to effective conservation at the landscape level (Perfecto & Vandermeer, 2015). The synergy between food production and conservation also works the other way: high levels of biodiversity often provide benefits for food production. Notably, well-designed polyculture systems often create synergies between yield and pest control (Iverson et al., 2014). For a deeper review of the ecological benefits of agroforestry systems specifically, see *Chapter 4: Benefits of Agroforestry for Biodiversity and People*.

2.4 Eco-entrepreneurship Can Reconcile Livelihoods and Biodiversity Conservation

Eco-entrepreneurship strategies have the potential to transform relationships to land for both producers and consumers. Through an eco-entrepreneurial lens, producers may view the land as a resource that provides greater productivity when it is healthier, and consumers may view the land as a resource that enables the production of high-quality products that they want. In a real-world setting, eco-entrepreneurship efforts face many challenges, but the potential for economic benefits from eco-entrepreneurship in tropical dry forests has been documented (Montes-Londoño, 2017). These economic benefits can exist in various forms and to varying degrees, dependent on context; sometimes producers primarily benefit financially from the sale of artisanal products, whereas other times governments may make payments to producers for land conservation, which may be an important source of income on top of product sales (Nikolaou et al., 2011). Eco-entrepreneurship grounded in agroecological systems can also support food security and income generation (see *Chapter 4: Benefits of Agroforestry for Biodiversity and People*). Regardless, when a high-quality agroecosystem matrix is an important resource for producers, consumers, and the broader public, market forces can theoretically reconcile posi-

Table 3.1. Definitions of Eco-entrepreneurship

Citation	**Term and Definition**
Mars and Lounsbury, 2009	"**Eco-entrepreneurship.**..blends oppositional logics (market and social activist) and provides entrepreneurial-minded activists with an avenue for advancing ecological agendas in ways not centered on the compliance or support of large bureaucratic organizations and the state."
Jayasinghe et al., 2021	"**Eco-entrepreneurs** are those who consciously seeking business opportunities to provide or support profitable yet resource-efficient and environmentally friendly products and services. Therefore, eco-entrepreneurship lies at the nexus of innovation, environment and entrepreneurship."
Kirkwood & Walton, 2010	"**Ecopreneurs** are those entrepreneurs who start for-profit businesses with strong underlying green values and who sell green products or services."
Perfecto et al., 2005; Verchot et al., 2007; see also Chapter 4	**Agroforestry** systems are a distinct form of agriculture that integrates commercial crop production with a diverse and dense canopy of tree species.
Chambers & Conway, 1992	"A **livelihood** comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a living is **sustainable** which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide **sustainable livelihood** opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term."
Ceballos-Lascuráin, 1987	**Ecotourism** is "tourism that consists in travelling to relatively undisturbed or uncontaminated natural areas with the specific object of studying, admiring and enjoying the scenery and its wild plants and animals, as well as any existing cultural manifestations (both past and present) found in these areas."

3 What Are the Potential Opportunities and Challenges of Eco-entrepreneurship in Manabí?

3.1 Potential Opportunities

Conversations in Manabí often revolve around food. The region is known to many as the culinary capital of Ecuador, and residents and farmers take pride in this reputation. Within the ACUS, many smallholder farmers (which we use here to refer to farmers operating farms of two hectares or less) cultivate diverse mixtures of crops in forest patches with high levels of both planned and associated biodiversity. The rich food system in Manabí relies on the region's high levels of biodiversity, excellent local growing conditions, and high-quality soil, which results in the capacity to produce high quality food items.

Numerous farms in Manabí currently produce a diverse set of goods, including coffee, cacao, and fruit—sometimes on the same plots—and use sustainable practices that contribute to a high-quality agroecological matrix. Eco-entrepreneurs pointed to several benefits to producing food in this way, including the benefits of a healthier environment to live in, income smoothing and insulation from price shocks or seasonal variation, and greater food security for their households. Growing a diverse set of foods helps to ensure consistent production across seasons, which is important both for selling products and improving food security for the farmers and their families. These benefits suggest that eco-entrepreneurship can play a critical role in addressing the social and economic drivers at the heart of deforestation and biodiversity loss, while providing sustainable and self determined livelihoods for local communities.

Figure 3.2. Local Manabí cuisine and coffee

3.2 Potential Challenges

Competition between monoculture and agroecological production causes economic mismatches both in farming inputs and market prices. We learned that farmers in in Manabí employ a variety of farming practices: some farmers rely heavily on intensive, monoculture farming practices with high levels of synthetic inputs, while others commit to agroecological or silvopastoral methods that allow for the preservation of on-farm biodiversity. This creates a challenge from the perspective of encouraging transitions to eco-entrepreneurial livelihoods: where monocultures predominate they can function as a "stable state" that precludes the introduction of agroecological systems due to competition (Griffon et al., 2021), as monoculture farming with high levels of synthetic input on larger land holdings enables some farmers to increase yield and profits while maintaining low labor inputs.

Indeed, despite the potential for eco-entrepreneurship to benefit both farmers and land conservation, eco-entrepreneurs are likely to face economic barriers of high opportunity costs, higher input prices, lower yields, and low market prices to offset their costs. Opportunity costs for smallholder farmers are particularly high because incomes might be boosted in the long term by agricultural intensification of cash crops, rather than pursuing more sustainable farming methods (Bustamante et al., 2014). Furthermore, despite inputs of time and energy being higher for sustainable agricultural products (Timmermann & Félix, 2015), conversations with current eco-entrepreneurs in Manabí (discussed in more detail in Section 4.0) revealed that market prices often do not reflect the level of inputs to, nor the high quality of, these products.

Beyond economic barriers, eco-entrepreneurs in Manabí depend on the productivity and resilience of their land, which is often affected by environmental degradation of the larger landscape due to loss of primary forest, agricultural intensification, and urbanization. Forests—primary forests in particular—play an important role in filtering water and allowing for groundwater flow into the larger hydrologic system of a region. The clean water that eco-entrepreneurs need for their crops is thus directly affected by nearby environmental degradation. As the only province in Ecuador that is not part of the Andean watershed, Manabí suffers from a lack of access to clean water for municipal and agricultural use due to land use change, industrial shrimp production, and deforestation (Jolley, 2013). Loss of primary forest also threatens other critical ecosystem services on which eco-entrepreneurs depend, such as biodiversity, climate regulation, carbon sequestration, and soil health. These changes have been exacerbated by agricultural intensification, which has driven further land-use changes in Manabí. In particular, monoculture plantations of crops like cacao and watermelon have become more common, and have reduced biodiversity relative to agroecological farms or primary forest (*see Chapter 4: Benefits of Agroforestry for Biodiversity and People*).

Furthermore, while the Pacific coast of Manabí was relatively undeveloped until recently, this is rapidly changing. In particular, there are a growing number of *urbanizaciones*—gated communities with services and amenities such as running water, electricity, and air conditioning—being built along the coast to cater to wealthy Ecuadorians and expatriate communities. Anecdotally, our observations suggest that urbanizaciones have an increasingly high land use footprint in the aggregate, though future research in this area could help clarify the extent of this issue. With ever-increasing pressures to clear and develop forested land, such as those posed by *urbanizaciones*, the surrounding ecological matrix in Manabí is facing further degradation. This degradation can decrease the productivity and resilience of land where farmers work, even if farmers' management practices remain constant.

Climate change can also destabilize potential economic gains for eco-entrepreneurs—especially smallholders—by shifting temperatures and causing erratic weather conditions and events (see *Chapter 4: Benefits of Agroforestry for Biodiversity and People*). The unpredictability of these conditions and events presents a significant challenge for eco-entrepreneurs, because sustainable agricultural methods are sensitive to alterations in environmental conditions. For example, a small increase in overall temperature could allow for the proliferation of a specific pest that a farmer may have to learn to control to preserve a certain crop species. Harmful effects of climate change on eco-entrepreneurs may continue to arise as climate change worsens, but due to the complexity and interconnectedness of agroecological ecosystems, it is challenging to predict possible effects. Instead, eco-entrepreneurs must quickly adapt to changing climatic conditions to ensure that they do not lose significant portions of their income.

Finally, natural disasters, such as earthquakes, can have large and lasting effects on smallholders. The 2016 Pedernales earthquake, which leveled towns in the surrounding area, presented a particular challenge for local livelihoods (Serrano-Valdiviezo et al., 2018). Though these events are sometimes independent from climate change, they force eco-entrepreneurs to adapt in a similar way: natural disasters are difficult to predict, and their sudden onset can threaten the conditions upon which eco-entrepreneurs rely to produce sufficient agricultural output. However, there is also evidence that farms with high levels of on-farm biodiversity tend to be better protected from natural disasters and climate change risks in relative terms compared to monoculture farms (Altieri & Nicholls, 2017).

Figure 3.3. Agroforesty farm in Manabí, Ecuador adjacent to primary tropical dry forest

4 What Are the Perspectives and Experiences of Landowners Currently Taking an Eco-entrepreneurship Approach in Manabí?

4.1 Interview Methods

We spent six weeks in Manabí, Ecuador to conduct ecological fieldwork, interview eco-entrepreneurs, and deepen our understanding of the social and ecological context. Within our research on the perspectives and experiences of landowners with regard to eco-entrepreneurship in Manabí, we conducted interviews to inform our analysis of two research questions:

1. *Why do local community members engage in eco-entrepreneurship?*
2. *What factors prevent eco-entrepreneurs from being more successful, and what can be done about it?*

All interviews were conducted between May 23 and July 1, 2022, during Manabí's dry season and the beginning of the coffee harvest season. Over this time, we conducted 11 interviews and one focus group of six participants, four of whom were also among the 11 interviews. Interview participants included local smallholder farmers, the president and members of a local peasant organization, members of a coffee cooperative, business owners, and other eco-entrepreneurs. The Ceiba Foundation staff identified an initial five participants, while snowball sampling identified an additional six participants. Respondents all met the criteria of 1) owning farming or livestock operations with significant levels of planned and associated biodiversity on their lands; and/or 2) producing products with high levels of added value, a key feature of eco-entrepreneurship identified above. Interviews were generally one hour, semi-structured and informal, and conducted in Spanish (with the exception of two interviews conducted in English with participants who were fluent in English). Interview questions focused on respondents' perspectives on the environmental and economic benefits and challenges of eco-entrepreneurship and what external support they felt might benefit them. While we used the interview and focus group guides as a reference (see Appendix D – Interview and Focus Group Guide), we expanded our questions to elaborate on responses that arose during the interviews, such as learning more about the motivating roles of family histories and farmers' wellbeing. We conducted interviews on eco-entrepreneurs' farms or land when possible, in order to maximize comfort and convenience for them and integrate informal observations of their operations into our results.

4.2 Results and Discussion

4.2.1 Why do Local Community Members Engage in Eco-entrepreneurship?

There is a diversity of experiences and professional backgrounds among interviewees, but we found a great deal of overlap in the reflections that participants shared regarding the benefits of eco-entrepreneurship and the qualities of a successful eco-entrepreneur. While we found a remarkable degree of resonance in eco-entrepreneurs' motivations across our 11 interviews, our discussion of challenges facing eco-entrepreneurs and potential solutions were more varied and complex, and we present analysis of these results later in this section. We found that eco-entrepreneurs' motivations fell into three main categories (Table 3.2) that we further discuss below.

Family emerged as a particularly salient theme, as eco-entrepreneurs frequently cited a familial connection to farming—sustainable farming in particular—as a key reason they chose this way of life. In particular, familial sharing of information was often a critical component of how eco-entrepreneurs learned to farm sustainably. As one respondent put it:

> *I come from a family of cafetaleros, my grandparents, uncles and aunts were all cafetaleros, so from very young I knew about coffee, and as kids we would accompany them on their work.*

While the intergenerational nature of eco-entrepreneurship is a key asset for the longevity and perpetuation of agroforestry farming methods and sustainable agricultural production, it also presents a challenge for scaling this model, as the notion of eco-entrepreneurship may resonate less with those who do not have family ties specifically to sustainable production.

The second salient theme that emerged in response to eco-entrepreneurs' motivations was a **desire to support the health of the land**, and by extension, the health of their community. Participants expressed feelings of strong connection to their own lands, but they also indicated a broader reverence for the cultural richness of Manabí, its biodiversity, and its unique location between ocean and mountains, which combined to be important motivators to carefully tend their lands. Participants also frequently cited the desire to live in a clean environment and the notion that a biodiverse farm created a more pleasant environment for their household and for the broader community.

One respondent who had migrated to the city before returning to run a small coffee farm explained her decision:

> *I'm from the country, and the moment came where I asked myself, 'why not live in a cleaner, less polluted environment, where you can live happily?'*

In a regional context with rapid land use change, deforestation, and public health challenges, the appeal of the aesthetic and health benefits of these systems should not be understated.

A third theme that emerged in response to motivations for engaging in eco-entrepreneurship was **la lucha**. In Spanish, this means "the fight," which insinuates that mere engagement in sustainable smallholder farming or artisanal production represents a fight for a way of life and a set of values threatened by economic, political and environmental pressures. This fight also takes place against a larger backdrop of social and economic dislocation exacerbated by the pandemic. As one interviewee explained:

> *We are talking about the beautiful aspects [of farming], but there are many necessities in this area, abandoned families, addiction, alcoholism, young people joining gangs, and so we are at a key moment for changing the social structure.*

This finding echoes van der Ploeg (2018), whose observations from a global survey of peasant movements found the fight for a marginalized way of life in the face of economic, environmental, and even ideological opposition from the state is an important characteristic of the peasant condition. The tangible feeling of involvement in the struggle for a way of life often contributed to a sense of community and solidarity between eco-entrepreneurs. It also underscored the reality that smallholder farming and sustainable production is intimately linked to the social fabric of communities; the healthier environments that smallholder farming supports create a greater sense of belonging, community, and identity for those who participate (see *Chapter 4: Benefits of Agroforestry for Biodiversity and People*).

Table 3.2. Summary of Motivators Based on Relevant Interview Responses of Eco-entrepreneurs

Key Motivators: Why do local community members engage in eco- entrepreneurship?	Implications
1. Familial connections	Familial connections are a salient value for eco-entrepreneurs, but the importance of these connections makes scaling the eco-entrepreneurship model beyond current eco-entrepreneurs difficult
2. Desire for healthier lands and communities	Eco-entrepreneurs' desire for healthier lands and communities brings tangible benefits to local communities
3. Desire to fight ("la lucha") for a marginalized and threatened way of life	Eco-entrepreneurs' defense of their way of life is integral to the social fabric of local communities, and provides a bulwark against social and economic crises exacerbated by the pandemic

2. What Factors Prevent Eco-entrepreneurs from being More Successful, and What Can be Done About It?

Turning to the question of what challenges eco-entrepreneurs face and what support could help them address these challenges, we found four main challenge areas each with associated potential solutions, and specific support opportunities for the Ceiba Foundation (Table 3.3). We first elaborate on the challenges discussed by respondents and the potential solutions they raised, and then provide specific guidance for the Ceiba Foundation for moving forward in ways that are ruly informed by the respondents' perspectives as well as economic and market realities. Respondents focused most on the issue of **low prices—**often articulated as **"unfair prices"**— and undervalued products. This theme surfaced repeatedly in interview questions about the challenges of smallholder farming and eco-entrepreneurship. As one respondent put it, *"the market pays you what they want to [pay you]...and the farmer always loses. There's not a balance where you can say 'this is the price.' So we make almost nothing."*

Table 3.3. Summary of Challenges & Potential Solutions Based on Relevant Interview Responses of Eco-entrepreneurs

Challenges: What factors prevent eco-entrepreneurs from being more successful?	What can be done about it?	What is the Ceiba Foundation's role in the proposed solution?
1. Eco-entrepreneurs face systematically low prices and undervalued products relative to quality and labor inputs 2. Global markets are risky and volatile, and competing against global industrial production is often prohibitive	Develop a locally-owned certification aimed at higher-margin specialty markets that overcomes risk and builds community	Play a key role convening stakeholders, and bring in future graduate student researchers or interns to address the technical and marketing aspects of developing a certification.
3. Lack of collaboration related to lack of local awareness of the ACUS	Awareness-raising and efforts to simplify process	Work with local governments to simplify the ACUS process and amplify outreach efforts to communicate the value the ACUS can bring to eco-entrepreneurs.
4. Difficulty of attracting eco-tourists to Manabí	Cater to specific communities (bird watchers, scientific tourists) Make operational changes that are not time- or resource-intensive	Continue to connect eco-tourists with local eco-entrepreneurs, and help eco-entrepreneurs make low-effort changes to improve operations. Help eco-entrepreneurs understand and cater to the specific needs of niche markets such as bird watchers. Help eco-entrepreneurs understand and cater to the specific needs of niche markets such as bird watchers. Communicate the limits of ecotourism locally to avoid raising expectations beyond what is achievable in the region.

Respondents were quite specific about the discrepancy between the prices they needed to make a profit versus the prices they received. In one interview, for instance, a coffee-producing eco-entrepreneur explained that they would need to sell a 12-ounce bag of coffee for US $8-10 to turn a meaningful profit, but that they could only sell their product locally for US $4. In the eyes of Manabí eco-entrepreneurs, simply selling their products at a fair price would enable them to avoid operating at a financial loss. More robust data regarding smallholder operations and more formal market data in Manabí would be a helpful avenue for future research to help inform eco-entrepreneurs' strategies vis-a-vis markets.

While **exporting farm products internationally** holds the promise of access to more lucrative international markets, these markets and strategies are also riskier and farmers have little control over prices. Local eco-entrepreneurs we spoke with were enticed by the potential benefits of international markets, but also well attuned to the risks that access to volatile global markets could bring. In a focus group discussion with a coffee cooperative in Manabí, participants noted that their coffee could receive significantly higher prices in the North American and European markets, but they also cited competition against low-priced industrial coffee from other international markets as a potentially prohibitive barrier to the efficacy of this strategy. Several respondents also noted that accessing North American and European markets was particularly difficult, since cooperatives of smallholder coffee farms often cannot meet the production scales required to attract international purchasers. More generally, large fluctuations in the price of coffee over the last ten years—influenced by scaling of industrial production in Latin America and Southeast Asia, increased impact of pests and diseases on production exacerbated by climate change, and the COVID pandemic (Guido et al., 2020)—underscore just how little control most local producers in Manabí exercise over prices.

Beyond the issue of control, the risk profile of export-oriented production often exceeds eco-entrepreneurs' appetite for risk, particularly in the face of environmental challenges. Export-oriented production would likely emphasize less on-farm diversity and greater production of cash crops that contribute little to farmers' own food security. Respondents voiced skepticism that this form of production was appealing to current eco-entrepreneurs. When asked for instance how they would adapt their operations to long-term changes in the price of coffee, one participant noted:

> *We already had that situation, not only for us but for coffee farmers generally; prices of coffee fluctuate, so we are promoting [diversification] and encouraging others to diversify.*

While coffee was the commodity respondents focused most on, respondents articulated similar concerns with regard to cacao, bamboo, and fruit supply chains. Changing climatic conditions in the region exacerbate these challenges from a risk-smoothing perspective. As one respondent explained:

> *all of us are feeling, observing, that there is a problem. From the beginning of the rainy season, there was basically no water. And little things, flowering times, fewer types of birds coming around, there are changes that [farmers] notice.*

As an alternative to increase income, several respondents discussed the possibility of developing a specialized and locally-specific certification to help bridge the gap between high-value-added and sustainable products and the low prices they currently receive, which are the same as prices for lower quality products produced through unsustainable means.

Participants pointed to the existence of higher-added-value markets for such products in specialty stores, and one participant suggested that distributing such products in specialty stores, and one participant suggested that distributing such products to specialty stores in the main cities of Guayaquil and Quito could be profitable for local eco-entrepreneurs. For this participant, this viewpoint stemmed from their belief that people in these cities are more willing to pay higher prices for sustainable, high-quality products. Notably, respondents felt that the high costs of obtaining and maintaining extant certifications such as USDA Organic, Fair Trade, and Rainforest Alliance outweigh the value that they provide to eco-entrepreneurs in Manabí.

Furthermore, several stakeholders voiced non-economic reasons for wanting a locally-owned certification, noting that they felt a community-owned verification process could contribute to building much-needed **connections between eco-entrepreneurs.** Several respondents noted a lack of connections and collaboration between eco-entrepreneurs, all of whom face similar challenges according to our interview data. The dearth of connection and information flow between local eco-entrepreneurs prevents the sharing of relevant, locally-specific knowledge and strategies that could provide important insights in their efforts to improve their farming techniques, care for their lands, and increase income. While this presents a challenge to efforts to address collective challenges, it is also an opportunity for the Ceiba Foundation and other actors in the region to catalyze such efforts with relatively little investment of capacity or resources.

We also found that significant challenges exist in collaboration efforts between eco-entrepreneurs and other local stakeholders, the most notable of which is the **lack of local awareness about the ACUS.** Although land management incentives designated for landowners within the ACUS are a proposed solution to bridge the gap between low prices paid for sustainable products and high positive externalities associated with eco-entrepreneurship, most respondents either did not know of the ACUS or knew little about it. No respondent provided significant input about the ACUS in Manabí, and no one knew how the ACUS might be able to assist them. This finding suggests a need for better communication from local government and conservation organizations, such as the Ceiba Foundation; without knowing of the ACUS and its purpose, eco-entrepreneurs cannot benefit from the resources it is designed to mobilize. An important part of this shift would be to clearly communicate the ways in which the ACUS adds value to eco-entrepreneurs' work. With clarity on this front, eco-entrepreneurs would be better situated to leverage ACUS resources.

Another theme that emerged in response to the issue of low prices and undervalued products was enthusiasm for ecotourism as an alternative to reliance on the sale of farm products for one's principal source of income. Respondents generally expressed enthusiasm for ecotourism as a way of generating additional income on top of continued sales of primary goods. Manabí's reputation as a culinary center within Ecuador may be helpful in this regard. At the time of writing, a local organization has started the *ruta gastronomica* (the gastronomic route), a tour of Manabí that will focus on local production and consumption of seafood, fruit, coffee, and cacao. Such efforts show local enthusiasm for ecotourism in Manabí, particularly when focused on the region's cuisine. However, it remains to be seen whether these efforts will generate meaningful market demand for ecotourism in Manabí and whether this will directly benefit eco-entrepreneurs.

4.3 Deeper Assessment of the Potential for Ecotourism in Manabí

Given the strong interest in ecotourism by respondents and local organizations, we want to elaborate on two principal reasons to be cautious about ecotourism as a potential solution for unfair prices and low incomes for local eco-entrepreneurs that are based on our understanding of the system and setting our observations and collected information into that context.

First, successful ecotourism operations often require significant input of resources into farms and as part of a larger effort to bring more tourists to the region. While eco-entrepreneurs dictate resource inputs into the farm, they mostly lack control over broader tourist trends.

Investing money and time in farm operations is a challenge for many smallholder farmers in Manabí, who tend not to have much liquid income and whose labor is often the principal input in their farms. Furthermore, the up-front costs associated with creating and marketing an ecotourism operation require additional time, capacity, and money. One participant with a successful ecotourism business noted that business operations required most of their time, which hindered their ability to more effectively tend to their farm. Key challenges for ecotourism operators in the area include maintaining lodging of a sufficient standard, preparing food, marketing the operation, monitoring reservations and correspondence in an area with poor cell service and internet connectivity, and working with tourists to navigate the sometimes-confusing transportation from nearby cities.

Second, there is a risk of market saturation given the relatively small number of tourists who currently visit Manabí. While eco-entrepreneurs with strong ecotourism operations may attract some ecotourists to the area, it is unclear what effect these operations may have on overall low tourism numbers in Manabí. Manabí is quite removed from the main cities in Ecuador, being five hours by car from Guayaquil, the country's largest city, and six or more hours from Quito, the capital and cultural center. Because almost all international flights arrive in these two cities, traveling to Manabí requires a significant investment of time and effort. The province is also far from many of the country's main tourist attractions, which include the national parks in the Andes, the Amazonian region, the cities of Quito and Cuenca, and the Galapagos islands. Further, one participant noted that many visitors to Manabí are working- and middle-class Ecuadorian families who tend to have less money to spend on tourist attractions and relatively less interest in activities related to sustainable food production.

Significant collaboration between civil society organizations, such as the Ceiba Foundation, and local eco-entrepreneurs is critical to ensure positive, self-determined, and equitable outcomes to investment in ecotourism. One potential area of further research might consider efforts like the mancomunades model in Oaxaca's sierra communities, which promotes locally-owned ecotourism and encourages reinvestment of resources and capacity in local communities. Similar models may be instructive in supporting eco-entrepreneurs. However, it should be noted that such models have usually succeeded in areas that already have strong tourism markets. Research on the development of ecotourism in other countries, most notably Costa Rica, highlights the importance of investment by local and national governments in infrastructure and ecotourism promotion, as well as efforts by well-resourced entrepreneurs to bolster local ecotourism operations (Jones & Spadafora, 2017).

While there are significant risks and challenges associated with ecotourism for eco-entrepreneurs, there are also opportunities. As an example, one respondent noted that Manabí does attract bird watchers due to the area's high levels of avian biodiversity. These tourists might choose to stay with local eco-entrepreneurs, as shade coffee farms provide excellent habitat for birdwatching. They also present a specific but manageable set of responsibilities for eco-entrepreneurs, such as the preparation of food to be taken into the field and coordination of activities for tourist engagement between birdwatching at dawn and dusk. Attracting and serving this sort of clientele could be a subject of further research and collaboration between local organizations such as the Ceiba Foundation and eco-entrepreneurs.

5 Priority Recommendations

The recommendations that follow are largely incremental and locally-grounded. The focus on manageable, locally-oriented solutions is not accidental: our review of relevant challenges suggests that attempting to catalyze transformative change by encouraging greater exposure to global markets presents significant risks to eco-entrepreneurs. Respondents were keenly aware of these risks, particularly concerning entry into volatile global markets. Indeed, the diversity of crops planted on local smallholders' farms and the resilience of local subsistence production by local eco-entrepreneurs serves as a hedge against such forces, ensuring a level of food security even in the face of unpredictable global shifts. As one respondent noted, "we cannot rely on only one product as farmers. Prices in Ecuador are not very regular, and agriculture in general is a very risky business due to climate change for instance." Ecotourism is also not immune to shifts in global market forces, as shown by the huge challenges ecotourism businesses in developing countries faced during the global pandemic (Buckley, 2021). Furthermore, attempts at top-down transformative change would be antithetical to the motivations of eco-entrepreneurs discussed above, which are grounded in local ownership, a community ethos, and prioritization of the environment and family in the face of economic, political, and environmental forces that threaten their way of life. Going forward, future research on and collaboration with eco-entrepreneurs in Manabí and beyond should consider how eco-entrepreneurs' desire for increased incomes can be balanced against the challenges and risks caused by climate change and external markeforces, and the desire for self-determination.

> ***... our review of relevant challenges suggests that attempting to catalyze transformative change by encouraging greater exposure to global markets presents significant risk to eco-entrepreneurs.***

Recommendation 1: Support Efforts to Develop a Locally-Owned Certification

Designing and implementing a sustainable product certification could improve livelihoods for eco-entrepreneurs in Manabí and lead to more successful local conservation efforts. Respondents felt that a locally-owned certification could provide access to specialty markets in regional towns as well as the main cities of Quito and Guayaquil. For the eco-entrepreneurs we interviewed, their products are high quality and sustainable due to high inputs of their time and energy, organic inputs from their own farms, and agroecological farming expertise. These inputs reflect the importance of eco-entrepreneurs' values in Manabí, notably the role that a desire for healthy lands and communities plays in their choice to pursue sustainable forms of production. A certification could help create a positive feedback loop, whereby consumers' increased willingness to pay a premium for products with a clear indication of their quality in turn supports eco-entrepreneurs' decision to create healthy products and engage in sustainable production processes, as well as invest more resources into sustainable production. Respondents clearly stated their interest in putting a sustainable certification on their products; they recognize that they receive a comparatively low price for their high-quality products, and they view a well-received certification as a straightforward solution to access opportunities for greater demand and higher prices for sustainably produced goods.

While this could be a value-add for eco-entrepreneurs, there will be challenges in creating and implementing a certification. Agreement over what is being certified (whether it is simply an organic certification or encompasses other management practices) and how recipients' operations will be monitored and verified are potential points of contention. The Ceiba Foundation has a key role to play in convening eco-entrepreneurs and other local civil society actors to come to a consensus on these questions. Marketing and branding a local certification would also likely necessitate specific business expertise that is beyond the scope of this project, but which the Ceiba Foundation, with its many connections with academic organizations in Ecuador and the United States, is well-positioned to pursue.

Recommendation 2: Low-Effort, Low-Impact Tourism Adaptations

Our above analysis of local ecotourism in Manabí suggests that catalyzing significant demand for this type of tourism will remain difficult and require effort and resources from the regional and national governments. The Ceiba Foundation and others should be candid with eco-entrepreneurs about these limitations and suggest that investments in ecotourism operations follow increased demand for ecotourism, rather than insinuating that investments from the eco-entrepreneurs will attract significantly more ecotourists. The performance of the ruta gastronomica may be used to predict the demand for ecotourism that might be generated in Manabí with greater investment in relevant infrastructure and operations.

In the short- to medium-term, however, eco-entrepreneurs with an interest in ecotourism should consider making marginal, low-effort improvements to better serve the ecotourists who do come to the area. These improvements will provide a higher-quality, and thus higher-priced, experience without necessitating significant input of time or energy from eco-entrepreneurs. Our analysis of ecotourism opportunities in Manabí suggests that the benefits of high-effort tourism adaptations by eco-entrepreneurs would not currently outweigh the costs of time and money they would incur. In this specific context, all high-impact adaptation options would be high-effort, so at this point, we recommend that eco-entrepreneurs pursue low-effort, low-impact adaptations until demand for ecotourism in Manabí increases (Figure 3.2). For instance, changes to the flow of a farm tour can be implemented at no financial cost and limited effort from eco-entrepreneurs, while markedly improving the tourist experience. A case study of how such an effort might provide value to an ecotourist experience is provided in *Chapter 5: Assessing Agroforestry Ecotourism: Farm Tour Analysis and Case Study of ASOPROCOFFEE.* The Ceiba Foundation can help in disseminating informa-

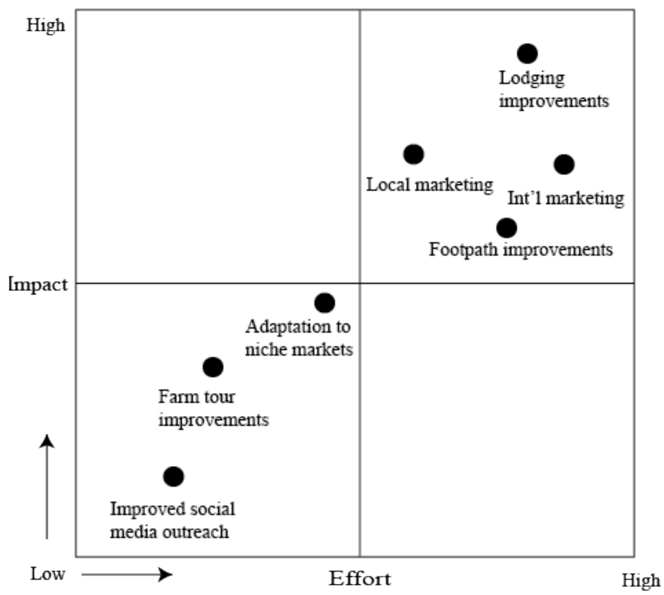

Figure 3.2. Matrix of Effort and Impact - Improvements in the bottom left (low effort, low impact) should be prioritized over improvements in the top right (high effort, high impact)

tion about which efforts in this vein have been successful and providing forums for interested eco-entrepreneurs to exchange knowledge and collaborate (see Section 5.4).

Recommendation 3: Communicate the Benefits of the ACUS

While we found that there was little local awareness about the ACUS, the Ceiba Foundation is in an ideal position to change this. The Ceiba Foundation was a key driver in the creation of the ACUS and has the greatest understanding of its potential. Furthermore, the Ceiba Foundation is undertaking a survey of landowner willingness to participate in conservation efforts within the ACUS. The survey presents an opportunity to gather data and communicate with local eco-entrepreneurs about how the ACUS may benefit them. For instance, if landowners are conserving land already as part of operations, the Ceiba Foundation should develop outreach materials and best practices to communicate with them about what resources the ACUS could provide. Greater awareness of eco-entrepreneurs' motivations for engaging in sustainable forms of production can help target these outreach efforts, for instance by demonstrating the role the ACUS plays in supporting healthy lands and communities. The Ceiba Foundation should also work with local government to make the ACUS more friendly to communities' interests and address some of the bureaucratic hurdles that prevent effective implementation of its strategies. Indeed, the Ceiba Foundation has already worked with a number of eco-entrepreneurs on the ACUS process; these efforts are an important step forward.

Recommendation 4: Provide Forums for Collaboration Between Eco-entrepreneurs

Finally, most of these recommendations stem from interviews and informal conversations with eco-entrepreneurs, either individually or in groups. The Ceiba Foundation has an opportunity to leverage its convening power to bring people together. Meetings could be structured around workshops or activities, or be informal or social. While there is a risk of workshop fatigue and burnout, our interviews and interactions suggested there is currently a desire for more, rather than fewer, opportunities for engagement and collaboration between eco-entrepreneurs. The sense of disconnection and isolation that eco-entrepreneurs feel with other eco-entrepreneurs in the region stands in sharp juxtaposition to the value of *la lucha* and eco-entrepreneurs' desire to fight for the viability of their way of life: there is a need and a desire for opportunities for eco-entrepreneurs in Manabí to strengthen their own community of practice, provide support to each other, and share resources when applicable. Furthermore, such opportunities could benefit the Ceiba Foundation and other conservation stakeholders, as eco-entrepreneurs can often provide valuable information about ecosystem changes, illegal logging, and other issues of note for conservation.

6 Conclusions

Manabí faces significant ecological stressors that threaten the health and continuity of its natural resources—resources that provide important ecosystem services and cultural value both for residents and non-residents of the region. The environmental challenges facing the forests of Manabí extend to the smallholder eco-entrepreneurs who live and work there, as they rely on high quality, biodiverse landscapes to effectively and efficiently produce their sustainable products. These eco-entrepreneurs serve as a canary in the coal mine of sorts; reductions in the quality and biodiversity of their lands immediately affects their output quantity and quality, whereas these same reductions more slowly and insidiously lead to the loss of important ecosystem services over time. Once these large-scale losses are realized, they are challenging, or in some cases impossible, to remedy, but reductions in quantity and quality of farm outputs at a local level can be remedied with appropriate targeted action to reduce environmental degradation. Eco-entrepreneurship itself is a strong strategy to achieve this goal from a holistic perspective, as it not only reduces environmental degradation, but also improves local livelihoods and safeguards lands with important cultural value.

Eco-entrepreneurship is a broad term, and even with the definition used within this project, there is significant room for flexibility in potential actions to advance eco-entrepreneurial goals. Our synthesis of the literature and interviews provide some clarity on common interests, issues, and desires among Manabí's sustainable farmers, as well as a way forward for both eco-entrepreneurs and conservation organizations such as the Ceiba Foundation.

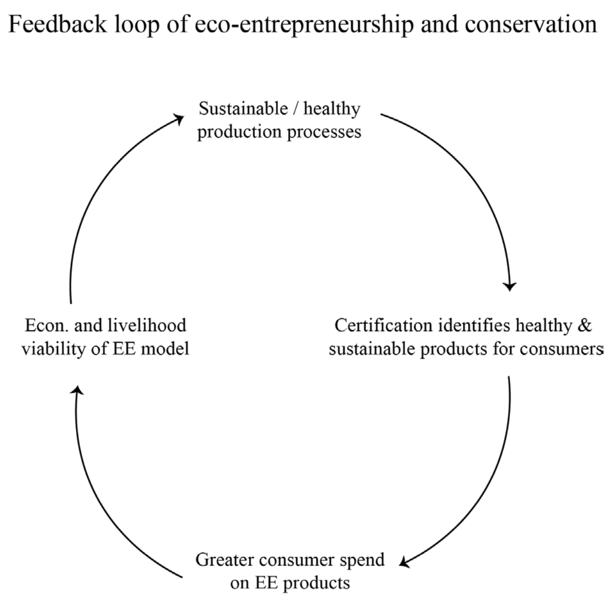

Figure 3.3. Feedback Loop of Eco-entrepreneurship and Conservation - Efforts to support eco-entrepreneurship through initiatives such as a locally-owned certification can facilitate a positive feedback loop between eco-entrepreneurship and positive conservation outcomes

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Chapter 4: Benefits of Agroforestry for Biodiversity and People

Supporting Forest Restoration and
Sustainable Livelihoods in Coastal Ecuador

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1 Purpose and Audience

Tropical dry forests make up one of the world's most threatened terrestrial ecosystems. Many of the remnant forest fragments exist today alongside working agricultural lands that differ in their effects on the ecosystem and wildlife. Efforts have been made in Ecuador's western tropical dry forests to promote sustainable livelihoods, such as agroforestry, that support biodiversity and associated ecosystem services. Despite the incredible potential of sustainable land use practices, they will not be adopted widely without clear communication of their tangible and site-relevant benefits.

In this chapter we use several sources to compile accurate and relevant information on the potential and actual ecological and socio-economic benefits of sustainable *agroforestry* practices specifically relevant to tropical dry forests. Our sources include existing research on Latin American tropical agricultural systems, as well as both interview and field data collected on-the-ground in western Ecuador, across a range of agricultural practices. The information we present here is relevant especially for:

1. *The Ceiba Foundation for Tropical Conservation* ("the Ceiba Foundation"), a NGO with almost three decades of conservation experience in Ecuador, who can share this information to motivate participation in the designated ACUS (*"Área de Conservación y Uso Sostenible del Noroccidente de Manabí"* or "Area of Conservation and Sustainable Use of Northwestern Manabí").
2. *Agroforestry Practitioners*: Landowners may use the findings and recommendations of this research to inform their existing and future agroforestry practices, as well as to diversify the livelihood methods on their farms, such as for ecotourism.
3. *Other scholar practitioners* with interest in the ecological and social value of agroforestry, monoculture, and remnant primary forest.

2 Introduction and Research Approach

Over the last few decades, the intensification of agriculture, development, external inputs, and deforestation have transformed tropical landscapes, leading to associated losses in biodiversity and ecosystem services (Mbow et al., 2014; Wilson & Lovell, 2016). Agriculture, in particular, has influences beyond its boundaries. Intensive, modern agriculture systems can interfere with regional biogeochemical cycles, increasing the rate of soil loss and detrimental nutrient enrichment (Drinkwater & Snapp, 2007). Large, private monocultures, that prioritize expansion, can directly cause species displacement through habitat loss. Government subsidies in agricultural communities currently encourage the acquisition of seeds and the use of pesticides without appropriate monitoring plans. These changes in land use threaten food production, ecosystem quality, and livelihoods locally and globally (Mbow et al., 2014).

Agroforestry systems are a distinct form of agriculture that integrates commercial crop production with a diverse and dense canopy of tree species (Perfecto et al., 2005; Verchot et al., 2007). For example in Ecuador, coffee agroforestry is a common traditional agricultural practice where coffee plants are grown together with timber and fruit trees such as papaya, lime, and cacao (Cristina et al., 2022). As we elaborate on in more detail below, agroforestry systems have been lauded as a potential biodiversity conservation tool in the tropics due to their abundance of tree species, richness, and vegetation structure that promotes biodiversity beyond the planned crops (Schroth, 2004; Perfecto et al., 2005). In South America, coffee polycultures and agroforestry systems have been a common traditional practice for many smallholder farmers (Perfecto et al., 1996), but these "shade" coffee practices have been replaced in many areas with more intense "sun" coffee farms. In the twentieth century, technical intensification of coffee production accelerated the implementation of new shorter coffee varieties, allowing for higher planting densities, increasing self-shading, and reducing the need for shade trees (Schroth, 2004). In Ecuador, coffee is grown in four natural regions including the Amazon rainforest, the Andean mountains, the Pacific Coast, and the Galapagos Islands. Due to the range of climate, altitude, and geographic characteristics, Ecuador is uniquely one of few countries able to produce the two commercial varieties of coffee that differ in their shade tolerance (*Coffea arabica* or arabica coffee and *Coffea canephora* or robusta coffee), and so Ecuador's coffee production currently employs

Figure 4.1. Mature, fruiting Coffea arabica *shrub typical throughout the agroforestry sites in the study*

both practices of agroforestry and large-scale "sun" grown monocultures (Cristina et al., 2022).

Efforts have been made in Ecuador's western tropical dry forests to promote sustainable land uses such as agroforestry of coffee and other crops, but a barrier to their widespread adoption is a lack of clearly documented and communicated benefits. An example of this would be the creation of the ACUS with the help of the Ceiba Foundation. The ACUS represents a significant step forward for conservation in Manabí province, providing a legal and institutional framework to protect the invaluable tropical dry forests of the region and preserve vital ecosystem services. One objective of the ACUS is to increase connectivity between forest remnants by implementing local incentives to produce sustainability through farm management practices through the reduction of agrochemicals and restoration of farm plans (Ceiba Foundation for Tropical Conservation, n.d.). A combination of agroforestry

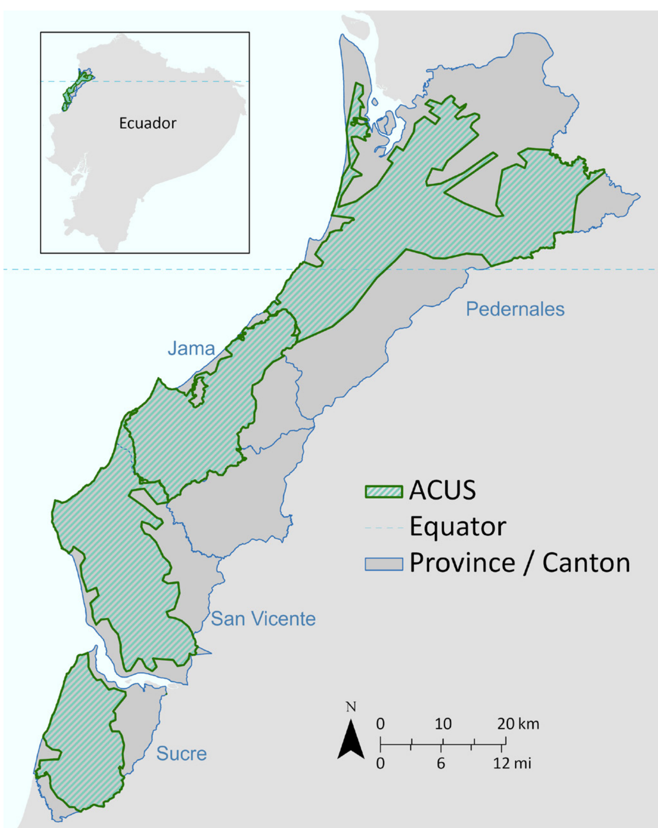

Figure 4.2. The Área de Conservación y Uso Sostenible (ACUS) in the study area

and monoculture practices (e.g., watermelon, bamboo, and cacao) are currently practiced in the region including a range of agrochemical and fertilizer uses. However, through the ACUS program, there is potential for more sustainable practices by implementing agroforestry techniques and reducing the use of pesticides and other inputs that have negative impacts on the ecosystem.

The goal of our research is to provide valuable information on the actual and potential benefits of agroforestry practices, generally in Latin American tropical forests, and specifically in the tropical dry forests of Ecuador. By providing clear, accurate, and *locally relevant* documentation of both the ecological and socioeconomic benefits of agroforestry we can inform and further incentivize sustainable use efforts in the ACUS to *increase the on-farm and landscape-scale benefits for biodiversity and people.*

We used three different research approaches - literature review, interviews, and field data collection - to answer the following three questions, respectively:

1. *What is known about agroforestry benefits from existing research in Latin American tropical forests?*
2. *What are the measurable differences in biodiversity among monoculture, agroforestry sites, and primary dry forest in Manabí, Ecuador?*
3. *How do landowners who practice agroforestry specifically in Manabí, Ecuador describe their practices and perceived benefits?*

Though many of our examples and sites studied are coffee agroforestry farms, our research has broad implications to dry tropical agroforestry systems in general.

3 Literature Review: What is Known About Agroforestry from Existing Research in Latin American Tropical Forests?

3.1 Ecological Benefits

One of the most common aspects of agroforestry systems is the diversification of crop species, which leads to the support of associated or unplanned biodiversity through resources and structural complexity. Many forms of agroforestry in tropical regions include the integration of shade trees and fruit trees such as papaya, plantain, lime, cacao, coffee, mango, and yucca. The high plant diversity and heterogeneous landscapes within these systems promote an environment that harbors diverse and abundant wildlife species by providing essential habitat and resources (Perfecto et al., 1996; Raj et al., 2020). Many forest species visit shade-grown coffee plantations, especially because of their arboreal habitat, including birds, bats, mammals, insects, amphibians, and reptiles (Schroth, 2004).

The ability of a coffee agroecosystem to harbor wildlife depends on the diversity and density of trees, the presence of plants in the understory, the management system (agrochemicals used), and the surrounding landscape. Overall, species have been reported to use coffee agroforestry sites as food resources, nesting, mating and foraging sites, shelter, and habitat, where sun-grown coffee plantations limit the habitat value for species due to the low structural complexity and homogenous landscapes (Schroth, 2004). Specifically in Costa Rica, comparisons of mammals in shade coffee, sun coffee, and forest habitats found that mammal abundance was highest in forest habitats followed by shade coffee then sun coffee. In addition, the species richness of mammals in shaded coffee emulated nearby forests, confirming the value of shade coffee to mitigate the negative impacts of habitat loss and fragmentation (Caudill et al., 2015). Arthropod populations in shade coffee can also match the species richness of remnant forests, due to the leaf litter, fallen twigs, trees, and weeds that provide habitat for arboreal and ground species. In Mexico, ground-foraging ant communities were found to be similar between forest fragments and a high-quality matrix of coffee agroecosystems (Perfecto & Vandermeer, 2002). In Chiapas, Mexico the effects of shade tree removal on birds in coffee agroecosystems were assessed to evaluate the result after a management shift. The study concluded that the reduced canopy complexity lowers the abundance and richness of birds, as well as key insectivore species. The observed patterns highlight that coffee farms with high structural complexity support a high diversity of birds and forest species, and as the canopy is simplified, that richness is lost (Philpott & Bichier, 2012).

Beyond the benefits of agroforestry directly for biodiversity, agroforestry systems also provide a range of ecosystem services that result from the interactions among the rich assemblages of plants, mammals, birds, arthropods, and humans in the landscape. In coffee agroecosystems, for example, biodiversity plays a significant role in the provision of these services, such as pollination, water distribution and retention, food production, pest regulation, nutrient cycling, climate buffers, soil fertility, pest regulation, pollination and seed dispersal (Raj et al., 2020; Schroth, 2004). However, biodiversity declines through anthropogenic disturbance, including land-use change for agriculture, are expected to further threaten tropical forests' ecosystem services essential for crop success (Beenhouwer et al., 2013). Agroforestry systems have the potential to foster these critical ecosystem services, while also supporting agricultural communities and output.

The ecosystem service of pest regulation is a particularly important benefit of agroforestry. Agroforestry systems harbor natural enemies of coffee pests, thus controlling pest populations and reducing outbreaks and the spread of disease (Liere et al., 2012; Schroth, 2004). In Costa Rica, 83% of 322 insect species found in coffee agroecosystems were potential biological control agents (Schroth, 2004), including mammals found in coffee farms by feeding on insects and rodents (Gallina et al., 1996). A common challenge faced by coffee farmers in Ecuador is the spread of pathogens and pests such as the coffee leaf rust (*Hemileia vastatrix* or "la roya" in Spanish) and coffee berry borer (*Hypothenemus hampei* or "broca" in Spanish), which devastate coffee cultivation and production around the world (Cristina et al., 2022). In the case of a monoculture system where natural enemies are absent, a pest outbreak is difficult to manage without the use of agrochemicals. In agroecosystems, where ecological interactions control pests and leaf litter provides nutrients, the dependence on chemical pesticides and fertilizers is significantly reduced or even unnecessary. The reduced use of pesticides has a variety of benefits to the soil, crops, water supply, and community, extending the longevity of the land and resources in production (Schroth, 2004).

Pest regulation in agroforestry systems also ameliorates the impacts of erratic climate, which affects pest and disease patterns and can have devastating impacts on coffee plantations globally. Pest patterns are strongly dependent on temperature and humidity and the changing climate can impact the distribution and severity of pests and diseases (Verchot et al., 2007). The productivity and quality of coffee plants have shown to demonstrate high sensitivity to changing climate conditions due to the changes of pest patterns (Altea, 2020). Agroecosystems have been suggested as important systems of regulation as farms respond to changes in coffee pest populations through planned high diversity on the farm.

Agroforestry systems also are important for climate adaptation measures, as they lessen the physical impacts of climate change. As changes in climate become more frequent and their impacts become more extreme, coffee agroecosystems are a climate adaptation solution because trees protect crops by buffering extreme physical conditions in several ways (Verchot et al., 2007). In recent years in Latin America, farmers have experienced extreme heat, cold frosts, precipitation variability, and strong winds that have affected their crop production, income, and subsistence. Tree-based systems buffer changes in the frequency and intensity of rain and drought events by maintaining and distributing water during wet and dry seasons through shade, soil cover, and deep root systems (Verchot et al., 2007). Shade trees increase soil porosity and shade cover, thus reducing runoff, optimizing water inflation and retention, and reducing drought stress compared to other production systems. The foliage of trees that collects on the ground of the farm provides nutrients to the soil and increases moisture retention, which not only benefits crops, but also provides microclimates for certain species, including pest control species.

Another benefit of agroforestry is the higher longevity and sustainable yield of the land compared to intensive systems. The compromise between yields and land longevity in agriculture is a common discussion.

Many smallholder farmers historically have practiced diversified, polyculture systems of fruit trees, timber, and firewood prioritizing the long-term health of the land (Schroth, 2004). The intentional and strategic management of diversification holds the capacity to restore agroecosystem functions and increase yields on previously degraded land from intensive systems (Drinkwater & Snapp, 2007). Although aspects of coffee agroforestry systems have the potential to be beneficial from a conservation viewpoint, drawbacks include a potential decrease in yield (Schroth, 2004). As intensive agricultural systems focused on high production with the use of agrochemicals and low shade may attain higher yields, they face reduced longevity of the land and resources. A difference between approximately 12-15 years in open sun plantations with 2-4 years without coffee productivity during land renovation and 15-20 years of longevity in shaded plantations. Furthermore, adding trees to conventional crop systems may not in fact negatively affect understory crop production in the long term, instead protecting them in drought conditions. Deep-rooted trees have the capability to exploit a larger volume underground for water and nutrients, allowing shallow-rooted plants to absorb nutrients with less competition (Verchot et al., 2007).

3.2 Socio-economic Benefits

Agroecosystems can provide food security and income generation, socio-economic benefits that are key to incentivizing farmers to transition into agroforestry management practices. Coffee agroforestry, for example, builds the resilience of local livelihoods because of the variety of income generation sources provided beyond coffee (Toledo & Moguel, 2012). The socio-economic benefits of diversification in crops include subsistence for the household, income generation, health and food security, built-in resilience to crop loss, and reduced fertilizer and pesticide costs (Verchot et al., 2007). The earnings generated by selling secondary crops, such as fruit and timber in the market can be an important source of income for smallholder farmers particularly in cases when coffee production is reduced (Beenhouwer et al., 2013). Agroforestry systems act as a socio-economic buffer in the face of disturbances such as changes in the market, coffee production success, extreme weather conditions, and personal obstacles. These systems have been recognized as contributors in reinforcing local self-sufficiency and indirectly promoting local self-governance in the role they serve in supporting local farmers (Toledo & Moguel, 2012). While a transition into new sun-grown coffee varieties has been effective to meet the short-term goal of producing higher yields, it comes at the cost of external inputs and negative side effects to natural resources and human health (Muschler, 2016). However, growing awareness that these systems cannot be sustained in the long-term has promoted the (re) introduction of agroforestry systems throughout Latin America, realizing the benefits traditional systems provide for biodiversity and farmers (Muschler, 2016). In Table 4.1 we provide a summary of the numerous ecological and socioeconomic benefits we have found across the literature on agroforestry systems in tropical dry forests.

Table 4.1. Summary of potential ecological and social benefits of agroforestry management systems (based on literature review)

Characteristic	Ecological Benefit	Social Benefit
Integration of Shade and Fruit Trees	• Resource availability for wildlife • Environmental buffer from extreme weather • Increased soil porosity, soil cover and reduced erosion	• Secondary crop production provides food and resources for farmers • Food security • Protection of primary crop species reduces crop loss
▪ Structural heterogeneity	• Habitat and microclimates for diverse taxa • Water regulation and distribution through deep rooted tree systems optimizing water inflation and retention	• Diversity in crop and fruiting shade tree species provides economic resilience
▪ Leaf litter	• Increased nutrient cycling • Moisture retention	• Increased soil moisture and nutrients improves growing conditions and reduces need and cost for fertilizer inputs
No pesticide use	• Habitat supportive of invertebrates, including beneficial insects • Enhanced soil conditions	• Reduced investment in pest control over time • Reduced exposure to harmful pesticides • Increased land longevity • Reduced chemical runoff and water contamination
Wildlife abundance	• Pest regulation by natural enemies • Pollination of primary and secondary crops • Seed dispersal	• Enhanced pollination for crop success

4 Field Surveys: What are the Measurable Differences in Biodiversity among Monoculture, Agroforestry, and Primary Dry Forest Sites in Manabí, Ecuador?

Photo credit: Mike Kelly

While existing research in the South American tropics supports the idea that agroforestry harbors biodiversity, practices in the ACUS are best informed and inspired by data collected locally. We sought to directly assess differences in biodiversity among intense monoculture, typical agroforestry, and remnant primary forest area, all located within Jama canton, in the Manabí province of Ecuador. We compared land use types in terms of the abundance of pollinators (insects and hummingbirds), birds, and *bioindicator* species (Table 4.2), as well as characteristics of the sites that may relate to the biodiversity measures such as proximity to uncultivated tropical dry forest patches.

We selected bioindicator species for this study because of their preference for high quality habitat. In ecological surveys, we recorded the presence of any bioindicator from the above list of species, as well as the specific species identified. We also approximated biodiversity via abundance of avian species. A wide array of bird species may be present in agricultural areas, whether foraging for insects or plant material or vocalizing from perches such as trees and tall shrubs. The observation of any of these behaviors can indicate the quality of the area as habitat. Additionally, hummingbirds native to the tropical dry forests of Ecuador also act as pollinators.

We assessed avian diversity primarily by listening for bird calls, less so through sightings, due to the dense canopy of both tropical dry forest and shade-coffee farms that make observation of birds extremely difficult. We took point calls at each survey point (see below), noting the number of distinct calls as well as any

Table 4.2. International Union for the Conservation of Nature Red List status of bioindicator species used in this study. Status based on species name and status in the Red List of Threatened Species (Cortes-Oritz, et al., 2021)

Species	Common Name	IUCN Status
Alouatta palliata aequatorialis	Ecuadorian mantled howler	Vulnerable
Ortalis erythroptera	Rufous-headed chachalaca	Vulnerable
Psittacara erthrogenys	Red-masked parakeet	Near-threatened
Cebus aequatorilais	Ecuadorian white-fronted capuchin	Critically endangered

calls accurately identified as belonging to a specific species.

On agroforestry plots with more than one crop, we counted the number of specific agricultural plant species along paths to assess the relationship between associated biodiversity and the variability in agroforestry practices. Though *agroforestry* for the purposes of this study refers specifically to shade coffee cultivation, almost every smallholder coffee farm we surveyed cultivated other domesticated plant species in close proximity to shade coffee. This intercropping of shade tree species along with a diverse array of agricultural species creates a heterogeneous vegetative structure on the agricultural sites we studied typical of traditional agroforestry systems. Despite variation in the agroforestry sites we studied (see descriptions below), they were notably different visually from the monoculture sites (Figure 4.3).

To determine any benefit conferred from connectivity to high-biodiversity areas like tropical dry forest stands, we also categorized each site in terms of its proximity to uncultivated tropical dry forest patches. Because the field sites in the study were concentrated in a relatively small geographic area consisting of a matrix of forest, monoculture, and agroforestry, most sites were already a short distance from forest patches. Therefore, we recorded each agricultural site, rather than individual points within each plot, as being either adjacent or nonadjacent to forest patches.

4.1 Field Sites

To compare associated biodiversity of naturally-occurring and agricultural tropical ecosystems, we conducted field surveys across eight sites that represented three distinct land-use types: a primary tropical dry forest (one site), agroforestry farms (five sites) and monoculture farms (two sites; Table 4.3). All sites are within the coastal Jama canton of Manabí province in western Ecuador (Figure 4.4).

Table 4.3. Size, age, and land use types of sites surveyed in the field

Site Name	Type	Size (hectares)	Years of cultivation
1. Lalo Loor Reserve	Primary Tropical Dry Forest	180	NA
2. Finca La Mago	Coffee Agroforestry	0.5	6
3. Finca La Tia	Coffee Agroforestry	0.41	8
4. Finca Milu	Coffee Agroforestry	2	2
5. Finca Don Ernesto	Coffee Agroforestry	NA	40
6. Mono Verde	Coffee Agroforestry	9.13	12
7. Finca de Duenas	Cacao Monoculture	NA	NA
8. Watermelon Patch	Watermelon Monoculture	1	NA

Figure 4.3. Photos of three land use types in the study. Clockwise from top left: Lalo Loor Reserve, primary tropical dry forest; coffee agroforestry; cacao monoculture

4.1.1 Site 1 (Lalo Loor Dry Forest Reserve)

Site 1 is the Lalo Loor Dry Forest Reserve, approximately 180 hectares of protected primary tropical dry forest located between the towns of Pedernales and Jama (Ceiba Foundation for Tropical Conservation, n.d.). Historically, Manabí's dry forest systems intersect the transition zone between the wet forests of the north and the dry forests of the south and harbor a diverse assemblage of species from both habitat types. The Lalo Loor Reserve is a relatively large patch of remnant primary forest in a fragmented landscape of smallholder agroforestry farms, monocultures, pasture lands and other small- and linear-patch forest fragments.

Despite being adjacent to the highway, the reserve is minimally developed, containing an open-air visitor center, maintenance quarters, and a primitive biological station. There are two small cultivated areas for demonstration: a shade-coffee plot and a local, medicinal herb garden. Throughout the Reserve are a network of hiking trails that are minimally maintained, and so are not likely to represent major disturbance relative to an inaccessible forest.

4.1.2 Agroforestry Farms

A total of five agroforestry farms were surveyed, all within the community of Tabuga in Jama canton. These farms all practice agroforestry management practices with the implementation of shade trees grown with coffee plants. Although they have similar management practices, each farm is unique in its characteristics in terms of forest proximity, pest management system, duration of farming practices, landscape characteristics, size and variety of plant species. All agroforestry sites were smallholder farms, cultivating shade-coffee on a small scale. With the exception of one farm in which shade-coffee was present but not actively managed for production, each farm was a member of the local ASOPROCOFFEE collective of multiple other coffee growers who share the operational costs required to meet market demand.

4.1.1.1 Site 2 (Finca la Mago) and Site 3 (Finca la Tia)

Sites 3 and 4 are adjacent smallholder, mixed-use, shade coffee farms. Site 3 was established 6 years prior to the survey, and Site 3 was established 8 years prior, and so they were sampled separately to capture any variation due to age. A small creek intersects the land owners' property, dividing the farm and an adjacent stand of tropical dry forest. Each farm contains several patches of two primary varieties of Arabica coffee (*Coffea arabica*), intercropped with tropical fruit trees such as lime, mango, "ovos" (a local fruit variety favored by wildlife), coconut and ivory palms, guanabana, avocado, cacao, nut varieties, and yucca. In addition to shade-grown coffee and tropical fruit trees, each farm contains separate plots of papaya and plantains grown in stand-alone clusters without intercropping, as these species have very low tolerance for shade.

Both farms are primarily organically managed, with some use of home-made, soap-based insecticides specifically targeting invasive coffee berry borer beetles (*Hypothenemus hampei*). These pest control measures are placed inside bottle traps hung on coffee bushes, rather than applied to the foliage.

4.1.1.2 Site 4 (Finca Milu)

Site 4 is a young agroforestry farm with still-developing coffee plants and very few mature shade trees. The site is surrounded by other mixed agricultural plots and is not adjacent to any forest fragments or water sources. These factors, in addition to the lack of shade from canopy-cover and a layer of leaf litter, create drier conditions than the other agroforestry sites. However, the plot is still being actively managed and in several years of optimal growth, may have the conditions similar to other sites with both mature coffee plants and

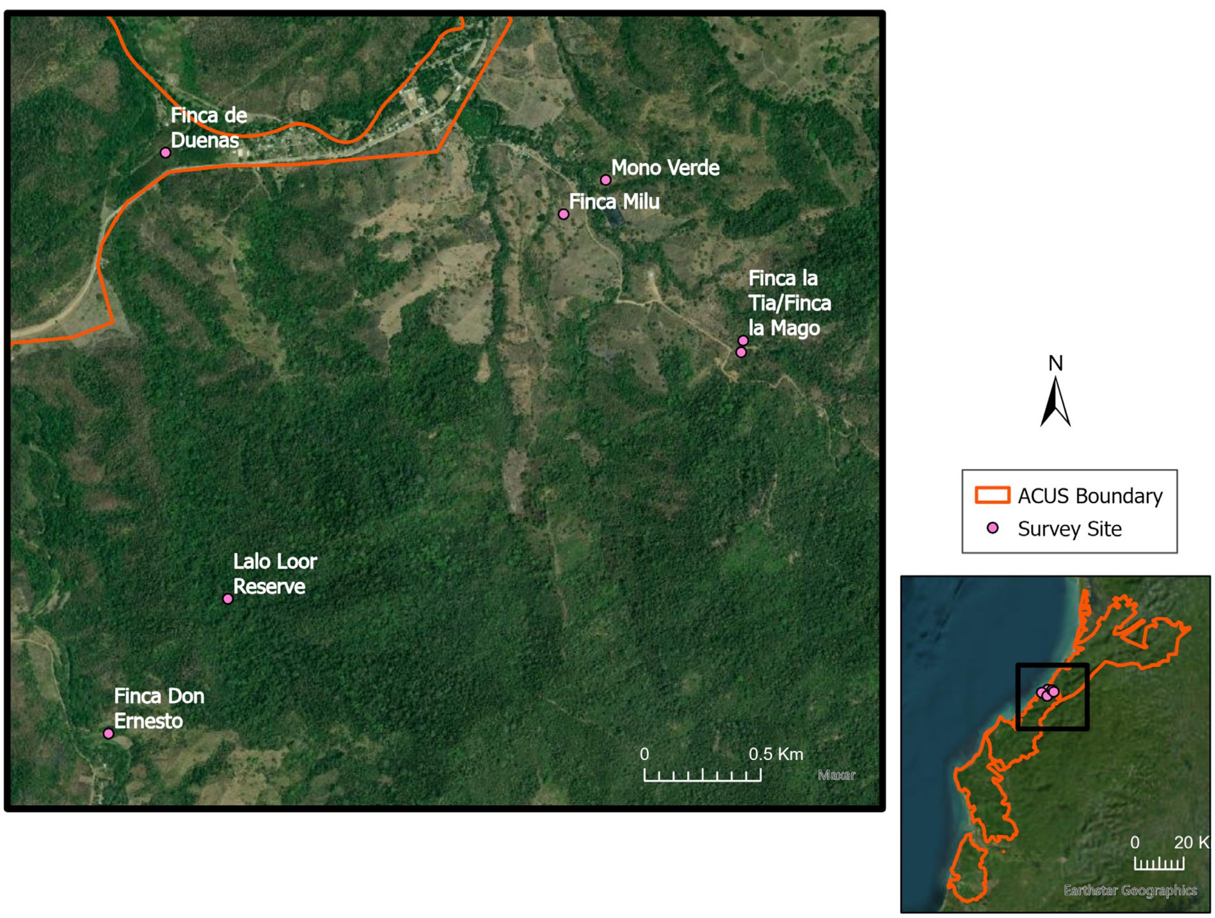

Figure 4.4. Survey area map and field site locations. Map layout: Barbara Nainiger

Figure 4.5. Site 5 is a minimally-managed farm with stands of agricultural crops surrounded by overgrowth of native vegetation

4.1.1.3 Site 5 (Finca Don Ernesto)

Site 5 was the largest agroforestry farm in the study sample and was notable in that it was not being actively managed for production and that the coffee-plots were not the largest plots on the farm. Other than Site 4, Site 5 was the only farm in the study not adjacent to forest stands, and instead was surrounded by mixed-use agriculture, including pasture lands. Several streams dissect the site, which, according to the property owner, are contaminated from chemicals dumped by shrimp-farming operations from upstream.

Site 5 is arranged in distinct clusters of agricultural plant types including fruit trees like guava, guanabana, lime, pomelo, mango, plantain, jackfruit, and cacao. Herbaceous crops such as aloe, ginger, and turmeric are present in the understory throughout the various plots. Large stands of bamboo have spread outward from the streambeds and into semi-open spaces between existing crops. The farmer does manage a small area of yucca and other medicinal plants, adjacent to an open field.

Cultivation of Site 5 began approximately 40 years prior to the survey. Because most of the crops are not being actively cultivated, much of the farm includes overgrowth of vines, bamboo, and dense canopy cover. Multiple signs of animal herbivory on fruits fallen from trees were noted.

4.1.1.4 Site 6 (Finca Mono Verde)

Site 6 is a smallholder farm of primarily shade-grown coffee adjacent to both a stream and a stand of tropical dry forest. Shade-grown coffee is cultivated in two adjacent plots intercropped with many large fruit trees such as lime, jackfruit, guanabana, fruitillo, as well as non-fruiting trees. Relative to other coffee farms in the sample, Site 6's coffee plots are more heavily shaded. A small stand of plantain plants sits between the coffee plots and small stands of semi-forested overgrowth. On the opposite side of the property from the shade-coffee plots are several open fields in which passion fruit monocultures are being cultivated.

The farm was established over 12 years prior to the survey as a field experiment in sustainable agriculture techniques, including shade coffee. The farmer currently engages in permaculture techniques, including the introduction of mycorrhizae to the soil, and uses no pesticides or pest control measures.

4.1.3 Monoculture Farms

Two monoculture farms were surveyed, each practicing the production of a single crop in open-sun plantations and with the use of chemical pesticides. Neither of the monoculture sites surveyed produced coffee, because unshaded, conventional coffee monocultures were uncommon in the study area. To compare the biodiversity levels between agroforestry and monoculture, our study instead focused on monocultures within the same landscape context as the agroforestry sites and tropical dry forest. The two monoculture plots surveyed were close in proximity to the Lalo Loor Reserve and several of the agroforestry sites.

4.1.3.1 Site 7 (Finca de Duenas)

Site 7 is a large farm with multiple, separate monoculture crops adjacent to a tropical dry forest patch that abuts the coast. Intersecting the property and forming one border of the cacao plot is a seasonal stream with some riparian tree species still standing. In addition to cacao, the farm cultivates orchards of mango and orange, which were not included in the survey.

The survey area of Site 7 is a large, open-sun cacao plantation managed with chemical fertilizers and localized irrigation. Site 7 is unique in the survey, due to its large size and the high uniformity of plants, which were planted at the same time and in accordance with conventional agricultural practices. The cacao trees stand in evenly-spaced, uniform rows and are roughly the same size and height.

4.1.3.2 Site 8 (Watermelon Monoculture)

Site 8 is a single, open-field farm using conventional agricultural practices on rotating monoculture crops, usually maize (corn) and another off-season crop. At the time of the survey, the off-season watermelon crop had just been harvested, and workers were planting new maize. The farm uses a variety of commercially-available chemical insecticides and fungicides. Site 7 is bordered by a highway and a stream, beyond which is a stand of tropical dry forest. Though nearly 2 kilometers apart, Site 8 and Site 7 are adjacent to the same continuous forest patch.

Figure 4.6. Site 7, a large-scale monoculture of mature cacao trees

Figure 4.7. Survey methodology of agroforestry sites

4.2 Survey Methodology & Analysis

We developed custom digital field surveys with ArcGIS Field Maps. This allowed cross-functional teams to share land use classification data for our project's GIS component (see Chapter 2) as well as to plot biodiversity measures spatially (see *Appendix B - Standard Operating Procedures for Ecological Field Data Collection* for a complete list of variables collected). For avian abundance, we uploaded audio recordings to Field Maps and the Merlin app (developed by the University of Cornell Ornithology Laboratory) simultaneously to check for species matches.

We collected observed species data at equidistant points along predetermined paths through survey sites. Because survey locations varied significantly in size, distance between points varied to allow us to sample a large enough area. For sites smaller than one square kilometer, we took points every 10 meters, and every 30 meters for sites between 1 and 3 square kilometers. For sites larger than 3 square kilometers, we took points between every 50 and 100 meters. In the Lalo Loor Forest Reserve (the largest field site) we took points along trail markers, spaced every 50 meters. For most agricultural sites in the survey, we sampled every 10 meters along a path - usually a zig-zag line through crops - to traverse enough of the plot to collect data representative of the entire site (see Figure 4.7). We conducted sixteen surveys, with approximately two surveys per site, across all land use types between May 30th, 2022 to June 27th, 2022, during the transition from the region's rainy season to dry season. We conducted surveys between the hours of 9AM and 12PM on weekdays in accordance with individual landowners' schedules and permission. Significant differences among long use types in the response variable were tested using analysis of variance on plots. We analyzed for differences among land on using survey points as our replicate within land use type. Given the proximity among sites, and unequal sample size of sites by land use type, we chose not to nest the analysis by site.

4.3 Biodiversity Assessment Results

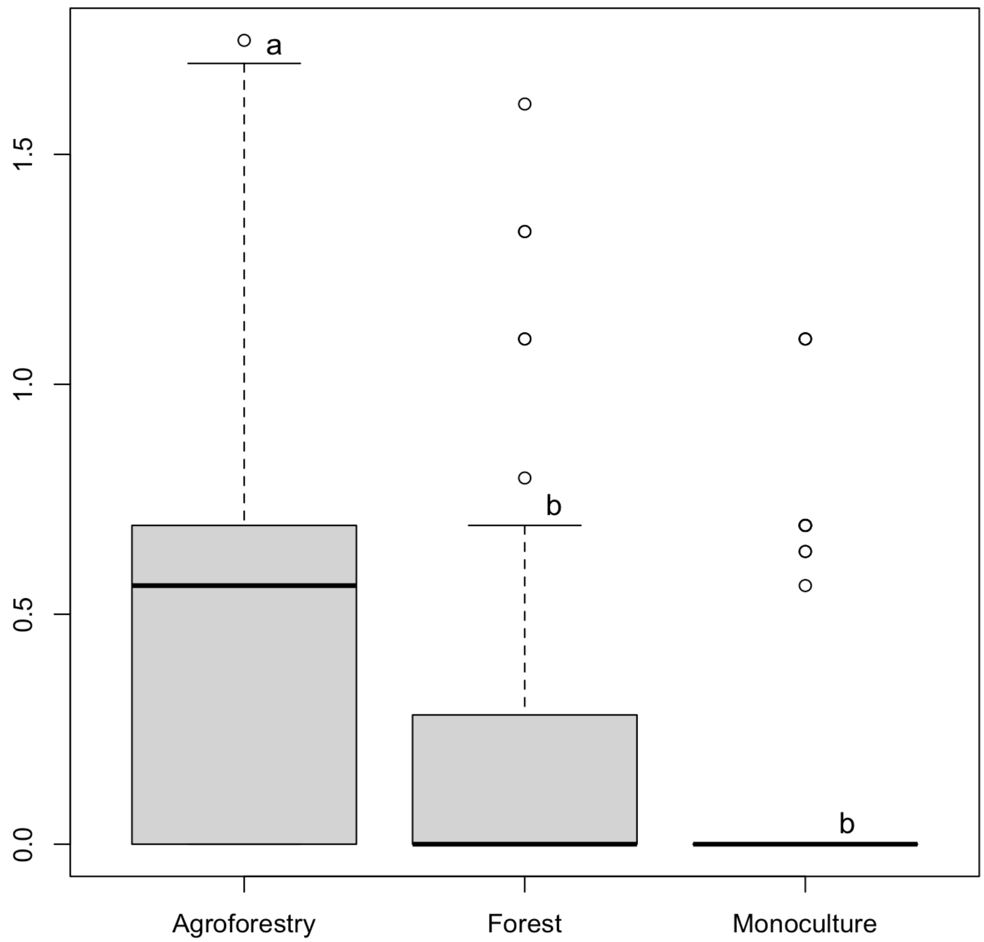

Figure 4.8. Bioindicator presence by land use type. The bioindicator presence was significantly lower in monoculture survey points (a) than in agroforestry and primary forest survey points (b, b)

4.3.1 Bioindicators

There was a significant relationship between land use type and the presence of bioindicator species (Figure 4.8; $F(2, 337) = 14.79$, $p < .05$).

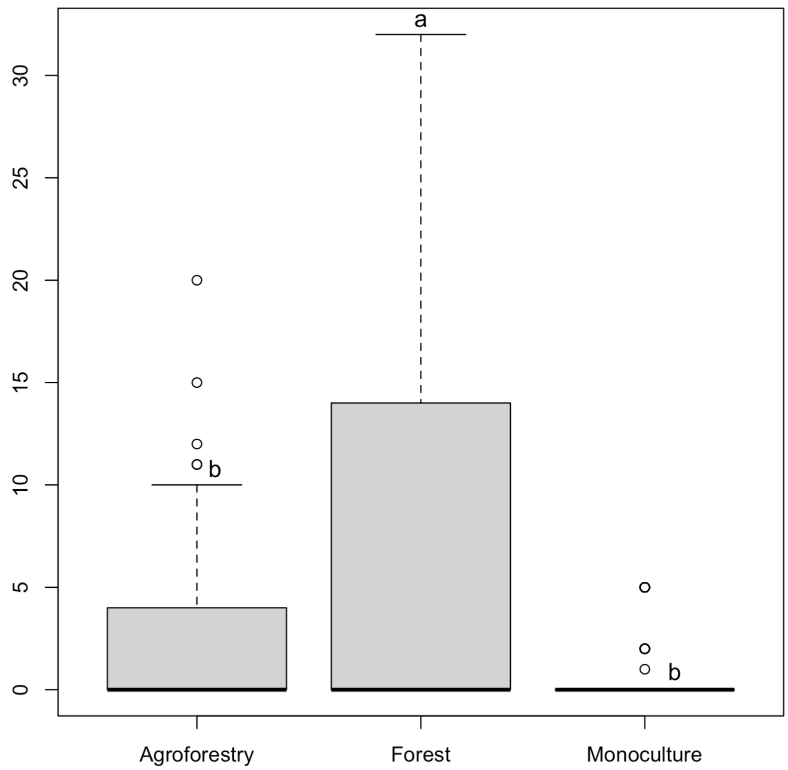

Figure 4.9. Pollinator abundance by land use type. Pollinator abundance was significantly higher in agroforestry survey points (a) than in primary forest and monoculture survey points (b, b)

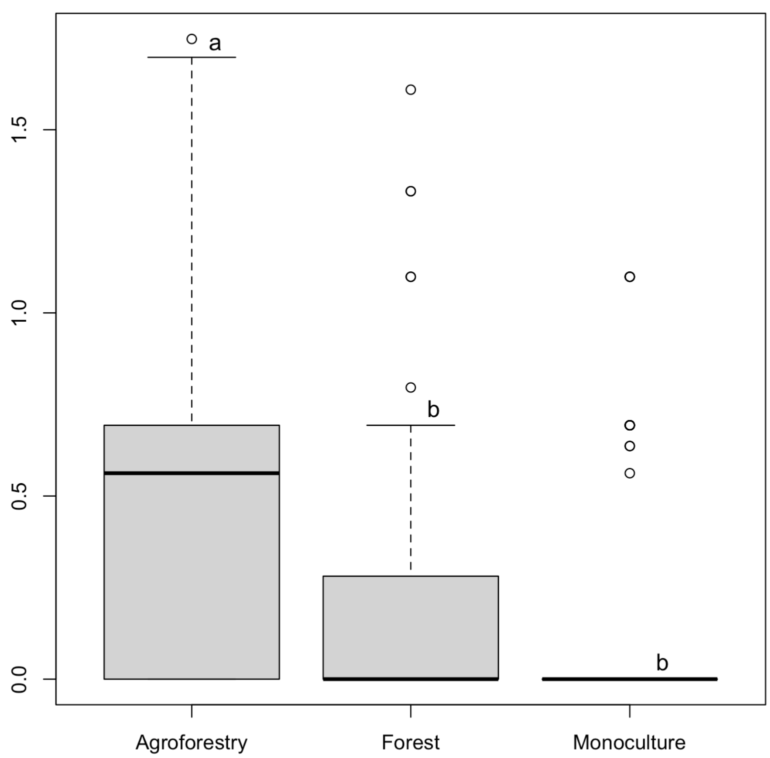

Figure 4.10. Pollinator diversity by land use type. Pollinator diversity was significantly higher in agroforestry survey points (a) than in primary forest and monoculture survey points (b, b)

4.3.2 Pollinator Abundance and Diversity

Pollinator abundance and diversity was higher at agroforestry sites than both monoculture and forest sites (Figure 4.9; $F(2, 337) = 25.44$, $p < .05$ & Figure 4.10; $F(2, 337) = 21.67$, $p < .05$).

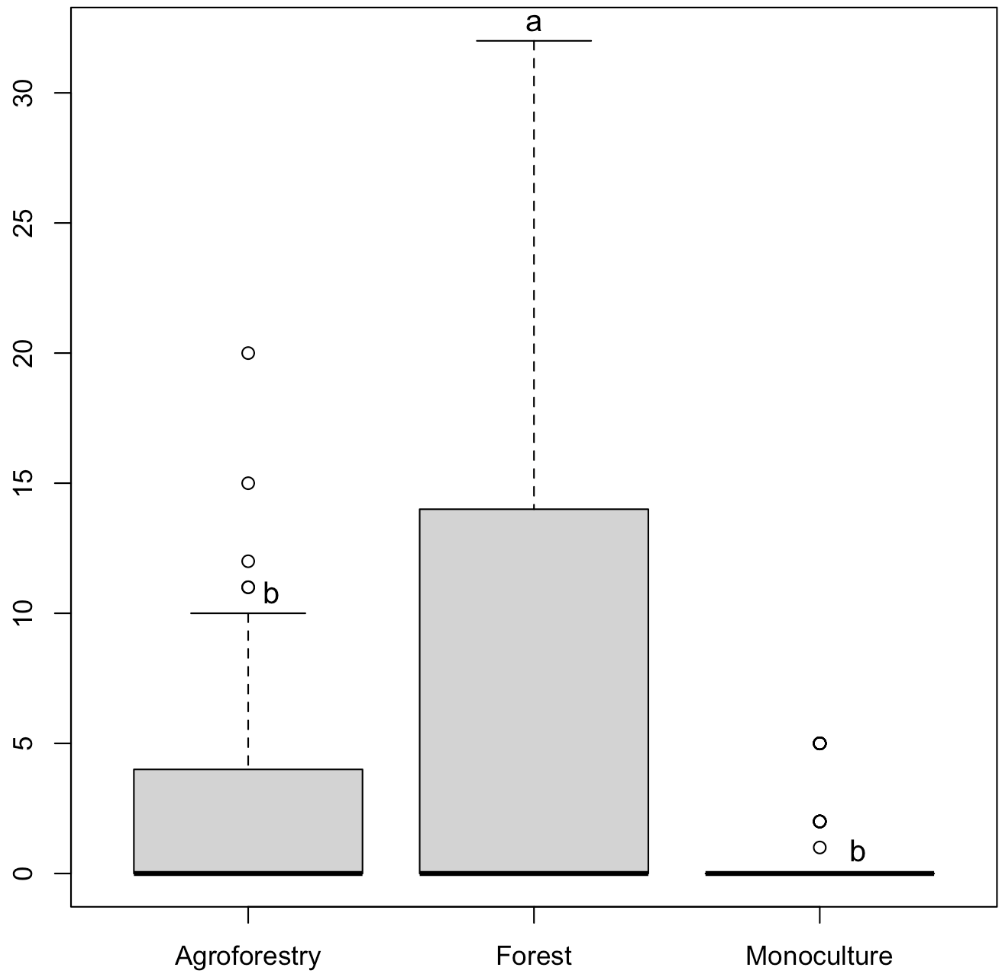

Figure 4.11. Bird abundance by land use type. Bird abundance was significantly higher in primary forest survey points (a) than in agroforestry and monoculture survey points (b, b)

4.3.3 Bird Abundance

While pollinators were both more abundant and more diverse in agroforestry sites than in the tropical dry forest, bird abundance was significantly higher at the primary forest site. An analysis of variance showed that the effect of land use type was significant on bird abundance, (Figure 4.11, $F (2, 337) = 35.89$, $p < .005$). A Kruskal-Wallis post hoc test showed differences between all three land use types ($p < .05$).

5 Interviews: How Do Landowners Who Practice Agroforestry In Manabí, Ecuador Describe Their Practices And Perceived Benefits?

To better understand the specific practices of agroforestry farmers specifically within the ACUS region of Manabí, and to document the biodiversity and other benefits of agroforestry that they observed on their own farms, we conducted individual interviews and focus groups with the same five agroforestry sites we surveyed for biodiversity (see above). The five farmers were chosen based on their existing relationships with the Ceiba Foundation. The criteria for including a respondent were farmers who had experience practicing agroforestry or sustainable agriculture within the ACUS in the Manabí, Ecuador region. We developed interview procedures prior to the onset of fieldwork in Ecuador, including receiving exempt status from the University of Michigan's Institutional Review Board approval process. These procedures included interview questions and methodology based on extensive literature review and conversations with the Ceiba Foundation surrounding biodiversity and sustainable livelihoods in the region.

Questions in interviews and focus groups encompassed two main areas relevant to our research: 1) details of the respondent's *farming practices*, including intercropping, inputs, and pest management, and 2) perceived *benefits* of their agroforestry practices. Specific questions included: *Do you think your farm helps support biodiversity or animals?, What are the benefits of growing diverse species in close proximity?* The complete list of questions and the interview guide for the study can be found in Appendix IV.

5.1 Agroforestry Practices: Tree Diversity and Pesticide Use

Landowners interviewed owned agroforestry farms that integrated coffee and cacao plants with a variety of fruit trees and shade trees. The most common agricultural plants grown aside from coffee and cacao include yucca, plantain, mango, lime, passionfruit, papaya, bamboo, sugarcane, coconut and a range of medicinal plants. Respondents reported practicing agroforestry methods by intercropping trees with agricultural crops. The range of respondents practicing this method of agroforestry varied, from four to forty years.

Currently, all six respondents reported not using synthetic chemical pesticides, and instead practice natural pest management. Several respondents developed their own natural pest deterrent with supplies from the farm such as medicinal plants, alcohol and fruit. Two of the farms practiced chemical pesticide use prior to the adoption of natural pest management through agroforestry practices in 2018 when they ob-

Figure 4.12. A homemade pest control trap made with alcohol instead of synthetic pesticides

served their plants suffering from pests such as burns on the coffee leaves from lack of shade. One farmer responded to the difficulty in managing a farm without chemical pesticides:

> *When we spray our product [natural pest deterrent] we have to wait to see if the pest dies or not. However, when we use chemicals, one fumigates and the pest immediately dies. But, it's worth the wait because then you know you are consuming organically.*

Prior to adoption of agroforestry, some respondents explained that outbreaks of the coffee berry borer continuously threatened coffee crops and production. At the advice of forest engineers from the Ecuadorian government, infected coffee plants were destroyed and all existing trees on their farm were removed, as they were thought to provide habitat for the pest. Only after borer outbreaks continued despite these containment measures, did the farmers take the advice of a relative who was practicing organic, shade-coffee cultivation, who explained that trees provide habitat for predators of the borer and could provide a form of natural pest control. When recounting the conversation about the adoption of shade trees, the relative stated to the farmers:

> *Remember before, your grandparents and great-grandparents used to grow coffee under trees and it was true. They used to have enormous trees and below you would find coffee and it wouldn't be harmed. So, we will plant trees on your farms and everything will be okay.*

Most farmers stated that they do not fumigate with chemicals because of the effect on the ecosystem and forest species. They note that when chemicals are applied to the plants, it is important to understand how the chemicals are interacting with the surrounding environment. Birds will consume the plants with chemicals and become ill, the chemicals drain into the soil, waterways, fruit produced and ultimately impact human health. Although the practice of chemicals is still present in the region due to generational pesticide use, farmers are noticing the trend to transition into adopting traditional practices historically practiced in the region. As one farmer said:

> *There are some farms that use chemicals. The larger farms are starting to learn how to manage the farms like us to not use any chemicals.*

Another farmer who does not apply any form of pest deterrent, shared that they regulate pest and disease by immediately cutting a crop at the trunk that appears to be sick or is dying, to allow a new plant to grow and to ensure that disease does not spread. They acknowledge the high quantity of insects on their farm, but stated that they do not necessarily impact the plants compared to other coffee farmers as "high impact pests." This same farmer shared their perspective on other farmers' management practices on chemical pest control use stating:

> *People here do use chemicals, even though they shouldn't. People will say they don't use them, they do. They just don't want to say so. A lot of people use them for the insects, but I know the insects will never end because that's their life, just like ours. The more you kill them, the more they will show up.*

They went on to share that they believe chemical use is to blame for low yields on local farms, and that the continued cycle of pesticide from acquired resistance from the pests also weakened agricultural plants, degraded soil, and spread infections within crops. Additionally, chemical inputs were perceived to cause discoloration and a bitter taste in harvested farm products that reduced their value. One farmer shared:

> *Why do you think people's farms are not producing? Because they use pesticides and then they have to use more pesticides. This is because they fumigate with pesticides all over the land and that is why all their plants are sick. That is why the plants die, the soil is hurt and all the other plants continue to be infected.*

5.2 Observation of Agroforestry Benefits: Services, Biodiversity, and Stability

Many benefits were mentioned of growing a diversity of plant and tree species together in a combined land management system including pest management, nutrient cycling from leaf litter, soil moisture retention, secondary crops for home consumption and additional income, habitat for forest species, and protection from extreme climate.

When asked about the benefits of growing species together:

> *There are lots of benefits, beginning with the guava trees. Their leaves fall onto the floor making the soil more fertile. Using the soil, we use it for other agricultural plants and that allows for the soil to remain moist during the summer months so that the plants do not suffer. The cane plant helps sustain the water. The caucho tree (rubber) helps sustain the animals, the birds, the monkeys and they help eat the seeds that benefit the soil.*

A common theme shared across respondents was the benefit shade trees provide for the local biodiversity of forest wildlife. Intentional management practices have been put in place to provide space, resources and an environment clear of pesticides for visiting species. Most farms shared the presence of bioindicator species such as the Rufous-Headed Chachalaca, Ecuador-

Figure 4.13. Some survey respondents stated that Ecuadorian mantled howler monkeys (Alouatta palliata aequatorialis), *a bioindicator species for this study, had been observed on older agroforestry farms with more mature trees. Photo credit: Mike Kelly*

adjacent farm, which has taller and more mature trees.

One respondent working on a forty year-old family agroforestry farm added that when the crops begin to bear fruit, wildlife presence on the farm increases and helps make use of the large quantity of fruit the farmers are unable to sell or consume themselves. Additionally, a range of animals were assumed to play an important role in seed dispersal in agroforestry systems. Certain agricultural tree species such as the Caucho tree, or rubber tree, also provided habitat for tree-dwelling wildlife and attracted beneficial species to farms. Overall, respondents held a benevolent opinion of forest-dwelling wildlife, and welcomed the diversity of forest species with which they shared space and resources:

The trees help shade the coffee plants for the benefit of the environment and the birds. We are both part of the environment and we need to give them their space and resources.

Observations of climate changes have become a common topic of conversation within the farming communities in the region, and agroforestry was seen as a possible buffer to these changes. One farmer shared their experience with the variability of weather in the region:

ian Mantled Howler Monkey, and amphibians in addition to a wide variety of birds and pollinating insects. One respondent with a six year-old forest-adjacent farm with young trees shared that although the howler monkeys do not fully reach her farm due to less canopy cover and mature trees, they frequently visit the

> *Here we have a climate that is very variable, sometimes we have very strong winds and then we have lots of cloudy days like in the mountains with strong wind. In August comes the strong frost. The frost is so terrible and worse than in the mountains, then the strong sun begins once again.*

The changes in climate have also impacted water resources with long dry spells or high intensity rain events that flooded the landscape. Respondents also observed phenological changes in their crop species, reduced richness of bird, pollinator, and even pest species. One respondent explained how diversifying the agricultural landscape could help them adapt to climatic unpredictability:

> *We cannot only rely on one product as farmers. Prices in Ecuador are not very regular and agriculture is a risky business due to climate change. Right now, we do not really know what is happening, temperatures are changing, water is not as regular as it used to be, so it is very important to diversify. In ecological terms, we need to bring different tiny ecosystems into the farm to balance the pests and other insects as a form of pest management. Farmers in Ecuador, I am going to generalize, are not aware of all the terminology of climate change, but definitely everyone is feeling and observing that there is a problem.*

The respondent added that although these changes are widely observed by farmers, the climate is not a major priority as farmers are focused on making ends meet and feeding their families. He hopes to be part of the process of helping to teach farmers to sustainably generate income.

6 Key Findings: Literature, Field Surveys, and Inteviews Agree on the Benefits of Agroforestry

6.1 Bioindicator Presence

The analysis of our ecological survey results showed several important trends relevant to the study. First, bioindicator presence is strongly correlated with land use type. Survey results show that bioindicator presence in the primary forest site was only slightly higher than in agroforestry sites. Because bioindicator presence was identified by sound, and surveys of farms adjacent to forest patches recorded increased bioindicator presence, we analyzed point data in terms of each farm's adjacency to forest patches. Forest-adjacency significantly affected bioindicator presence, with adjacent farms of any type having a higher presence of bioindicators, suggesting that primary forest habitat is critical for maintaining biodiversity, especially with large-bodied animals like howler monkeys and chachalacas. Forest-adjacency was not found to significantly affect pollinator abundance, diversity, or bird abundance.

Through qualitative data collection, most respondents noted the presence of bioindicator species on their farms. Respondents appreciated forest-dependent wildlife, rather than viewed as threats, and added that wildlife benefitted the farm through seed dispersal, and by consuming surplus crops that would otherwise rot. Indeed, in Site 5, multiple signs of animal herbivory on fruits fallen from trees were noted during surveys. This was a compelling finding on the relationship between farm productivity and wildlife that could not have been elucidated through field surveys alone.

Figure 4.14. Signs of animal herbivory on a ripened jackfruit on Site 5

6.2 Agroforestry and Pollinators

Second, land use type showed a significant effect of agroforestry on pollinator abundance and diversity. Pollinators (bees, wasps, butterflies, moths and hummingbirds) were twice as abundant in agroforestry sites than in the primary forest site, and almost three times as abundant than in monoculture sites. The trend for pollinator diversity (calculated with the Shannon diversity index) was similar, with pollinator diversity significantly higher in agroforestry sites than in sites of both monoculture and primary tropical dry forest land use types.

Monoculture sites surveyed were both non-shaded and managed with chemical pesticides, including insecticides. These characteristics effectively create an environment that not only lacks vegetative habitat, but is toxic to insects including pollinators. On Site 7, the large cacao monoculture, no herbivory was observed on any leaves of the cacao trees during both surveys. Structural heterogeneity in vegetation and a lack of toxic pesticides indicate the potential of agroforestry as high quality habitat for a variety of insect species which provide ecosystem services in the form of pollination and food sources for a variety of insectivorous wildlife, especially birds (Philpott & Bichier, 2012).

Lower levels of pollinator abundance and diversity in primary tropical dry forests compared to agroforestry may seem like a surprising study finding, but there are potentially several explanations. One potential explanation is the difference in canopy height and density between agroforestry and primary forest environments. Because surveys were conducted on foot at the ground level, the lower canopy height in agroforestry plots may have made it easier to observe pollinators. In the primary forest site, the canopy layer was too high and thick to observe, obscuring any potential pollinator activity. Increased pollinators in agroforestry plots may also be the result of human modification of plant communities for more fruit-producing, and therefore flowering, plants. Relatively more food in a smaller area or more compact environment would result in increased abundance of pollinators per survey point in agroforestry surveys compared to primary forest surveys. We recommend further study on the differentiation between pollinator species abundance and richness between agroforestry and primary forest.

6.3 Bird Abundance

Third, there was a statistically significant effect of land use type on bird abundance, with bird abundance in the primary forest site twice as high than in agroforestry sites. Bird abundance in monoculture sites was significantly lower than both agroforestry sites and the primary forest site. While primary tropical dry forests represent a higher quality habitat for a greater abundance of avian species, agroforestry sites in the study

Figure 4.15. An abandoned bird nest on agroforestry Site 2. A developed canopy provides habitat and resources for bird species

had significantly higher bird abundance than monoculture sites, demonstrating the continuum of wildlife habitat across the landscape matrix.

Literature supports the characterization of tropical dry forests as habitat for an incredibly diverse array of avian species. However, because the tropical dry forest ecosystems of Ecuador remain under-researched, bird species identification with the Merlin app was inconsistent. Combined with the difficulty observing and identifying species by sight in dense canopy layers, it was not possible to adequately calculate the diversity of avian species across land use types in this study.

One bioindicator, the rare red-masked parakeet (*Psittacara erythrogenys*) was observed via point-call surveys of the two monoculture sites and agroforestry Site 3. In Sites 7 and 8 red-masked parakeet flocks were not observed on the monoculture sites, rather in the tropical dry forest stands adjacent to them that now contain development of vacation homes. This bioindicator species was not observed in surveys of the Lalo Loor Reserve, despite its seeming suitability as high-quality habitat for the species. This finding demonstrates that despite efforts to protect remaining large-patch primary tropical dry forest, loss of any remaining habitat to development can impact local populations of key species.

Figure 4.16. Red-masked parakeets (Psittacara erythrogenys) *were a bioindicator species for the study, but were only observed twice, and never in the primary forest site. This species is classified as Near Threatened by the IUCN Red List and local reports claim that populations in the study area are in decline. Photo credit: "Red-masked Parakeet-Aratinga erythrogenys in a tree" by Jef Poskanzer is licensed under CC BY 2.0*

Figure 4.17. An agroforestry site demonstrating the density of vegetation created by intercropping fruit trees to shade coffee plants

6.4 Farmer Assessment of Ecological Benefits

Quantitative and qualitative methodologies provide complementary data and, together, a more comprehensive assessment of coffee agroforestry as a socioecological system. Qualitative content analysis of interviews with agroforestry practitioners found that shade-coffee farmers preferred management practices that select for a more biodiverse environment and a more resilient business.

Across all interviews, respondents viewed the shade provided by trees in agroforestry systems as the most critical and necessary component of successful coffee agroforestry. Shade-trees were reported to control a multitude of factors that created significantly better growing conditions than monocultures, with fewer inputs and lower effort. The structural complexity that shade trees created in the environment and the resulting increases in wildlife were seen as an auxiliary, yet welcome, effect.

The literature is clear that shade coffee's higher structural complexity increases biodiversity through provision of habitat for diverse wildlife, including natural enemies of agricultural pests. Respondents were voluble and spoke with first-hand experience on the complex situation of pest management in a region where the dominant way of life is agriculture. Though none explicitly mentioned predator-prey interactions regulating pest species, most mentioned the lack of pest outbreaks even with very high insect abundance on their farms, with some respondents recounting personal experiences with increasing pesticide applications failing to reduce insect herbivory on crops, a phenomenon broadly referred to as the "pesticide treadmill."

The natural pest regulation of shade-coffee farms resulted in discontinued use of chemical pesticides that, in turn, increased habitat suitability for arthropods, including beneficial insects. Additionally, respondents with previous experience on monoculture farms with pesticide use noted the differences in species richness compared to agroforestry systems that attracted more forest species. These quantitative data supported our ecological survey results, showing higher diversity and abundance of bioindicator species, pollinators, and birds on agroforestry sites compared to monocultures.

Lastly, crop diversification was identified across qualitative interviews as an economic benefit of coffee agroforestry. Coffee agroforestry systems in our study are essentially diversified polycultures, which can increase the resilience of farmers not dependent on a single crop. Respondents perceived that large-scale forces such as volatility in global commodity prices and even variable weather patterns brought on by climate change increased the risk to smallholder farmers who over-relied on a single crop. A diverse mix of cultivated species was seen as a useful tactic to minimizing risk and managing unavoidable losses, and these opinions are supported by the literature.

6.5 The Agroecological Matrix

Growing literature and results of this study recognize agroecosystems as capable of harboring high levels of biodiversity. Because the majority of the world's biodiversity is concentrated in tropical regions, broadening conservation's focus to landscapes surrounding remnant primary forests, including agroecosystems, is crucial. We identify shade coffee agroforestry systems as landscapes capable of promoting a high-quality matrix, due to high planned biodiversity of coffee bushes and shade trees that support rich bird, mammal, plant, and insect diversity. Though coffee agroforestry systems may not have sufficient structure to support all forest organisms, they provide permeable routes between habitats for shelter, resources, and to promote genetic diversity (Perfecto et al., 2009).

Although shade coffee may support more biodiversity than other land use types, as small patches on the landscape, their overall biodiversity value is low. One interview respondent noted that their farm is the only shade-coffee farm in the immediate area that functions without pesticides. Additionally, intensive agricultural practices, especially chemical input use, can impact neighboring farms and their ability to foster biodiversity. Therefore, increasing the adoption of agroforestry to monoculture farms nearby will help increase landscape connectivity in the region.

7 Recommendations and Conclusions

7.1 Share and Promote the Benefits of Agroforestry, Using the Deliverables Provided

By nature of their work, interview respondents had an awareness of the ecological conditions on their farms that supported higher species richness and abundance than did monoculture farms. However, many expressed interest in learning about findings from biodiversity surveys, especially with regards to specific species. They may also be interested in the evidence supporting the positive relationship between their farming practices and the heterogeneous structure of their farms' environments, species diversity, and ecosystem services. Through qualitative data collection, most respondents noted the presence of bioindicator species on their farms. Respondents appreciated forest-dependent wildlife, rather than viewed as threats, and added that wildlife benefitted the farm through seed dispersal, and by consuming surplus crops that would otherwise rot. Indeed, in Site 5, multiple signs of animal herbivory on fruits fallen from trees were noted during surveys. This was a compelling finding on the relationship between farm productivity and wildlife that could not have been elucidated through field surveys alone.

7.2 Expand Field Surveys to Overcome Dataset Limitations

Limitations to our field survey methods restrict the conclusions we can draw from our results, but also provide ideas for additional or expanded studies of agroforestry systems. Small sample sizes of each land use type (limited by access), and of the number of replicates within each site (limited by our time in the field) means that it is likely we do not fully capture the variation among and within sites and that we cannot generalize our results to other regions with a very different landscape mosaic. To better isolate the effect of land use on biodiversity metrics we recommend increasing the number of sites sampled to include sites where pesticide use, crop types, age, and proximity to forest are independent of the land use category. Specifically, we would suggest comparisons with coffee monocultures to keep the main crop consistent between land use types, but this option was not with easy access from our field station.

Proximity to forest merits further study to determine if it can be more important than land use type to the species observed on farm sites. For example, the two monoculture sites surveyed were coincidentally adjacent to a primary forest patch, and at times recorded increased avian abundance at points close to forest stands. Additionally, calls of the "rare" Red-masked Parakeet were observed at both monoculture plots, though obviously emanating from adjacent patches. These data do not implicate the positive effects of monoculture practices for biodiversity, but do suggest the role of even fragmented forest patches in providing habitat for forest species, especially avian bioindicators.

Sampling at more times of the day and across different seasons would likely highlight additional species diversity patterns that we did not capture in our study. The equatorial tropical dry forest ecosystem experiences seasonality of precipitation, with distinctive rainfall patterns in wet and dry seasons. Our surveys were conducted during the transitional period from wet to dry season, after regular rainfall had ceased but the ambient humidity was still high and deciduous tree species had not yet dropped their leaves. This intermediate state likely allowed us to observe species present during seasonal rains and not yet dispersed to search for food, including primate, avian, and amphibian bioindicator species. Biodiversity surveys of increased duration would be beneficial in order to observe transience and seasonal behavior of wildlife. Other timing variation should be captured with additional sampling. Our point call surveys for birds, for example, were conducted simultaneously with collection of other biodiversity measures beginning daily at mid-morning, which allowed for visibility to observe pollinators, properly identify agricultural species, and to navigate uneven terrain safely, but failed to incorporate early dawn hours when many bird species are highly vocal around sunrise, limiting the number of species we might have included.

Extremely high levels of biodiversity and endemism in the Tumbes-Choco-Magdalena biodiversity hotspot in which our field sites were located presented challenges for species identification for surveyors new to the area, even when using available identification resources. For example, bird call identification with the Merlin smartphone app (developed by the Cornell University Ornithology lab) was accurate only for a relatively small number of species recorded. Compared to commonly observed species in North America, species in our study region have few robust song or call recordings which the app can recognize with certainty. At each point in bird call surveys, a 90-second recording was collected and uploaded to the Merlin app. Whenever a species was identified, that species was recorded in the survey, while all unidentified calls were recorded as unidentified species. We also had limited ability to identify other species. With the exception of large-bodied and recognizable bioindicator species, biodiversity surveys recorded abundance as observed instances of types of organisms (birds or pollinators), rather than attempting to identify the species of each organism observed. Tropical dry forests are relatively under-researched, especially compared to tropical wet forest (rainforest) ecosystems, such as the neighboring Amazon

Recommendations for further research:

- Increase and standardize sample sizes of experimental groups to test for affects of pesticide use, crop species, forest adjacency, farm age, etc.
- Identify shade coffee *monoculture* farms within the study area
- Expand duration of biodiversity surveys to control for the effects of seasonality on vegetation and wildlife behavior
- Recruit expert tropical dry forest taxonomists to improve accuracy of species identification

Figure 4.18. Agroforestry's modified, forest-like environment may allow tourists to more easily move through the terrain and view wildlife than in a primary forest

River Basin, but species diversity assessments remain critical. The Ceiba Foundation might consider hosting a Bioblitz event with expert tropical dry forest taxonomists recruited internationally so that actual species diversity could be assessed and to raise awareness about biodiversity in the region.

7.3 Market Wildlife Viewing Opportunities on Agroforestry Farms

If they can be accessed, our field survey data confirm that agroforestry farms have high potential for ecotourism activities. Given the rich diversity of species in agroforestry farms and their relatively walkability, they could be marketed to eco-conscious travelers seeking to view birds, wildlife, or sustainable livelihoods in action. Cultivation tends to render the terrain more accessible with paths both to and in between crops, as well as the removal of difficult-to-navigate debris or dense vegetation like those common to uncultivated, forested areas. Tourists may have an easier time traversing this modified terrain than even managed trails of primary forest. Shade coffee has specific benefits over primary forest for bird watching activities. The tall, crowded canopy of primary forests makes spotting wild birds extremely difficult, even for experienced birders. In contrast, in agroforestry plots trees are less numerous and easier to monitor for birds perching or foraging.

7.4 Value Agroforestry as Much as Reforestation in Landscape-scale Restoration Planning

Another component of our project includes a restoration prioritization map (Chapter 2), in which the landscape is analyzed to assess areas most needed to secure and increase remnant tropical dry forest con-

Figure 4.19. Site 4 is a young agroforestry farm with immature coffee plants, minimal canopy cover, and an understory dominated by grasses. As the farm ages, the densification of shade and vegetative structure will shift the environment towards one similar to the more established agroforestry sites in the study, which also supported more biodiversity. Converting deforested, open areas to agroforestry as above can increase biodiversity across the landscape and promote forest connectivity

nectivity through reforestation efforts. Based on our findings, agroforestry patches could also be considered a type of restoration and a viable part of creating connectivity corridors for forest species within the landscape, as agroforestry may improve the matrix between remnant forest just as much if not more than efforts to reforest with native tree species.

Quasi-restoration to agroforestry has a higher restoration success rate due to increased levels of monitoring and care of valuable agricultural plant species. In past discussions with the Ceiba Foundation, some planned restorations were unsuccessful because tree saplings were unable to survive the harsh conditions of the dry seasons. Because agricultural tree species represent a monetary investment and a source of future income, they are likely to receive supplemental care and water that can increase chances of survival, resulting in a higher restoration success rate.

This recommendation does come with the distinction that quasi-restoration should be considered as restoration only when adjacent to intact or restored forest, where it can function as a connectivity corridor. Our study found that the agroforestry field sites nonadjacent to forest patches had significantly lower levels of biodiversity than those adjacent to them. Nevertheless, we highly recommend further consideration of inclusion of agroforestry in restoration planning.

Should areas of restoration be used for agroforestry, communication with landowners is key to convey the importance of these areas as wildlife corridors. Landowners should be aware that quasi-restoration should apply to agroforestry only, but that such practices do benefit the crops and the farm. Keeping the coffee shaded and free of chemical inputs increases the effectiveness of natural pest control while maintaining lower inputs. Additionally, as quasi-restored areas mature into quality habitat, resultant increases in wildlife are to be expected, and care should be taken to preserve safety of both wildlife and cash crops. Collaborative action between conservation organizations and local landowners is crucial to promote both sustainable livelihoods and biodiversity conservation in the region.

7.5 Aid Community Transition to Agroforestry via Likely Mechanisms for Adoption

While shifting agricultural practices from intensive monocultures to agroforestry may have many documented benefits, enacting this shift involves complex human behaviors that may not be possible to change without sufficient time, education, and long-term and well-informed change management programs. Given the urgency of the biodiversity crisis, it is important to consider how best to encourage transitions to more sustainable agricultural practices in the region, and what situational, cultural, or social factors might impede or expedite this transition.

7.5.1 Potential Mechanisms of Agroforestry Adoption

Inducing a conversion to agroforestry involves complex human behaviors that may be influenced by landowners' values, attitudes, and beliefs towards multiple environmental and social factors, not all of them monetary. As discussed in the chapter on eco-entrepreneurship (3), agroforestry practices do not necessarily alleviate financial pressures for farmers, and communication about the benefits of this practice should not misrepresent persistent economic challenges associated with small-scale farming for a living.

Overemphasizing the potential monetary gain of biodiversity-supportive land use practices, such as product certification, or even payments for ecosystem services, has the potential to erode more durable intrinsic values that connect people to their lands, such as sense of place (Ruiz-Mallén et al., 2015). This framing also presents a narrow view of low-income earners' choices to evaluations based purely on potential financial outcomes, which, as Chapter 3 highlights, are highly uncertain for smallholder farmers. Further, monetary gain was decidedly not the driving factor to pursue agroforestry for the respondents in our study, many of whom expressed dissatisfaction with previous working conditions in large-scale agriculture and aquaculture as the driving force to work in agroforestry. Therefore, potential to increase income should not be the only factor emphasized in encouraging the adoption of agroforestry.

> ***"Overemphasizing the potential monetary gain of biodiversity-supportive land use practices, such as product certification, or even payments for ecosystem services, has the potential to erode more durable intrinsic values that connect people to their lands."***

Respondents in our study expressed their preference for working in agroforestry over other farming environments. In their view, agroforestry's shaded environment creates better growing conditions than open-sun monocultures, but they also perceived the overall environment to feel "cleaner." Though respondents did not explicitly relate the increased levels of biodiversity on their farms to their experience of agroforestry's better working conditions, exposure to a variety of taxa is positively associated with increased human well-being (Fuller et al., 2007, Hammoud et al., 2022, Marselle et al., 2021, Sandifer et al., 2015). Agroforestry's better conditions for farmers may be a distinction worth emphasizing, especially as rural communities are significantly more likely than urban ones to value the relationship between ecosystem services and health over household income (Aguado et al., 2018).

Disillusionment with pesticide use could represent a compelling point of entry to agroforestry adoption as well. Respondents had strong attitudes about pesticide use in terms of increasing operational costs, inability to effectively control pest outbreaks and even exacerbate them, and concerns about some level of toxicity to humans and animals. While continued heavy, regular use of pesticides is concerning from an ecological standpoint, if our study respondents' experiences are typical of farmers in the region, agroforestry practices may be viewed as an effective, pragmatic solution to the problem of pesticides.

Not only are the agricultural benefits of agroforestry evident for individual farmers (as discussed earlier in this chapter), but values of identity and social belonging are powerful drivers to continuing to practice a sometimes difficult way of life. The role of the ASOPROCOFFEE farming cooperative is ostensibly to increase income security for individual smallholder farm members, however, it also performs a vital role in the maintenance of social capital. Focus group respondents were nearly unanimously in agreement on the reasons for coffee agroforestry's superiority as an agricultural method. The strength of these shared beliefs and values among the group contributes to an in-group identity and social support system. These relationships and shared beliefs have also been shown to support adaptive capacity to complex threats such as volatile commodity prices and environmental uncertainties caused by global climate change (Frank et al., 2011).

Figure 4.20. Farming cooperatives like the ASOPROCOFFEE collective serve important social functions

Social identities are also related to family heritage, which several respondents discussed during the study. In a region where land-based livelihoods predominate, these findings are unsurprising, but no less important, as local ecological knowledge is often transmitted through family networks (Aswani et al., 2018). The fact that many farmers in the region may have generational knowledge associated with agroforestry suggests that highlighting an appreciation for family heritage and traditional agricultural practices may resonate strongly with potential adopters.

Both sources of social identity and their associated agroforestry knowledge may regulate self efficacy, which is an individual's beliefs about their abilities to exercise control over their own life (Ajzen, 2002). In turn, a strong sense of self efficacy can affect *perceived behavioral control* on any number of *specific* behaviors related to practicing or adopting agroforestry (McGinty et al., 2008). These distinctions are important, because uncertainty about one's knowledge and abilities may heighten perceptions of risk and negatively affect adoption of new agricultural methods.

7.5.2 Recommendations

While self efficacy is a key variable signifying readiness or intentions to adopt agroforestry in suitable conditions, there is potential for enhancing self efficacy and perceived behavioral control among existing agroforestry practitioners in the realm of biodiversity conservation. Local environmental knowledge among farmers in the study was high, but the relationship between their current practices and local biodiversity was not mentioned in any interview. Increasing understanding about the ecological impact of their work may serve to further strengthen self efficacy in agroforestry as not only beneficial to their farm, but to the broader landscape.

This research offers several findings on the relationship between agroforestry and ecosystem integrity that can be shared with practitioners, but future research about these practices and ecological benefits must continue to be shared to maintain farmers' self-efficacy in their role as beneficial environmental stewards.

Whether working with existing or potential agroforestry practitioners, it is crucial not to frame smallholder shade coffee farmers, like ASOPRO's members, as abnormal in their adoption of non-normative practices. Just as agroforestry practitioners may have strong in-group identities, so do farmers with other approaches, and perceptions of in-group approval of certain practices is often a significant indicator of intention to adopt behavior (Cortés-Capano et al., 2021, Fielding et al., 2008, Schirmer & Bull, 2014). The inverse is also true, and perceptions about social disapproval over performing non-normative behaviors can impede steps toward adoption. For the wider ecosystem to benefit from this beneficial agricultural practice, agroforestry must gain broader appeal within the local community by becoming normalized.

If agroforestry is valued as a conservation tool, we recommend the development of a locally-based social program that can manage education and outreach to encourage farmers to transition to agroforestry, either within the Ceiba Foundation or in partnership with another organization. This program should center a behavioral approach that stewards long-lasting change through organizational support of cooperatives and other avenues for communal learning and consistent messaging aligning with the following aspects of agroforestry:

- Better growing conditions for important crops
- Healthier working environments for farmers
- Pest regulation without chemical pesticides and their associated costs
- Practicing agroforestry is a way to respect and/or rediscover one's family heritage
- Easily accessible to anyone interested in learning about it

Changing such significant behaviors as farming practices is a complex endeavor that requires time and consistent community engagement, but the benefit of reducing threats to biodiversity through voluntary human action is a compelling potential solution to the complex problem of tropical dry forest conservation.

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Chapter 5: Assessing Agroforestry Ecotourism: Farm Tour Analysis and Case Study of ASOPROCOFFEE

Supporting Forest Restoration and
Sustainable Livelihoods in Coastal Ecuador

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1 Purpose and Audience

Eco-entrepreneurship offers a possible solution to widespread deforestation caused by short-term economic pressures by providing an opportunity for farmers to prioritize land conservation while using their resources to support their livelihoods. In this way, eco-entrepreneurship provides benefits both for the biodiversity of an area and the people who live there. Specific eco-entrepreneurship strategies often differ between regions—and even within a region—due to variations in external stressors, market factors, ecological contexts, and business choices. Strategies can include sales of wild-harvested or sustainably-grown products and various forms of ecotourism, but specific approaches to these strategies can differ significantly. This regional and local variation in eco-entrepreneurship, combined with a lack of information exchange and shared assessment frameworks, often makes it difficult for eco-entrepreneurs to learn from each other or know how to most efficiently and effectively improve their operations.

We address a portion of this gap by developing a systematic and informed approach to assess a specific type of eco-entrepreneurship: ecotourism on small agroforestry farms. We apply this approach to an in-depth case study of a multi-farm cooperative in Ecuador called ASOPROCOFFEE (hereafter, ASOPRO). In this chapter we provide answers to the following questions:

1. *What are ASOPRO's ecotourism goals and visions?*
2. *What are the key elements of a successful ecotourism farm tour?*
3. *How can ASOPRO improve their ecotourism farm tours?*

We use several methods, including interviews and literature review, to answer the first two questions, and from that develop Farm Tour Assessment Criteria. We then answer the third question by implementing the assessment criteria during on-site ASOPRO farm tours, from which we provide specific recommendations for improvement.

An effective ecotourism strategy can improve local conservation efforts and environmental conditions by linking sustainable, agroecological farming practices to a direct income stream. The analysis and recommendations in this chapter aim to directly benefit ASOPRO by elucidating specific aspects of an ecotourism strategy, and they are also designed for use by the locally active nonprofit Ceiba Foundation to inform their efforts to support eco-entrepreneurship in the region. While our analyses do not explicitly focus on ventures outside of Manabí, our Farm Tour Assessment Criteria could be adapted for use to support farm ecotourism efforts in other regions of Ecuador and globally.

2 Development of the Farm Tour Assessment Criteria

2.1 What Are ASOPRO's Ecotourism Goals and Visions?

There is a small, but dedicated group of eco-entrepreneurs operating in Manabí, Ecuador, and they are paving the way for sustainable livelihoods within a biologically diverse but threatened ecosystem. A significant contingent of these individuals are members of ASOPRO, a local food association composed of 17 smallholder coffee and cacao farmers who use sustainable agroforestry management techniques to produce high-quality, specialty coffee and cacao. The farmers avoid using synthetic pesticides and fertilizers and diversify their crops to include a variety of plants like papaya, plantain, limes, coconut, yucca, sugarcane, and bamboo. These techniques provide shade and pest control for farmers' essential crops and contribute to a healthier, more productive agroforestry system (See *Chapter 4: Benefits of Agroforestry for Biodiversity and People*). Some of these farmers are also increasingly pursuing ecotourism efforts to improve their livelihoods, specifically focusing on offering farm tours for visitors. They have limited experience in this area, so they sought support from our team in collaboration with the Ceiba Foundation to provide informed feedback on their current farm tour offerings.

As a first step to support ecotourism efforts on farms in Manabí, we sought to gain a better understanding of why farmers choose to pursue farm tours as a primary ecotourism strategy and what they hope to achieve. Collecting this information was critical to help us make an informed assessment of the farm tours and target our suggestions to the farmers' needs. We interviewed a total of seven ASOPRO association members, including the two individuals who lead the association. The semi-structured interviews were conducted in Spanish both as individual interviews and through a focus group, and our team also engaged in informal conversations with the farmers during tours of the three farms that are discussed in this chapter. These farms are located in Tabuga, Jama on the coast of Manabí, Ecuador. All below quotes are italicized and were translated from Spanish to English.

ASOPRO is led by smallholder, women farmers, and all members strongly believe that the association's identity as a women-owned entity is critical to its unique story. The association consists of over 80% women, which is uncommon in the region, since there are pervasive gender stereotypes which often prevent women from farming. An association member shared her perspective that the local *machismo* culture often prevents women from being seen as leaders, especially in technical and manual labor-based occupations:

I am pushing forward a group that used to be discriminated against. It used to be the hard work of the man, women were not the ones using the machete, that was meant for the man. The women would stay in the kitchen and the man would do all the laborious work. As you can see, our farms are led by women, and that's the change we want to display—that we too can participate in doing things well.

As a group, ASOPRO believes that their story and identity can and should be shared with consumers through their products and farm tours.

Two other important themes that arose in interviews and other conversations with the farmers were the desire to sell products at a fair market price and the desire to increase tourism in the region. While one way to access markets that will yield fairer prices is by selling products in areas outside of the farms—like the largest Ecuadorian cities, Quito and Guayaquil—another opportunity to access these customers is if they visit Manabí. An increase in general tourism in Manabí—whether the tourists are domestic or international—will bring more ecotourists and increase local sales of these high-quality, sustainable products. One association member shared:

As more tourism arrives, we sell more products. Compared to the local people, they don't value quality coffee like tourists. At $4, locals will say that it is very expensive, but in reality, if they saw the quality that we offer and the artisan work that we employ, that is not easy.

The ideal end goal, as shared by the farmers, is to have tourists visit their farms directly and attend a tour; learn about the specific farmer(s) who work on the farm, as well as ASOPRO more generally; and purchase farm products after the tour: *"Tourists can come buy products, visit the farms to learn about the management practices and see the diversity of species on the farm to showcase the benefits of the farm."* The farmers are keenly aware that more tourist visits will result in increased income and improved livelihoods, as well as increased recognition of ASOPRO's products and the local agroforestry practices happening in Manabí. Almost all ASOPRO members expressed a desire to do what they can to help improve farm conditions to accommodate more tourists. One member mentioned the possibility of improving trails and overall accessibility of her farm to allow a larger audience to visit, stating that *"during the rainy season, the stairs down to the farm are very dangerous."*

Figure 5.1. Stairs at one of the ASOPRO farms

As part of the strategy to increase tourism, the farmers hope to increase collaborative efforts with the Ceiba Foundation, other nearby organizations, and governmental programs that focus on tourism, as they feel that this approach will increase their visibility. When we asked ASOPRO members how the Ceiba Foundation can best support the association, a common response was attracting tourists, since tourists who connect with the Ceiba Foundation are more likely to visit an ASOPRO farm and buy ASOPRO products.

2.2 What Are the Key Elements of a Successful Ecotourism Farm Tour?

In addition to using interviews and ASOPRO's stated goals to inform our assessment of and suggestions for the farm tours, we also pulled from existing ecotourism research and relevant in-team experiences. While there are some general ecotourism assessment frameworks available for use by ecotourism business operators, they do not focus on tour details, highlighting the need to provide an informed assessment strategy specifically for eco-entrepreneurs who focus on ecotourism through farm tours (Butler et al., 2015; McKeown, 2021). To develop informed and relevant farm tour assessment criteria, we used a variety of sources, including the literature, discussions with the Ceiba Foundation and ASOPRO, and on-the-ground personal experiences on domestic and international sustainable farms outside of Ecuador. Our relevant in-team farm experiences include Nature and Nurture Seeds (Ann Arbor, Michigan), Quarry Hill Farm (Montgomery County, Pennsylvania), and the School for Field Studies Organic Farm (Atenas, Costa Rica). From all the above sources, we noted several important themes for an effective ecotourism farm tour.

An important part of successful ecotourism operations is positive, in-person experiences (Di Domenico & Miller, 2012). Studies indicate that visitors may seek variable outcomes from in-person experiences on farms depending on their specific interests and what part of the world they are visiting; however, there appears to be strong overlap in the finding that tourists at farms hope to feel a connection to the land, develop a stronger understanding and appreciation for the specific contexts and customs of the region they are visiting, and gain insight into the operations of the specific farm (Cruz et al., 2019; Jones & Spadafora, 2016). At the School for Field Studies Organic Farm in Atenas, Costa Rica, for example, student visitors stay within the farm boundaries for several weeks to months in an effort to learn about the region's culture and ecology in great depth. In Manabí Province, where ASOPRO is located, survey data indicate that focus on nature and cultural heritage is an important motivator for tourists who visit the area, and this drives many of these tourists towards farms (Cruz et al., 2019). Farm tours are thus positioned to play a particularly important role in tourism experiences in Manabí.

Eco-entrepreneurs are uniquely identity-driven in their farming practices and business creation, and it is important to assess how well and completely a tour communicates this information and identity. A tour provides an opportunity to intimately and directly display and share a farm and its farmers' identities—a crucial piece of small, sustainable farms and ecotourism ventures (Iles et al., 2020; Holloway et al., 2021). Farms that focus on ecotourism have a unique identity, because they monetize sustainability beyond just the production of their goods and extend this to the sharing of their methods and way of life. Furthermore, there are many technical aspects of small-scale, sustainable farming methods that distinguish them from other farming methods, and the sharing of this information during a farm tour is a good way to highlight the uniqueness of an eco-entrepreneur's work. These farming methods benefit the land where the farming occurs, of course, but they also play an important role in regional sustainability efforts—another important area in which tours can capture the interest and attention of diverse audiences.

Narrative and stories are also essential for effective farm tours, since they help audiences to connect with people and place and to better understand the specific ecosystem (Dionisio et al., 2016). In our conversations with the Ceiba Foundation and with Geo, the Legal Representative for and leader of ASOPRO, we learned details about

ASOPRO's story and the story of farming efforts in Manabí Province. These stories were essential in helping us to feel connected with the local land and practices, and it is important to share the stories with ASOPRO's audience, both to provide relevant context and to provide an opportunity to connect directly with the farmers.

It is also essential to share and showcase a farm's best assets and its processes, whatever they may be in individual cases, even if they may seem ordinary or commonplace for the farmer in question. Every farm has particular assets that provide an opportunity for new experiences for ecotourists. These assets can be considered broadly and may include the land itself, the view from the farm, the product processing operation, the crop growing areas, or any other part of the farm that may be of interest to a tourist. Farmers, like everyone else, get accustomed to their work and may not realize how interesting these assets may be to outsiders. For example, Quarry Hill Farm in Montgomery County, Pennsylvania leverages its assets—which include large vegetable crops and various groups of animals—by allowing visitors to view these parts of the farm and develop a personal connection to the land where they can then purchase food. There is also much focus in ecotourism on farm-to-table processes, specifically because it enables tourists to experience the growing, processing, and consumption process as closely as possible (Pehin Dato Musa & Chin, 2022). This is a powerful experience, and it drives much of the interest in ecotourism.

Farming is a hands-on, tactile experience, so to experience that important aspect of the farm during a tour, interactive opportunities should be available to ecotourists to facilitate their connection to the land. Prior to beginning work in Ecuador, our team attended a tour of a small, sustainable farm called Nature and Nurture Seeds in Dexter, Michigan, near the University of Michigan - Ann Arbor. We spoke with Mike Levine—the owner of the farm—during the tour about the impact on visitors of moving around the farm and having an opportunity to explore it via touch, smell, and sight. Nature and Nurture Seeds is particularly focused on growing different types of seeds, so it was useful for our team, as visitors, to see and touch some of these different seed species and see where they grew on the farm. This tour solidified for us the importance of opportunities for hands-on interaction during a farm tour.

Figure 5.2. Two of the main structures at the ASOPRO Facility

2.3 Farm Tour Assessment Criteria

Based on the common themes across the literature, interviews and other conversations with ASOPRO members, as well as our prior relevant in-team experiences, we developed six distinct Farm Tour Assessment Criteria (FTAC) for use in evaluating and assessing tours of small, sustainable eco-entrepreneurship ventures in Manabí:

1. Showcase Farm's Best Assets
2. Demonstrate Sustainable Coffee Farming Practices
3. Highlight Regional Benefits of Sustainable Agriculture
4. Share Story and Histories of the Farm & Lands
5. Provide Opportunities for Hands-on Interaction and Learning
6. Provide a Complete View of Process (Farm-to-Table Understanding)

These six criteria reflect the importance to farm tours of farm identity, connection to farmer and land, hands-on experiences, understanding of regional contexts and heritage, farm-to-table experiences, and narrative storytelling. The FTAC encompass these lessons in a structured framework that also incorporates focus on ecology and environmental issues. The FTAC were developed specifically with ASOPRO in mind, but they are applicable to any agro-ecotourism farm tour.

2.4 Application of the Farm Tour Assessment Criteria to ASOPRO

During our time in Ecuador, we attended full tours of three farms—Finca La Tía, Finca La Mago, and Finca Milú, all of which are part of ASOPRO—as well as the ASOPRO facility itself, where coffee is dried, roasted, and processed. We applied the FTAC to the tours of Finca La Tía, Finca La Mago, and the ASOPRO facility. Finca La Mago and Finca La Tía share a border and thus combine their tours, so we attended these tours back-to-back. Because Finca Milú was not fully operational when we visited, we did not use the FTAC to assess that tour, though they could be applied at a later date.

We took careful notes of everything we observed and experienced during and after each of the three tours and then assessed each tour by sorting and expanding on our notes in the FTAC framework within a week of the tour. We chose to use the FTAC after the tours, instead of during, to ensure that we could listen carefully throughout the tours, and note down as much information as possible. While utilizing the FTAC during the tour may be a more direct method for its implementation, it may bias the observers to only pay attention to aspects of the tour that meet the criteria, instead of assessing the full experience as it is delivered. Applying the FTAC to the notes from each tour after the tour concludes offers a systematic method to assess each tour and compare relative strengths and weaknesses of tours to each other without biasing the initial tour assessment notes. Since each additional tour we assessed enriched the cross-tour comparison, it would be beneficial to scale the use of the FTAC across more farms in Manabí and beyond.

2.5 Geographic Information System (GIS) Mapping of ASOPRO Boundaries and Structures

We also found that a map might be a useful addition to a farm tour to help tourists better understand a farm's layout, as our team would have benefited from having a map at the beginning of the ASOPRO tours we attended. The two farms within ASOPRO whose tours we assessed, as well as the ASOPRO facility, had not been reliably mapped using geospatial tools when our team arrived in Ecuador. Using a GPS device and cellular devices, we mapped the boundaries of these farms and the facility, and we also mapped all structures within these boundaries. These geospatial data can be used to develop a map for these ASOPRO farm tours, along with geospatial data showing where crops are located in the farms and where tourists can go to see specific farm assets. The Ceiba Foundation should use its resources to create this map, as discussed in more detail in the Priority Recommendations section of this chapter.

Figure 5.3. The research team during a visit to Finca La Tía and Finca La Mago

3 How Can ASOPRO Improve Their Ecotourism Farm Tours?

3.1 Overview

The recommendations below are presented within the FTAC framework and are further segmented by farm. Since Finca La Mago and Finca La Tía share a border, we combined our recommendations for these two farms. Recommendations for the ASOPRO facility tour are separate. However, the tours of these two farms and the ASOPRO facility tour would be conducted one after another for visiting tourists, and our recommendations reflect this order regarding how the tours should connect to each other. The below recommendations are split into three sections for each of the six criteria:

1. "Maintain and Expand" refers to aspects of the tour that we felt were strong and could or should be expanded upon to improve the tour even further;
2. "Suggested Addition" proposes additions to the tour to fill gaps that we identified using the FTAC;
3. "Narrative Feedback" provides more nuanced insight into the high level recommendations.

Tables 5.1 and 5.2 provide high-level recommendations for the farm tours our team assessed. See "Narrative Feedback" in text for more details. These recommendation tables are translated into Spanish language in *Appendix E*.

Table 5.1. High-level recommendations for Finca La Mago and Finca La Tía

Farm Tour Assessment Criteria	Maintain and Expand	Suggested Addition
1. Showcase Farm's Best Assets	• Highlight farmers' passion for conservation throughout the tour • Provide opportunities to see the variety of species on the farms	• Provide a more structured discussion of the farming process and important farm assets related to this process
2. Demonstrate Sustainable Coffee Farming Practices	Engaging discussion of: • Their transition into sustainable farming • Consequences of chemical usage in farming • Benefits of sustainable farming methods	• Share more information about their specific agroforestry practices and the resulting biodiversity • Show examples of sustainable management and methods on their farms
3. Highlight Regional Benefits of Sustainable Agriculture	• Discuss benefits of sustainable agriculture for the local ecosystems	• Provide more details about regional ecosystem benefits from sustainable agricultural methods and how the local benefits connect to those at the regional level
4. Share Story and Histories of the Farm & Lands	• Storytelling ability is amazing; their stories are the most effective way to share their energy and joy for what they do	• Tell more stories throughout the tour; weave stories into all sections of the tour where possible • Emphasize the sharing of stories that share experiences and histories that are unique to Narcisa, Margarita, and their land
5. Provide Opportunities for Hands-on Interaction and Learning	• Opportunities to touch and smell plants and fruit	• Integrate more opportunities to touch and smell plants and fruit • Provide a few more opportunities for hands-on interaction with items used in coffee processing
6. Provide a Complete View of Process (Farm-to-Table Understanding)	• Eat locally-sourced food, and drink ASOPRO coffee • Discuss where this food and coffee originated	• Provide more structured discussion of the farm-to-table process for each food and drink item consumed

Table 5.2. High-level recommendations for the ASOPRO Facility

Farm Tour Assessment Criteria	Maintain and Expand	Suggested Addition
1. Showcase Farm's Best Assets	• Distinguish ASOPRO from other associations — women-led; smallholder farmers; sustainable farming methods and diverse products • Strong discussion of drying, roasting, and processing coffee at facility	• Provide more detail about educational programming through ASOPRO and the other crops besides coffee that it provides
2. Demonstrate Sustainable Coffee Farming Practices	• Provide excellent information about sustainable techniques they employ	• More detailed discussion of sustainable techniques beyond those that substitute for synthetic chemical usage • Provide more information about their decision to use sustainable methods and the perceived benefits
3. Highlight Regional Benefits of Sustainable Agriculture	• Discussion about circular economy; can expand to incorporate regional benefits	• Provide perspective and details about how the benefits of their sustainable farming methods extend beyond their individual farms and the local community and all the way to the regional level • Discuss the implications of their farming methods on climate mitigation, adaptation, and resilience at the regional level
4. Share Story and Histories of the Farm & Lands	• Focusing on the background of ASOPRO and its farmers • Candid sharing of goals and challenges, specifically maintaining brand identity and the difficulties and opportunities of being women-led in a culture with lots of machismo • Continue to share unique stories	• Share more micro-level, personal anecdotes from farmers when possible to provide audiences with stories with which they can connect

Farm Tour Assessment Criteria	Maintain and Expand	Suggested Addition
5. Provide Opportunities for Hands-on Interaction and Learning	• Seeing, feeling, and smelling coffee beans • Viewing and walking around the processing and drying tools and machines	• Expand interaction; provide opportunity to view and move through full coffee-making process, from bean selection to coffee drinking
6. Provide a Complete View of Process (Farm-to-Table Understanding)	• Discussion of the connection between coffee flavor profile and the farm management and growing techniques responsible for these flavors • Coffee tasting and demonstration of coffee preparation	• Provide a meal with locally-sourced food • More detail about the coffee and food production before, during, and after the coffee tasting and meal

3.2 Finca La Mago and Finca La Tía

1. Showcase Farm's Best Assets

Maintain and Expand

- Highlight farmers' passion for conservation throughout the tour
- Provide opportunities to see the variety of species on the farms

Suggested Addition

- Provide a more structured discussion of the farming process and important farm assets related to this process

Narrative Feedback

The tour revealed an incredible passion for conservation from the farm owners, Narcisa and Margarita, which provided important insight into one of the biggest driving forces behind their work. Narcisa and Margarita love what they do and love caring for their land. This passion was contagious and influenced the feel of the tour from start to finish, allowing us, as the tourists, to viscerally understand their level of connection to the land. This extended to the excitement Narcisa and Margarita displayed while showcasing the diversity of species on their farms. They were enamored with this diversity, just as we were, which helped us to connect with their land even further.

The tours did show all portions of each farm, but the purpose behind each stop on the tour and each species or item we saw and discussed was not always clear. For example, it was unclear how often Narcisa and Margarita generally work in each area of the farm they pointed out. It would be helpful to understand why they value each area of the farm—whether it is a coffee plot, papaya tree grove, or a table used for coffee processing—since this information can help a visitor to understand the importance of the farm's different assets and how various aspects of farm operations connect.

Furthermore, a more structured discussion of how each stop on the tour relates to the overall farming process would provide a more concrete understanding of the holistic growing process. An example would be to explain how the spacing of the coffee plants enables for more efficient harvesting of coffee cherries, which ties in well to the overall process of picking coffee and eventually processing it. We address opportunities for a more detailed discussion of the complete farming process, from farm to table, in Criterion 6, but it is important to contextualize that more in-depth information by first detailing relevant farm assets.

2. *Demonstrate Sustainable Coffee Farming Practices*

Maintain and Expand

- Engaging discussion of:
  - Their transition into sustainable farming
  - Consequences of chemical usage in farming
  - Benefits of sustainable farming methods

Suggested Addition

- Share more information about their specific agroforestry practices and the resulting biodiversity
- Show examples of sustainable management and methods on their farms

Narrative Feedback

Narcisa and Margarita have fascinating life stories, and they comprehensively explained and narrativized their transition away from participating in large-scale agriculture in more urban settings into using sustainable farming practices on their own land in a rural area. This brought a realistic element to the tours, showing that they did not always farm in this way, but now choose to do so due to the myriad benefits these methods provide, like improved health, better food, and increased biodiversity. Narcisa and Margarita both passionately explained the potential consequences of chemical and pesticide use in an agricultural setting as well, and they placed specific emphasis on dangers to human health and the potential for acute environmental degradation, especially in water and soil.

While the tour provided excellent information regarding their sustainable coffee farming practices, it did not effectively show these practices. Ecotourists are likely to have particular interest in seeing sustainable farming practices up close, so Narcisa and Margarita should weave displays of their sustainable farming practices into the tour, making sure to point out relevant examples when applicable. Some examples would be to show that the coffee plants are shaded, and thus largely protected from sun, wind, and rain, or to point out the slope of the farm and explain how synthetic pesticide application would enter the water table and follow this slope down into the stream at the bottom of the farm.

Narcisa and Margarita can also call attention to the wide variety of tree and plant species all around the farm and explain how sustainable, agroforestry farming methods allow for this biodiversity. As part of this focus on biodiversity as a benefit, Narcisa and Margarita can use deliverables from this report in *Chapter 4: Benefits of Agroforestry for Biodiversity and People*, which include infographics showing the high levels of biodiversity on agroforestry farms in the region. Examples of visible sustainable farming methods are ubiquitous in these farms, so Narcisa and Margarita should make a point of highlighting them whenever possible.

3. *Highlight Regional Benefits of Sustainable Agriculture*

Maintain and Expand

- Discuss benefits of sustainable agriculture for the local ecosystems

Suggested Addition

- Provide more details about regional ecosystem benefits from sustainable agricultural methods and how the local benefits connect to those at the regional level

Narrative Feedback

This aspect of the tour is straightforward and simple to adjust. The local and regional ecosystem benefits of sustainable agriculture are well-documented in the academic literature, and farmers who use sustainable methods know them well. Narcisa and Margarita discussed details of the benefits of their farming methods on local flora and fauna, like soil quality improvements that support the growth of healthy plants and trees on the farm, as well as how the diversity of tree species on their farms supports a wide variety of bird species who live on or travel through the farm. However, they did not provide many details on how these local benefits connect to regional-level benefits. To be clear, Narcisa and Margarita touched on regional ecosystem benefits briefly during the tours; they mentioned positive water quality impacts of their farming strategies on the regional watershed and how using agroforestry methods helps to provide quality habitat for birds and other animals that live in the region. However, this was the extent of the discussion of regional benefits.

Figure 5.4. Coffee beans at an ASOPRO farm

Providing more details about these benefits would add an interesting and important perspective to the tour, especially since visitors to these farms are likely to be invested in efforts to reduce wide-scale deforestation and environmental degradation. Narcisa and Margarita can provide context about the physical location of their farms within the larger regional watershed and explain details of how their farms help to improve water quality for the region through filtration and by reducing the amount of water-bound synthetic pesticides. They can also discuss how their farming methods reduce forest fragmentation and improve the ecological matrix quality, thereby providing important, high-quality habitat that increases the capacity for biodiversity at the regional level. This broader focus will provide clear examples of how micro-level practices in farming have important positive impacts throughout larger ecosystems. The practices Narcisa and Margarita employ on their farms will take on new meaning and significance when they highlight the interconnectedness to the surrounding area, especially given the high rates of deforestation in the region.

4. *Share Story and Histories of the Farm & Lands*

Maintain and Expand

- Storytelling ability is amazing; their stories are the most effective way to share their energy and joy for what they do

Suggested Addition

- Tell more stories throughout the tour; weave stories into all sections of the tour where possible
- Emphasize the sharing of stories that share experiences and histories that are unique to Narcisa, Margarita, and their land

Narrative Feedback

Simply put, Narcisa and Margarita's passion for sustainable agriculture is infectious, and their particular histories—to each other, their families, and their land—are heartwarming and relatable. Their life stories and the ways in which they came to sustainable farming are also fascinating. Storytelling is their bread and butter, and their dynamic, engaging storytelling abilities made the tours of their farms memorable and enjoyable. They should weave stories into every possible portion of the tour to most effectively engage their audience.

We recommend that Narcisa and Margarita have a list of relevant stories ready to share that show their uniqueness as well as the uniqueness of their farms, and we also recommend that they tell more stories throughout the tour, tying in these stories to different stops on the tour when possible. For example, when the tour stops near the coffee plants, Narcisa and Margarita can share stories that help to show why they feel such a deep connection to coffee. They can also provide a more detailed story when they stop near the stream at the bottom of their farms about why they decided to transition away from shrimp farming and towards agroforestry farming, potentially drawing on the bad smell of the water near shrimp farming operations and contrasting it with the clear, clean stream on their properties.

Narcisa and Margarita have many relevant experiences that led them to sustainable farming in Manabí, and given their strong storytelling abilities, audiences will appreciate hearing about these experiences in detail. This will be especially true when these stories relate to specific portions of the farm tour that enable visitors to attach visual stimuli to the stories they are hearing. All audiences will love Narcisa's and Margarita's energy and warmth, and emphasizing narrative and storytelling as much as possible during the tours is the most surefire way to engage a diverse array of audiences.

5. *Provide Opportunities for Hands-on Interaction and Learning*

Maintain and Expand

- Opportunities to touch and smell plants and fruit

Suggested Addition

- Integrate more opportunities to touch and smell plants and fruit
- Provide a few more opportunities for hands-on interaction with items used in coffee processing

Narrative Feedback

There were a few opportunities to touch and smell plants and fruit during the tour, and these moments were impactful and fun. A couple memorable examples were crushing up and smelling a small leaf that smelled intensely minty and stopping to smell the fruity aromas around us during a conversation about how the coffee beans soak in the scents of nearby plants and fruit. Providing more structure behind this—even just a few more opportunities to safely touch and smell nearby plants and fruit—can provide a novel and memorable experience for tourists who do not usually interact with this type of flora.

Additionally, touring coffee farms like these provides an opportunity to physically interact with materials used to harvest and process coffee. These materials were not part of the tour, so we suggest adding a brief activity on the tour to see and touch some of the items used for coffee growing, harvesting, or processing. One option would be to show the woven fabric sheets on which Narcisa and Margarita store coffee cherries after picking them, as well as the buckets they use to carry these cherries up to their homes at the tops of the farms. Showing small items like these and sharing their purpose may help visitors to gain a better understanding of the farm operations and how physically challenging some of the farm work can be.

There is a significant amount of hands-on interaction with coffee processing materials during the ASOPRO facility tour, which will happen directly after the tours of Finca La Mago and Finca La Tía, so it will be sufficient for Narcisa and Margarita to just show a few small items that they use specifically on their farms.

6. *Provide a Complete View of Process (Farm-to-Table Understanding)*

Maintain and Expand

- Eat locally-sourced food, and drink ASOPRO coffee
- Discuss where this food and coffee originated

Suggested Addition

- Provide more structured discussion of the farm-to-table process for each food and drink item consumed

Figure 5.5. Picking a papaya during an ASOPRO farm tour

Narrative Feedback

The farm-to-table understanding for the tours of Finca La Mago and Finca La Tía on their own cannot be fully complete, since the processing of their coffee harvests occurs at the ASOPRO facility. Therefore, the most comprehensive view of the agricultural process would be most visible at ASOPRO. Nevertheless, at the conclusion of our tour of Finca La Mago and Finca La Tía, we had a delicious meal with food that was grown either locally or at the farms we had just toured. This meal was a perfect opportunity to discuss the farm-to-table process and expand upon the interconnections between sustainable agriculture and local and regional ecosystems. Narcisa and Margarita provided us some of this information at our request, but we suggest openly providing this information before the meal on future tours, whether that is verbally or in writing.

Explaining in detail the origins of the food and drink the tourists are consuming, such as the farm it originated from and details about that farm, is an excellent strategy to help visitors connect to the farms and land and to enjoy the food more. This discussion will draw attention back to the farms and the tour during the meal, deepening the whole experience rather than the meal being a separate experience that does not build on what they just learned. Presenting this meal with intentionality is a powerful way to close out the tour experience. During future tours we suggest offering the food with coffee at the ASOPRO facility, instead of at the farm (see below recommendations for the ASOPRO facility).

3.3 ASOPRO Facility

1. Showcase Farm's Best Assets

Maintain and Expand

- Distinguish ASOPRO from other associations:
  - Women-led
  - Smallholder farmers
  - Sustainable farming methods and diverse products
- Strong discussion of drying, roasting, and processing coffee at facility

Suggested Addition

- Provide more detail about educational programming through ASOPRO and the other crops besides coffee that it provides

Narrative Feedback

Throughout the tour of the ASOPRO facility, Geo, the legal representative and leader of ASOPRO, made clear how this association is different from others—both near and far—and this was essential to showcase ASOPRO's best assets. The discussion of operations highlighted that ASOPRO works exclusively with small farms that use sustainable, natural farming methods and focus on producing specialty, high-quality products—especially coffee. This helped to immediately build an understanding of ASOPRO's identity across all of the farms. Geo discussed ASOPRO's product certifications to drive home the point of the quality of their products, as well as their ongoing efforts to obtain more certifications. Furthermore, Geo discussed that the association is a women-led initiative—a critical piece that makes ASOPRO different from many other farms and associations in a male-dominated profession, especially in Manabí. The association also advocates for women farmers to have market power and a voice within the local farming community. The focus on empowering women is the factor that distinguishes ASOPRO most sharply from other associations. It was clear throughout the tour how much work Geo has done to build the association and to support small-scale, sustainable farmers in the region—especially women. Her drive to do this work will connect well with many audiences. During the tour, we were also introduced to many of the farmers that are part of the association, and this personalization on the tour helped us, as the tour audience, to connect more meaningfully to ASOPRO and the hard work behind each of its products. While this may not always be a feature of the ASOPRO facility tour, it certainly will be a strength whenever the farmers in the association can join.

During the tour, Geo briefly mentioned community education work related to coffee that she does through ASOPRO, and she also briefly discussed the construction materials the association uses and how these materials are locally-sourced. The tour would benefit from more detail about these topics and any other similar information that might provide an audience more context about ASOPRO's interconnectedness with the local community, its other products, and any other activities in which it participates. Geo is deeply passionate about coffee, so it makes sense for her to focus the tour on coffee. However, if she also included a brief discussion of other aspects of ASOPRO's operations, like its educational programming and other crops, the tour would better communicate ASOPRO's overall work, mission, and identity.

2. Demonstrate Sustainable Coffee Farming Practices

Maintain and Expand

- Provide excellent information about sustainable techniques they employ

Suggested Addition

- More detailed discussion of sustainable techniques beyond those that substitute for synthetic chemical usage
- Provide more information about their decision to use sustainable methods and the perceived benefits

Narrative Feedback

The demonstration of sustainable farming practices in the context of the ASOPRO facility tour is less consequential, since this tour will occur after the tours of Finca La Mago and Finca La Tía, both of which focus heavily on these sustainable practices and show them clearly on the farms. However, it is still important to discuss sustainable farming practices in the context of ASOPRO to pull together the threads of the previous tours and explain the significance of these practices in the broader context of the association.

The ASOPRO tour mentioned that the association's strategies rely on the concepts of circular economy and sustainability; the sustainable harvesting of its cacao, coffee, and bamboo enables cash flow year-round, and unsustainable extraction techniques would likely lead to more uneven and unpredictable harvests. Geo also explained on the tour that agroforestry techniques are ubiquitous in ASOPRO farms, and there is no synthetic chemical usage, which enables each farm to grow and produce high-quality, sustainable products.

While sustainability concepts were weaved into the tour at a high level, there was not sufficient discussion of the specific practices ASOPRO and the farms in the association use. There does not need to be im-

Figure 5.6. Making coffee at the ASOPRO Facility

mense detail about this, but more discussion of other aspects of sustainable farming methods within the association would provide relevant context and would help audiences to better understand the farmers' work. For example, the ASOPRO tour could mention timing of harvesting, harvesting methods, and challenges involved in implementing sustainable practices. It would also be beneficial to discuss how ASOPRO and other farmers in the association began using sustainable methods and what differences they experience in their farming as a result. Mentions of the local benefits of these methods for the forests, animals, and people would be interesting for tourists and would also provide insight into the value the farmers see in using these methods.

3. Highlight Regional Benefits of Sustainable Agriculture

Maintain and Expand

- Discussion about circular economy; can expand to incorporate regional benefits

Suggested Addition

- Provide perspective and details about how the benefits of their sustainable farming methods extend beyond their individual farms and the local community and all the way to the regional level
- Discuss the implications of their farming methods on climate mitigation, adaptation, and resilience at the regional level

Narrative Feedback

There was no explicit mention during the tour of the regional benefits of the sustainable agricultural methods that farmers in ASOPRO use. It is important to address regional benefits, because doing so provides important context for the audience about each farm's connection to a broader environmental and ecological context. Providing a clear link between methods at the individual farm level and the regional benefits of these actions will help a wide array of audiences to better understand how sustainable farming methods create positive impacts beyond ASOPRO's borders.

There was some discussion during the tour about circular economy, which specifically related to sustainable use of different materials grown on farms within ASOPRO, and we recommend expanding the scope of this discussion to address the regional benefits that result from this sustainable farming and resource use. This could include benefits to water quality or reduction of deforestation in the region, for example. Additionally, focusing on the regional benefits of local, sustainable farms provides an opportunity to address the roles these farms play in climate mitigation, adaptation, and resilience at the regional, and even global level. The methods used by farmers in ASOPRO have positive cascading ecological effects for the larger ecological systems of which they are a part, and many of these benefits relate directly to climate mitigation, adaptation, and resilience. Examples include high levels of biomass on farms, improved adaptive capacity due to high species diversity, and strong resiliency due to more extensive and undisturbed root systems. These topics are salient for most people who are concerned with environmental issues, and this is likely to include the vast majority of ASOPRO's visitors. Illustrating the connection between the local farming methods and their regional benefits—specifically as they relate to climate change—is a strong strategy to improve the tour experience for diverse audiences, so the ASOPRO tour should mention these topics at least briefly, as time allows.

4. *Share Story and Histories of the Farm & Lands*

Maintain and Expand

- Focusing on the background of ASOPRO and its farmers
- Candid sharing of goals and challenges, specifically maintaining brand identity and the difficulties and opportunities of being women-led in a culture with lots of machismo
- Continue to share unique stories

Suggested Addition

- Share more micro-level, personal anecdotes from farmers when possible to provide audiences with stories with which they can connect

Narrative Feedback

The tour began with the backstory of ASOPRO and its farmers, which provided excellent context for the rest of the tour. Additionally, the tour contained great information about ASOPRO'S challenges and long-term goals, as well the ways in which its varied experiences influence its current operations. This detailed information provided realistic and relatable context. It was interesting to hear about some of the issues Geo and others in ASOPRO have experienced related to their association being women-led, as these stories provided important detail behind the realities of working within a male-dominated profession and region. Geo stated that she draws strength from the other women in ASOPRO and that she keeps pushing forward because of them and due to their support. The stories she told provided powerful insight into how deep and meaningful the relationships between farmers in ASOPRO are and how much they lean on each other to try to ensure that the association flourishes.

Sharing the stories and histories of the individual farmers and their lands provides a strong opportunity for audiences to connect to ASOPRO, its mission, and its brand. In discussing ASOPRO's story, Geo shared the importance of the story of their brand, which transcends simply attempting to increase sales and overall production. ASOPRO's products all have stories of people and land behind them, and Geo wants to ensure that these stories come through in the quality of the products and the brand itself. Part of this effort involves ensuring that ASOPRO's brands remain front and center in any and all markets where they are sold, and Geo shared stories about her efforts to ensure this outcome.

Overall, Geo and the other farmers shared stories and relevant histories in a way that helped us, as the tour audience, to better understand and connect with the farmers and their work. To enhance the effect of this storytelling, we recommend sharing more personal anecdotes from Geo and the other farmers in ASOPRO to provide more opportunities for audiences to connect with and learn about the various, micro-level factors involved in working as sustainable farmers. Examples of these stories might include challenging or rewarding experiences from working on their farms, like an underwhelming harvest and its impacts, a difficult day on their farm due to bad weather, or a great meal they recently made using various fruits from their land.

5. Provide Opportunities for Hands-on Interaction and Learning

Maintain and Expand

- Seeing, feeling, and smelling coffee beans
- Viewing and walking around the processing and drying tools and machines

Suggested Addition

- Expand interaction; provide opportunity to view and move through full coffee-making process, from bean selection to coffee drinking

Narrative Feedback

Seeing, feeling, and smelling the coffee beans was a strong point on the ASOPRO tour, especially since we had the opportunity to see the difference between lower-quality or damaged beans that they discard and the high-quality ones that are sold. Beyond this, we recommend that the ASOPRO tour includes a more interactive element, since its facility is the perfect setting for an audience to see and experience the essential steps in the coffee-making process. While the beans ASOPRO uses are grown on other farms in the association, the rest of the coffee-making process—bean selection, drying, roasting, grinding, and bagging—all happens at the main facility.

Our team had the opportunity to visit the ASOPRO facility several times, though we only toured the facility once. During one of our non-tour visits, a farmer in the ASOPRO association was on-site helping with the bean drying process. She took a break from her work during our visit to walk one of our team members through the entire coffee-making process, which included the chance to see, touch, and smell the beans at every part of this process. The entire process occurs over weeks, so walking through the process provides an opportunity to walk through time and see a coffee bean at each stage. This walk-through concluded with our team member grinding up beans that were then immediately used to brew coffee for us. Providing the opportunity to move through this process and then drink the coffee at its conclusion—just like one our team members experienced on a non-tour visit—is precisely what we recommend adding to the ASOPRO tour.

6. Provide a Complete View of Process (Farm-to-Table Understanding)

Maintain and Expand

- Discussion of the connection between coffee flavor profile and the farm management and growing techniques responsible for these flavors
- Coffee tasting and demonstration of coffee preparation

Suggested Addition

- Provide a meal with locally-sourced food
- More detail about the coffee and food production before, during, and after the coffee tasting and meal

Narrative Feedback

It was exciting to see the coffee preparation process and hear about how it brings out the specific flavors of the farms in ASOPRO. We could feel the farmers' passion for their work while tasting the coffee, and we tried to smell and taste the fruits and aromas from their farms that they explained were present in the coffee beans. This made the coffee tasting experience feel special and unique, especially as we could see the obvious care, focus, and precision that went into the preparation of the coffee right in front of us. This was a huge highlight of the tour.

At the conclusion of the Finca La Mago and Finca La Tía tours, we had a delicious, home-cooked meal that contained food either from the farms we toured or from other nearby farms. We recommend serving this meal at the conclusion of the ASOPRO tour instead and providing the context and information regarding the food that we recommend in the Provide a Complete View of Process (Farm-to-Table Understanding) section of the Finca La Mago and Finca La Tía tour recommendations. Since the overall tour will begin at Finca La Mago and Finca La Tía before going to the ASOPRO facility, it is more sensible to end the full, multi-farm tour with food and coffee, rather than serving food in the middle of the tour experience. Furthermore, serving the food at the end of the tour experience provides an excellent opportunity to bring all the tour content full circle and discuss how much of what is grown on the farms ends up as high-quality products, many of them consumable. It will be important to have a quick, well-structured discussion of the farm-to-table process at ASOPRO before serving the food and coffee, which can simply include brief descriptions of the farms where the food and coffee was sourced and how those items came to sit on the table in front of the visitors. Some of this information will briefly recap information shared previously on the tour, and some may introduce new farms to the visitors. A meal that is intentionally connected to the local land will be the perfect way to end the tour experience and will encourage visitors to purchase bags of ASOPRO's coffee before leaving.

Figure 5.7. Coffee processing equipment at the ASOPRO Facility

4 Priority Recommendations

The analysis in this chapter leads to a few key next steps for ASOPRO and its farms, as well for the Ceiba Foundation to support ASOPRO:

1. Farmers in ASOPRO should charge a higher price for their farm tours. Rather than charging US $5 per person, we recommend charging at least US $10 per person and potentially more, depending on local price fluctuations for comparable services.
2. Farmers in ASOPRO whose farm tours we assessed can apply the feedback provided to improve their farm tours, and there is no need to spend money or alter the farms to achieve these improvements.
3. Other farms in ASOPRO can apply the FTAC framework to their farm tours to assess their tours and determine how the tours may be improved. As time allows, farmers in ASOPRO can attend each other's farm tours and use the FTAC framework to assess the tours and guide discussions about potential improvements.
4. The Ceiba Foundation should focus on connecting more tourists with ASOPRO and its farms.
5. The Ceiba Foundation should work with Finca La Mago, Finca La Tía, and the ASOPRO Facility to develop an ASOPRO Map using the GPS data our team collected in conjunction with future data to be collected by the Ceiba Foundation. Ceiba Foundation students and researchers should collect additional GPS data such as the location of certain crops on the farms; easily identifiable tree groves; specific assets on the farms that have special significance to the farmers, like a certain tree or plant; and any other relevant assets that might be interesting to ecotourists. Once sufficient data are collected, the Ceiba Foundation should work with a graphic designer or visual artist to develop a simple, user-friendly map for tourist use during farm visits. This map should be non-technical and attractive and should use the available geospatial data simply to place farm assets on the map with relative accuracy to each other so that tourists can easily understand the layout of the farms.
6. ASOPRO farmers should only work towards improving their farm tours if they deem that this strategy provides them value in their current contexts, since it is unlikely that improved farm tours will address structural limitations on tourism in the region in the short term (See *Chapter 3: Eco-entrepreneurship in the ACUS region: what is the potential and what is missing?*). At this time, the farmers should place only low effort into improving their farm tours, because there is not significant demand for ecotourism in the region.

Spending lots of time and effort on farm tour improvements without a sustained supply of tourists is not the most effective use of ASOPRO farmers' limited time and resources. Rather, incorporating some of the easy content improvements laid out in this chapter's recommendations should require little time and effort and will improve the tours for the ecotourists who currently visit. As and when demand for these farm tours increases, the farmers should focus more on efforts to improve the tours, for which they can use the recommendations in this chapter in more detail.

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Appendix A:
Prioritization Map Development Process

The following sections represent the full development process for each spatial variable used in the development of our Final Prioritization Map ("FPM"). For each spatial variable, we provide (1) Source Citation, (2) a Download Link, (3) the Data Year, i.e., the year the data was created / updated, (4) the Original Resolution of the data source, (5) the Factor / Constraint used in the FPM development process, (6) the Relative Weight used in the FPM development process, and (7) the actual development process. Some of the open source databases we considered in the creation of the FPM included:

1. ESRI
2. Google Earth Engine
3. OpenStreetMap
4. Ecuador Census
5. United States (US) Department of Agriculture
6. US Environmental Protection Agency (EPA)
7. National Aeronautics Space Administration (NASA)
8. The European Space Agency (ESA)
9. GADM
10. Statista
11. United Nations CEPALSTAT
12. Global Forest Watch
13. Global Carbon Atlas
14. DIVA-GIS
15. Various websites listed on FreeGisData

At the end of Appendix A we have provided a Python script to help the Ceiba Foundation for Tropical Conservation (the "Ceiba Foundation") identify possible restoration sites within the ACUS. By overlaying potential restoration sites on the FPM, the Ceiba Foundation can use the map to generate a score for sites based on the FPM output cells.

Proximity to Surface Rivers or Streams

Source Citation	(Kelly, 2022; NASA JPL, 2020)
Download Link	Provided by the Ceiba Foundation for Tropical Conservation
Data Year	2020
Original Resolution	30 meter - Line
Factor / Constraint	Closer to Water Body = Higher Priority
Relative Weight	15

Development Process:

1. Import Ceiba polyline file into ArcGIS Pro
2. Feature to Raster
    a. Output cell size = 10
3. Mosaic to New Raster - To join the raster layers together prior to running Euclidean distance
4. Reclassify >=1 =1
    a. 1 = water
    b. Everything else = no data
5. Euclidean Distance
    a. Output cell size = 10
    b. Environments Processing Mask = ACUS
    c. Environments Processing Extent = WGS_1984_UTM_Zone_17S
6. Raster Calculator (stretch values to = 100)
    a. 100 - ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Slope

Source Citation	(NASA JPL, 2020)
Download Link	https://developers.google.com/earth-engine/datasets/catalog/NASA_NASADEM_HGT_001
Data Year	2020

Original Resolution	30 meter		
Spatial Variable (Layer)	Slope (0–8%)	Slope (8-16%)	Slope (>16%)
Factor / Constraint	Low Priority within slope range	High Priority within slope range	Low Priority within slope range
Relative Weight	2	10	2

Development Process:
The bounds of the DEM do not extend to all of Ecuador. Slope and Aspect Calculations done before clipping to ACUS boundary to maximize use of neighborhood statistics

1. Import tif files into ArcGIS Pro
2. Build Pyramids and Calculate Statistics
3. Calculate Slope - Surface Parameters Tool - Slope - Z unit Meters / Project Raster with Environment Output Coordinate System
   - Neighborhood distance of 30 meters (Esri Inc., 2022; Minár et al., 2020)
   - Output slope measurement = Slope Degree
4. Geoprocessing - Extract by Mask - to ACUS Boundary
5. Raster Calculator - Split into three (3) steepness / grade categories: (1) 0–8%, (2) 8–16%, and (3) less than >16%. These categories were based on Ecuador soil classifications outlined in (de Koning et al., 1998).
   - Layer, true, false, condition (Esri Inc., n.d.-a)
   - Layer 1 = Con("Layer", "Layer", "0", "Value <=8")
   - Layer 2 = Con("Layer", "Layer", "0","Value > 8 and Value <= 16")
   - Layer 3 = Con("Layer", "Layer", "0", "Value >16")
6. Raster Calculator (stretch values to = 100)
   - ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Proximity to Roads

Source Citation	(*OpenStreetMap*, n.d.)
Download Link	https://www.openstreetmap.org/relation/108089

Data Year	2022
Original Resolution	Line
Factor / Constraint	Closer to Roads = Higher Priority
Relative Weight	5

<u>Development Process</u>:

1. Import file into ArcGIS Pro - Road - highway, trail, offroad
2. Feature to Raster
3. Reclassify
    a. Raster to 1 = Road and all others = no data
4. Euclidean Distance
    a. Output cell size = 10
    b. Environments Processing Mask = ACUS
    c. Environments Processing Extent = WGS_1984_UTM_Zone_17S
5. Raster Calculator (stretch values to = 100)
    a. 100 - ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Proximity to Buildings

Source Citation	(Facebook Connectivity Lab & Center for International Earth Science Information Network - CIESIN - Columbia University, 2016)
Download Link	https://data.humdata.org/dataset/ecuador-high-resolution-population-density-maps-demographic-estimates
Data Year	2022
Original Resolution	30 meter
Factor / Constraint	Closer to Buildings = Lower Priority
Relative Weight	4

Development Process:

1. Import Raster
2. Reclassify >=1 =1
    a. 1 = Buildings
    b. Everything else = no data
3. Euclidean Distance
    a. Output cell size = 10
    b. Environments Processing Mask = ACUS
    c. Environments Processing Extent = WGS_1984_UTM_Zone_17S
4. Raster Calculator (stretch values to = 100)
    a. ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Forest Proximity/Connectivity

Source Citation	(Karra et al., 2021)
Download Link: Land Cover	Sentinel-2 10m Land Use/Land Cover Timeseries Downloader (Mature Support) (arcgis.com)
Download Link: Conefor Software	GIS extensions | Conefor
Data Year	2020
Original Resolution	10 meters
Factor / Constraint	Varying Priority Levels
Relative Weight	15

Development Process:
https://cds.climate.copernicus.eu/cdsapp#!/yourrequests?tab=form
Land Cover Classification 2020
Import nc files into ArcGIS Pro using Make NetCDF Raster Layer tool

- https://pro.arcgis.com/en/pro-app/latest/help/data/multidimensional/reading-netcdf-data-as-a-raster-layer.htm

Forest Proximity Development Process

2. Reclass landcover raster (all_land.tif) - reclassify - forest = 1, all other landcover types = NODATA
3. Geoprocessing - Extract by Mask - to ACUS Boundary
4. Raster to Polygon - Convert resulting raster into a polygon shapefile
5. Create new field in attribute table, Unique_identifier. In Calculate Field put unique_identifier = FID + 1
6. Create new field in attribute table, Area. Calculate geometry within that field to show area in hectares.
7. Select by attribute - all forest patches < 10 ha - delete the selection
8. In ArcMap, use conefor inputs extension to create nodes and distance files (required for Conefor software to perform analysis). This step can also produce a connections shapefile that shows all the possible connections between patches (this will be needed later). Select the 'id field' as your unique_identifier field and your 'attribute field' as your area field. Select Calculate distances between all features, Calculate from Feature Edges, dBase Table of Number of Features within Distance, dBase Table of Distances to Each Feature, and Polyline Shapefile of Connection lines.
9. Upload resulting files into the Conefor program. Under 'Binary indices' select IIC and set the distance threshold (we chose 1000m). Also, under 'Link importances' select Link Improvement. Click the 'Run' button.
10. Under the upper 'Results' tab download both node importances and link importances as text files.
11. Upload both text files in Excel. Create new column and populate it with some sort of identifier that includes the values from both columns 'NodelD1' and 'NodelD2'. Save both sheets as csv files.
12. Upload both csv files into ArcGIS pro (Node_importances.csv) and (Link_improvements.csv). Also be sure to include the reclassified forest patch shapefile (patches_greaterthan10ha.shp) and the connections shapefile (connections.shp).
13. Perform table join with node_importances.csv (Common column: node) with patches_greaterthan10ha.shp (common column: unique identifier). Your patches_greaterthan10ha.shp now has a node importance score (dA) for each patch.
14. Polygon to Raster - convert resulting polygon into a raster file with the value as dA (patches_greaterthan10ha.tif)
15. Raster Calculator - rescale patches_greaterthan10ha.tif on a 0-100 scale using the equation (Layer– minimum distance) * 100) / (maximum raster cell value - minimum raster cell value)

16. Reclassify landcover raster (all_land.tif) - reclassify - forest = NODATA, all other landcover types = 0 (reclass_0.tif)
17. Merge patches_greaterthan10ha.tif with reclass_0.tif, the resulting raster (Merge_almostallcells.tif) still does not have data for the forest patches <10ha that we deleted
18. Reclassify merge_almostallcells.tif - reclassify - NODATA = 0. Resulting raster (merge_allcells.tif) will have a large rectangle of value 0 cells surrounding the ACUS in a large rectangle BUT now those forest patches <10 have a value of 0.
19. Geoprocessing - Extract by Mask - to ACUS border
20. Euclidean Distance Allocation - input raster= patches_greaterthan10ha.tif, Source field = Value, Output Cell Size = 10, Output Raster: EucDistAllo.tif. In Environments tab: Coordinate System: WGS_1984_UTM_Zone_17S, Mask: reclass_0.tif, Extent: merge_allcells.tif, Snap Raster: merge_allcells.tif
21. Euclidean Distance - input raster = patches_greaterthan10ha.tif, Output Cell Size = 10, Output Raster: EucDist.tif.
22. Raster Calculator - rescale EucDist.tif on a 0-100 scale but in the OPPOSITE direction of typical euclidean distance (closer to object = higher value) using the equation 100-((Layer– minimum distance) * 100) / (maximum raster cell value - minimum raster cell value))
23. Raster Calculator - multiply EucDistAllo.tif *EucDist.tif to create proximity_noforest.tif
24. Raster Calculator - rescale proximity_noforest.tif on a 0-100 scale (Layer– minimum distance) * 100) / (maximum raster cell value - minimum raster cell value)
25. Reclassify landcover raster (all_land.tif) - reclassify - forest = 0, all other landcover types = NODATA (onlyforest0.tif)
26. Mosaic onlyforest0.tif with proximity_noforest.tif to create the final Forest Proximity Layer

Connectivity Development Process:

1. In the Link_improvements.csv file from the conefor results in the proximity development process, create a new column called “FromTo”. In this column, combine the number from each rows “From” Column and “To” column. For example, the connection From node 11 To node 63 should have the unique identifier of 1163 in their FromTo column.
2. In ArcGIS add a field to the connections.shp file attribute table called “FromTo”
3. Table join Link_improvements.csv and connections.shp file via both of their “FromTo” column. Be sure to check the box that keeps only matching fields
4. Select by attributes in the attribute table to select rows in which the column dIIC has a score above -1 (negative values here actually represent high importance for connectivity). Delete the selected rows.

5. Select by attributes in the attribute table to select rows in which the length of the line represented is over 10,000 m. Deleted the selected rows.
6. Delete any lines manually that intersect with areas outside of the ACUS and you should be left with ~34 improvement lines. Make these edits permanents and save the resulting files as improvement_lines.shp
7. Feature to Raster improvement_lines.shp into imp_line_Raster.tif
8. Raster calculator - multiply imp_line_raster.tif by -1 in order to get positive values and save resulting raster as imp_line_positive.tif
9. Euclidean Distance Allocation - input raster=imp_line_raster.tif, Source field = Value, Output Cell Size = 10, Output Raster: EucAllo_line.tif. In Environments tab: Coordinate System: WGS_1984_UTM_Zone_17S, Mask: reclass_0.tif, Extent: merge_allcells.tif, Snap Raster: merge_allcells.tif
10. Euclidean Distance - input raster = imp_line_raster.tif, Output Cell Size = 10, Output Raster: EucDist_line.tif.
11. Raster calculator - rescaleEucDist_line.tif on a 0-100 scale but in the OPPOSITE direction of typical euclidean distance (closer to object = higher value) using the equation 100-((Layer– minimum distance) * 100) / (maximum raster cell value - minimum raster cell value)) to create EucDist_inverse.tif
12. Raster Calculator - multiply EucDAllo_line.tif *EucDist_inverse .tif to create imp_areas.tif
13. Raster Calculator - rescale imp_areas.tif on a 0-100 scale (Layer– minimum distance) * 100) / (maximum raster cell value - minimum raster cell value).
14. Mosaic imp_areas.tif with onlyforest0.tif to create the final layer con_improvements.tif

Locations of Active Fires in 2021

Source Citation	(Earth Science Data Systems, 2016)
Download Link	https://firms.modaps.eosdis.nasa.gov/country/
Data Year	2021
Original Resolution	Point
Factor / Constraint	Closer to Active Fires = Lower Priority
Relative Weight	5

Development Process:

1. Import csv file into ArcGIS Pro
2. XY Table to Point
3. Select By Attribute: where confidence is equal to h (high) or n (nominal). Low confidence filtered out in order to remove potential false positive alarms (Earth Science Data Systems, 2016).
4. Feature to Raster
    a. Output cell size = 10
    b. Field = version
        i. Due to only containing "1" values
5. Euclidean Distance
    a. Output cell size = 10
    b. Environments Processing Mask = ACUS
    c. Environments Processing Extent = WGS_1984_UTM_Zone_17S
6. Clip Raster to ACUS
7. Raster Calculator (stretch values to = 100)
    a. ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Average Precipitation from Years 1970 - 2000

Source Citation	(Fick & Hijmans, 2017)
Download Link	https://www.worldclim.org/data/worldclim21.html
Data Year	1970 - 2000
Original Resolution	30 seconds (~1 km^2)
Factor / Constraint	Higher Average Precipitation Level = Higher Priority
Relative Weight	7

Development Process:

1. Import tif files into ArcGIS Pro
    a. Tif files represent average monthly rainfall for 1970-2000 for each of the 12 months
2. Build Pyramids and Calculate Statistics

3. Merge 12 rasters using Mosaic to New Raster function - Mosaic Operator = Mean. The output cell value will represent the average rainfall for the year (Esri Inc., n.d.-b, 2021)
4. Resample to cell size 10 for a common value
5. Geoprocessing - Extract by Mask - to Ecuador Boundary
6. Geoprocessing - Extract by Mask - to ACUS Boundary
7. Raster Calculator to stretch values to common value of 100
    a. ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Flood Risk

Source Citation	(Ministerio de Agricultura et al., 2018)
Download Link	https://data.humdata.org/dataset/wfp-geonode-ica-ecuador-flood-hazard
Data Year	2018
Original Resolution	Polygon
Factor / Constraint	Higher Flood Risk = Lower Priority
Relative Weight	4

Refer to https://geonode.wfp.org/documents/9589/metadata_detail for more information on how layer was made.

Development Process:

1. Import shp file into ArcGIS Pro
2. Clip to ACUS / Project with Environment Output Coordinate System
3. Polygon to Raster
    a. Cell Size to 10 used for common scale
    b. Value field - Area Flood Risk
4. Raster Calculator to stretch values to common value of 100
    a. ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Ownership

Source Citation	(*Censo Ecuador*, n.d.)
Download Link	home – National Institute of Statistics and Censuses (ecuadorencifras.gob.ec) (we obtained through UofM geospatial library)
Data Year	2010
Original Resolution	Polygon
Factor / Constraint	Higher Levels of Ownership in Area = Higher Priority
Relative Weight	6

Development Process:

1. From the census website, download the shapefile of Ecuador that's separated by census sector, the Excel sheet that describes each variable and it's table ID, and the geodatabase containing multiple table files that contain data from each variable
2. Add shapefile and geodatabase to ArcGIS
3. Table Join - between shapefile and H15_Ownership table in the geodatabase using the common column "Variable" (a unique identifier of each sector)
4. Create new numeric field in the attribute table called "Percent_Ownership"
5. Right click on the newly created table and select "Calculate Field"
6. Add the fields E83, E84, and E85 (all different forms of ownership) and divide by the total number of respondents (sum of E666) in order to have the percent ownership of each sector
7. Clip to the ACUS border
8. Visualize the new field "Percent_Ownership" n the Symbology tab of the clipped sector shapefile by selecting "Graduated Colors" option
9. Polygon to Raster
    a. Cell Size to 10 used for common scale
    b. Value field - Percent_Ownership
10. Raster Calculator to stretch values to common value of 100
    a. ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Population Density

Source Citation	(*Censo Ecuador*, n.d.)
Download Link	home – National Institute of Statistics and Censuses (ecuadorencifras.gob.ec) (we obtained through UofM geospatial library)
Data Year	2010
Original Resolution	Polygon
Factor / Constraint	Higher Levels of Ownership in Area = Higher Priority
Relative Weight	6

Development Process:

1. From the census website, download the shapefile of Ecuador that's separated by census sector, the Excel sheet that describes each variable and it's table ID, and the geodatabase containing multiple table files that contain data from each variable
2. Add shapefile and geodatabase to ArcGIS
3. Table Join - between shapefile and AGE_GROUP table in the geodatabase using the common column "Variable" or "Code" (a unique identifier of each sector)
4. Create new numeric field in the attribute table called "Percent_Population"
5. Right click on the newly created table and select "Calculate Field"
6. Add the fields for each age group and divide by the sum of all the age group field in order to have the percent population of each sector
7. Clip to the ACUS border
8. Visualize the new field "Percent_Population" n the Symbology tab of the clipped sector shapefile by selecting "Graduated Colors" option
9. Polygon to Raster
    a. Cell Size to 10 used for common scale
    b. Value field - Percent_Ownership
10. Raster Calculator to stretch values to common value of 100
    a. ((Layer– minimum raster cell value) * 100) / (maximum raster cell value - minimum raster cell value))

Python Script

```
# Connect to ArcGIS to get started

from arcgis.gis import GIS

gis = GIS("home")
# Import necessary packages/tools

import arcpy

import os

from arcpy.sa import *

import pandas as pd

from arcgis.features import GeoAccessor
# Setting up local work environment

arcpy.env.workspace = input('Please Enter In Path to Work Environment: ') #Enter personal work environment

# set it so you can re-run and overwrite the output while troubleshooting

arcpy.env.overwriteOutput = True


# MUST RUN THIS CODE BLOCK #

# view list of feature classes are in your working directory

shapefiles = arcpy.ListFeatureClasses()

print(shapefiles)
# MUST RUN THIS CODE BLOCK #

# view list of rasters that are in your working directory

rasters = arcpy.ListRasters("*", "GRID")

for raster in rasters:

  print(raster)
# Creating geodatabase that the output rasters can be placed in. Ceiba can enter in the name of the property to hold the resulting rasters in order to create organization if multiple properties are run
```

through the script

 # arcpy.management.CreateFileGDB(input('Enter in location to save new geodatabase that will hold resulting rasters: '), input('Enter property name: ')+".gdb")

Run Zonal Statistics as Table Tool

For tool information please refer to: [Zonal Statistics as Table (Spatial Analyst)]()

Parameters:

> *ZonalStatisticsAsTable(in_zone_data, zone_field, in_value_raster, out_table, {ignore_nodata}, {statistics_type}, {process_as_multidimensional}, {percentile_values}, {percentile_interpolation_type}, {circular_calculation}, {circular_wrap_value})*

```
# setting parameters

#in_zone_data

fc_input = input('Please enter the name of the Feature Class "boundary file" you will use as an input for the stats')# This is where Ceiba would enter a shapefile of the farm they are looking to restore on

if len(fc_input) < 1 : fc_input = shapefiles[0] #defaults boundary file name to first file in gdb if nothing is entered

inZoneData = os.path.join(arcpy.env.workspace, fc_input)

# print("in_zone_data"+ "=" + inZoneData)

#zone_field

zoneField = input('Enter name of Id Column')

if len(zoneField) < 1 : zoneField = r'OBJECTID' #default column name if nothing is entered

# print("zone_field"+ "=" + zoneField)

#in_value_raster

raster_input = input('Please enter the name of the Prioritization Map file: ')# This is where Ceiba would enter the raster file of the final map (could eventually be hardcoded)

if len(raster_input) < 1 : raster_input = rasters[0] #defaults to 1st raster file name in gdb if nothing is entered

raster_file = os.path.join(arcpy.env.workspace, raster_input)
```

```
# print("in_value_raster"+ "=" + raster_file)

#out_table

outTable = input('Enter name you would like your output rasters to be saved as: ')# This is what Ceiba would like their resulting rasters to be named (perhaps the zonalstat)

if len(outTable) < 1 : outTable = r'zstat' #default output raster name if nothing is entered

# print("out_table"+ "=" + outTable)

# run tool

arcpy.sa.ZonalStatisticsAsTable(inZoneData, zoneField, raster_file, outTable, "NODATA", "ALL")
# List Tables Created
datasetList = arcpy.ListTables("*")
print(datasetList)
#export csv file
arcpy.conversion.ExportTable(datasetList[0], 'zstatTable.csv')
# Visualize New Tables Created
table = outTable
arr = arcpy.da.TableToNumPyArray(table, '*')
# convert to a Pandas DataFrame
df = pd.DataFrame(arr)
print(df)
```

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Appendix B:
Standard Operating Procedures for Ecological Field Data Collection

A Standard Operating Procedure ("SOP") is a set of written instructions that establishes routine or repetitive activities to be followed by an organization. The development and use of SOPs are an integral part of a successful quality system as it provides individuals with the information to perform a job properly and consistently, as well as maintain the quality and integrity of a product or end-result (US EPA, 2007). This Data Collection Plan was developed by modifying methods provided in the (US EPA, 2015), (US EPA, 2020), (*Safety in the Field – GPS Data Collection – Geospatial Technology*, n.d.), (*Capture—ArcGIS Field Maps | Documentation*, n.d.), (Curry, n.d.)

1. Definitions

Ceiba Foundation	Ceiba Foundation for Tropical Conservation
Ground Truthing	The accuracy of remotely sensed or mathematically calculated data based on data actually measured in the field.
U-M SEAS	University of Michigan School for Environment and Sustainability
Site Inventory	Site Inventory refers to the number, location, and general characteristics of sites located within the exterior boundaries of the ACUS to be used for analysis in the UM-SEAS Master's Project.
Site Inventory Log	Site Inventory Log refers to the system or process that can provide a reasonable estimate of the number, likely location, and general characteristics of sites within the exterior boundaries of the ACUS.

2. General Information

2.1. Purpose/Objective

The purpose/objective of this SOP is to define the procedures/protocols required for preparing, recording, and maintaining the records and information, pertaining to site inventory logging.

2.2. Scope Application

This SOP is applicable to and lays out procedures for all Restoration Prioritization field work pertaining to, site logging, data entry for site logging, and record keeping for site logging.

2.2.1. Changes

The procedures in this SOP may be varied or changed as required, dependent on site conditions, equipment limitations, or other procedural limitations. In all instances, the procedures employed must be documented in the surveyor's field logbook, then both electronically and hard-copy.

2.3. Documentation/Verification

This SOP was developed by persons deemed technically competent by the University of Michigan and the Ceiba Foundation for Tropical Conservation, based on their knowledge, skills, and abilities. These procedures within this SOP have been tested in practice and reviewed in print by a subject matter expert.

2.4. Safety

These guidelines outlined in this SOP should only be used to complement the judgment of an experienced professional. When using the procedures within this SOP, minimize exposure to potential health hazards through the use of protective clothing, eye wear, and gloves. Address chemicals, plants, and animals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate. Under no circumstance enter any area suspected of containing hazardous materials or substances, unless proper precautions have been taken to prevent safety concerns. Appropriate precautions should be observed when working in and around bodies of water, areas with tall grass, and any sites deemed dangerous by site investigators.

2.5. Buddy System

While conducting site visits / site investigations, a buddy system must be used. At no point will site visits / site investigations be conducted by one person. Two people at a minimum will be conducting site visits / site investigations. Site investigators do not need to be side by side during the entirety of the investigation. However, site investigators should stay in contact with one another via walkie-talkie or some other means.

Additionally, the Buddy System is helpful for ecological surveying. One site investigator will be entering information/measurements into the Field Maps app and taking directional pictures, while the other investigator will be pointing out notable species/information to enter into the survey.

2.5.1. Field Equipment

While conducting site visits / site investigations, make sure proper equipment is brought with you. This equipment can include:

- Phone / tablet that has relevant Field Maps applications and maps downloaded to the device
- Cellphone
- Camera (if phone is not capable of capturing photographs)
- Extra batteries for technological equipment
- Compass
- Map of area
- Any helpful identification material (e.g., species identification booklet)
- Field medical kit
- Extra water
- GNSS/GPS
- Paper and pencil (in case of technological failure)
- Bug spray
- Sunscreen
- Walkie Talkie (not required but ideal) to communicate with other team members on site
- Binoculars

2.5.2. Pack In Pack Out

While conducting site visits / site investigations, whatever you pack into a site, pack the same things out of the site. This will ensure no equipment is left behind and or no trash will harm the environment.

3. Internal Documents

3.1. Overview

Accurate site logging documentation is essential for proper site evaluation, data entry, and record keeping. A clear traceable paper / electronic trail must follow each site visit from the first preliminary visit to the final deliverables for clientele. It is important that specific procedures be adopted so that the desired degree of accuracy and completeness is achieved.

3.2. Document Development

The following steps are used to develop, review, author, control, and distribute internal documents related to the Ceiba Restoration Site Inventory. Potential Site Inventory locations will be identified using methods outlined in the Project's Plan. These methods include but are not limited to the development of a baseline prioritization model for species restoration within the exterior boundaries of the ACUS. While on the Project Site, potential Site Inventory locations will be visited to determine validity of the site to be entered into SEAS Master's Project records, using the procedures laid out in this SOP.

3.2.1. Step One

Gather field equipment to be used in the field. Refer to Section 2.4.2 for required field equipment.

- Phone / tablet that has relevant Field Maps applications and maps downloaded to the device
- Global navigation satellite system (GNSS) unit (e.g., GPS unit)
  - If GNSS unit is not available, use phone / tablet with GNSS/GPS capabilities
- Camera if phone / tablet does not have photo capability
- Field datasheets (e.g., the Site Investigation log)
  - To be used if *Field Maps* is not available and or is not working while out in the field
- Rite in the Rain field books and or other field notebooks
- At least two pencils and or pens
- Clipboards
- Flags (for plot location picture references)
- Compass
- Convex spherical densiometer (measure canopy cover)
- Tape Measure (50-100 meter)
- Tree Diameter tape measure
- Binoculars
- Field first aid kit for safety

3.2.2. Step Two

Using a phone/tablet, download relevant *Field Maps* applications to be used while out in the field. Field datasheets (i.e. the Site Investigation form) may be used at site if *Field Maps* is not available. Refer to Section 6 of this SOP to find documents required to be filled out during site visit / site investigation if *Field Maps* is not available.

3.2.3. Step Three

If using a GNSS/GPS device capable of pairing with a phone / tablet, follow relevant instructions outlined in the user manual.

3.2.4. Step Four

Identify and proceed to a site that will have a site visit / site investigation conducted. Bring all required field equipment and any other pertinent equipment needed for site visits / site investigations. Note: if a site requires permission to access the site, proper documentation must be obtained and noted in field logs, including *Field Maps*.

3.2.5. Step Five

Once you arrive at the site location, mark your entry location using 1) a phone / tablet with a paired GNSS/GPS and *Field Maps* downloaded to the device, 2) a phone / tablet with GNSS/GPS capability, or 3) a GNSS/GPS unit and field notebook. If using a GNSS/GPS unit and field notebook, mark location data from a GNSS/GPS unit in field notebook for future reference. GNSS/GPS models may vary. Refer to the model's manual for specific instructions on how to mark your location.

Marking your entrance location prior to entering the site will be helpful later when leaving the site and needing to find your vehicle.

3.2.6. Step Six

Proceed to site for site visits / site investigation.

3.2.7. Step Seven

While on site, using a phone / tablet with a paired GNSS/GPS and *Field Maps* downloaded to the device, collect relevant points, lines, and or polygon for the site. A minimum of four points must be collected for each site. This will ensure enough data is collected for future analysis.

Field Maps will have points, lines, and polygon feature templates available for editing. Information on how to use *Field Maps* can be found here: https://www.esri.com/arcgis-blog/products/field-maps/field-mobility/get-to-know-arcgis-field-maps/

Choose an appropriate feature template to edit and collect. With appropriate feature template paired or a field datasheet (i.e., the Site Investigation form) ready, collect relevant points, lines, and or polygon for the site.

While on site, *Field Maps* or a field datasheet (i.e. the Site Investigation form) must be completed accurately and completely. Each line, table, and or checkbox present on any field datasheet (i.e. the Site Investigation form) must be completed. If there are reasons why certain areas or portions of a field datasheet are not used, field personnel are required to explain within the field datasheet, the reasons why the sections were not completed. Any hardcopy corrections, revisions, and or deletions must be made by crossing out the incorrect entry and initialing and dating the error. This will ensure all relevant information that was incorrect has proper documentation for editing.

Any qualified person may fill out field data sheets, but the current Project Manager must sign and approve the document before these field data sheets can be added to the Site Inventory.

When visiting any site make sure to keep proper safety precautions in place (refer to section 2.4 of this SOP).

4. Field Point Collection

Start recording points by clicking the "(+)" icon in the lower right hand corner and choose "collect field points". For the first point, name the point after the name of the site and clearly label that this is the initial point (e.g., Finca de la Mago - Entrance). In order to name the point, enter its title in the "site name" attribute. Other points can be named based on the location of the point within the site, or this field can be left as "field point".

Place a flag marker down at the first point. Before taking any pictures, record the exact date and time of the start of the survey. The field maps app will automatically start averaging 20 points of gps coordinates for an accurate location of the point. If the app states that GPS accuracy is over 10m, a separate GPS device should be used to take the coordinates of the location. Either with a compass or GPS device, take a picture of the marker facing North, East, South, and West. After each photo is taken, rename it after the cardinal direction it is facing. Also include a picture of the canopy cover directly above the marker. Once the directional pictures have been taken, the rest of the ecological field point attributes should be recorded. Most, if not all, of the attributes should be filled out for the first point. For the remaining points on the same site, these attributes can be copied or added in during post processing unless any information (ex. weather) has changed during the survey.

4.1. Attribute Descriptions:

Start date and time: As previously mentioned, this attribute should be filled out (by clicking the entry field) as soon as a new field point is created. In order to collect consistent data, each survey should begin as close to 8:15 am as possible. Ecological surveys should not be started in the afternoon

Your full name: full name of SEAS members performing the survey ex. Barbara Nainiger and Ylexia Padilla

Title Occupation: Title of position as a surveyor ex. Student

Surveyors Relationship to site: How surveyors became connected with the site ex. Working with Ceiba

Surveyor Information Notes: Any relevant or dynamic information about the surveyors

Site Name: As previously mentioned, this should either be the name of the site and descriptor of location within the site (if possible) or left as blank if either option is not applicable

Address: address of location (if known)

Property Owner: Primary owner(s) of the farm ex. Margarita

Land Owner Willingness: this describes how willing the farm owner(s) is to participate in the ACUS/sustainable farming practices. Choose from the selections: willing, not willing, unknown, or other

Granted Access: were surveyors granted access to the site by the owner(s)? Choose from the selections: yes/no

Authorization by who: enter in who authorized the completion of the survey ex. Land owner, Ceiba

Current Use of Property: In less than 50 words describe the current land use of the property ex. Agriculture: agroforestry

Land Cover Type: Choose the applicable majority land cover type from the selections: Forest, Res, Open, Farmland, Water, Other (please specify)

Site Description Notes: Enter in any additional information regarding the land use or land cover type of the site.

Road Access: Choose from the selection: yes or no. Yes should be selected if the property borders or intersects with a road (paved or unpaved). No should be selected if the site needed to be accessed by foot (or horse etc.).

Distance from Road: Enter in the estimated distance of the site/closest border to the road (closest) in meters

Trail Access: Choose from the selections: yes or no. Yes should be selected if a trail runs through the site and can be used to gain entrance into the site. No should be selected if the site does not contain a distinct trail.

Trail Distance: Enter in the estimated distance of the trail in meters (or km). This can also be added in post-processing for increased accuracy.

Site Accessibility Notes: Enter in any additional information regarding accessibility

Land Use: Choose from the selections: Agriculture, Forest, Water, Shrubland, Grassland, coastal, developed, Barren/Extractive, Wetlands, Other (please specify)

Forest Type: Choose from the selections: Primary Forest if the area represents forest that has never been cut/damaged, Secondary Forest if the area has been partially (or fully) cut at some point and has gone through forest succession, Riparian Forest if the site/area is within 50 m of a major river, and unknown.

Tree Height: Height of the tallest tree on the property/visible in meters

Canopy Cover Density: Using either the densiometer, canopio app w/ canopy pictures taken at each point, or estimation, enter in the % of visible sky covered by the forest canopy

Agricultural Type: Choose from the selections: monoculture (1 crop), Agroforestry, Pasture, Aquaculture (ex. Shrimp farm), or other.

Duration of farming practices: Enter in how long this site has been farmed or has been using its current farming practices

Weather Conditions: Choose from the selections: Sunny, Rainy, Windy, Cloudy, or other. *remember to update this attribute if there is a change in weather conditions while survey data is being collected*

Temperature: Enter in temperature a the site in celsius, This can be collected via a phone app or a GPS unit

Slope: Choose from the selections: steep if there is a significant slope to the terrain that makes traversing difficult, not steep if there is a slight slope but traversing is unaffected for the most part, or Flat if there is no slope to the terrain.

Aspect: If a slope is present, enter in the cardinal direction (N,E,S,W) the slope is facing.

Approximate size of the property: enter in the area of the site in hectares either via estimation, from the landowner, or from ArcGIS in post processing.

Fence: Enter in yes if there is some sort of fence present on the property and No if no fence is present at all.

Fence condition: describe the condition of the fence, make sure to indicate any significant issues or damage.

Noise level: Choose from the selections: No Noise if the site is silent, Some Noise if there is a moderate amount of nature noise (animal calls etc.), or High Noise if there is a significant amount of natural and anthropogenic noise (ex. Road noise etc.)

Building on Property: Choose from the selections: yes if there is a building present on the property and No if there are no buildings present

Building Type: Describe the buildings and their purposes/uses on the site ex. Residential

Number of buildings: Enter in the number of separate buildings on the property

Distance from Vertical Water: Choose from the selections: unknown, <50 m, 51-599 m, or >600 m

Distance from Horizontal Water: Choose from the selections: unknown, <50 m, 51-599 m, > 600 m from rivers or other water bodies

Distance from resident water: Choose from the selections: unknown, <50m, 51-599 m, >600 m depending on how close the nearest residential water source is from the site.

Distance from Home: Choose from the selections: <50 meters, 51-599 m, >600 m depending on how close the nearest residence is to the site (not necessarily the landowners home)

Distance from School: Choose from the selections: <50 m, 51-599 m, >600 m depending on how close a school is to the site (if known)

In a floodplain: Choose from the selections: yes if the site is located within the floodplain of a river or no if it is not or unknown

Adjoining Property Section: If known, list the property/property owners of the properties to the North, East, South, and West of the site

Human Indicators: Choose from the selections: yes if the terrain/vegetation has been altered or added to via human activities or objects, or No if the terrain/vegetation has not been altered ex. Trash, fire pit, etc.

Number of Human Indicators: Indicate the number of objects or degree of alteration humans have left.

Types of Indicators: If Yes was indicated on previous related attribute, elaborate/describe the human indicators

Animal Indicators: Choose from the selections: Yes if <u>any</u> animal species were observed (visually or audibly) at that point during the survey or No if no animal species could be observed

Animal Type: this attribute highlights the species with top observation priority due to their status as bioindicators. Choose from the selections: Rufous-headed Chachalaca, Howler Monkey, Red Masked Parakeet, White Fronted Capuchin Monkey, Ocelot, Tucan, Tamandua, Amphibian (any species), Grey-backed hawk or other if bioindicator not listed is observed (either visually or audibly).

Animal Type 2: Choose from the same selections as attribute “animal type” if a 2nd bioindicator species is observed within the same field point

Animal Type if more than 2: Manually enter the name of the 3rd bioindicator species and/or enter <u>and</u> describe the number and description of all animal species not included on the bioindicator list ex. 4 different bird calls, 1 lizard, 2 fer de lance snakes, bird w/ red belly and blue/black back etc.

Plant Indicators: Choose from the selection: Yes if <u>any</u> identifiable plant species were observed at that point during the survey or No if no plant species were observed (unlikely) *always take pictures of unknown plants for identification during post-processing*

Plant Type: Choose from the selections: Orchid if any species is observed during that point (our plant bioindicator species) or other if any other plant species is observed

Other Plant Types: Manually enter in plant species not on the bioindicator list and describe the number and condition (this can include agricultural plants but there is a distinct attribute for those species as well)

Surrounding Agricultural Plants: (especially relevant for farm surveys) manually type in the species of agricultural plants, fruits, or seeds at that point *again remember to take pictures of leaves or fruits in order to identify unknown species during post processing

Pollinators present: Choose from the selections: Yes if any pollinator species were observed at that point and No if no species were observed. Pollinator species can include: bees, wasps, butterflies, hummingbirds, bats, moths, etc.

Pollinator notes: If observed, describe any unknown species of pollinators and how many were observed at that point ex. 2 butterflies (1 all orange, 1 black with pink and yellow spots)

Pest Control Use: Choose from the selection: Yes if pest control is used at this sight, if it is not, or unknown

Type of Pest Control: Choose from the selection: Chemical if man-made (artificial) pest control that may contain harmful chemicals is applied to the site, Natural if (homeopathic?) man made pest control is applied, No pest control if nothing is applied to reduce of kill pests, or Other

Specify Other: describe if that selection was chosen

Water Contamination: Choose from the selections: Yes if the water (on site) is contaminated, No if it is not, or Unknown

What type of Contamination (if known): if Yes was chosen for the above attribute, describe the type of contamination ex. E-coli

Where is the water contaminated: Enter the location of the contaminated water and/or contamination source ex. Upstream

Where did the information come from?: Enter how it is known if the water is contaminated ex. From interview with landowner, from casual conversation with landowner, from Majo/Ceiba

Picture Section: If pictures were taken externally from the field maps app, make sure to indicate this by choosing “Yes” in the “was a picture taken?” attribute. Include the device type, picture ID of the photo, and any other significant notes to ensure the correct photos get attached to the correct field points

Other notes: Include any additional relevant information to the survey in this attribute. This can be entered during the survey or as an edit/correction during post-processing ex. First 3 field points had incorrect start time - subtract 1 hour from each etc.

End Date and Time: Once the survey has been sufficiently completed, all pictures have been taken, and all surveyors have agreed that all relevant info has been recorded, the end date and time can be entered and the survey can be submitted.

5. Additional Protocol

Copy Function- in order to save time and promote efficiency, the survey attributes can be copied over for the next field point. Once a field point survey has been submitted, the surveyor can press the "(+)" icon in the bottom middle of the screen and choose "copy attributes". Once this button is pressed, a new field point survey will appear, and the app will automatically start averaging the GPS location of the new point. The surveyor can press the "stop averaging" button in order for them to move to the location of the next point. Once in the proper location, "start averaging" can be pressed in order to get the coordinates of the new point. *it is important to note that all attributes will be copied over from the previous point so start time/date will need to be updated almost immediately upon opening the copied survey. This also applies to the animal, plant, and pollinator indicators, so it is important to update/change these sections if this point's information does not align with the copied survey. Also remember to update any changes in weather or site conditions if they have changed between points.

Choosing distance between field points- Distance between points will depend on length of path taken at each site. For smaller sites (less than 1 km), a point can be taken ~ every 10 meters (or paces if lack of tape measure) ex. Finca La Mago. For medium sites (1-3 km) a point can be taken ~ every 30 meters. For large sites, (>3km), a point can be taken every 50-100 meters. Surveys that are performed on Ceiba trails should use the trail markers for measuring out 50 meters between each field point.

6. Field Datasheets

Field datasheets (e.g., the Site Investigation log) need to be created for field data collection with information outlined in Section 4. These field datasheets will be used if *Field Maps* is not available and or is not working while out in the field. It is up to the discretion of the organization collecting field data to create and distribute field datasheets to field members. If field datasheets are not available and *Field Maps* is not working, use Field Equipment outlined in Section 2.5.1 to document all Field Point Collection criteria outlined in Section 4.

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Appendix C:

Landowner Willingness Survey

Key Questions to Assess Landowner Willingness for Restoration

How long have you owned the land?

A. Less than 5 years
B. Less than 10 years
C. 10 - 20 years
D. 20+ years
E. …

What is your land tenure?

A. Untitled
B. Liened
C. Long-tenure problems
D. Short-tenure problems
E. Titled

Farm size

A. <50 hectares
B. 50 - 100 hectares
C. …

How many hectares of land would you consider for restoration?

A. <20 hectares
B. 20 - 50 hectares
C. >50 hectares
D. …

Please mark any features on your land:

- Riparian Area/Stream
- Remnant Forest
- Open-sun crops
- Agroforestry
- Pasture
- Structures

- Paved Road
- Dirt Road
- Fencing

Please mark any of the following that have occurred on your land:

- Illegal logging
- Illegal hunting
- Forest fires
- Land invasion
- Agricultural chemical contamination
- Aquaculture contamination
- Livestock contamination

Please mark any of the following animals you have seen on your land in the past *year*:

- Ecuadorian White-fronted Capuchin Monkey
- Mantled Howler Monkey
- Red-masked parakeet
- Grey-backed Sparrowhawk
- Slaty-headed ant wren
- Ocelot
- Margay

What are the main reasons why you want to begin a restoration project?

A. To create a conservation easement for my property
B. To improve agricultural conditions, i.e. agroforestry or silvopasture
C. To improve water quality in stream areas
D. To reverse previous land degradation
E. To conserve and improve forest habitat

If ranked-choice response is available with technology: Below are some reasons for wanting to begin a restoration project. Please rank them in terms of importance to you:

1. To create a conservation easement for my property
2. To improve agricultural conditions, i.e. agroforestry or silvopasture
3. To improve water quality in stream areas
4. To reverse previous land degradation
5. To conserve and improve forest habitat

Have you attempted a restoration project on your land in the past?

A. Yes, and it was successful
B. Yes, and it was *not* successful
C. No

D. Not sure

→ If B: Why was the previous restoration project unsuccessful?

A. Plants did not survive
B. Not enough funding to complete the restoration
C. Not enough technical support or expertise to continue the restoration
D. Other:

Do you plan to change the use of your land in the next 5 years?

A. Yes
B. No
C. Undecided

In each of the following statements, choose from options between 1 to 5, with one being "Strongly Disagree," and 5 being "Strongly Agree":

I understand the process of ecological restoration and restoration techniques.

Other landowners I know are also interested in restoration.

If it takes too long to see the positive effects of restoration, then it's not worth it.

Successful restoration needs a lot of expert knowledge and support.

I don't know of any other restoration projects in the area.

There is not much I can do about protected endangered forest species.

Recommendations for Use

Communicating the benefits of protecting remnant primary tropical dry forest to the local community is important as a local conservation entity, however, achieving a stronger alignment with conservation goals may require more actionable next steps, such as community inclusion on restoration projects specifically designed to improve water quality. Evidence from recent research in Ecuador suggests that participation and engagement in local ecological restoration is a strong motivator for continued participation and long-term success (Mazón et al., 2021), suggesting that targeted restoration projects aimed to improve connectivity may be less valuable to the community at-large if they are not visible. Community support and eventual adoption of conservation practices is predicated on broad stakeholder inclusion on the restoration process with a demonstrated effort to build capacity and spread knowledge about how to effectively restore local ecosystems (Powlen & Jones, 2019, Cortés-Capano et al., 2021).

Additionally, Ceiba Foundation can emphasize their ability to effectively manage the restoration process through technical guidance, trees, monitoring, etc. to improve long term outcomes of restoration projects. Ultimately, more investment in developing partnerships and visibility within the community will help to build knowledge about stakeholder networks, attitudes about land use and collaborative conservation initiatives for more widespread adoption needed to produce connectivity on a large scale.

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Appendix D:
Interview Questions and Focus Group Guide

Interviews with ACUS Bio-Entrepreneurs

What determines whether someone becomes an *eco-entrepreneur*- a farmer, harvester, or business owner using ecologically sustainable methods to generate products for the market- in the *Area de Conservacion y Usos Sustenable* (ACUS) of Manabí, Province Ecuador? What are the sociocultural values and influences of bioentrepreneurs? What forms of knowledge and support are key to successful bioentrepreneurship? What do successful bioentrepreneurs view as the most important benefits of this type of sustainable livelihoods and how can conservation organizations support them?

This interview guide aims to answer these questions in order to help local conservation organizations in Manabí better support bioentrepreneurs operating within the ACUS and increase adoption of sustainable livelihoods that benefit the local community and biodiversity. Questions are framed around respondents' farming practices but will allow interviewers to understand values and associations farming culture and methods have with local ecology, community, and local livelihoods. Interviews are semi-structured, following the question guide below, while allowing for the interviewer to go off script and explore new topics and themes introduced by the respondent.

Informed Consent Script

We are a team of graduate students from the University of Michigan, in the United States. We are researching reforestation (tree planting) in the Manabí ACUS and are interested in your knowledge and opinions on local plants. The purpose of this research is to understand how to support sustainable farms (and bioentrepreneurs) in the ACUS. Your participation will involve one informal interview lasting about one hour, and should not cause you any risks, other than losing one hour of your time.

We will do everything we can to protect your privacy and what you tell us during this interview. While we will ensure that no one will hear our conversation or recordings after the interview is completed, members of Ceiba may be able to recognize the information you have provided if you provide specific details about your farm. All information you provide during the interview, including audio files and notes, will be kept in a secure location, so no one outside of the research team from the University of Michigan, School for Environment and Sustainability can access it.

Please keep in mind that participation is voluntary. You may choose not to answer any question at any time during the interview. If you do not want to answer any question, just tell the interviewer and we will skip that question. You may also stop the interview at any time if you do not want to continue. Do you have any questions before we get started?

I. Personal History

A. Can you tell me about your farm?
   1. What primary crops do you grow at the farm?
      a) Do you rotate your crops?
   2. How long have you been farming here?

B. Can you tell us about how you started your farm? How did you learn how to farm?
   1. What crops were you growing when you first learned?

C. How did you choose where to farm?

This section begins the interview and grounds it in the topic of the respondent's farm. We ask respondents about their history with farming to understand the influence of generational knowledge, family legacy, and sense of place on farming practice.

II. Farming Practices

A. How do you deal with pests?
   1. Is it difficult to deal with pests in this way, instead of using a lot of chemicals?

B. Do you use fertilizer? What kind?
   1. Do you ever use food waste or crops you can't sell as fertilizer?
   2. Is this more or less than other farmers around here?

C. Have you changed the way you control pests or apply fertilizers?
   1. What made you change?

These questions help define what criteria of "sustainable farming" the farmer or bioentrepreneur meets, especially their use of any material inputs common to agricultural practice in the local area. We expand questioning to identify any factors that may lead to or influence a transition to sustainable farming practices.

III. Market

A. What do you sell? For how much?

B. Where do you sell what you grow?
    1. Is your farm open to the public?
C. Do you have any "specialty" products?
D. Do you change your farming practices according to market prices of your crop?
    1. If the price you got for one kilo of [coffee] went down, what changes to your growing practice would you make?

With these questions we aim to understand the role of the distribution of farm products as well as pricing on the bioentrepreneur's business and farming practices. We ask presupposition questions to gauge the sensitivity of sustainable farming to market volatility and the individual farmers' level of risk tolerance.

IV. Local Ecology

A. Do you think your farm is helpful to the nearby forest?
B. Do you think your farm helps support biodiversity or animals?
    1. What's the most common animal you see around your farm?
    2. Are there any animals that you like to see on your farm?
    3. Have any animals caused problems for your farm or crops?
C. We've heard that some people in Manabi have problems with getting clean water. Do you have any problems getting clean water for irrigation for your crops?
D. Did you have to change any of your farming practices because of environmental conditions?

This set of questions aims to identify any values or associations between sustainable farming practices and biodiversity or other ecosystem services, such as water. We also look for evidence that ecological conditions or problems positively or negatively affect sustainable farming practices.

V. Challenges (and Successes!)

A. What are some of your challenges with farming here?
    a. What have been some of the other biggest challenges you faced?
    b. Are these similar or different to challenges other farmers or bioentrepreneurs have faced?
    c. Are there any future challenges you think you should prepare for?
B. What do you think helped your farm become successful?

C. What aspect of your farm has benefitted you the most?
D. What other benefits do you feel you have gotten out of sustainable farming (bioentrepreneurship)?
E. What vision do you have for your farm in the next 5 to 10 years?

VI. Relationships to the ACUS

A. What do you know about the Ceiba foundation?
    a. Have you participated in any training offered by Ceiba?
B. What are your thoughts on the ACUS? Does it affect your farming practices or how you run your business?
C. How do you feel about reforestation (tree planting) in the ACUS?

VII. Is there anything else you want to tell us about how you came to be doing this type of farming?

Understanding the challenges and obstacles to sustainable farming and bioentrepreneurship is key to supporting current and future bioentrepreneurs in the ACUS. For the Ceiba Foundation, local farmers' and bioentrepreneurs' perception of the ACUS is important for framing future communication and outreach about sustainable livelihoods.

Focus Group Conversation Prompts

What determines whether someone becomes a *bioentrepreneur*- a farmer, harvester, or business owner using ecologically sustainable methods to generate products for the market- in the A*rea de Conservacion y Usos Sustenable* (ACUS) of Manabí, Province Ecuador? How are bioentrepreneurship, sustainable farming, and the ACUS viewed within the local community? What salient sociocultural associations exist for bioentrepreneurship? What do stakeholders view as the biggest obstacles to adopting this type of sustainable livelihood and how can conservation organizations support them in a transition?

This guide of focus group prompts aims to answer these questions and understand the larger sociocultural context of bioentrepreneurship in Manabí. Questions are open-ended and starting points for a larger discussion. Facilitators will follow the prompt guide below to frame the discussion, but interject where necessary to bring conversations back to the main point. Many prompts are provided, but providing all to the focus group is neither required nor feasible. Facilitators will introduce new prompts as necessary and as time allows.

Informed Consent Script

We are a team of graduate students from the University of Michigan, in the United States. We are researching farming practices (and bioentrepreneurship) in the Manabí ACUS and are interested in learning about your knowledge and opinions about it. The purpose of this research is to understand how to support sustainable farms (and bioentrepreneurs) in the ACUS. Your participation will involve one informal interview lasting up to two hours, and should not cause you any risks, other than losing two hours of your time.

We will do everything we can to protect your privacy and what you tell us during this interview. While we will ensure that no one will hear our conversation or recordings after the interview is completed, members of Ceiba may be able to recognize the information you have provided if you provide specific details about your farm. Your identity and what you say during the interview will also be known by the other people participating in this group. All information you provide during the interview, including audio files and notes, will be kept in a secure location, so no one outside of the research team from the University of Michigan, School for Environment and Sustainability can access it.

Please keep in mind that participation is voluntary. You may choose not to answer any question at any time during the interview. If you do not want to answer any question, just tell the interviewer and we will skip that question. You may also stop the interview at any time if you do not want to continue. Do you have any questions before we get started?

I. **Bioentrepreneurship Overview**

   A. Today we are going to talk about bioentrepreneurship [sustainable farming practices]. What are your general feelings about this?

      1. *If no response try:* What's the first thing you think of when talk about "bioentrepreneurship?"

   B. What do you think of when you think of sustainability or sustainable farming?

   C. How did you first hear about farming in the ACUS?

II. **Ecosystem Services**

   A. We've heard that some people in Manabí have problems with getting clean water. Do any of you have problems getting clean water?

   B. Do you think sustainable farms are helpful to the forests in Manabí?

   C. Do you think it's important for farmers and the community to have healthy (intact) forests?

III. **Ceiba Foundation and Reforestation**

   A. What do you associate with the Ceiba foundation? What about the ACUS?

   B. How do you feel about reforestation (tree planting) in the ACUS?

IV. **Success and Livelihood Adoption**

   A. What do you think makes a farm successful?

      1. What do you think has helped local sustainable farmers (bioentrepreneurs) become successful?

   B. What kind of support would you need to become a bioentrepreneur?

Interviews with Local Stakeholders

What preferences exist for native plant species among rural communities in Manabi Province, Ecuador? Is knowledge of plant species informed by specific livelihoods or land use practices, such as agriculture, gathering, or hunting? Do community stakeholders feel that the abundance or distribution of particular plant species or the character of use of the land has changed over time? What are local perceptions of reforestation and of the current areas being prioritized for forest restoration projects?

This interview guide aims to answer these questions and to incorporate cultural relevance of land use and local preference for native plant species into a model designed to prioritize locations for reforestation. Interviews are structured and follow the provided question guide, but interviewers may allow respondents to discuss more about a certain topic if they wish.

Informed Consent Script

We are a team of graduate students from the University of Michigan, in the United States. We are researching reforestation (tree planting) and preferences for native plant use in Manabi and are interested in your experience as someone who has lived in the area. The purpose of this research is to develop a prioritization model of reforestation in the ACUS. Your participation will involve one informal interview lasting about half an hour, and is of very minimal risk to you.

We will do everything we can to protect your privacy and what you tell us during this interview and no one will know your identity or what you tell us after the interview is over. All information you provide during the interview, including audio files and notes, will be kept in a secure location, so no one outside of the research team from the University of Michigan, School for Environment and Sustainability can access it.

Please keep in mind that participation is voluntary. You may choose not to answer any question at any time during the interview. If you do not want to answer any question, just tell the interviewer and we will skip that question. You may also stop the interview at any time if you do not want to continue. Do you have any questions before we get started?

I. Landscape History

- A. How long have you been in the area? What about your family?
- B. What is your occupation?
  1. Is this something your family has always done here?
- C. Do you know anything about the history of the area where you live now?

The questions begin the interview by assessing personal history and contextualize respondents' answers in terms of duration of residence in the area. We also ask about occupation or land use to understand the ways in which respondents have developed ecological knowledge.

II. Perceptions of Land Use and Landscape Preference

- A. Is there an area that you think should be reforested (replanted)?
  1. Why?
- B. We've learned that areas like this… may be more important for reforestation (replanting). Do you agree with this?
- C. What types of areas, or specific locations, do you think are most important to reforest?
  1. *If a specific location is mentioned:* Do you remember anything about this specific location? Was it an area where people were farming or cutting trees?

These questions gauge stakeholder opinions on current reforestation efforts and elicit information on the historical activities of land degradation and/or improvement that may not be included in existing reforestation models.

III. Native Species Preferences

A. Are there certain forest plants that you like to use for building, medicine, ceremony, or for other purposes?
   1. Where do you find this plant now?
   2. Have you found this plant somewhere else in the past?

B. Are you familiar with ebano, higueron, guaba, balsamo, jigua, cascol, matapalo, or canas?
   1. *If yes:* Which of these plants is most important to you?

We end the interview by asking about uses for native plants and familiarity with specific species (referred to by their local names) that are currently being planted in reforestation initiatives, to assess the potential significance of reforested areas to the local community.

Appendix E:
ASOPRO Farm Tour Recommendations in Spanish Language

Recomendaciones de alto nivel para Finca La Mago y Finca La Tía. Para más detalles, consulte “Comentarios narrativos” en el capítulo.

Criterios de evaluación de la visita a la finca	Mantener y ampliar	Adición sugerida
1. Mostrar las mejores ventajas de la finca	• Subrayar la pasión de los agricultores por la conservación durante toda la excursión • Dar oportunidades para que los visitantes veían la variedad de especies en las fincas	• Ofrezcan comentarios más estructurados sobre el proceso de cultivo y los activos importantes de la finca relacionados con este proceso
2. Demostrar prácticas sostenibles del cultivo del café	Conversación convincente sobre: • La transición a la agricultura sostenible • Consecuencias del uso de productos químicos en la agricultura • Beneficios de los métodos de cultivo sostenible	• Compartan más información sobre las prácticas agroforestales específicas que se emplean en las fincas y la biodiversidad resultante • Muestren ejemplos de gestión y métodos sostenibles en sus fincas
3. Subrayar los beneficios regionales de la agricultura sostenible	• Explicación de los beneficios de la agricultura sostenible para los ecosistemas locales	• Den más detalles sobre los beneficios que la cultivación sostenible tiene para los ecosistemas regionales y cómo los beneficios locales se conectan con los de nivel regional
4. Compartir la historia de la finca y sus tierras	• Tienen una habilidad de contar sus historias personales, que son la forma más eficaz de compartir la energía y alegría que tienen por lo que hacen.	• Cuenten más historias a lo largo de la visita; incluir historias en todas las secciones de la visita siempre que sea posible. • Subrayen el intercambio de historias que comparten experiencias e historias que son únicas de Narcisa, Margarita, y su tierra
5. Ofrecer oportunidades para la interacción y el aprendizaje prácticos	• Oportunidades para tocar y oler plantas y frutas	• Integren más oportunidades para tocar y oler plantas y frutas en la excursión • Den algunas oportunidades más para la interacción práctica con artículos utilizados en el procesamiento del café

Criterios de evaluación de la visita a la finca	Mantener y ampliar	Adición sugerida
6. La visita da una visión completa del proceso (comprensión del principio de "desde la finca hasta la mesa")	• Comer alimentos de origen local y beber café ASOPRO • Hablar sobre el origen de los alimentos y del café	• Ofrezcan comentarios más estructurados sobre el proceso “desde la finca hasta la mesa” para cada alimento y bebida consumidos.

Recomendaciones de alto nivel para las instalaciones ASOPRO. Para más detalles, consulte “Comentarios narrativos” en el capítulo.

Criterios de evaluación de la visita a la finca	Mantener y ampliar	Adición sugerida
1. Mostrar las mejores ventajas de la finca	• Distinguir a ASOPRO de otras asociaciones: dirigida por mujeres; pequeños agricultores; métodos de cultivo sostenibles y productos diversos. • Conversación convincente del secado, tostado y procesado del café en las instalaciones	• Dar más detalles sobre la programación educativa a través de ASOPRO y los otros cultivos, además del café, que se ofrecen
2. Demostrar prácticas sostenibles del cultivo del café	• Información excelente sobre las técnicas sostenibles que se emplean	• Conversen en más profundidad las técnicas sostenibles más allá de las que sustituyen el uso de productos químicos sintéticos • Den más información sobre la decisión de utilizar métodos sostenibles y los beneficios percibidos
3. Subrayar los beneficios regionales de la agricultura sostenible	• Conversación sobre la economía circular; puede ampliarse en incorporando los beneficios regionales	• Ofrezcan una perspectiva y más detalles sobre cómo los beneficios de sus métodos de agricultura sostenible se extienden más allá de sus fincas individuales y de la comunidad local, hasta el nivel regional

Criterios de evaluación de la visita a la finca	Mantener y ampliar	Adición sugerida
4. Compartir la historia de la finca y sus tierras	• Un enfoque en la historia de ASOPRO y sus miembros • Intercambio franco de objetivos y retos, en concreto el mantenimiento de la identidad de la marca y las dificultades y oportunidades de estar liderado por mujeres en una cultura con mucho machismo • Sigan compartiendo las propias historias que tienen	• Comparten más anécdotas personales de los agricultores cuando sea posible para ofrecer al público historias con las que puedan conectar
5. Ofrecer oportunidades para la interacción y el aprendizaje prácticos	• Ver, sentir y oler los granos de café • Ver y recorrer las herramientas y máquinas de procesamiento y secado	• Amplíen la interacción; den la oportunidad de ver y recorrer todo el proceso de elaboración del café, desde la selección de los granos hasta su consumo
6. La visita da una visión completa del proceso (comprensión del principio de "desde la finca hasta la mesa")	• Conversación sobre la relación entre el perfil del sabor del café y las técnicas de cultivo y gestión de la explotación responsables de esos sabores. • Degustación de café y demostración de su preparación	• Ofrezcan una comida con alimentos de origen local • Den más detalles sobre el café y la producción de alimentos antes, durante y después de la degustación de café y la comida