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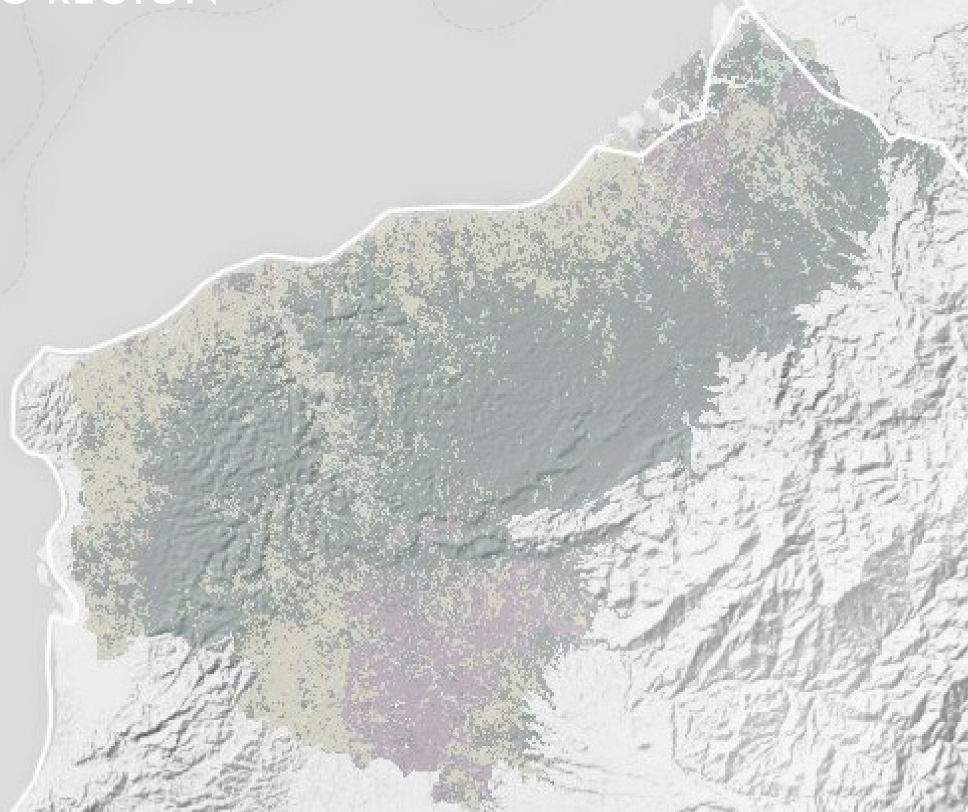
USING INNOVATIVE TOOLS FOR MAPPING THE CHANGES OF THE CULTURAL LANDSCAPE OF THE ECUADORIAN NORTHWESTERN CHOCÓ REGION



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ABSTRACT

The Cultural Landscape concept has evolved into a combination of the importance of nature and the work of humankind. In addition to biological diversity and human interaction, Cultural Landscapes are fundamental for feeding societies by representing their identities and their systems of beliefs (Cultural Landscapes: the Challenges of Conservation, 2002). The adaptation of this concept could be of special interest in developing countries, like Ecuador, because having a new vision of managing unique natural and cultural areas can generate a sustainable economic, social and cultural development for the benefit of the communities that inhabit it, while preserving its heritage (León B., 2018). A unique landscape that fits into these concepts is the Chocó Region of Ecuador that is considered one of the biodiversity hotspots in the world. But beyond its ecological importance, the link between nature and culture and the relationship of the people to the land has an evident distinctiveness and authenticity and it can be explored to start changing the countries' perception of heritage and preservation of valuable sites. Nevertheless, extensive agriculture is significantly this landscape, and in the last 30 years the rapid palm oil expansion has been one of the main drivers for this change. Therefore, to combine historical maps, geospatial data, and a cultural narrative through a mapping process, is key to define what makes the Northwestern Ecuadorian Chocó a 'cultural landscape'. Using Remote Sensing and geographical information system (GIS) techniques it is possible to find tools for planning and developing this cultural landscape in a sustainable way. One of these tools are Land Use and Land Cover Maps. These can be obtained from optical satellite imagery and be used for tracking the changes in a region and are important to delimitate cultural landscapes and to identify its threats and vulnerabilities. Nevertheless, classification with these methods in tropical areas like the Chocó Region, is very challenging due to cloud and fog cover. Seeking for alternative solutions on mapping the cultural landscape of the Chocó Region of Ecuador, resulted in the development of an innovative methodology land cover mapping using Sentinel -1 data. The challenge of this methodology relies in the fact that unlike optical based images that can be assessed by visual interpretation or pixel-based classification, SAR imagery looks very different and needs to be pre-processed and processed in several levels to accomplish a result that removes the speckle effect of the data and allows an accurate classification. The aim of this innovative methodology is to generate multi-temporal land use maps and exploit this information to analyze the main characteristics of this region, its threats and vulnerabilities to raise awareness on the importance of preservation and valorization of its historical and traditional landscape. The analysis carried out is an instrument to understand and characterize the landscape, so it is possible to develop tools to rehabilitate the degraded landscape through the creation of more ecological and sustainable systems. This can result in improving local economy, reduce hunger and poverty, and incentivize a more sustainable way of living.

ABSTRACT
(ITALIANO)

Il concetto di paesaggio culturale si è evoluto verso la combinazione tra l'importanza degli aspetti naturali e il lavoro dell'uomo. Oltre alla diversità biologica e all'interazione umana, i paesaggi culturali sono centrali per nutrire le società, rappresentando le loro identità ed i loro sistemi di credenze (Cultural Landscapes: the Challenges of Conservation, 2002). L'adattamento di questo concetto potrebbe essere di particolare interesse nei paesi in via di sviluppo, come l'Ecuador, poiché avere una nuova visione della gestione di aree naturali e culturali uniche può generare uno sviluppo economico, sociale e culturale sostenibile a beneficio delle comunità che lo abitano, en el comtemmpo prservarne il loro patrimonio (León B., 2018). Un paesaggio che si adatta a questi concetti è la regione del Chocó dell'Ecuador, considerata uno deglo hotspot della biodiversità a livello mondiale. Al di là della sua importanza ecologica, il legame tra natura e cultura e il rapporto delle persone con il territorio ha un carattere distintivo e un'evidente autenticità e può essere esplorato per iniziare a modificare la percezione del patrimonio e la conservazione dei siti. prezioso nel paese. Tuttavia, l'agricoltura intensiva sta profondamente modificando questo quadro e negli ultimi 30 anni la rapida espansione della palma da olio è stata uno dei principali motori di questo cambiamento. Pertanto, combinare mappe storiche, dati geospaziali e una narrativa culturale attraverso un processo di mappatura è la chiave per definire ciò che rende il Chocó del nord-ovest dell'Ecuador un "paesaggio culturale". Utilizzando tecniche di telerilevamento e Sistemi Informativi Geografici (GIS) è possibile trovare strumenti per progettare e sviluppare questo paesaggio culturale in modo sostenibile. Uno di questi strumenti è l'uso del suolo e le mappe di copertura del suolo. Questi possono essere ottenuti da immagini satellitari ottiche e utilizzati per monitorare i cambiamenti in una regione e sono importanti per delineare i paesaggi culturali e identificare le loro minacce e vulnerabilità. Tuttavia, la classificazione con questi metodi in aree tropicali, come la regione del Chocó, è molto impegnativa a causa della copertura nuvolosa. La ricerca di soluzioni alternative per la mappatura del paesaggio culturale della regione ecuadoriana del Chocó ha portato allo sviluppo di una metodologia di mappatura innovativa utilizzando i dati Sentinel-1. L'aspetto peculiare di questa metodologia sta nel fatto che, a differenza delle immagini ottiche che possono essere valutate mediante interpretazione visiva, le immagini SAR devono essere pre-elaborate a vari livelli per ottenere un risultato che elimina l'effetto "speckle" dei dati e consentono una classificazione accurata. L'obiettivo di questa metodologia innovativa è generare mappe multitemporali dell'uso del suolo e utilizzare queste informazioni per analizzare le principali caratteristiche di questa regione, le sue minacce e vulnerabilità per sensibilizzare sull'importanza della conservazione e della valorizzazione del suo paesaggio storico e tradizionale. L'analisi svolta è uno strumento per comprendere e caratterizzare il paesaggio, in modo che sia possibile sviluppare azioni per riabilitare il paesaggio degradato creando sistemi più ecologici e sostenibili. Ciò può portare a migliorare l'economia locale, ridurre la fame e la povertà e incoraggiare uno stile di vita più sostenibile.

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CHAPTER 1: INTRODUCTION

"[I]n its widest sense, culture may now be said to be the whole complex of distinctive spiritual, material, intellectual and emotional features that characterize a society or social group. It includes not only the arts and letters, but also modes of life, the fundamental rights of the human being, value systems, traditions and beliefs; that it is culture that gives man the ability to reflect upon himself. It is culture that makes us specifically human, rational beings, endowed with a critical judgement and a sense of moral commitment. It is through culture that we discern values and make choices. It is through culture that man expresses himself, becomes aware of himself, recognizes his incompleteness, questions his own achievements, seeks untiringly for new meanings and creates works through which he transcends his limitations (UNESCO, 1982)."

Culture can have many definitions, but the most meaningful associations for the term can be that culture is a way of life in a specific group of people, an artistic activity and the collection of common habits of thinking and acting that give meanings to existence. It is the center of distinctive spiritual, intellectual, emotional, and material features that are characteristic of a specific society or social group. It includes the art, architecture but also human modes of life, value practices,
creativity, knowledge, traditions, and beliefs. The definition is inclusive on what makes people human and gives them identity and it can be associated to different places that are meaningful. These places have a fundamental value to the people that have experienced them and the efforts to preserve them as they are, for future generations to share it, is what has raised in the latter the definition of a landscape (Taylor, 2013).

A landscape is a combination of cultural features that is linked with physical attributes of the land with the social and the ecological understanding of how people live. The article 1 in the ELC (European Landscape Convention) it is defined as landscape 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (Council of Europe, 2000). In this convention one of the main concerns has been to include that a territory has to be considered as a whole and that a landscape not only needs to be considered as outstanding but also as every day and degraded landscapes (Council of Europe, 2000). This definition has been widely used since then, and the understanding of a landscape involves having a definition that isn't simply physical, or tangible, but that it can be perceived as visual reality that is also intangible, mental, spiritual and artistic experience (Stefano & Davis, 2017).

These are the places that have a shared heritage that needs to be preserved through cultural sustainability, which is the connection of people and the environment in an efficient way that can give a community a social and economic value. From the need to preserve the different features and characteristics of communities, cultural resources by identifying them and recording them, emerges 'Cultural Mapping' (Taylor, 2013).

Mapping components that are physical components but are also intangible like memory, meaning and values of a society are a crucial tool to preserve culture but with a methodology that can make these aspects more visible so they can be used in many ways. The information gathered through cultural mapping is a tool that can be used for conserving a cultural landscape, for planning, and for developing it in a sustainable way that it increases its value (Taylor, 2013). Nevertheless, still with this tool, there is often neglect and inappropriate development of landscapes that increases the risk of losing its legacy. This is the case of many countries in South America, and more specifically, of Ecuador.

Ecuador is a developing country that depends on its soil's quality and environmental resources to maintain its economy. Most of the productivity unit of this country relies in familiar agricultural practices. (FAO; CAF, 2009)It is also a very rich country from the environmental point of view, the outstanding climatic features has allowed some of its regions to become some of the world's biodiversity 'hotspots' (Ministerio del Ambiente del Ecuador (MAE), 2014). But in recent years the variety of ecosystems and endemic species have had a great loss due to the expansion of agriculture. Particularly, the coastal plain where the tropical rain forests extend, known as the Chocó Region, has had a great loss of natural habitat, but also many cultural characteristics of its cultural landscape. As a developing country, most economic efforts are directed towards developing its agricultural sector and industries but has disregarded the importance of the preservation of places that constitute an important role in some societies lives. One of the most harmful trends in the last 30 years has been the expansion of palm oil plantations in Ecuador, but more importantly, in the Ecuadorian Chocó Region. Although it started as a more effective crop that substituted other present in the area, it has deleted a big portion of the landscape of the region. Unfortunately, keeping track of palm oil plantations expansion is challenging with the current availability of data in Ecuador and field methods are difficult to have accuracy.

Preserving the cultural landscape of the Northwestern Ecuadorian Chocó Region can be achieved with a deep understanding of all its cultural features and collective value. Nevertheless, agriculture is having an immense impact on this region, agriculture is the highest consumer of natural resources and it is responsible for extensive land clearance for agricultural fields and plantations. The emphasis of this study is the importance of the use of accurate land use maps and the analyses that can be achieved with them. Multi-temporal maps that combine information of historical maps of land use with produced land use maps, can help understand the previous delimitations of the territory and observe what elements of the landscape maintain continuity and which are being interrupted or deleted. Then, after land uses have been identified a biophysical criterion is set and it is articulated with other cartographic maps that include climate, hydrography infrastructure, elevation, population patterns (León B., 2018).

To understand if the changes of the region are balanced or in line with the preservation efforts of the cultural landscape, the most important indicator to is the identification of the land use change's type and magnitude. Land use/ land cover (LULC) maps are extensively used for understanding land cover information and the changes regionally and nationally. Generally, satellite imaging allows to have high quality images taken from satellites that cover the entire globe. Satellite data such as Sentinel-2 products from the European Space Agency (ESA) are optical sensor-based, which means that depend on solar energy to capture electromagnetic energy that is being reflected by elements on the earth's surface. MODIS, Landsat, Sentinel-2 and other optical imagery are used in classification methods that have been used extensively explored. (Ramdani, 2019). Nevertheless, classification with these methods in tropical areas like the Chocó Region, are very challenging due to cloud and fog cover. There are other methods that can produce accurate results, but most of them are not available for free and are difficult to achieve in developing countries. Therefore, seeking for alternative solutions on mapping the cultural landscape of the Chocó Region of Ecuador, resulted in the development of an innovative methodology of mapping using Sentinel -1 data. Unlike other satellite sensors, Sentinel-1 uses its own instrument to reflect energy from the earth and is an active radar sensor that does not depend in solar energy and can penetrate cloud cover and ground level cover. The complication of this methodology relies in the fact that unlike optical based images that can be assessed by visual interpretation or pixel-based classification, SAR imagery looks very different and needs to be pre-processed and processed in several levels to accomplish a result that removes the speckle effect of the data and allows an accurate classification.

Lastly, using this methodology were created multi-temporal images that allowed a stronger precision for land -use maps and deeper analysis in how the land cover was in past decades in comparison to now. This study has made possible to quantify the loss of tropical forests and land use in the region, identify the main drivers of the land use change, and identify the most vulnerable areas that need to be protected the most. Finally, this study allowed to identify the most important threats to the Ecuadorian Northwestern Chocó Region and understand the role of the expansion of the palm oil plantations in the loss of its cultural landscape. This study can be explored further to use this methodology for monitoring the expansion of palm oil plantations nationwide, but also as a reference on understanding the importance of this region and as a reference on the planning tools that need to be strengthen, regionally and nationally, to help preserve this landscape and other important ones in the country.

Aim

The aim of the thesis is to combine historical maps, geospatial data and a cultural narrative through a mapping process, into the definition and frame of what makes the Northwestern Ecuadorian Chocó a 'cultural landscape'. With an innovative methodology of mapping it is possible to study the collective value of the region and to identify the main threats for preserving this landscape, specifically the palm oil plantations that have significantly expanded in the region. By using remote sensing, geographical information system (GIS) techniques and this innovative method to create land use maps, it is also possible to define main drivers for palm oil plantations and cultivation, one of the main features that in the recent years characterize this area, and define monitoring measures that can to protect the most vulnerable areas for the palm oil expansion and the areas that can be recovered.

CHAPTER 2: LITERATURE REVIEW

2.1 Cultural Landscapes and The Chocó Region of Northwestern Ecuador Case Study

2.1.1 The Choco Darien

Amongst many efforts to preserve biodiversity, both worldwide and regionally, the WWF (World Wildlife Foundation) has implemented a tool to identify and mark the most biodiverse places in the world that are threatened by human action. This tool is a map is a biogeographic framework to highlight those areas that have unmistakable or have high representation value and are in this way deserving of more noteworthy consideration. These areas with high biodiversity value are then recognized as the world's biodiversity 'hotspots' with high risk of degradation. The subdivision of these extensive areas is called ecoregions. Ecoregions were positioned in rank by the peculiarity of their biodiversity highlights—species endemism, the rarity of higher taxa, species richness, abnormal biological or transformative phenomena, and worldwide uncommonness of their territory type. Ecoregions can likewise be ranked by dangers to biodiversity, the status of their characteristic living spaces and species, and level of assurance. (Olson, et al., 2001)

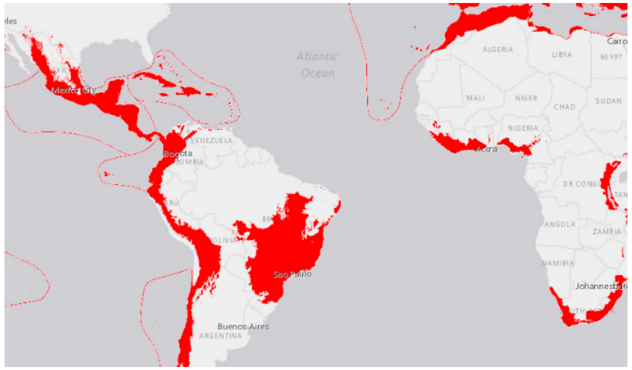


Figure 1 Biodiversity Hotspots. [Source: (Olson, et al., 2001)]

In South America, there have been recognized some areas as biodiversity 'hotspots'. The Amazon region that covers most of Brazil and other countries including Ecuador, the Paramo in the Northern Andes (highlands) and the Choco Darien ecoregion that consists of the extension of the Humid Tropical Forests between the Pacific Coast and the Andes (Olson, et al., 2001).

The Chocó-Darién ecoregional complex ranges across roughly 17 million ha, from Eastern Panamá to Northwestern Ecuador (Figure 2). It is one of the most biodiverse areas on the planet, perceived for its large number of woodland and freshwater ecosystems, including mangroves, estuarine timberlands, swamp and montane downpour forests. These unmistakable highlights all add to its biological peculiarity. There are approximately 7.500 types of plants (of which 1.300 are endemic, 700 different types of butterflies and 1.500 species of birds. Because of its key area at the intersection of the migration courses of various species, its waterfront biological systems harbor significant populaces of marine turtles, shorebirds and also, humpback whales. (WWF Colombia, 2014)

Additionally, the Choco-Darien is a very multiethnic region, it is the home of nine indigenous groups, various Afro-descendent communities, and a developing mestizo populace. Some indigenous domains coincide with national reserves and this type of land residency favors preservation and economic development at a regional level, as both conservational efforts, cultural and biodiversity, can be addressed simultaneously.

2.1.2 Preservation of the Cultural Landscape of the Choco Region of Ecuador

As the world's changes have become more evident in recent decades, the effort to preserve the most important places has become a priority worldwide. There are efforts worldwide to preserve the natural environment of which all living species depend on and there are efforts to preserve the cultural values of different places that provide identity to its inhabitants. And to protects these places, World Heritage has come into play, as a way to ensure that such important places are preserved and last for generations to come. In the UNESCO World Heritage Convention in 1972 the typology of Landscape was incorporated as natural heritage in which there is 'interaction between man and his environment' (Cultural Landscapes: the Challenges of Conservation, 2002). Then, At the World Heritage Convention in 1992 the concept of Cultural Landscape was introduced, and it became a recurrent and evolving concept that combines the importance of nature and the work of humankind. Cultural Landscapes are more than just places, but they represent identities and the systems of beliefs worldwide. They have also delivered more than just biological diversity in the blended with human interaction for times but are also fundamental for feeding societies. These important landscapes are home to native populace and have richness in intangible aspects as well. They encompass cultural diversity that is key for sustainable practices (Cultural Landscapes: the Challenges of Conservation, 2002).

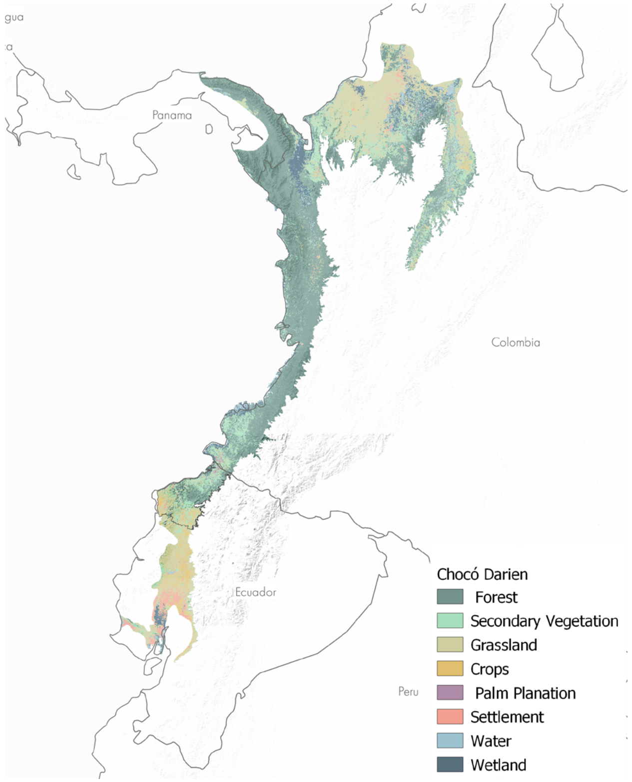
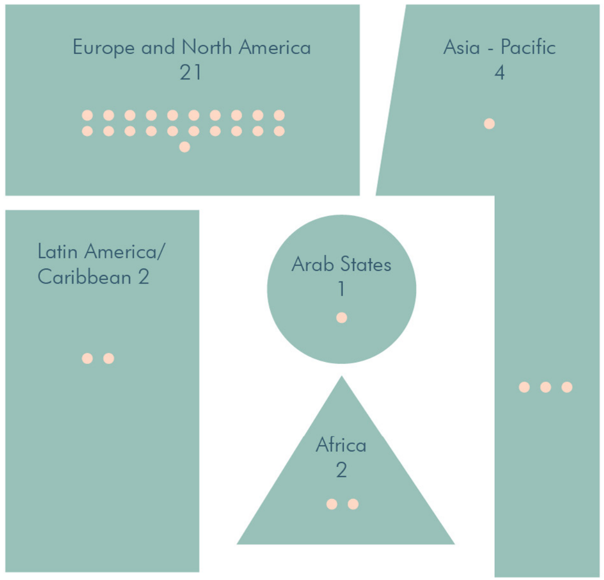


Figure 2 Chocó-Darien extension. [Source: (Fagua, Baggio, & Ramsey, 2019)]

The concept of World Heritage Cultural landscape has been highly embraced in America and even more in Europe, but the concept in Latin America and the Caribbean (view Figure 3) has made almost no impact, and therefore, has been highly disregarded. There is an evident mismatch in the fact that Between Europe and America the

Figure 3 Schematic World Maps Showing Distribution of Cultural Landscapes by Region. [Source: (Cultural Landscapes: the Challenges of Conservation, 2002)]



list makes up for 21 Cultural Landscapes, and for the rest of the world there are only 9. The problem relies on many factors for this unevenness, but mostly because of a lack of nominations from other parts of the world in which expressing their culture is perceived differently (Cultural Landscapes: the Challenges of Conservation, 2002). Perhaps it's the fact that this concept has not been familiarized in other regions in the world, and that heritage is only to be preserved when it is natural or cultural, but not perceived as a whole landscape with intrinsic characteristics of both aspects.

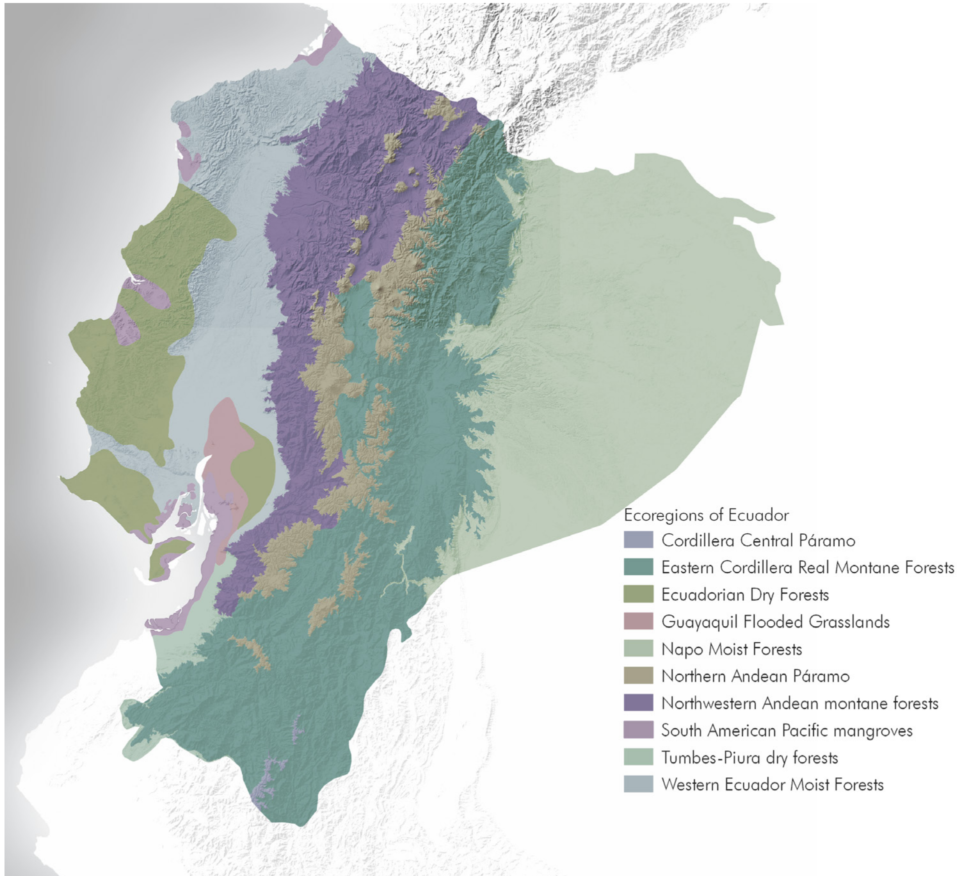
Nonetheless, the evolving concept of Cultural Landscapes should be of special interest in developing countries since already UNESCO's Word Heritage sites have been an important tool to attract tourism and encourage economic development. Nevertheless, Cultural heritage sites have managed to give private entities economic benefits, but not necessarily the heirs of these sites. The recent global ecological awareness has encouraged to have in the Cultural Landscapes categories, category V that incorporates protected areas (Cultural Landscapes: the Challenges of Conservation, 2002). And in this situation, the relationship between ecological problems and social inequity become intrinsically inseparable. Cultural Landscapes are the result of human action in nature, and so ecological problems are strictly linked with exploitation and poverty issues. (Álvarez M., 2011). The exploration of this concept in Ecuador can be a tool for a better understanding how to protect and manage landscapes that have unique characteristics but that are endangered. Whether these unique areas are natural, productive, cultural, or geographic, the population that inhabit these areas can learn how to protect it and benefit from it. This tool can allow to have a better understanding of the entire Ecuadorian territory and define planning and management instruments that for a sustainable development (León B., 2018).

To explore the concept of Cultural Landscapes in Ecuador, it is needed to define what are the main steps. First it is necessary to identify potential landscapes, then characterize them, consequently, delimitate them, and finally, the valorization. Once the landscape has been valorized it can be presented to the relevant institutions for validation and further intervention in the area. For the identification process it's important to have an overview of the main characteristics of Ecuador.

With a territory of 277 thousand km2 and a population of around 14 million occupants, Ecuador, although it is one of the smallest nations in South America, has a very dense population. Its mainland regions can be contrasted not only by its topographical features, but also financial and ethnic-social differences: each one of them with significant development issues. Moreover, Ecuador is a multiethnic nation, and in this manner multicultural for further detail).

The current population growth in Ecuador is around 1.8% ev-

Figure 4 Ecoregions in Ecuador



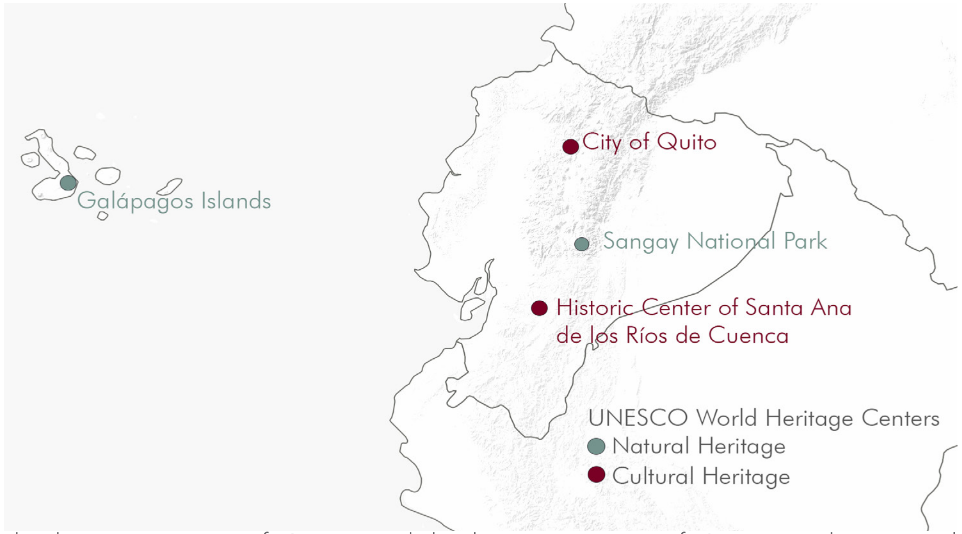
ery year and the Gross Domestic Product (GDP) per capita is approximately at US $ 2,500 (2005), distributed unevenly. Therefore, the poverty, characterized by the standards of Unsatisfied Basic Needs, impacts 61% of the country's population. Despite the dollarization of the financial system in the end of the 90's, Ecuador's economy yields a poor social and financial landscape, particularly to the rural population that is the one that experiences the greatest insufficiencies (FAO; CAF, 2009). Ecuador is a country in South America whose location and relief have divided the country into three Continental Regions, the Coastal Plain, Highlands and Amazonia (Figure 5). The Andean ridge separation gives place to differentiated climatic patterns that have offered a spot to a set of various ecosystems and species for which Ecuador has been named one of the biodiversity hotspots on the planet (Moreno, Bernal, & Espinosa, 2018).

All three main continental regions, in addition to the Galapagos Islands, have distinguished Ecuador as a megadiverse country in the world and has the most biodiversity per square kilometer of any nation (Secretaría Nacional de Planificación y Desarrollo, Senplandes, 2017). The exceptional biodiversity is enhanced by a considerable lot of endemic species to the nation's regions that are dependent upon various sources of anthropogenic behavior. Despite national and subnational preservation efforts to monitor the biodiversity, the National System of Protected Areas (PANE) and the Socio Bosque program (PSB), further activities are needed to moderate and converse the impacts and the threats of biodiversity nationwide (Cuesta, et al., 2017).

Ecuador started to take part in the UNESCO World Heritage Convention in 1975, and since 2012 Ecuador has included in the World Heritage List (Figure 6), 2 cultural sites and 2 natural sites. The outstanding universal value of the cultural sites relies in being among the best-pre-

Figure 5 Biogeographic regions of Ecuador. [Source: (Ministerio del Ambiente del Ecuador , 2012)]

Figure 6 UNESCO World Heritage Centers in Ecuador. [Source: (UNESCO, n.d.)]



served historic centers of Latin America, which are the historic center of Quito and the historic center of Cuenca. The natural sites are the Galapagos Islands for having become a living museum and showcase of evolution, and the Sangay National Park because amongst two active volcanoes there is a wide range of ecosystems of Ecuador (UNEP-WCMC, 2017).

Currently, this hotspot for biodiversity in the Chocó Region is not considered a World Heritage, neither for natural nor cultural value. But, the importance value of the Chocó lies beyond its ecological importance, as it relies in its link between nature and culture and the relationship of the people to the land. Furthermore, the landscape has co-evolved with the communities in the area and is based in its interaction between humans, nature, and time. And because this landscape is rich in biological diversity and other natural values, its future relies on sustaining people's relationship to the land itself, and its resources (Brown, Mitchel, & Beresford, 2005). Therefore, this region has been recognized as one of whose landscape has an evident distinctiveness and authenticity and it can be explored to start changing the countries' perception of heritage and preserve valuable sites. For which reason it has been identified with potential to be considered a Cultural Landscape in Ecuador, as it possesses certain peculiarities, and singular natural characteristics. For the characterization of this Cultural Landscape it is important to integrate, delimitate, and the evaluate expressions and characteristics that constitute the different dimensions of the landscape. The first characterization is the Biophysical characterization that constitutes those components that establish structure and ecological function of the region. Geography, fauna, vegetation, and climate.

Each element is interrelated with each other, so it is important to also acknowledge also how humans handle and manage the nature of this landscape.

1. Biophysical Values

The coastal region extends from the coastal profile to about 1000 m elevation in the western foothills of the Andes. It is approximately 670 km long and 150 km wide, from the Mataje river to the north to the Zarumilla river to the south. It is made up of low plains, sedimentary basins, foothill areas and several low-lying coastal ridges, which reach elevations between 400 and 700 m in height. The coastal mountain ranges found in the Northwest region are Mache Chindul and Cojimíes.

The Chocó has different bird species that, including migratory ones, the number is approximately 830, of which 85 (10.2%) are endemic. There is also great diversity and endemism of mammals, with 235 species of which 60 (25.5%) are endemic (CEPF, 2005). On the northwest part of the region there are at least 91 species of amphibians, 149 reptiles, 400 of birds and 133 mammals which makes it one of the richest regions in the country (Vázquez, Freire, & Suárez, 2005).There are many species in this region that are endangered and that are a primary concern, for example the Jevon Forest, south of Esmeraldas province, is the home of the spider monkey, which is an endangered species because of habitat loss. The scientific name of this monkey is Ateles fusciceps fusciceps (Proyecto Washu, n.d.).

There are two main types of characteristic vegetation in the Chocó Province: the evergreen lowland forests and the piedmontal forests of the western mountain range. Lowland forests (Figure 9) are characterized by presenting a canopy close to 40 meters, with a high diversity of lianas and epiphytes, many of they are endemic. In contrast to the Amazonian Tropical forest its tree richness is less but the proportionality of singular species is greater. Likewise, the richness of species of epiphytes, lianas and vines is greater than in the Amazon. In permanent plots of one hectare, it has been recorded between 110 to 120 tree species. The canopy is approximately 40 m high and is continuous with few gaps. The absence of gaps and relative abundance of large trees are characteristics that differentiate them from the Amazon forests where the gaps are more frequent and there are fewer large trees (Ministerio del Ambiente del Ecuador , 2012).

Most of the humid tropical forests of the Chocó are found mainly in the province of Esmeraldas, to the northwest of the country, although they extended historically south to the provinces of Guayas and Los Ríos. The most dominant forest formation is the ever-

Figure 7 Extension of Chocó Region in Ecuador (Western Ecuador Moist Forest)


Figure 8 Spider Monkey in Jevon Forest. [Source: (Proyecto Washu, n.d.)]

green forest of the lowlands, which reaches 300 m altitude and is dominated by tree species of the families Myristicaceae, Moraceae, Fabaceae and Meliaceae. The diversity of life forms is such that, for example, in just one hectare of forest more than 100 tree species have been found tree species of more than 10 cm of dap (10 parcels of 10x100 (Vázquez, Freire, & Suárez, 2005).

The temperature and rain, in the near coastal area are impacted by the cool Humboldt current that streams north from Chile to Ecuador, and changes east at about the equator, where it meets the warm central current that streams southward from the Gulf of Panama. Consequently, the coastal areas have moist air throughout the year, intensifying precipitation from December to April, and decreases among August and November, when the cool current predominates (Justicia, 2007). The province of Choco is characterized by a humid pluvial bioclimate (e.g, La Concordia) to a hyper-humid one (e.g, La Tolita) with precipitation values ranging from 2,000 mm to 7,000 mm. The annual temperature fluctuates between 23-27ºC with slight seasonal variations of just 2 to 3ºC between the warmest and coldest months (Ministerio del Ambiente del Ecuador , 2012).

Based on the combination of all this biophysical values, the Chocó Region landscape is regarded as unique because its forests are viewed as areas of incredible biodiversity significance because of the high amount of species and endemism present (Parker and Carr 1992). Hence and because of the effect of human action, it has been named an ecoregion with greatest local protection need (Dinerstein et al. 1995). Although the Colombian portion of the Choco is considered by some researchers the most floristically diverse of the region, the Ecuadorian Chocó is evaluated to sustain 25% of the country's vegetation, of around 6,300 species of plants, 13% to 20% of which are endemic. The

Figure 9 The village of Wimbi lies in Ecuador's northern province of Esmeraldas. [Source: (Brown K. , 2018)]

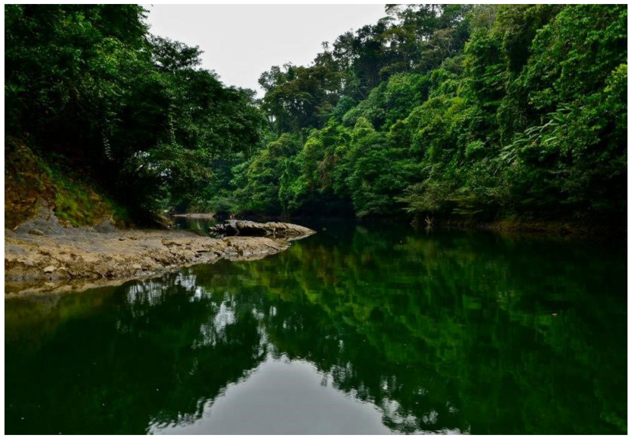


Figure 10 Forest in Esmeralda Province [Source: (Morales, n.d.)]

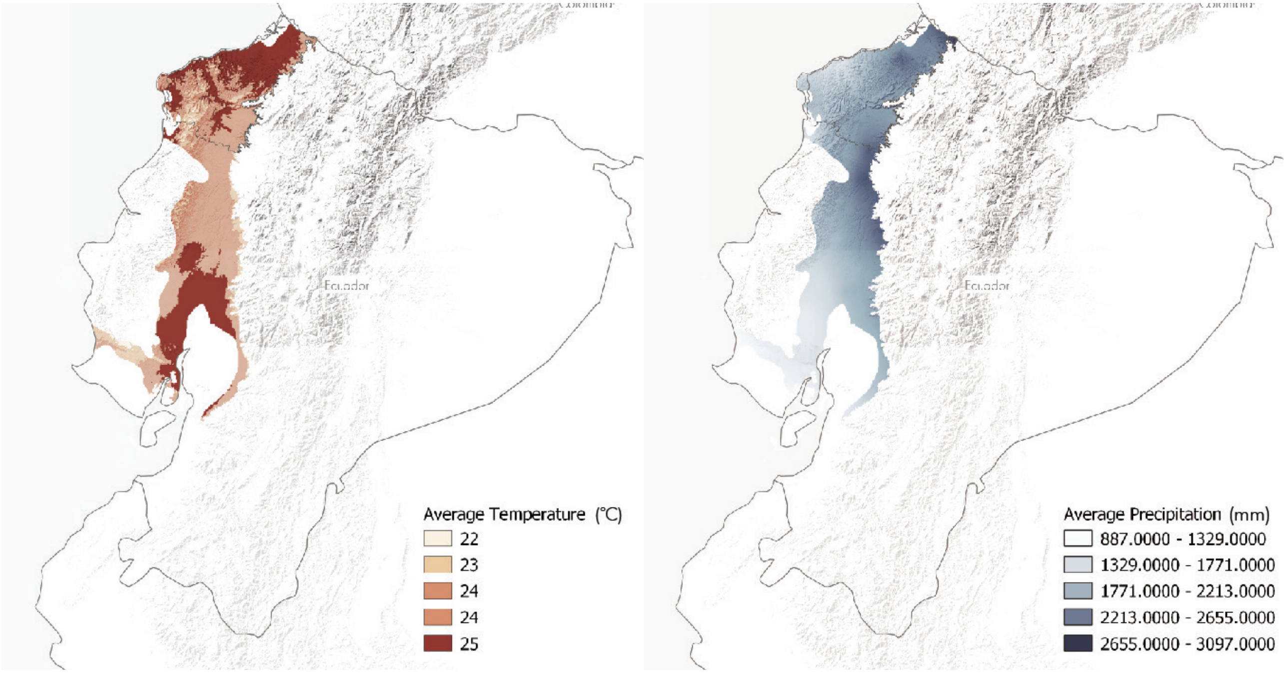


Figure 11 Climatic Patterns of The Chocó Region

region is additionally home to more palm species than some other place of the world (CEPF, 2005).

The importance of the Chocó resides not only in the great variety of endemism and biodiversity, but also in the fact that the fragmentation of the ecosystem could be the key by which the species specialized and diversified. Numerous families, genera, and species appear to be normally compelled to heights underneath 2,300-2,500 meters, and many are incredibly confined. The area shows countless vegetation types, for example, thorny desert scrubs, to the seaside hilly coastal areas. While a premontane vegetation takes over on the lower regions and slopes of the Andean range amid the 300-900 meters of altitude that also contain specialized and endemic flora (CEPF, 2005).

Moreover, besides the flora diversity, the fauna is of great variety as well. For example, the bird species, that includes migrant species, have a variety of around 830 species, of which the 10% are also endemic. Additionally, the population of mammals is also of great importance with around 142 species, of both marine and land, of which also around 10% are endemic to the area. There are roughly 350 types amphibians, including 210 endemics (60%), and 210 types of reptiles, 63 (30%) endemic. Many of these species are, like turtles and some amphibians are endangered species or threatened (CEPF, 2005).

The climate of the Chocó is also very favorable for agriculture expansion because it has a fertile soil that allows many productive activities. Particularly, the coastal plain is very renowned for agricultural expansion and economic dynamism which poses a conflictive choice between production and environmental conservation. For this reason, the Ecuadorian portion of the Chocó-Darien is highly endangered. This Cultural Landscape has a delicate balance of nature that is essential for the survival of its inhabitants, but also from Ecuadorian population.

2. *Agro-historical Value*

The Cultural Landscape of the Chocó can be described as the transformation of the natural value described hereabove, but shaped, used, managed, and enjoyed by its inhabitants and its own cultural patterns. One of the most significant values is its agricultural landscape that has a rich cultural variety that has preserved but needs further preservation efforts of historical practices that were more sustainable than modern ones. To understand these characteristics of the agro-historical value it's important to have an overview and background on how this landscape has been shaped.

In the 19th century plantations were in the hands of landowners, these were worked by slaves or workers under the system called 'concertaje' or 'concert of workers', by which they agreed to work for a certain owner in exchange for a wage. The cultivation of cocoa on the coast was the main export item for this period. The large plantations were forged by expropriation of land of small farmers, peasants and indigenous people, as well as under the illegal appropriation of public lands. In this way, the former owners would end up becoming day laborers and sowers of the new owners. This colonizing process was decisive in the coastal territorial development, as well as the migratory waves arriving from the inter-Andean floors that made up the semi-salaried workforce on the plantations.

Then in the period 1920-1948 happened the Cocoa crisis and the United Fruit Company entered the country. The North American company would be installed as Compañía Bananera del Ecuador in Guayas where the South American Fruit Company of Chilean origin also operated. And consequently in 1948 the banana production boom began on the coast and with this crop is transformed also the social and productive landscape. This Compañía Bananera del Ecuador, also operated since 1948 in the province of Esmeraldas, the Fruit Trading Company (Carrillo García, 2013).

The period of 1957-1976 was marked by conflicts between peasants and landowners, the latter supported by the army, sometimes belonging to the same hacienda. These events became serious after the banana crisis of 1962 and the siege of farms of the banana companies. Thus, there were union movements taking relative strength, that consequently led to the Agrarian Reforms. (Carrillo García, 2013). The Agrarian reforms resulted in a division of land of big farms 'or latifundios that had already affected the primary forests in the region' (Nápoles, 2020).

The Agrarian Reforms began in an international context determined by productivity and modernization demands that had to be applied in rural countries with primary economies, supplying markets and expansive industry of the golden years in developed countries (Carrillo García, 2013). For this reason, the agricultural history of Ecuador, and more importantly of the Northwestern Chocó Region, has always been strictly linked to market prices and demand and still is.

As mentioned before, one of the most exceptional issues related with country development is the high concentration on land ownership. As indicated in the Census of 2000, 64% of the Agricultural Productive Units (UPA) are farms of size under 5 ha, which possess scarcely 6.3% of the total area; on the contrary, just 6.4% of the UPA are farms are bigger than 50 ha but have 61% of the surface (FAO; CAF, 2009). The lack of competitiveness of the agricultural sector is also essentially lower than those of different nations in the hemisphere, and because a great portion of the territory is tropical or subtropical it is suitable for the production of various export products, deforestation is affecting the entire country.

The rural economic activities of this region have mainly a family farming structure with an extractivist component. Agriculture is mainly characterized by using family labor, it has a marked dependence on the goods and services provided by the natural (ecological) environment and its own agroecosystem. Additionally, the agriculture also works on a small and highly diversified production scale and the communities have developed its own technologies adapted to its ecological, social and cultural condition. Families have fields for cultivating mainly permanent crops, like palm oil plantations, coffee, and cocoa plantations in addition to the use of natural forests and cultivated forest for the lumber industry and livestock development of beef mainly meat. Large areas prevail as data protected areas that are an important basis for tourism. In the province of Esmeraldas, the main product is oil palm, second is cocoa. Following, dried almonds, bananas that is destined for self-consumption or local markets (GADPE Prefectura Esmeraldas, 2015). In the Esmeraldas province, there are many rural communities that have a direct relationship with the resource that forests provide. In the Ecuadorian coastal line are the mangroves, which are very important life zones for their ecosystem functionalities; and around these inhabit populations that depend to a high degree on these forests (GADPE Prefectura Esmeraldas, 2015).

In Esmeraldas historically the type of construction (Figure 12) consisted on elevated houses of medium to high heights, using wood or cane for pillars, the whole construction was made with light materials: wood, cane, leaves, etc, and the roofs were either gable or hopped roofs made of palm tree leaves or other ecological materials. The reason why this particular type of housing should still be used is because it is of an ecological nature, at the same time that it already constitutes a cultural tradition. Moreover, in

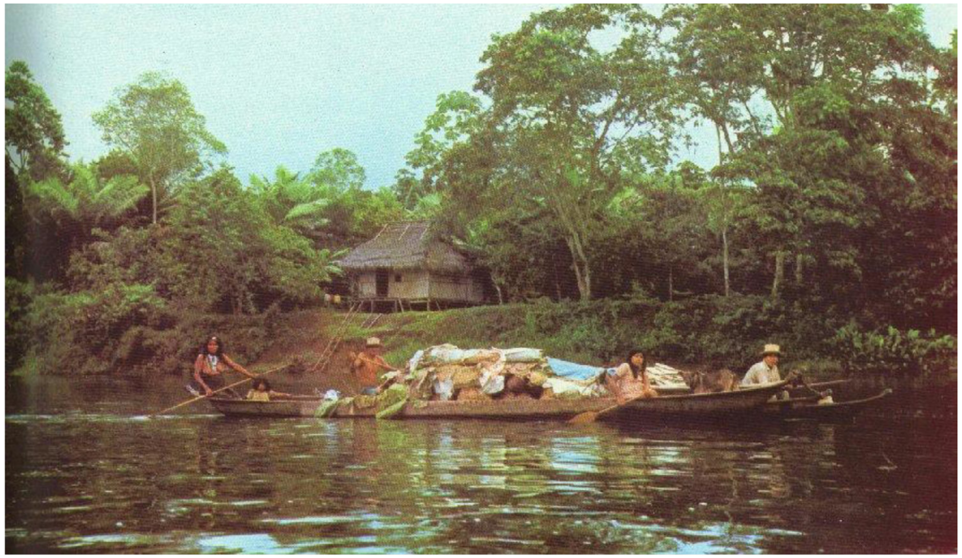


Figure 12 Typical landscape of the Esmeraldas region, with vernacular architecture and canoes manned by Indians. [Source: (Camino Solórzano, 1998)]

a hot and extremely humid climate, the elevated housing provides a better aeration and isolation from soil and flooding (Camino Solórzano, 1998).

3. *Socio-historical Values*

The Cultural Landscape cannot be understood as an isolated element, but as combination with human interactions. For which reason, to perceive the socially and culturally constructed landscape its important understanding the culture and traditions of its inhabitants. The people that live or own land in this region have a notorious sense of stewardship, as its needs are deeply dependent of its natural surroundings. There is an essential role of the communities is that the cultural features of the landscape have been kept alive because of their wealth in knowledge of the place, they still use traditional management systems, and they love managing the landscape (Brown, Mitchel, & Beresford, 2005). For example, the Chachi community by being located in the National Reserves of Mache Chindul, and the Mangroves of Cayapas-Mataje.

The Chocó-Darien is a multi-cultural area that hosts various indigenous groups, afro-descendent communities, and an expanding mestizo (mixed-raced) population (view Figure 12). Moreover, many of these territories where indigenous communities live are overlapping with national parks and reserves which favors preservation efforts by regional authorities (Gomez, et al., 2014).

In the region and in general in the country, the Afro- Ecuadorian communities are concentrated in the Province of Esmeraldas, their settlements cover approximately 800,000 hectares, mostly along Esmeraldas' rivers. They located in this region of the country after the ban of slavery in Ecuador in an attempt to find an isolated area where they could feel safe. Unfortunately, their economic and social discrimination still causes them to abandon their lands migrate to bigger cities and towns, where many falls into a vicious cycle of poverty. Moreover, due to palm oil and forest extraction their poverty has aggravated when they have been forced to displace. Their

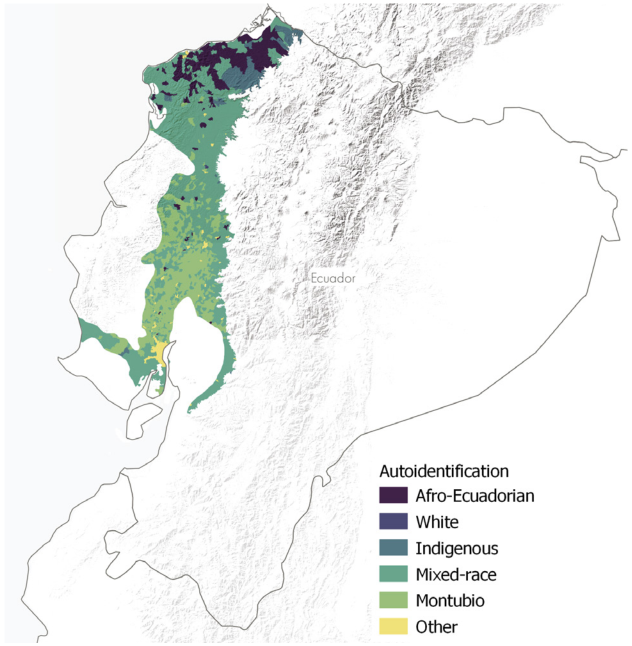


Figure 13 Ethnic groups in Ecuador according to their own auto-identification group. (Intituto Geográgico Militar Ecuador , 2010)

Figure 16 People from Chachi Community in Esmeraldas. [Source: (Hablemos de Cultura - Chachi, 2019)

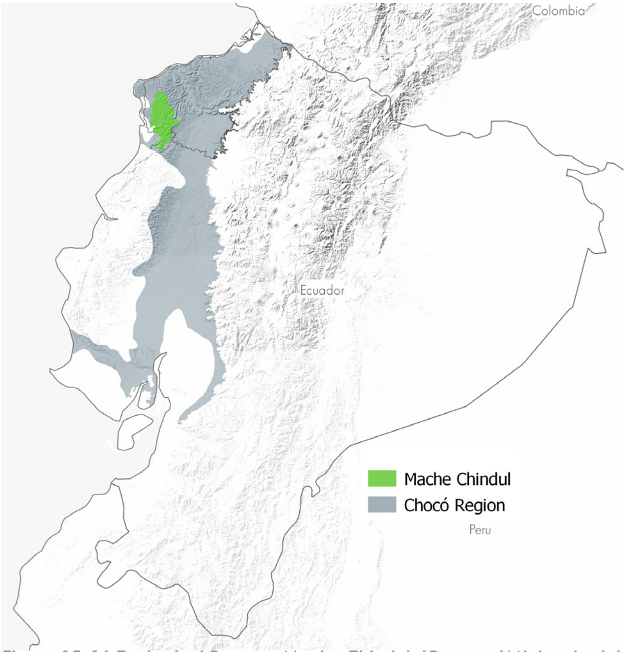


Figure 15-16 Ecological Reserve Mache Chindul. [Source: (Ministerio del Ambiente del Ecuador (MAE), 2014)]


Figure 15-16 Ecological Reserve Mache Chindul. [Source: (Ministerio del Ambiente del Ecuador (MAE), 2014)]

legal rights to their lands is facing many problems with the economic pressure the country is facing, denying them a prompt solution (CEPF, 2005). According to the census carried out in 1990, the indigenous communities (Chachi and Awá and Epera) only represent a 5% of the population in Esmeraldas (less than 5000 people) (Vázquez, Freire, & Suárez, 2005).

The Chachi communities have settled in Esmeraldas in the cantons Muisne, Quinindé, Rioverde and Eloy Alfaro. Its natural cultural identity is highlighted by the Chapala language, which is transmitted from generation to generation despite the influence of civilization and the Catholic religion. Currently, they also maintain their diet, their free and reserved way of life with the colonists, the mingas, fishing, hunting wild animals, traditional festivals and their organization (Diario La hora, 2015). Currently they are in charge of the Ecological Reserve Mache Chindul which is one of the most important in the region.

The relationship of this community with its natural environment is that the lifestyle is free, and their main food source is agriculture, fishing, hunting wild animals. They have a collective property where they grow bananas, plantains, cassava, and raise some domestic animals. They fish and collect shells, and love many species of animals that live in the jungle (Hablemos de Cultura - Chachi, 2019).

The Epera communities are located in the Province of Esmeraldas in the canton Eloy Alfaro and their language is the 'siapadee'. It is composed by 6 communities. Their costumes are linked to community work and time dedicated to nature. Its economy is based on agriculture in small family farms, harvesting, fishing and hunting for self-consumption. Towards the market their main focus are crafts, mainly basketry; There are also a good number of people who work as wage earners in large agricultural farms in the area and in logging companies. (Hablemos de Cultura, 2019).

The Awá communities are multi-national as they are both settled in Ecuador and Colombia. The symbol of their identity is their language the 'awapít'. They live in small communities of extended families, distant from each other. The houses are built on wooden stilts with high walls and gabled roofs (Diario La hora, 2015). The approximately 3,500 Awá indigenous people in Ecuador live in 22 villages that have joined the Federation of Ecuador Awá Centers (FCAE). The Awá live in extreme poverty and permanent threat on the Pacific coast in the border area with Colombia. Despite legal recognition of their territory, timber, palm oil, and mining companies, as well as settlers and land speculators, are trying to seize the land and its natural resources. Due to the great power of the lumberjack companies over the legal system, in most

Figure 17 Girl from Epera Cumminity in Esmeraldas. [Source: (Hablemos de Cultura, 2019)]

Figure 18 Photograph from the indigenous community of Awá. [Source: (Hablemos de Cultura, 2019)]

cases, legal disputes came to the detriment of the Awá. The protection of the Awá territory is, therefore, of international importance. FCAE (Federation of the Awá Center of Ecuador) counteracts pressure from external actors with alternative programs, which may include: its own school and health system, which includes sustainable forest management of the legal community, activities in agriculture and crafts, work with women's groups, and strengthening of the organization (Hablemos de Cultura, 2019) .

Esmeraldas, in addition to Afroecuadorians, Chachis, Eperas and Awá, also has ethnic groups such as the montubio and the mestizo. The Montubio is a farmer, who geographically and demographically is located, settled, and concentrated in the rural area of the country's tropical coast. Preferably, they live and develop their particular 'Montubio' way of life in the provinces of Guayas, Manabí, Los Ríos, El Oro and the southern part of Esmeraldas. The mestizo (mixed raced) is the result of the multiple biological and cultural mixtures that occurred due to the arrival of the Spanish people in the 15th century (Diario La hora, 2015).

All these communities of different ethnic groups live in extreme poverty which account for one of the Highest Basic Unsatisfied Needs Indices (NBI) of the country. Because of many remote locations and difficult

access to the villages where many communities are located, public sanitation services are almost nonexistent, while, in the rest of Ecuador, they are in consolidation. The educational situation is a good reflection of the historical social exclusion that these communities live in. The percentage of illiterate people exceeds 15%, while the Average national indicator is 6.8%. Nowadays, to adapt to economic pressures Ecuador is enduring, the government has allowed to continue exploiting this region.
But the environment, the forests and the settlements are being highly affected by the extractive activity that has exponentially intensified by the entry of new intensive extraction methods and mainly by the unfair agreements that the loggers are doing with the forest-owning communities (unfair payments on valuable wood, opening of roads through forest extensions without paying, etc.) This has involved deep problems of land trafficking in conditions of conflict, pressure, illegality and inequity. In 2013, the Ecuadorian state has decreed the State of Exception in Esmeraldas but there were no substantial improvements in deforestation and it continues to develop irrationally (Comité para la Eliminación de la Discriminación Racial de Naciones Unidas (CERD), 2017).

2.1.3 General Threats for the Preservation of the Chocó in Ecuador

There are currently NGOs and Governmental organizations protecting different areas of the region, but there is still potential endangerment to the humid tropical forests. Deforestation has generated an issue of fragmentation of natural ecosystems and landscape degradation.
The delimitation of protected areas falls into different classifications among National Reserves, National Parks and Protected areas. All of which comprise 1.7 million hectares of the Chocó region, but still falling short into protecting the forest's fragmentation. Many human activities pose different threats to this valuable area. The main threats are deforestation, intensive agriculture, road construction, illegal timber extraction and population growth (Justicia, 2007).
Deforestation is an important threat that is deleting the landscape. The main driver of poor management are settlements and development of farming due to poverty, land shortage, and populace development. Poverty in the rural areas pose a threat to deforestation because farmers convert forested land close to the communities for cultivation and cattle (CEPF, 2005). Speculation on land value and conservation policies is also a driver of deforestation, areas that are not protected can be cleared and claimed by locals allowing them future expansion when needed.
I ntensive agriculture in one of the primary direct drivers for deforestation, and therefore, a threat to the Chocó-Darien region (deeper analysis in Chapter 3.2.2). The extensive production of the main export products of Ecuador are displacing forests, watersheds, and wetlands. These products, although also consumed nationwide, that are plantain, cocoa, cacao and palm oil have a high trade demand and impact in the country's economy. Besides the extraction of petroleum that affects mainly

the Amazonia, these products have high market value and therefore have pulled in outside capital displacing also Afro-Ecuadorian and indigenous populations and forcing them to move inside protected areas. The outcomes incorporate overexploitation of land, environment discontinuity, and relocation of indigenous networks from their customary grounds (CEPF, 2005).

Furthermore, road construction is very well linked to the threats mentioned before. As the commercialization of goods strengthens, the connection between the main cities and main ports in the territory is highly needed. In the last decade infrastructure investment in mega-projects that were part of the National Development Plan were essentially focusing on the expansion and recovery of road network, with accentuation on reinforcing the east – west associations. The hydroelectric, oil (substantial rough pipeline venture), port and rail segments, additionally have in any event one megaproject each (WWF Colombia, 2014). Leading to disregard to the continuity of the landscapes, the preservation of species and protection of many ethnical groups that depend on this land for survival.

Additionally, the elevated demand for timber for construction and furniture have led to inappropriate timber extraction practices. The poverty of the communities in these areas and an attempt to improve their living situation has driven Afro-descendant and indigenous populace to increasingly change their low-impact extraction practices to convert into a more abusive practice. Unlicensed logging is encouraged by short-term logging grants, frequently given for a single year and allowing the territorial independent companies to specifically remove high-esteem wood species. The lumber division is inclined to misuse by brokers, who benefit from the business at the cost of poor people (CEPF, 2005). Fundamentally tree-cutters and haulers are poor residents that hardly ever profit of the advantages and returns of logging.

Finally, population development has led directly to land cover change and degradation in the Chocó Andino Region, and to other protected areas in the country. The rising need of providing food to a growing population involves an expansion of agricultural practices. The last census made in 2010 determined that the population growth has slowed down in rural areas but still accounts for 1.60%. This demographic development has constrained mestizos to settle in protected regions, causing loss of biodiversity and natural surroundings. This includes not only the expansion of crops, but also the need of expansion of cattle ranches to sustain the need for meat and dairy.

1. *Threats and Opportunities of conservation: National policies*

Since 2008 there have been increased efforts to preserve natural heritage in Ecuador. The Ecuadorian society has recognized that there has been an important loss of natural heritage landscapes across the country and that, to give a halt to this and restore degraded landscapes, a new approach was needed. In 2008, the National Constituent Assembly redacted the New Constitution of Ecuador that gave Ecuador a prominent drive to reinforce policies of national and regional scale. The Constitution contains several references to ecosystem restoration goals that triggered restoration targets in multiple plans and strategies from national development plans to sector related strategies with focus on forests, agriculture, biodiversity, climate, and water. The Ministry of Environment (MAE) has been the main promotor for building reforestation, restoration, and preservation policies and the previous National Planning and Development Secretariat (Senplades) has been instrumental in local implementation as a major aspect of a more extensive decentralized process (Wiegant, Peralvo, Van Oel, & Dewulf, 2019). Nevertheless, there are still many gaps in the policies that impose a major threat to preserve the forests and biodiversity in the country. For starters, the government still lacks interest in protecting areas outside of the national protection system, also the pressure to revert the economic crisis that Ecuador has endured in the last decades has given more power to other ministries such as the Ministry of Agriculture (MAG) or Ministry of Commerce, instead of the Ministry of Environment (MAE) (Justicia, 2007). Moreover, short term planning doesn't align with long-term planning objectives and timelines, cross-scale (national and local) objectives are mismatched in planning experiences, and finally funding of preservation projects is not sufficient to cover all the needs in the country (Wiegant, Peralvo, Van Oel, & Dewulf, 2019).

Limitations of National Protected Areas

The Natural Protected areas refer to the set of actions implemented for a responsible management and use of flora and fauna in a given territory. This function must be accompanied by public policies that determine commitments and obligations regarding the conscious care of natural assets and resources, within local communities and populations, to improve the living conditions of future generations. In this context, Ecuador implemented a project for the maintenance of infrastructure and Heritage of the Natural Areas of the State (PANE), as the most important management of the national government carried out within protected areas. Its scheme is focused on preventive maintenance work on the equipment and facilities of various ecological and heritage sites that contribute to the country's tourism potential ((MAE), 2016). Nevertheless, the Natural Protected Areas in Ecuador have three main limitations. First, the protected areas in Ecuador have been created as static islands in a highly transformed environment and so, are not able to conserve biodiversity in the long term. Likewise, they are not all located in strategic positions, but instead, in marginal areas that are not large enough to include essential ecological processes in all their dimensions. Finally, they are disconnected to the local population, which means that these areas are being managed under the belief that the protected biodiversity can only be conserved prohibiting many of the activities that take place inside and outside its limits.

A more interdisciplinary and integrative approach is needed to overcome these limitations among which is the framework of socio-ecosystems and resilience. Socio-ecosystem means a system of an adaptive complex of humans and nature made up of a biophysical unit interacting with social actors and their institutions. From this perspective the separation between ecological and social systems is artificial and arbitrary because they are closely linked. In this way the dualities between natural and human protected versus unprotected can be broken. The opportunity in this gap of management of isolated or dispersed protected areas is mapping vulnerable areas that can help managers of protected areas to reformulate its zoning integrating new 'hotspots' in the form of gradients, to avoid direct or indirect land use changes that affect biodiversity inside their limits. Moreover, the growing deterioration of areas that link the different either the ecosystems of the Andes and the Amazon, or the Pacific ecosystems with the Andean ecosystems is highly pressuring the biodiversity in the country. For this reason, protecting the areas in the periphery (buffer zones) of the protected areas can help to create a corridor for connecting the variety of ecosystems (Barborak, Cuesta, Montes, & Palomo, 2015).

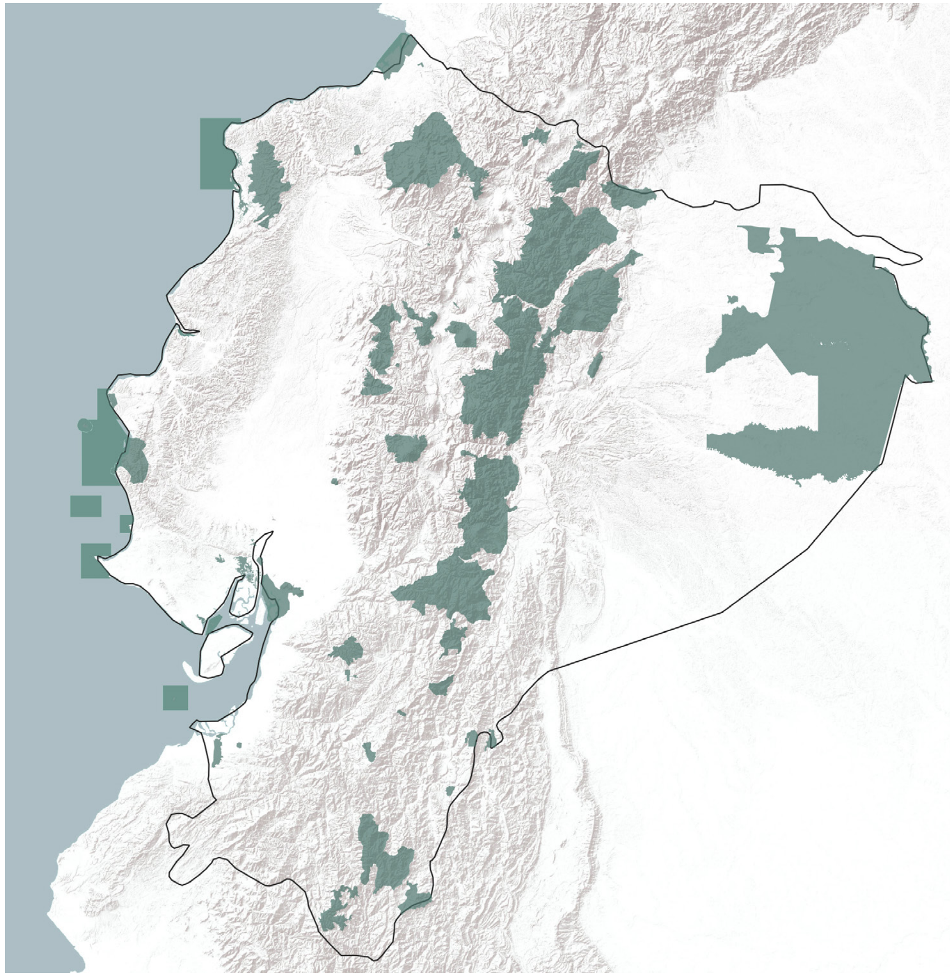


Figure 19 Protected Areas in Ecuador. [Source: (UNEP-WCMC, 2017)]

Limitations of the Regulatory Framework

Moreover, cross-scale planning is needed for accomplishing the national and local objectives. For understanding the problematic, it is important to understand Ecuador's regulatory framework related to Protected Areas (Table 1) and it's actors or stakeholders. First, the Ministry of Environment (MAE) has been mainly responsible for implementing restoration and preservations because it is framed in the application of the guidelines that defines the Political Constitution of 2008 and that implies development of a new model of society in line with the principles of inclusion and social equity, respect for the rights of the people and respect for the rights of the nature. The Constitution defines the structure of the National Protected Areas (SNAP) that was created in 1989 in the processes of planning and territorial ordering and participation

community in the management and administration of conservation areas. SNAP is made up of four subsystems 1) State; 2) Decentralized autonomous governments; 3) Community and 4) Private. Currently, the state subsystem is called Heritage of Natural Areas of the State (PANE). This subsystem covers 48 protected areas representing approximately 20% of the national territory ((MAE), 2016). Then, the decentralized autonomous subsystem brings together the protected declared by Decentralized Autonomous Governments (GAD) which consist of the provincial, municipal, and parish governments. The roles and responsibilities of these local governments to obtain funding are required to revise their Territorial Land Use and Development Plans after each local election. To combine resources and bet-

Legal Norm	Enabling body
1. Political Constitution	Constituent Assembly
2. International Treaties	Ratified by the Legislative Assembly
3. Laws	Enacted by the Legislative Assembly
4.Agreements and Decrees	Promulgated by the Executive Power
5. Procedures	Promulgated by entities of the Executive Power
6. Ordinances	Promulgated by decentralized autonomous governments (GAD)

Table 1 Ecuador's Regulatory Framework related to Protected Areas, ordered from highest to lowest as hierarchy. [Source: (Chemonics International, 2013)]

ter execute their roles and duties, more local governments also have the possibility to form a local government association such as– mancomunidad. Mancomunidad is the group of two or more GADs of the same level of government, which are located contiguously, be they at the regional, provincial, cantonal or rural parish level (Wiegant, Peralvo, Van Oel, & Dewulf, 2019). Furthermore, the indigenous community and Afro-Ecuadorians subsystem is still being structured. Initiatives such as the creation of a large reserve Chachi in the province of Esmeraldas, and the proposals of community areas for mangrove conservation in various points on the Ecuadorian coast. Finally, the private subsystem is also moving towards consolidation, of which many NGO's are already active in the preservation protected areas in Ecuador ((MAE), 2016).

As a result, there is an extremely large level of organized activity in the regions with the common objective of preservation and sustainable development (Justicia, 2007). Nevertheless, the subdivision and assignation of different responsibilities results in a lack of collaboration and coordination of actions. For instance, The GAD implemented a plan called the National Restoration Plan that establishes the operational framework for the implementation of restoration programs for forest that effectively contribute to the conservation, recovery of services ecosystems and the sustainable management of forest resources (Ministerio del Ambiente del Ecuador (MAE), 2014). However, 'these objectives were not accompanied by land use planning norms that determined how local governments could integrate explicit restoration and conservation goals in their Territorial Land Use and Development Plans' (Wiegant, Peralvo, Van Oel, & Dewulf, 2019).

The opportunity that can help with the functionality of the implementation of the current and future policies can be the integration of a network of smaller reserves that can be arranged along environmental gradients that can guarantee the displacement of the species along the bigger-scaled reserves. Therefore, creating landscape permeability and connectivity through the incorporation of new areas in specific locations that minimize the spatial distance between existing reserves (Barborak, Cuesta, Montes, & Palomo, 2015).

Heritage Preservation Policies

The Organic Law of Culture (Ley Orgánica de Cultura), stablishes that the national culture system aims to strengthen national identity; by protecting and promoting the diversity of cultural expressions; by encouraging free artistic creation and the production, dissemination, distribution and enjoyment of cultural goods and services; and safeguarding social memory and cultural heritage. Additionally, it states that the Cultural Heritage the following elements, whether they are tangible or intangible, that are relevant to the social memory and identity of individuals and groups, and the object of the State's safeguard, among others: languages, forms of expression, oral tradition and various cultural manifestations and creations, including those of a ritual, festive and productive nature; buildings, urban spaces and complexes, monuments, natural sites, roads, gardens and landscapes that constitute references of identity for the peoples or that have historical, artistic, archaeological, ethnographic or paleontological value (Pazmiño A. & Perez Torres, 2018). Although the Organic Law of Culture, does include tangible and intangible elements that constitute reference of identity for people, there is no network of cultural heritage landscape, or mention of any specific one whatsoever.

A nother aspect that is disregarded in the Organic Law of Culture is the recognition of agricultural as part of the Cultural Heritage of the country. The only agricultural element that is considered as cultural heritage are the Agricultural dirt and ridges that are part of Archaeological heritage, but that does not include any other agricultural practices and technique that could have been used after the colonization of Latin America (Correa Delgado & Espinosa Garcés, 2012). It is important to evaluate the practices of human coexistence that still exist in the country, but that, together with heritage, are disappearing.

The heritage in Ecuador has historically remained undervalued, decreased, and minimized. In Ecuador, heritage is threatened by migration, modernity social prestige, poverty, and lack of maintenance. Migration because people leave their hometowns and traditions to go to the main cities to look for a job. Modernity and social prestige, because new construction systems are embraced in Ecuador and are a mean for people to feel that they belong to the modern world. Lack of maintenance because the plans for preservation are usually applied by state institutions, which can often be influenced by political visions. Moreover, these institutions are managed by people who are historical and cultural narrow-mindedness which it contributes to losing the perspective of the collective privilege (Cardoso Martínez, 2015).

Furthermore, actions on heritage have focused exclusively on historic centers, monumentality or certain distinctive assets of a certain location, whose actions are limited exclusively to conservation or rehabilitation projects per se. Moreover, there is lack of studies of articulation and link to other resources and to the reality and social, economic, productive, cultural and even political problems of a certain territory (León B., 2018).

Moreover, the lack or limited state ownership regarding heritage, results in a lack of public policies, regulations and laws for the benefit of heritage, users and carriers of these resources and the territories where they are located. The distinctions of various sites such as Cultural or Natural Heritage of Humanity, has attracted the investment of large companies, especially in the tourist field. This has triggered economic development but has also centralized the resources obtained by these private entities, increasing inequality between the social actors, legitimate heirs of these sites, and the entrepreneurs of tourism services and infrastructure. Therefore, there is huge wealth in terms of the diversity of natural and cultural resources but, simultaneously, a situation of deep poverty and inequality of the bearers and creators of authentic cultural expressions. This inequality is generated from processes of exclusion, marginalization towards the populations and localities that are actually people who are aware of the deep meaning of declared expressions. Finally, the lack of knowledge, appreciation, appropriation and respect for cultural heritage from Ecuadorians, in general, has resulted in illicit actions, illegal, anti-technical interventions and loss of authenticity and originality (León B., 2018).

2. *Palm Oil Plantations: Threats in Northwestern Ecuador*

Northern Ecuador has shown a high trend of deforestation in the last 30 years. Specially in the tropical forested cantons where the development of permanent crops grows every year. One of the main permanent crops that have been replacing forested areas are palm oil plantations (Sierra, 2013). The economic interest in this permanent crop is that it constitutes the 4% of the gross domestic product (GDP) in Ecuador. Its production has increased at an 8% annual rate from 2010-2016, and for this reason it has become the seventh most exported product of the country. In the last 5 years, 42% of its production was consumed nationwide, and the other 58% was exported as crude palm oil as semi-finished products, generating US $271 million in export currencies, contributing positively to the balance of the country's trade balance. Ecuador is the seventh largest exporter of palm oil and its derived products worldwide. According to data from 2016, the main export destinations are Colombia, Venezuela, European Union, Mexico, among others (Ministerio de Comercio Exterior Ecuador, 2017). Furthermore, this sector generates approximately 150 thousand jobs, both directly and indirectly, specifically in marginal and vulnerable areas, which contributes to the reduction of poverty.

Due to climatic features, the optimal conditions for an increased yield is the Province of Esmeraldas in Quinindé, La Concordia and San Lorenzo. The first two cantons have been exploited for over 30 years, starting with the replacement of other crops, like cocoa, to expanding to forested areas. Until 2005 these still represented the 83% of the total area of palm oil plantations in Ecuador (Potter , 2011). It has not been determined that the palm oil plantations are the sole responsible for deforestation in the Esmeraldas province, but overlapping both the location of new palm oil plantations with forested areas in multi-temporal images the results are evident (Potter , 2011). Likewise, overlapping maps of palm oil plantations and biodiversity values in the region shows that the most important province for its biodiversity in the region (view Figure 24) is Esmeraldas and also, it is the province with the highest expansion of palm oil plantations (Potter , 2011).

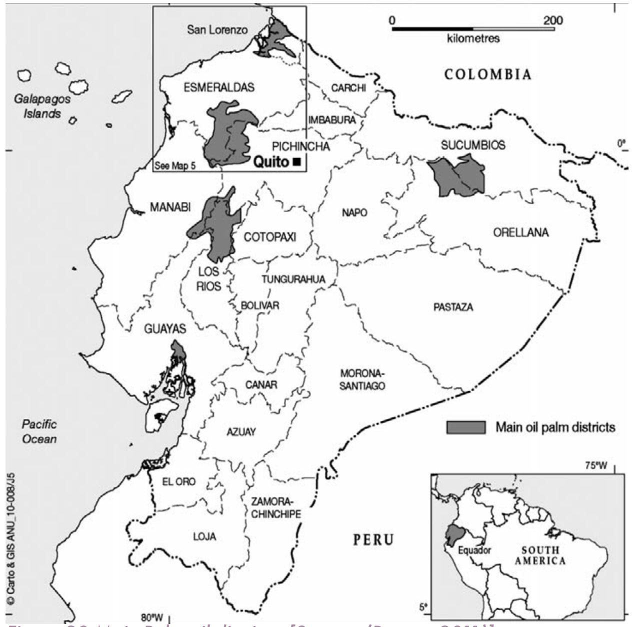


Figure 20 Main Palm oil districts. [Source: (Potter , 2011)]

Social threats

Although most of the farmers of this crop are considered small (with productive land of less than 50 hectares) they only account for 39.6% of total area of palm oil plantations in Ecuador (Table 2). Which means that the pressures on exploiting land for producing this crop is mainly driven by powerful companies. This has produced a series of problems, it has affected local communities and created conflict, there is illegal deforestation, and the government is pressured to allow further exploitation of land.

As mentioned before, the local communities have encountered conflict because of the expansion of palm oil plantation. In 1999, Ecuador suffered an important economic crisis driven by the hyperinflation of the currency dropping significantly daily, that led to bankruptcy in both the private and public sectors of the country. The desperate situation of the government in addition to the recent construction of a new road connecting the coastal canton San Lorenzo to the capital of Ecuador (Quito), revealed a new source of employment and development in the poor areas of the region: the palm oil plantations (Potter , 2011). Businesses, large and small, bought land in the buffer areas of the national reserves in San Lorenzo and, illegally appropriated the ancestral Afro-Ecuadorian community's (Wimbi). The Constitutional Court was forced to intervene in a legal battle now also facing the Ministry of Environment (MAE) and the Ministry of Agriculture (MAG), the MAE won. But the economic pressure resulted in the ex-minister to still grant 50.000 hectares of forest to be converted into palm oil plantations. Since the Afro-Ecuadorians were not able to recover their lands, the government now suggested to have co-managed area in the indigenous territory of Awá. The Awá community rejected this measure.

Currently the local communities experience a series of conflicts fighting for land. First, the Awá community has lost a significant area of the forested expanse they manage and protect. Then, the Afro-Ecuadorians condition does not allow them to have legal rights of the land where they stablish in the 19th century. And finally, there

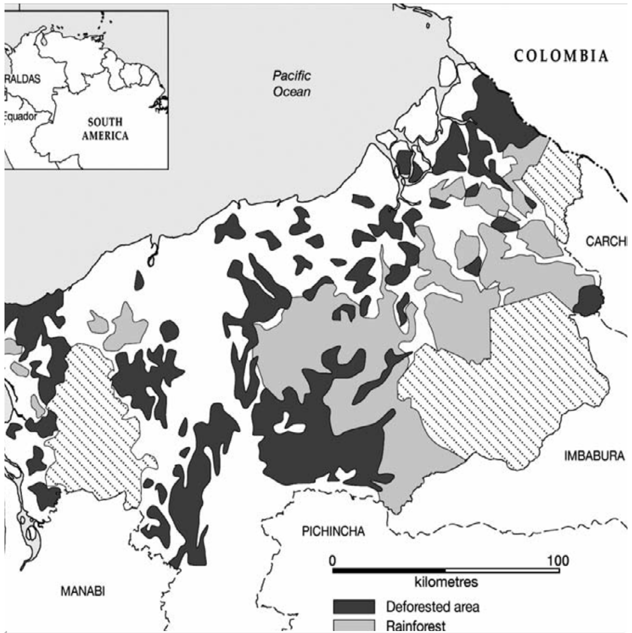


Figure 21 Palm oil plantations in Esmeraldas. [Source: (Potter , 2011)]

Stratification of Palm Oil Plantations				
Range (ha)	Extension (ha)	%	Farmers	%
From 0 to 10	18.868	6.98	2927	41.81
From 11 to 20	24.311	9.00	1476	21.09
From 21 to 50	63.931	23.66	1696	24.23
From 51 to 100	50.517	18.70	589	8.41
From 101 to 200	40.569	15.01	222	3.17
From 201 to 500	23.153	8.57	66	0.94
From 501 to 1000	14.695	5.44	13	0.19
More than 1000	34.161	12.64	11	0.16
	270.205	100	7000	100

Table 2 Stratification of Palm Oil Farmers - 2013. [Source: (Aguinaga E., 2015)]

is an overall violation of rights apprehended by the oil palm companies that 'employed several tactics in order to get the land they want, including buying the land through intermediaries, buying from the community directly, invasion, and using pressure and threats (Brown K. , 2018). Lastly, these poor communities in the north of Esmeraldas that seek to protect the forests, are still forced to cut and sell wood of the forest's trees because, despite the claim that palm oil industry brought employment and development to the area, they still live in very poor conditions below the poverty line. Selling wood to timber companies is the only way to balance up their wage.

Figure 22 Deforestation in Esmeraldas, Ecuador. In its way to become land for pasture and palm oil plantations. [Source: (Chávez & Gertrudis, 2016)]

Environmental threats

Ecuador had a complete replacement of its Constitution in 2008, which strengthened the protection of natural areas and workers' rights. Several reforms were established to guarantee reinforcing these rights, within production processes in many productive areas, including the palm oil production. There have also been efforts from the ANCUPA and local authorities, to carry a process of standardization to promote the sustainable palm production in Ecuador. Nevertheless, the palm oil production still poses a huge environmental threat.

The first immediate threat to produce palm oil is that it requires to completely clear out land and strips of natural areas for its plantation. Furthermore, to protect the plantations from plagues and insects it is necessary to use great quantities of pesticides. The spread of these pesticides poison wildlife as well and conclude in entering rivers polluting and spreading further. This has resulted in the decline of species and destruction of natural habitat (Verité Fair Labor Worldwide, 2016).

Although initially the production of palm oil was a practice of a mixed-use framing technique in Africa, it is currently expanding as a monoculture crop, thus inflicting further ecological threats. The cultivation of this crop in commonly exemplified by a large uniform structure, low and narrow canopy that leaves soil exposed, and overall generates a low-stability microclimate. The life cycle of this crop dictates that it starts being productive starting from the 3rd year reaching full maturity at the age of 20-25 years old in which it needs to be replaced. Likewise, its cultivation requires high amounts of water which consequently reduces the availability of freshwater and the quality of the soil. Finally, from the ecological point of view, it causes an imbalance in ecosystem services and a decline of ecosystem products availability for both wildlife and humans (UN Environment Programme , 2011).

Figure 23 Palm oil Plantations in San Lorenzo, surrounded by forest.

"The main threat of any plantation in an intensive production: is monoculture" (Venegas,2020)

Additionally, the original palm oil crop that started to expand in the 1950s is from African origin, which is not adapted to the endemic condition in America (Bravo, 2018). This had led the plantations of oil palm trees to be hit with a disease called Pudrición de Cogollo (PC) or commonly known as bud rot. The bud rot disease is a very limiting factor for the extraction of oil because in the initial phase of the disease its productivity decreases but then leads to mortality. Thousands of hectares have been affected already, leaving palm oil plantations abandoned and small farmers without a significant income. The main weapon to attack this disease it is the extraction of the diseased trees. But since it affects the bud of the palm tree, without the right technology in mature trees it is very difficult to identify the disease until it has already started to kill it (Potter , 2011). The ANCUPA and other organizations in the continent have found that by creating a hybrid with native plants the palm trees aren't affected by the bud rot. Nevertheless, neither of the two solutions are viable to small farmers because to replace full plantations with the hybrid Elaeis oleífera (HBK) or remove the diseased plants takes a few years to recover fully and it leads to a lower income until new crops are productive.

> "The main threat of any plantation in an intensive production is monoculture. The impact is the change in the native plants, which live in the surroundings since the flora and fauna are affected. By clearing an area - cleaning an area, taking out everything that are plants and trees and leaving directly soil - to sow a crop, flora and fauna are moved. 5 palm oil extraction companies own more than 50000 hectares of monoculture palm areas in the area you are studying. This causes the displacement of wild flora and native plants, which become considered weeds. If you sow palm, you only want to see palm, so that all nutrients and water are used only by the palm and not by other plants. Getting rid of the other plants makes selection pressure, eliminating one type of individuals and leaving another type of individual predominant. The biological risk of making an individual predominantly introduced is that this individual has no genetic vigor in that environment [...] (Venegas, 2020)".

To conclude, generally the highest environmental threat that palm oil plantations have caused is the loss forested areas (thus GHG emissions), degraded agricultural lands that contribute to biodiversity loss, increased soil erosion and nutrient loss (UN Environment Programme , 2011.

Agricultural Landscape Threats

The agricultural landscape has changed in the last 20 years because of the introduction to industrialized technologies in the region. Industrialized agriculture lays its foundations on obtaining maximum performance from agrarian systems. In this way, the agro-industry launched a series of mechanisms whose purpose was to maximize the productivity of its human resources. These mechanisms where the mechanization of agricultural work, monoculture practices, and the use of a large quantity of chemical inputs. All of these are intimately united in a cause-effect relationship. Thus mechanization led to monoculture, continuing with the reduction of labor, the most laborious fertilization practices, such as the application of manure or crop rotation, were replaced by chemical fertilizers; finally, the absence of rotation and diversification eliminated self-regulation mechanisms, so that

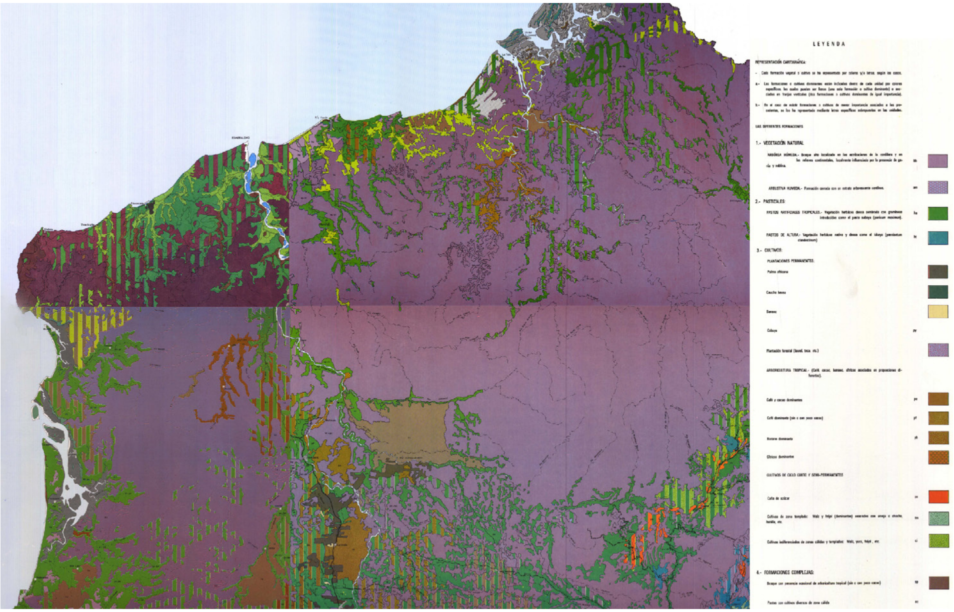


Figure 24 Combination of 4 Historical Maps of 1983. [Source: (De la Torre, Manrique, Trujillo, & Zuñiga, 1983)

monocultures became highly vulnerable agricultural systems and, therefore, dependent on large quantities of inputs of chemical origin (UROCAL, 1999).

The land use of the area was very diversified by mixed use croplands, of which the most important ones were coffee, cacao and bananas. This map has been digitalized to study the land use change in the period of 1983-2015 in Chapter 3.2. The current landscape is very different from the one that could be perceived in 1983. Palm oil plantations have substituted both, the natural environment, and the agricultural landscape.

The agrarian history of Ecuador is characterized by the boom and crisis of different export products (Mora A. , 1986). When agronomists of professionals of any field related to agriculture mention the history of agriculture in the country, it is normally referred to as before or after a specific crisis there has been, instead of the years in which it happened. So, when there is a description of certain events, in the 1970s, it is referred to as the 'banana crisis' (crisis bananera) and in the 1980s, as the cacao crisis (crisis cacaotera). The coastal plain of the country, but more importantly, this region's agriculture is characterized by export products (bananas, cocoa and coffee) whose cultivation trends depend on global market prices (FAO; CAF, 2009). And currently, another important product of exportation is the palm oil and its derivates. Which in recent years producing and exporting these products to international markets is experiencing some setbacks. First, there is an increasing consumer awareness in recent years by mass media and social media channels launching special initiatives against the use of palm oil. This has resulted in the inclusion of palm oil free products, which, for example in Europe are very common (Bernet & van den Berge, 2019). Then, farmers are dealing with the problem of the bud rot plague which has been identified as the most limiting factor for the development of palm oil plantations (Potter , 2011). This threat of global awareness about the effect of palm oil plantations, with the bud rot problem that Esmeraldas is experiencing, means that it is necessary for the people in this area to find other crops to cultivate, so they are not wholly dependent on the palm oil and its derivates.

Opportunities of the Roundtable of Sustainable Palm Oil

The Roundtable on Sustainable Palm Oil (RSPO) is a multi-stakeholder non-profit organization that works to promote the growth and use of sustainable oil palm products through co-operation within the supply chain and open dialogue between its stakeholders. Roundtable members represent every link in the palm oil supply chain: oil palm growers, palm oil processors and traders, consumer goods manufacturers, retailers, banks and investors, environmental conservation NGOs and social development NGOs' (Roundtable of Sustainable Palm Oil, 2014).

With the collaboration of ANCUPA and FEDEPAL, the Roundtable of Sustainable Palm Oil was introduced to Ecuador, to seek a sustainable palm oil production. There are 8 main principles that need to be met by the stakeholders to achieve this certification:

1. Commitment to transparency
2. Compliance with applicable laws and regulations
3. Commitment to long-term economic and financial viability
4. Use of appropriate best practices by growers and millers
5. Environmental responsibility and conservation of natural resources and biodiversity
6. Responsible consideration of employees and of individuals and communities affected by growers and mills
7. Responsible development of new plantings
8. Commitment to continuous improvement in key areas of activity

All this principles need to be met to be able to apply to this certification, and to maintain it in the long-run (RSPO, ANCUPA, FEDEPAL, 2006).

Nevertheless, this certification has some protection gaps that are not met to preserve the natural environment and ameliorate the social impacts of this industry. The RSPO aims also to halt the social and environmental effects that can be adverse in association to the acquisition of legal and illegal land for palm oil plantation. But the communities in the areas where this cultivations take place are often of small farmers that don't have the land title of their properties, nor the planimetry, and it can be exclusionary to people without enough economic resources to meet this principle (Johnson, 2014). The RSPO demands that it is done a soil surveys and topographic planimetry that has to be used for the site's management and in the for new plantings, so that the results can be incorporated into plans and operations (RSPO, ANCUPA, FEDEPAL, 2006). But the access to this information is not available for all farmers, as Dávila explains in the interview:

'[...] The big challenge nationwide, is to certify the small farmers, because the 89% of palm oil farmers are small farmers, with less than 50he. These people do not have the interest or the economic resources to go through this process of certification. So, we are working with the RSPO so the certification is done nationwide, or at least in many areas of cultivation that have an important value (Nápoles, 2020).'

Moreover, the bureaucracy in the country slows down any access to green certifications for the farmers. The RSPO demands an environmental license, that the local authorities take up to 2 years to deliver, 'and the cost is quite high for a small farmer for whom $10.000 is a considerable cost that with a small farm it would mean reaching its equilibrium point or have no profit at all. With the addition of all the administrative baggage that means that it is needed to hire an environmental expert, do all the paperwork with The Ministry of Environment (MAE), all the certifications that are needed, all the planimetry required, and so on. So, it's all these limitations that are administrative and economic that are very limiting for the small farmer (Nápoles, 2020)'.

For this reason, '[i]n Ecuador, only big companies have access to the RSPO certification, and the percentage ranges from 15% in relation to the hectares of the country that have this certification. Now, the importance of this certification, besides the sustainable practices that it promotes, is that now the market asks for this certification in order to purchase the oil, and eventually, any product that doesn't have this certification will not be bought (Nápoles, 2020)'.

2.2 General Framework and Background

2.2.1 Interview recompilation: The Cultural Landscape of the Northwestern Chocó Region in Ecuador and its Main Threats

The cultural landscape has changed because the region allows an extensive and diversified agricultural production, due to its favorable characteristics of the soil, climates, hydrographic basins and geographical location (Varela Guzmán, 2000). The main features that have been identified are environmental, social, and cultural. Palm oil plantations have become a permanent crop that is expanding nationwide in Ecuador, but its introduction to the Chocó region has had important consequences in the landscape. First, it is replacing traditional agriculture that was based in a diversity of crops that were associated in time and space with the history of agriculture in Ecuador. Secondly, it has serious environmental effects like soil degradation, erosion and loss of biodiversity. And finally, it has a high social cost because its technologization has substituted labor by mechanized production, and the expansion to forested areas depletes the ecosystem services of the local communities and results in the invasion of local land by large companies.

To have a deeper understanding on how the palm oil plantations have expanded and how it is affecting the cultural landscape in the Ecuadorian Northwestern Chocó Region it has been carried out 4 interviews. Since this landscape hasn't been identified as heritage or as a landscape worth preserving nationwide yet, all the information available is either focused on the agricultural and economic point of view of the region, or the ecological value that the region has, and on the history of the region. So, to have a wider picture, that includes all the important characteristics of the region, as well as all the threats related to its cultural, ecological and social threats, it was decided to interview palm oil key stakeholders. It was important to have insight from the owner or manager of a palm oil company to understand, beyond the economic benefits that this crop has, why has it expanded so much in recent years in Ecuador. Also, it was important to understand why this expansion is a threat to the environment, and therefore to the cultural landscape. Finally, it was important to have a deeper comprehension of the impacts of this crop and what measures can be taken to reduce its effect in this region.

The first interview is with a stakeholder, Andrés Dávila Nápoles, that has worked in this field for over 15 years and has a great deal of knowledge of the region. The objective of this interview was to have a broader perspective in why have these crops expanded so much in the last decades, how is the land cleared out for its plantation, what is the impact in a social, economic and ecological perspective. Also, to understand the role of the certification on the Roundtable of Sustainable Palm Oil, and how has the bud rot disease affected the fields in recent years.

The second and third interviews were carried out to agronomists, first to agronomist Diego Cordovez and then to Agronomist Fausto Venegas, both who have experience in the region. Unfortunately, with the time difference it was difficult to schedule a meeting with the second interviewee, and so he decided to send the answers directly. The interview with Fausto Venegas was a structured interview in which he answered the questions that are in the Appendix and the most relevant information is explained hereunder. Agronomist Venegas also explains what the preservation policies limitations are and what can be reinforced to have better results.

The fourth interview was carried out to have a more in depth understanding on the ecological and natural threats that this cultural landscape is experiencing, and to understand better the role of the palm plantation in the degradation of the landscape. To arrange a meeting with an expert on this field was challenging, and for this reason it was decided to instead of having a structured interview, to carry out an informal discussion on the subject with Dr. Michaël Moens, he is the Conservation Director of the Jocotoco Foundation, and has a PhD in Biology and a Master degree in Biodiversity in Tropical Areas and its Conservation.

The main highlights in the interview with Andrés Dávila is that he states that although he and his family benefit from the production of palm oil, he realizes that there needs to be measures taken to ensure the preservation of this landscape. He has been working of the palm oil industry for over 15 years, his family has been in the industry since the 80's, and for this reason he has seen the landscape change for decades.

> "So, many years ago, more than 15, it was possible to see monkeys in the area, also some specific types of native fish, the landscape in general was a lot more natural in that sense. But mainly it has been an introduction to the technology in the area that has changed the landscape. Before, the harvest of the palm oil fruit was carried out with a 'machete' or cutlass, that is a manual way for harvesting. Also, it was previously used small hydraulic trucks that were used to harvest. And this changes, with the use of technology, has been changing the forested areas (Dávila, 2020)".
>
> "[..]Also, the expansion of palm oil that has a strong economic pressure that has turned the landscape into a more civ ilized environment. It used to be a lot more natural and this has changed a lot. Finally, I wanted to point out that the pandemic has brought back the wildness to the region. In the area where we had the original 250 he, it has been possible to see for the first time the new home of large white egrets (garzas blancas), they have located near a natural lagoon that has never been altered, and walking around the area it's possible to see hundreds of them in the same seven trees. It is quite impressive, with the pandemic there has been a reduction of workers working at the same time, and the harvest is being done manually, and this has allowed nature to return to the area. Just recently, after spending some days at the farm, we realized how impressive nature is, when human activity stops it returns so fast [...](Dávila, 2020)".

Dávila states that with the reduction of the use of technology, just for a few months nature has returned to the area very fast, and that: "[...] although nature can return so fast, also humans have to realize how small changes can have such a positive impact in the landscape (Dávila, 2020)".

The main highlights from the interview to Agronomist Venegas were that he suggests sustainable measures that are applicable for palm oil production, specifically in this region. Since most reports and studies of Sustainable Practices are based on the practices of Asia, because Indonesia, Malaysia and Thailand are palm oil biggest exporters (Bernet & van den Berge, 2019), it was needed to have a local perspective. Venegas states that:

> "[In] the years 1930s - 1940s, in Esmeraldas the main crops were tagua, a type of palm that serves for the elaboration of buttons and crafts. It was a harvesting and subsistence crop, native, but there were also palm trees, to which the leaves are harvested for use on the roofs of the housing types of the coastal area. There were also coconut palms and raft forests, used to make canoes and boats. Around World War II a lot of rubber was exported, which was considered indigenous to the province of Esmeraldas (Venegas,2020)".

The region is characterized and has been for over 50 years for growing non-native species crops, which are coffee, cacao and bananas, and now palm oil trees. And there are few crops that can be as productive as palm oil, but there are a few measures that can be taken to have sustainable practices in the region.

> "[...] The native crops that could replace these exotic species would be mainly tagua, [and] forest trees [...]. Wild grazing areas could also be encouraged as a native crop, which are options that help recover soil quality and do not generate a high impact on the flora and fauna of the area.
>
> "Another option could be the Guadua cane, in the surroundings of Santo Domingo are guadua cane fields, since one of its uses is to shore up banana plants, which by the weight of the banana cluster the plants begin to fall and the cane is used to support them straight. This is practiced by low-tech banana trees. Guadua cane contributes a lot to soil conservation (Venegas,2020)".

Finally, Agronomist Venegas also states the importance of sustainable practices in the area, how this could have a really beneficial impact in the region, how this landscape once looked and why it is worth preserving:

"A very personal experience. The first time I went to an African palm crop in Mataje was in 2002. I was 24 years old, I had an impressive experience, driving along the road of La Unión that leads to the province of Esmeraldas, close to the town of San Mateo, very close to the Esmeraldas River. It looks like all vegetation from the interior of the province following the riverbed towards the mouth in the Pacific Ocean and shows the change of vegetation, where the union of the river in the ocean is observed, and very rich and diverse vegetation is observed. What with a better system of responsible and sustainable management to the whole province, this province would have wonderful vegetation conditions (Venegas, 2020)".

The main highlights of the discussion with Dr. Michael Moens were that he points out many of the natural values that this region holds, and also the social needs of its inhabitants.

> "Why the Chocó? Because it is the most threatened forest in Ecuador, and also, perhaps, in South America. Only 2% of the original coverage remains and we are losing the forest at a rate of about 100 football fields a day (Moens D. , 2020)".
>
> "[...] in the geographical area of Chocó there are 62 endemic species, therefore there is this great importance of birds, but [also] other threatened flora and fauna such as the brown-headed spider monkey, which is one of the most threatened primates in the world. There are around 500 individuals of that species left. And this area is also a key area for the conservation of ths species. [The] Chocó is very important due to the flora issue, there are 9000 species of plants in Chocó of which 25% are endemic, so that is also super important for the conservation of flora (Moens D. , 2020)."

Dr. Moens also mentioned that it is important to start thinking about the preservation of this region from the landscape scale. The Jocotoco foundation started in 1998 with small reserves and has been expanding ever since. But their efforts now are to think of the reserves from a landscape scale in which it is possible to connect them with bigger ones, focusing also on the transition areas from one ecosystem to the other.

> "[...] making the connection with Cotacachi-Cayapas [...] is so important because if we achieve this connection, we would be protecting an altitude gradient from 100m above sea level, up to 5000m to the tip of the Cotacachi volcano. That for many species, considering the effects of climate change, taking into account that some species change their distribution upwards, is very important to achieve this connection (Moens D. , 2020)".

Finally, with the compilation of interviews it was possible to have a richer comprehension of all the values and characteristics of this cultural landscape. Likewise, it was possible to understand trends in land use and the changes that this landscape has experienced because of its interaction of men and the natural environment. This interaction cumulatively impacts the structure, function, and dynamics of ecosystems of different scales, national, regional, and global. Currently these changes in land use have become more evident, since they have accelerated in recent decades due to population growth and its consumption and economic need too. The impact of humankind on this natural environment becomes more complex when it is contextualized with spatial and historical aspects of the area, because for centuries men have shaped the area with the similar patterns and way of living. So, the collective legacy of the historical land use, has been imprinted in this modern landscape. The sequence of these multi-temporal events and the analysis of the history of a landscape can be a tool to understand the spatial patterns of natural and human-modified landscape elements. Moreover, long-term multitemporal mapping analysis can be a tool to identify trends in land use changes and can help understand and define relevant contexts in land use-planning processes. The history of a landscape can be captured and under covered by the patterns and causes of landscape change and it needs to be geographically specific and allow to reveal key processes that shape the landscape over multiple time frames. Environmental history can be interpreted as landscape history that has cultural heritage because it is a summary of environmental stages and cultural periods that are linked with key underlying processes and drivers. Environmental historians in collaboration with geographers have been measuring the rate and extension of landscape change, this involves multitemporal maps that show historical sequences of landscape change. The way to approach the creation and development of these maps is highly dependent on the available data and the purpose of the analysis (Etter, McAlpine, & Possingham, 2008). In this case, the main concern was to track the land use change in the Chocó region of Ecuador and understand the rate, extent and drivers of these changes in relation to palm oil plantations trends, and also to narrow down the analysis to the most vulnerable areas that need to be addressed.

The Military Geographic Institute of Ecuador (IGM), provides a wide range geographical information that are published in Geoportal (Intituto Geográgico Militar Ecuador , 2010). This data was used to compare and understand many characteristics with national level at 1: 25000 scale maps that have different themes. Land use maps at this scale where not sufficiently detailed to analyze deeper this region, and where also not multi-temporal, for which reason it was decided to explore other options which are deeper explained in (Chapter 3:).

2.2.2 Delimitation of The Northwestern Ecuadorian Choco Region

With a clearer, more articulated idea of what this landscape contains, it is important to establish different elements that constitute it, which will help define the possible ways of ranking and evaluating the Cultural Landscape. Hence, it is important to delimitate the landscape and structure it with 'polygonization' (León B., 2018). 'Polygonization' is to set the perimeters that define the borders of the cultural landscape in its different gradients, and this can be done with Cultural mapping.

> "Cultural mapping has been recognized by UNESCO as a crucial tool and technique in preserving the world's intangible and tangible cultural assets. It encompasses a wide range of techniques and activities from community based participatory data collection and management to sophisticated mapping using GIS (Geographic Information Systems). (Cultural Landscapes: the Challenges of Conservation, 2002)."

For monitoring, characterization, and identification of Ecuador's Cultural landscapes with its intrinsic cultural, ecological, and historical value it is necessary to record all the cultural information that can be both tangible and not tangible. For this to be possible it is imperative to have a reliable methodology on consistent information sources and so, the gathering of relevant data is essential. Cultural information can be collected from literature, poetry, paintings, handcrafts, oral mediums, media, cultural activities, and travel material (Natural Resources of Wales, 2016). But landscape features can be gathered with maps that indicates the historical elements found in a landscape, which elements from the past remain, and how has this landscape changed and why. For this reason, mapping is a very important tool for capturing a cultural landscape as a whole, and so, its precision is very important.

It is important to also understand, that culture is also ordinary, it does not have to be 'outstanding' to be worth preserving. And, the interests of the maintaining the everyday culture, the styles of living and doing things, strengthens the sense of place that is palpable. These everyday continuous living/nourishing traditions of this region are part of a sophisticated and beautiful combination of elements of everyday life: the ordinarily sacred. Cultural mapping has been developed as a tool to help interpret, document, and present the cultural diversities of landscapes like this that can be linked to natural heritage management (Taylor, 2013). Mapping can be done in many different ways, with many different purposes and goals, it can be done to indicate deforestation, land degradation, land recovery, water trends, among many others. In this study it was done in three different stages. The first one was using a series of different maps to understand the extension of the Chocó region and then compare it with maps of other studies, bioclimatic patterns, biodiversity patterns, ethnicity maps, national reserves locations, land use trends, historical maps, geological maps, hydrological risks, urban areas location, waterways, roads, administrative boundaries and illiteracy. Then, using the extension of the bioclimatic region of the Western Moist Forest with the delimitation of the provinces in was stablished the limit of the Case study Area, which was decided to maintain in the convergence of the four provinces of Esmeraldas, Imbabura, Carchi and Pichincha, that have been characterized for having the highest biodiversity level of the region, and because of the need of this region to improve the life quality of the people that live there. Then, mapping was used to create accurate maps that will allow to understand one of the main threats that was identified in the region, the expansion of palm oil plantations. Then finally, mapping was used to understand what the main drivers for the rapid changes in the area are and to understand why and where the expansion of this crop happens.

So, for the first stage of delimitation of the Cultural landscape it is important to start with a wider delimitation of the landscape, so it is important to understand what the Chocó Region is. Located in the Northwestern Ecuador and extending through the coastal plain between the Andes and the Cordillera (or mountain range) parallel to the coast along 350 km from the city of Esmeraldas to Guayaquil in the south. This cultural landscape has an important ecological value because it is part of the Choco-Darien region in South America that is considered one of the biodiversity hotspots in the world. Likewise, the variety of ecosystems in the Ecuadorian Chocó has given origin to the present biodiversity and a high degree of endemism. Mountains catch humid air from the coast and contribute to the survival of the Humid Tropical forests and very humid Premontane forests. It is estimated that Chocó maintains some 9,000 vascular plant species, of which approximately 25% are endemic. Moreover, the Ecuadorian Chocó maintains 25% of the flora of the country, or approximately 6,300 plant species, 13% of the 20% of endemic species. The region is also home to more palm species than any other part of the world (CEPF, 2005).

The Northwestern portion of the Ecuadorian Chocó is very rich in both socio-cultural and ecological aspects. Nevertheless, it is currently enduring many conflicts related to deforestation and natural environment loss. So, to further delimitate the cultural landscape to subdivide it in a smaller portion that contain different unique characteristics, but also consider the part that is most threatened, so it is possible to collect efforts to protect it. This subdivision with be referred in this study, as the Case Study area. The Northern Chocó has become of great importance on conservational aspects because it still preserves its high ecological value because, as it can be

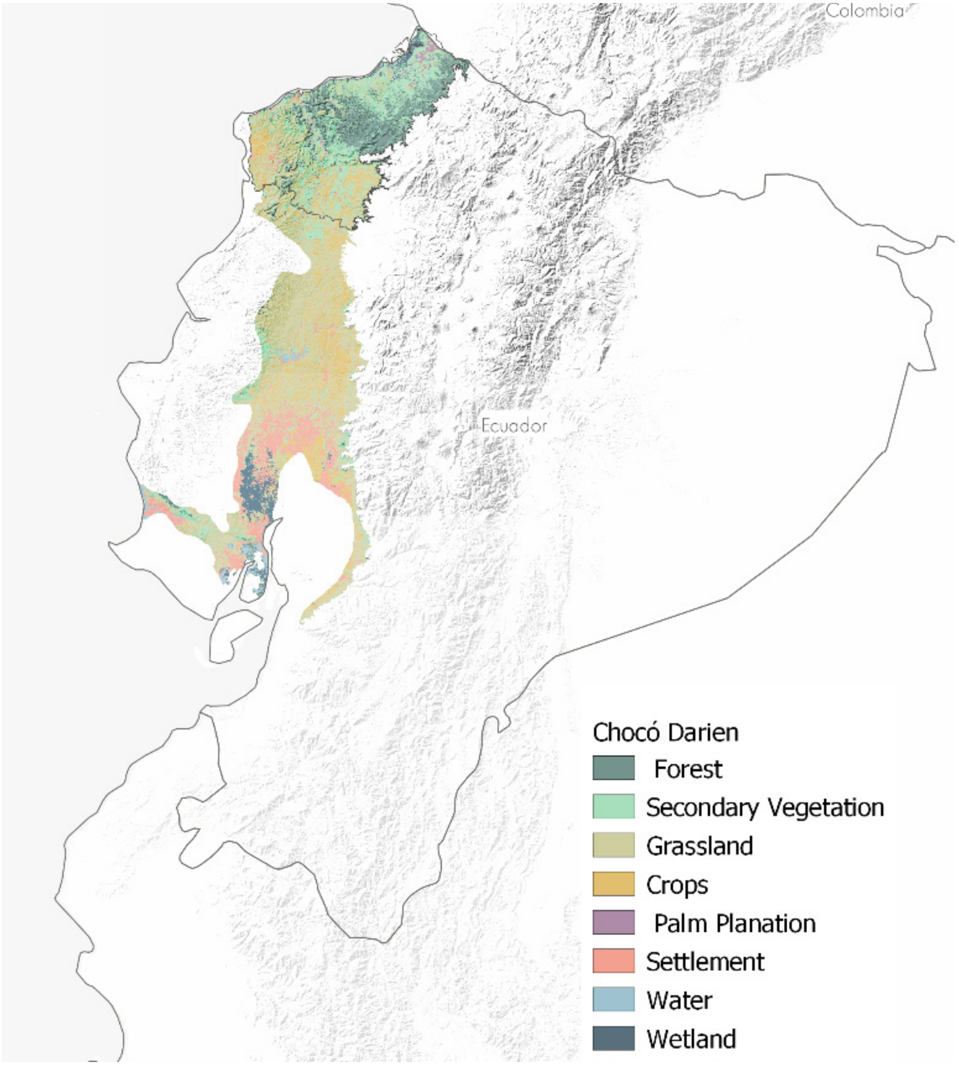
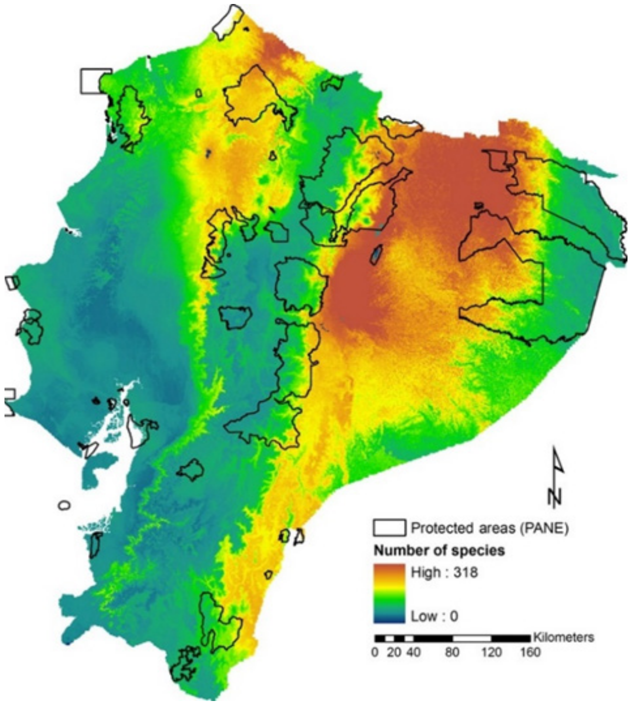


Figure 25 The Chocó Region of Ecuador. [Source: (Fagua, Baggio, & Ramsey, 2019))]

Figure 26 Potential biodiversity richness. [Source: (Lessmann, Muñoz, & Bonaccorso, 2014)Natural capital



seen in Figure 23, it presents relatively large fragments of forest in good state of conservation, especially in northern portion, in the province of Esmeraldas. It also constitutes a transition strip between the humid forests of the north and the forests from the Tumbes-Manabí region, to the south. Likewise, in several literature documents (please refer to (Justicia, 2007) and (Gomez, et al., 2014)) concerning the Choco-Darien portion of Ecuador, the focus is also in Northern Ecuador because of its higher biodiversity richness and because it has a very important cultural value. For these reasons, it has been chosen to analyze deeper this portion of the Ecuadorian Chocó.

The extent of the Case Study area in comprised mainly in the Province of Esmeraldas that, as mentioned in the previous chapters, has very rich in both socio-cultural and ecological aspects, and also in a small portion of the Province of Carchi, Pichincha and Imbabura. Inside this area are several Protected Areas, the Mache-Chindul Ecological Reserve, El Pambilar Refuge, Estuario del Río Esmeraldas Refuge, Manglares Estuario del Río Muisne Mangrove Refuge, Ecological Reserve Manglares Cayapas Mataje, La Chiquita Ecologicla Reserve, Ecologicla Reserve Cotacachi-Cayapas, Marine Reserve, Galera San Francisco, Proyecto Washu, among others. These protected areas, despite lacking connection, among each other, and protection, still preserve small patches of natural vegetation and larger ones like the Ecological Reserves with high ecological value.

2.2.3 Introduction to Mapping Land Use Change

It is important to acknowledge that global warming and climate change have resulted from human activity. Climate change has been triggered by humans who are responsible of global warming, land degradation, air and water pollution, rising sea levels, loss of ozone layer, extensive deforestation, and acidification of the oceans. And at the same time, humans depend on agriculture, which provides food, fiber and other products that sustain life. Agriculture is one of the most widespread drivers of environmental change globally because it impacts negatively, directly and indirectly, on climate, biodiversity, land degradation and freshwater. Food production is threatened by water shortages, climate change, and land degradation. Land degradation means a reduction of land productivity because of the overuse or over-appropriation of resources by humans.

Expansion and intensification of agriculture contributes to land degradation because it extracts and consumes limited natural resources, such as water, forests and nutrients and its intensification might lead to depletion of nutrients in the soil and of groundwater reserves (Cherlet, Reynolds, Hill, Sommer, & Von Maltittz, 2018).

Deforestation can be considered as a type of land degradation when forest ecosystems, with all their important cultural, regulating and provisioning services, are exchanged for another land use (Cherlet, Reynolds, Hill, Sommer, & Von Maltittz, 2018). A portion of the harms supported by the land degradation are the prompt decrease or loss of biomass productivity with a connected misfortune in natural habitat, biodiversity, and carbon stock. The clearance of timberlands quickens soil erosion and

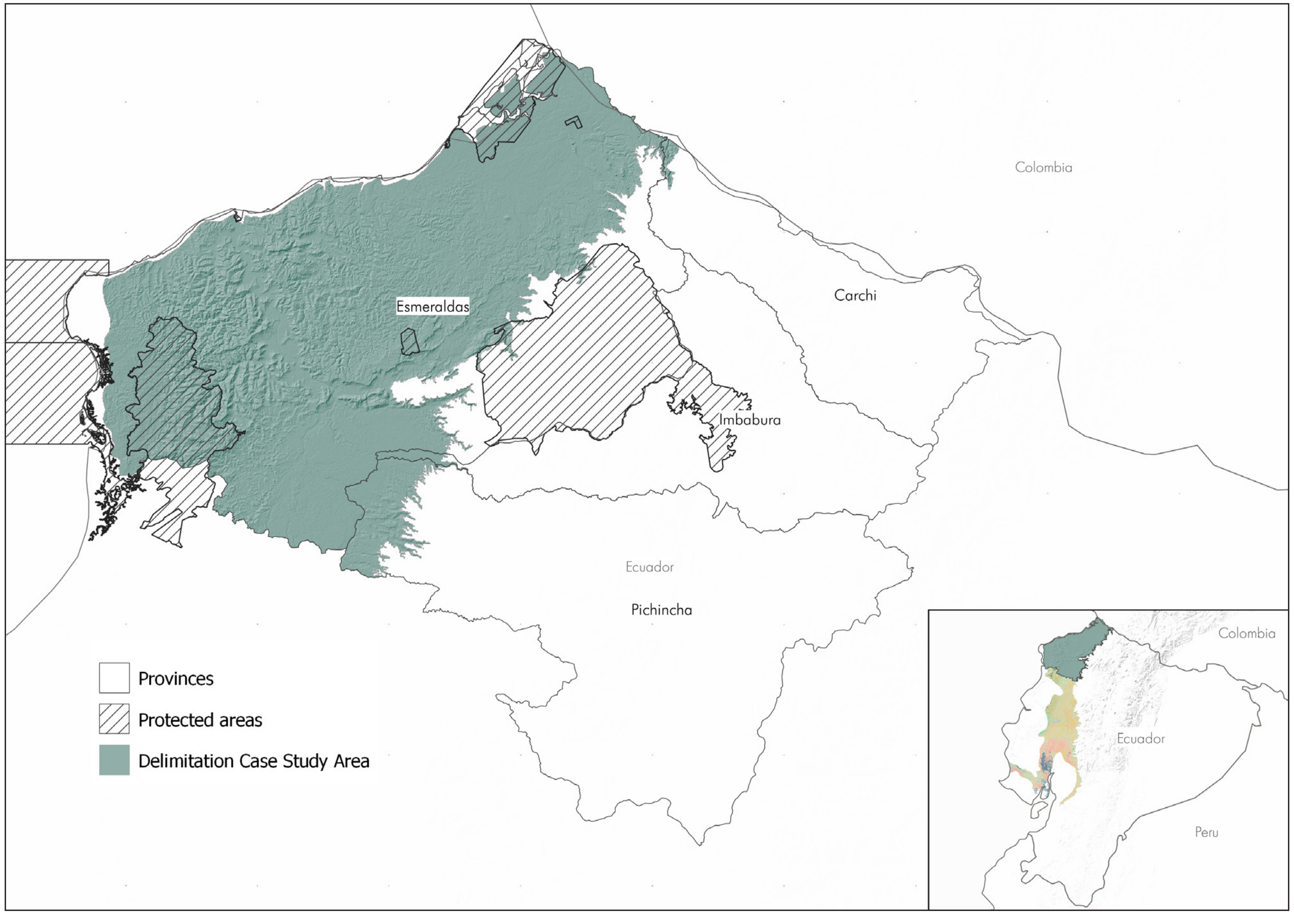


Figure 27 Study area extent and relevant Protected Areas

the modification of soil functioning. This can incite a decrease in carbon, nutrient and water storage, and cycling limits that truly influence land productivity and capacity in the future. (Cherlet, Reynolds, Hill, Sommer, & Von Maltittz, 2018). Therefore, deforestation is an important matter because it leads to a less fertile soil, water scarcity and soil erosion that can potentially affect land productivity on which rural communities depend on. Tracking land use change is imperative, for it can affect biodiversity, accessibility to natural resources and ecosystem services, and be a key factor in the production of goods.

Tropical regions are enduring, as mentioned before, the most accelerated land cover change due to elevated deforestation. Understanding the relationship between direct and indirect drivers of these changes could help identify which are the hotspots that could potentially become most affected and that are already endangered. But tracking land use changes go beyond the importance of tracking the loss of natural resources and land degradation, as it is

Landscapes are changing constantly, when they do naturally these changes are slowy and balanced, nevertheless, when they do due to anthropogenic reasons these changed are faster and have an effect of ecological functions and processes. The consequences of these accelerated anthropogenic changes are desertification, deforestation, habitat fragmentation, the loss of biodiversity, reduction of ecosystem series and global warming. In the las decades, there has been an increasing interest in mapping land use and land cover (LULC) changes with classification land cover maps because there is a growing need to have land cover information, interest in analyzing land cover changes in large areas and at different scales, the reduced cost of using remote sensing data, and for the capacity of doing so in inaccessible areas of the world in which field-intensive methods are not possible or reliable. Using digital imagery techniques to detect LULC changes in multi-temporal satellite data allows to have a LULC described as 'from-to' and binary change and non-change information that uses techniques to detect changes from image differencing, rationing vegetation index and others. The repercussions of this changes can be understood from an environmental and socioeconomic point of view and provide tools for land planning and management, policy decision making and strategies at regional and bigger scales. These maps can give a deeper comprehension on whether or not changes in LULC are consistent with balancing socioeconomic interests with environmental and cultural preservation goals (Muñoz-Villers & López-Blanco, 2008).

2.2.4 Importance of Land Cover/ Land Use Maps

Sensing imagery can be used to acquire several types of earth observation data. Such images produced by satellites like Landsat or Sentinel, are in consistent use for agriculture, for land use and land cover change, for forestry, water management, research of ecosystem services, for climate and environmental change and for contemplating snow and ice, beach front territories, deserts, soils, urban transformation, among numerous different applications (Cherlet, Reynolds, Hill, Sommer, & Von Maltittz, 2018). Depending on the type of study required to perform, each image provides different sensors that allow the recognition of specific features. And, depending on the detail quality, they can be used to study areas of different scales.

Scientist have often assigned different types of habitats to specific species. Nevertheless, numerous species experience landscapes in manners more unpredictable than as a "habitat-matrix" polarity and use resources from various land cover types. In this manner, landscape management can be viewed as a complex procedure that requires describing the landscape composition and structure reasonable for the specific species. Habitat selection are broadly utilized as a choice support tool since they can apply to different gatherings of species. Landscape maps are fundamental for building up these models, and most environmental features utilized in the models are created from remote sensing imagery (Mercier, et al., 2019).

Using remote sensing tools to classify the land cover of a region, has its limitations. The primary limitation is that the land cover classes in forests and agriculture mosaics are conveyed along changing slopes, which often causes misclassification. Imagery with high and extremely high spatial quality give more noteworthy spatial detail and exact data. Nevertheless, the low-quality images do not allow to separate similar spectral values to observe vegetation dynamics (Mercier, et al., 2018).

Another limitation is that people in charge of landscape management do not necessarily know how to perform these analyses and are subject to expect the analysis made by experts on remote sensing. Although this information can be somewhat reliable, the readiness of it can be time consuming. For this reason, and like mentioned before, because of the lack of available data to open access in third world countries like Ecuador, it has been found that it is important to develop a simple processing method that could be more viable in this circumstances.

Also, direct, and accessible data for observations, including long monitoring programs term, can be applicable to a wide range of scales and can be used to assess multiple dimensions of vulnerability. This type of information allows to explain the adaptive capacity and the degree of risk that the biological entities will endure in the future. Using statistics based on correlations between the geographical patterns of distribution land use and habitat conditions can assess determine the sensitivity or adaptive capacity of an ecosystem (Barborak, Cuesta, Montes, & Palomo, 2015).

Finally, another limitation is that people in charge of landscape management do not necessarily know how to perform these analyses and are subject to expect the analysis made by experts on remote sensing. Although this information can be somewhat reliable, the readiness of it can be time consuming. For this reason, and like mentioned before, because of the lack of available data to open access in third world countries like Ecuador, it has been found that it is important to develop a simple processing method that could be more viable in this circumstances.

Finally, utilizing land use–land cover maps has facilitated the recognition of these hotspots in the Chocó ecoregion of Ecuador. In this manner, I have tried to map and understand the impacts that, specifically palm oil plantations' expansion, is currently and will still be, in the near future, one of the main indirect drivers for land cover change. Analyzing land use maps components can give an important insight concerning potential processes that can determine a pattern of land use/land cover change. One of the most practical ways to analyze land change use multitemporal maps and examine the changes with a transition matrix so it can be identified the most relevant transitions. With the understanding of these transitions then is possible to do research on what are the drivers and the process that have led these transitions (Pontius, Jr. , Shusas, & McEachern, 2003). This methodology to analyze and have accountability for these changes is explored in Chapter 3.2.2 and are used to understand the drivers of land use change in the Northwestern Chocó region and identify the trends of these changes that can lead to the identification of the most vulnerable areas.

2.2 General Framework and Background

Remote sensing (RM) refers to obtaining information about the Earth's surface through electromagnetic radiation (light) as a mean of interaction (De Jong, D. van der Meer, & Clevers, 2007). Satellite remote sensing has been used for decades to obtain detailed information about the earth's surface. The satellite image analysis is created from images of the entire the earth that are captured by earth-orbiting satellites. Satellite imagery are managed by authorized associations or organizations that have been licensed with the approval of governments (Kulkarni & Bodhale, 2017). These imageries have a synoptic view of the Earth's features that cover large areas repetitively and also, a digital mode to capture data, which suggest an efficient method for monitoring, mapping, and manage land resources and environmental impacts in multi-temporal frames. The extraction of data from the satellites' sensors is performed by the measuring of the transmission of energy from the surface that is transmitted in different electromagnetic spectrum (EMS). Optical RM deals with different types of sensors that are used in combination with geographical information system (GIS) and geographical position system (GPS) analyses. The optical sensors use a portion of electromagnetic spectrum that are the visible, the near-infrared, the middle infrared and the shortwave infrared. The sensitivity of these sensors is a range between 300 nm to 3000nm. The thermal infrared sensors that are collecting radiation reflected and emitted from the Earth's surfaces operate in wavelengths of ranges of 3000-5000nm and 8000-14000nm. Likewise, satellites a microwave sensor that that records the backscattered microwaves that have a wavelength that ranges of 1mm to 1m of electromagnetic spectrum (Obi Reddy, 2018).

There is a variety of data available nowadays, that are being managed by different entities and that either for free access to any user or have private access. Governmental authorities like the U.S.A government or the EU, offer free access to these data sets.

Examples of accessible data come from Moderate Resolution Imaging Spectroradiometer (MODIS), IRS-IC, Quickbird and the Landsat satellites from the NASA, and the Sentinel 1 and Sentinel 2 satellites from the EU, among others. These remote sensing data in conjunction with tools like geographical information system (GIS), global positioning systems (GPS) and other ground data collection systems provide a wide variety of applications for monitoring and managing in respect to geology, agriculture, meteorology, cartography, oceanography, environmental and resource monitoring, urban and land management, and more (Obi Reddy, 2018).

2.3.1 Optical Satellite: MODIS, Landsat and Sentinel 2

The MODIS (Moderate Resolution Imaging Spectroradiometer) has been a key tool of the Earth Observing System (EOS) Terra and Aqua Platforms that have been designed to monitor earth's atmosphere, ocean, and land surface with a combination of the visible channels, the NIR, the MIR and thermal. It has been operating since its launch by the NASA in 1999 and it data products are available in several sources (Moore & Zhang, 2015). Although its maximum spatial resolution is of 250m it has been extensively used for land cover classification (Mercier, et al., 2018).

The Landsat series offer a better quality of spatial resolution of 30 m and is the longest running enterprise to have acquired satellites (1972), for which reason their data platforms offer an essential continuously acquired collection of data. It was originally launched by the NASA and it has a an 8-day revisit (Mercier, et al.).

The Copernicus Sentinel 2 series were launched in 2015. Its aim is to monitor the variability in land surface conditions and its revision time is of 10 days at the equator and 2-3 days in mid-latitudes. The S-2 satellite data have a higher capacity and have been extensively used in the last few years (Mercier, et al.).

Nevertheless, despite the great capacity and uses of this satellite data, unfortunately they are greatly influenced by climatic conditions and are more subjected to identify information of the top layers of vegetation cover.

As mentioned before, the satellite imagery provided by MODIS, Landsat and Sentinel 2 have been widely used for different types of analysis regarding the Earth's surface characteristics and its changes in the last decades. Moreover, the free availability of these images is making the public be able to use satellite images more fully for different studies. The sensors of the satellites are sensitive to electromagnetic radiation over a restricted wavelength range, for which these imageries collect information that corresponds to different visible and near infrared (NIR) radiation in different bands (or channels). These imageries also contain information of differentiated intensity levels across the spectrum that allow to analyze the reflected energy and use it for classifications maps.

These methods are very useful when tracking land use/land cover change maps because the spectrum NIR and the red band allow to identify vegetation indices that describe vegetation by its greenness due to the chlorophyll absorption of the red light. For this reason, it has become very important the use of Landsat images, more specifically because with the Normalized Difference Index (NDVI) parameter can be tracked many global land degradation problems, expansion of agricultural fields, loss or gain of forested areas, among others. The NDVI is a ratio of the NIR and the visible red that allows separability of the vegetation quality and an indicator of vegetation and non-vegetation covers. There is another parameter that is also very powerful, the NDI (Normalized Difference Index) that uses a normalized ratio of green and red bands and has been proving to be able to identify classes that are often misclassified like palm oil plantations because it is able to use a high discrimination power using histogram metrics (Chong, Kanniah , Pohl , & Tan, 2017).

Nevertheless, all these satellite imageries have limitations. Although for creating land use maps the spatial resolution can be very high it is based in optical identification of tree plantations from natural forests. For sampling classes, it is needed a visual interpretation of the context such as texture, position, shape and associations which makes the classification process very time consuming and often leads to misclassification (Miettinen, Chin Liew, & Keong Kwoh, 2015). Furthermore, the evaluation from optical imagery is limited by weather, especially in Tropical regions, where there is constant intense cloudiness and fog (Application of Sentinel-1 satellite to identify oil palm plantations in Balikpapan Bay, 2018).

2.3.2 Results of Optical Satellite Analysis

As mentioned before, optical remote sensing has its limitations due to resolution, weather conditions and ease of separability of natural forests and tree plantations. MODIS data can provide data products that can describe features of the land, the oceans and the atmosphere. These features can be used for studying processes and trends on local to global scales. The relevance of this type of imagery has been that there is a high number of available products that are used for mapping LULC. Normalized Difference Vegetation Index (NDVI) time series has been used frequently because vegetation types can be characterized using seasonal or phenological variations, and these have the potential to improve cover separability, proving to be very effective in several studies (García-Mora, Mas, & Hinkley, 2011). The map here under has been developed with MODIS and, what is most interesting is that each band is assigned to a different year starting from band 5 in 2001 to 2015. So, it allows to have a multi-temporal analysis on land cover changes.

Having available this data of a wide year range allows to have a series of analysis on deforestation and reforestation trends, land use changes trends, expansion of croplands, preservation of natural areas, among many others. Nevertheless, at a first glance it seems that the land cover in Northwestern Chocó region is characterized by an extensive tree cover. And, although the tree cover type in this classification is not specified, it is evident that this map could suggest that this region is characterized by forested areas and that croplands are not a predominant land cover. But, from information gathered from other sources, like land use maps from the Military Geographical Institute, (Intituto Geográgico Militar Ecuador

, 2010), and information of the soil and its uses from The Book of Soils of Ecuador (Moreno, Bernal, & Espinosa, 2018), and many other studies, it has been recognized, that the coastal plain of Ecuador, and particularly this area, is characterized by extensive agricultural cover. Additionally, extracting data from the land cover maps of different years from (ESA, 2017) in would seem that from 2006 to 2015 the tree cover area has expanded and the croplands cover has reduced. This suggests that, the separability of tree cover with palm oil plantations can be inefficient.

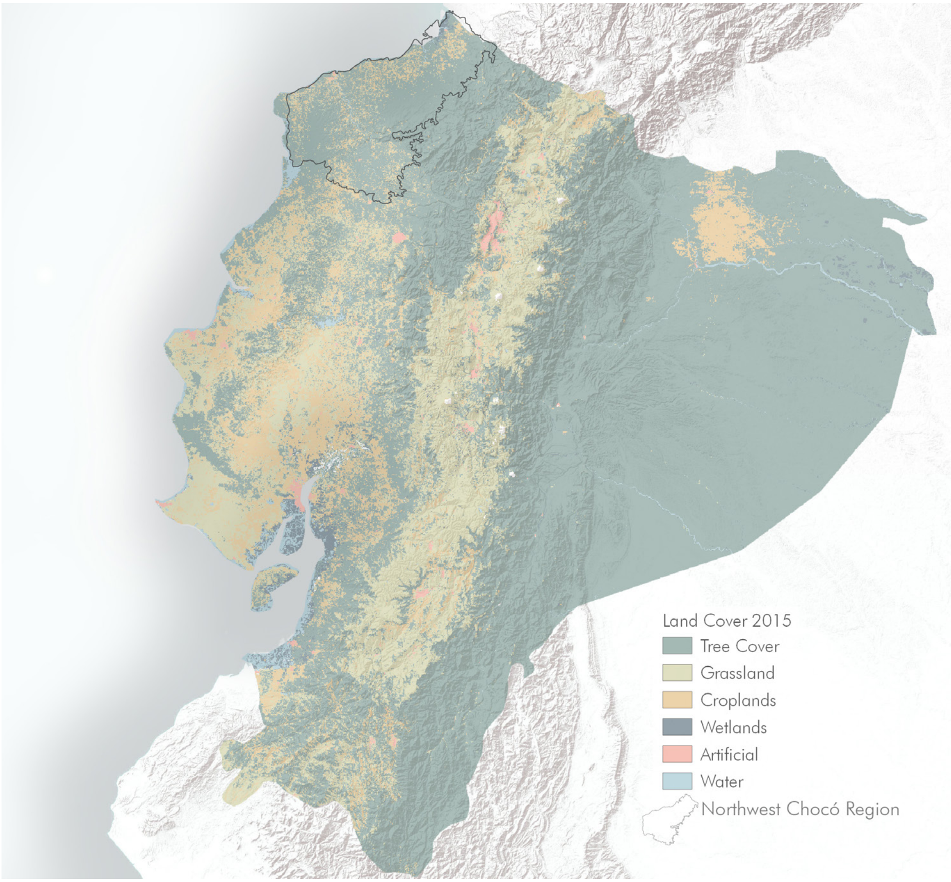


Figure 28 Land Cover in 2015 from MODIS data base. [Source: (ESA, 2017)]

	2001	2006	2011	2015
Tree Cover	77.59	70.44	72.64	78.10
Grassland	7.64	8.87	8.66	7.69
Croplands	12.33	18.36	16.36	12.41
Wetlands	1.44	1.43	1.45	1.45
Artificial	0.17	0.07	0.07	0.18
Water	0.82	0.84	0.82	0.18
Total	100.00	100.00	100.00	100.00

Table 3 Total Extension of each class in the years 2001, 2006, 2011 and 2015 in percentage. [Source: Data extracted from Maps of (ESA, 2017)]

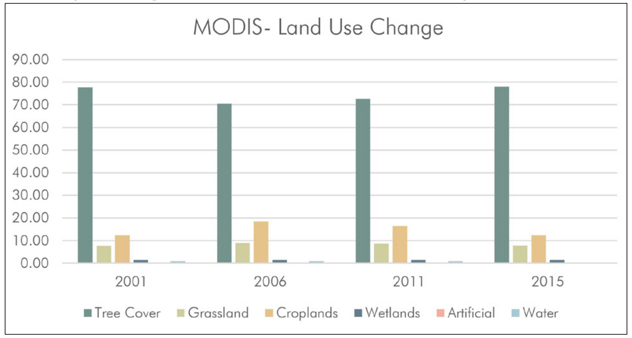


Table 4 Histogram of the Total Extension of each class in the years 2001, 2006, 2011 and 2015. [Source: Data extracted from Maps of (ESA, 2017)]

Quinindé

To have a better exemplification of the misclassification the same analysis of LULC change was performed in only the region of Quinindé. Here the trend suggests, that since 2001 the tree cover has increased 20% and that croplands area has reduced 17% as it can be seen in the charts.

	2001	2006	2011	2015
Tree Cover	59.44	59.13	65.92	79.56
Grassland	10.72	10.84	10.06	7.56
Croplands	29.38	29.57	23.55	12.30
Wetlands	0.03	0.03	0.03	0.03
Artificial	0.01	0.01	0.02	0.12
Water	0.42	0.42	0.42	0.42
Total	100.00	100.00	100.00	100.00

Table 5Total Extension n Quinindé of each class in the years 2001, 2006, 2011 and 2015 in percentage. [Source: Data extracted from Maps of (ESA, 2017)]

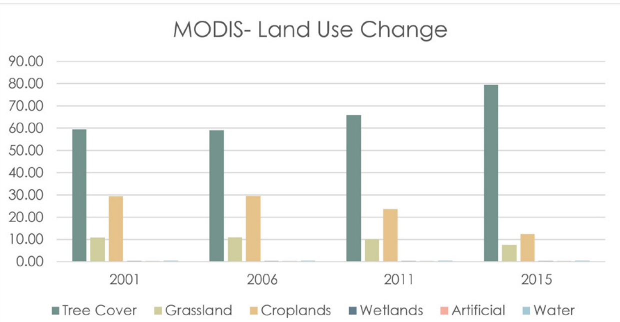


Table 6 Histogram of the Total Extension in Quinindé of each class in the years 2001, 2006, 2011 and 2015. [Source: Data extracted from Maps of (ESA, 2017)]

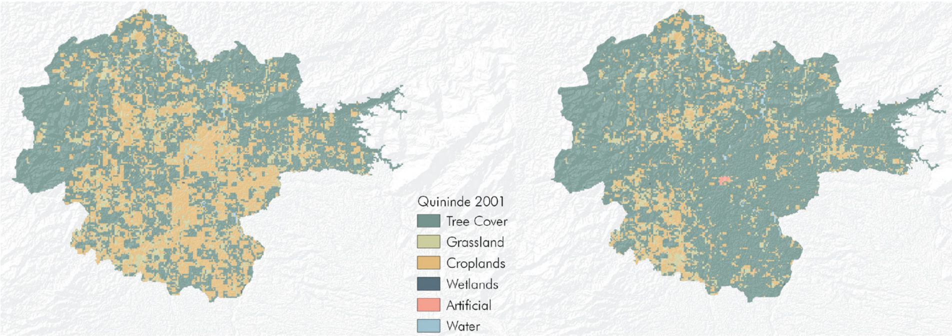


Figure 30 Comparison of Land use Maps of the Quinindé Canton. [Source: Data extracted from Maps of (ESA, 2017)]

Astonishingly, when this data is analyzed also from visual interpretation in 2015 the canton of Quinindé seems to have recovered the tree covered area. And palm oil plantations in this region have expanded in the last decade (Potter , 2011) significantly, so these maps are not providing information about the typology of tree cover increase, and palm oil plantations are not being considered croplands.

Since it has been determined that palm oil plantation are a threat to this region (Chapter 2.1.3) it is needed to find a different data base to track the changes of LULC of this region.

Another study suggests that quantifying tree cover without separability from tree plantations can be concerning is this study carried out globally by (Hansen M. , et al., 2013) that quantified the global forest change with earth observation satellite data that was used to map global forest loss and gain from 2000-2012. Nevertheless, looking in depth to this study it is possible to notice that for example, in the Province of Esmeraldas, and other regions, it shows significant forest gain when in fact, previously crop lands have been replaced with Palm Oil Plantations. These areas that are shown in white as forest gain, correspond to areas that in previous years were croplands and now how become palm oil plantations. Overlapping this map of forest gain in the region of Quinindé in a Google Earth zoom-in, it is possible to notice that also in this study, palm oil plantations are regarded as forests instead of croplands.

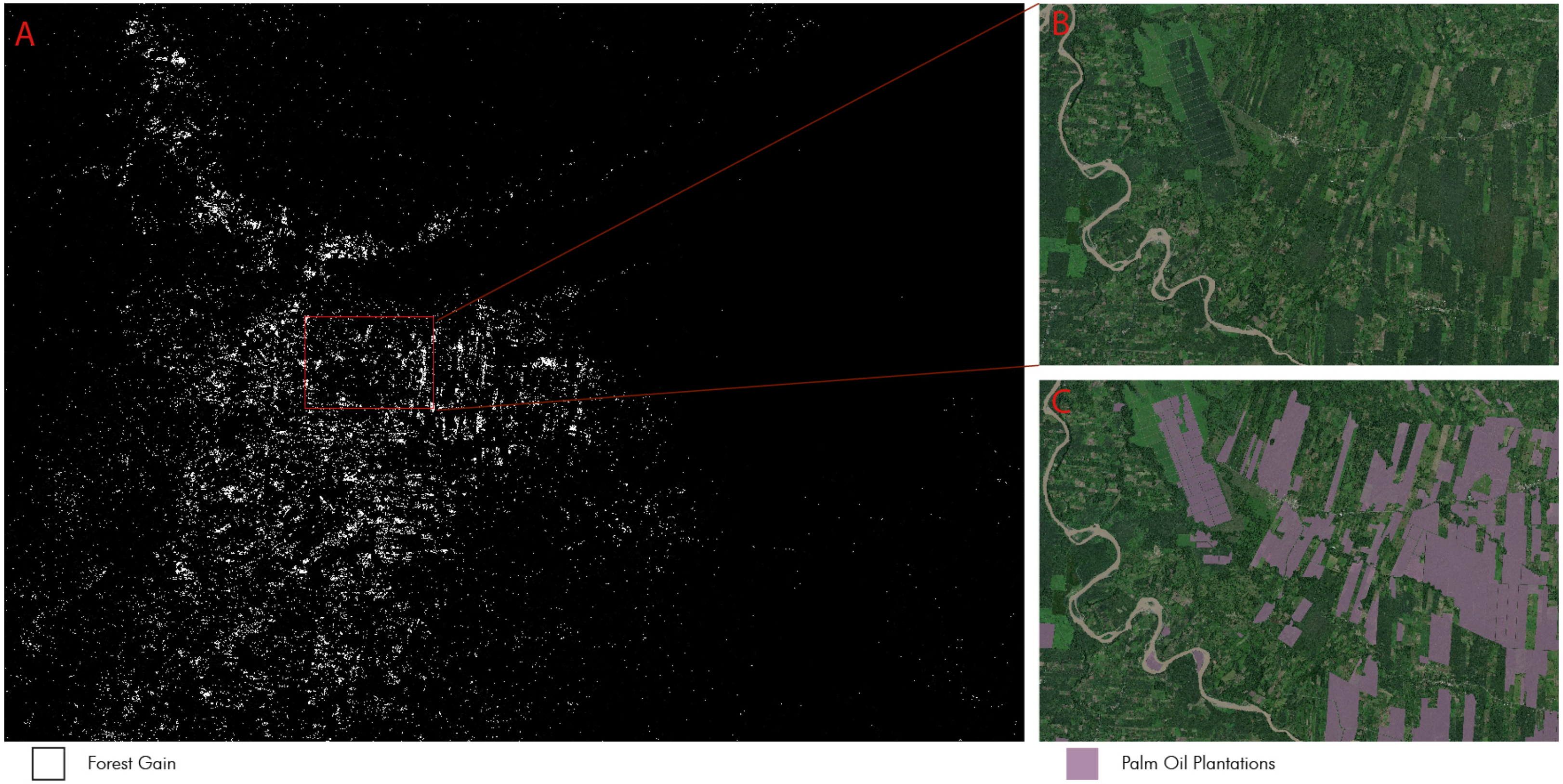


Figure 31 Hansen/UMD/Google/USGS/NASA - Forest Gain 2019: A. Hansen Forest loss map that shows in white the Forest gain; B. Zoom-in in Esmeraldas Province; C. Palm oil plantations in the area.[Source: (Hansen M. , et al., 2019)]

Therefore, optical imagery was shown to be inefficient in being used for land cover classification in areas that are characterized by having large extensions of palm oil plantations because it is not possible to distinguish them from forests. For this reason, it was needed to find a new methodology that allows to have a more accurate interpretation of the changes that this region has experiencing in the last decades. With the lack of availability of high quality multi-temporal land-use maps in regions characterized, other methodologies of studying land use change were needed. It was decided to perform classification of satellite imagery of the region to create multitemporal land use maps.

2.3.3 Multitemporal images and Sentinel 1 Separability Analysis

Seeking for methods of image classification for landcover evaluation and to identify the changes of the spatial delimitation of palm oil plantations, it was considered to use free and high definition optical imagery. Nevertheless, classification with optical imagery was not possible in this region. To cover the entire region, it was needed several satellite images and that correspond to two different year ranges, and this resulted very challenging because Tropical regions are characterized by cloud and fog cover. Even after removing the clouds and fog from the images, in an attempt to have a mosaic of maps that allow to compare the land use change was not feasible because the Ecuadorian Chocó region's climate is characterized by high precipitation all year round. Therefore, other methodologies needed to be explored.

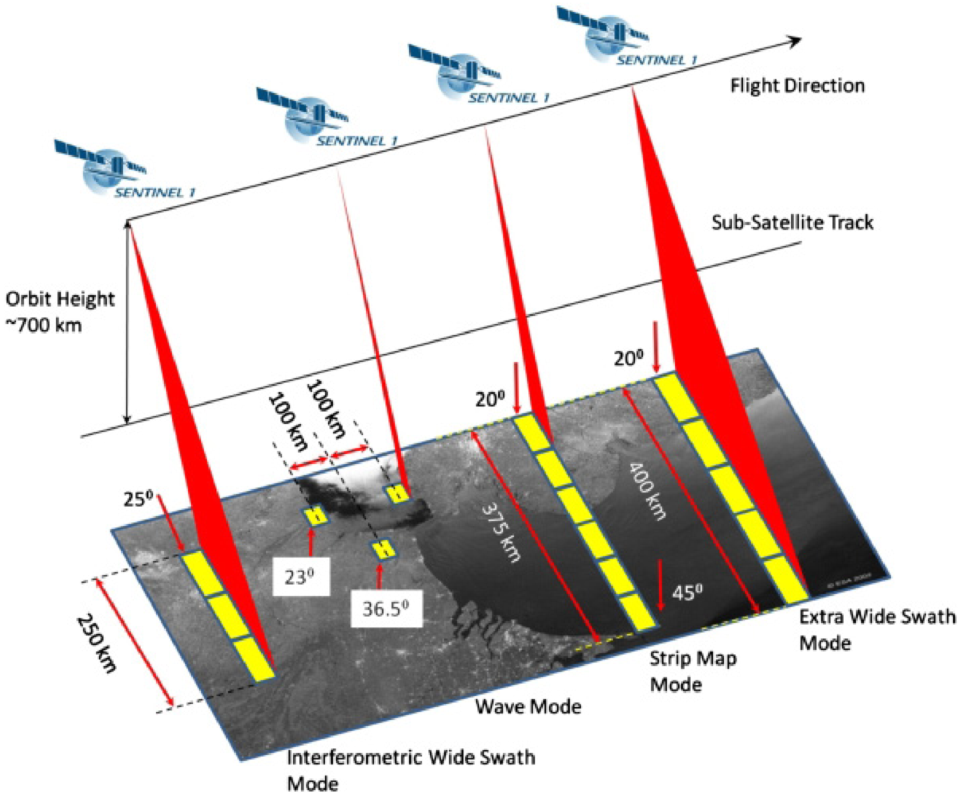
The Copernicus program is a collaborative European initiative for the implementation of information services that deal with environment and security. There are three priorities that have been identified for this program Marine Core Services, Land Monitoring and Emergency Services. Inside the Copernicus, the ESA is responsible for the development of an entirely operational space based capacity to use satellite data to feed the information services, This capacity can be achieved with the facilitation of access to data from existing missions and by the development of new Copernicus dedicated Earth Observation Missions, the Sentinel missions. The ESA Sentinel missions comprise the first sequence of operational satellites as a response to the Earth Observation needs of the ESA Copernicus program. As a component of this endeavor, ESA developed a European Radar Observatory (Sentinel-1), a polar orbiting satellite system for the continuation of Synthetic Aperture Radar (SAR) operational applications. Sentinel-1, that contains two satellites, is an imaging radar mission at

Figure 32 Sentinel-1 in Orbit. [Source: (European Space Angency , 2014)]

C-band Sentinel-1 data products whose applications are: monitoring sea ice zones and the arctic environment, surveillance of marine environment, monitoring land surface motion risks, mapping of land surfaces: forest, water and soil, agriculture, mapping in support of humanitarian aid in crisis situations (Davidson, et al., 2010).

Sentinel-1 has been designed to work mostly in a pre-programmed conflict-free operation imaging all earth's landmasses, coastal zones, with routes in full resolution and covering the entire ocean with imagettes. The reliability of the service is achieved by being consistent with the demand of operational services and long-term data archive that has been built for applications that are based on long time series. Sentinel-1's two-satellite constellation offer six days exact repeat and with the conflict-free operations based on a main operational mode it is possible to exploit every single data take. Sentinel-1 design addresses principally medium resolution applications that have a main mode of operation that features a wide swath (250 km) and a medium resolution (5 m x 20 m) (Davidson, et al., 2010).

Figure 33 Sentinel 1 Product Modes. [Source: (European Space Agency, 2020)]



For maximizing the benefits of the program, the Copernicus data policy has been based on efficient and free on-line data distribution without charges and the need for having to go through an ordering process. The data products contain "raw" level-0 data and "SAR processed" level-1 data that contain complex imagery with amplitude & phase and that has also been detected with intensity only. Various "higher level" products have also been provided with the inclusion of the level-2 geophysical parameters and level-3 mosaics and temporal data stacks (Davidson, et al., 2010). Sentinel-1 Level 1 data can be accessed in the Copernicus Open Access Hub with the distinction of two product types: Ground Range Detected (GRD) and Single Look Complex (SLC) (European Space Agency, 2020). Sentinel-1 level-1 GRD products contain focused SAR data that are detected, multi-looked and projected into ground level with the use of an ellipsoid model of the Earth. The Sentinel-1 GRD scene is made-up of pixels that have reduced speckle because of the multi-look processing, and that is represented only in the detected amplitude (Filipponi, Rome

The C-band data of Synthetic Aperture Radar (SAR) whose images are provided in all light and weather conditions has been successfully tested for the identification of agricultural crop and plantation species (Miettinen, Chin Liew, & Keong Kwoh, 2015). Microwave remote sensing generates its own irradiation with the ability to penetrate the surface, which can solve the problem of images with cloud cover, especially in Tropical countries where precipitation in very high. The information generated is based on backscattered energy from the ground surface, and the microwave wavelength has a deeper penetration power (30 – 15 cm wavelength) that allows to distinguish the near-ground level information that is covered by canopies providing information of subcanopies structures. Moreover, it also provides information on the texture that can help distinguish a smooth surface, like water or bare soil, from an uneven surface, like trees and shrubs (Chong, Kanniah , Pohl , & Tan, 2017). The relevance on how Sentinel-1 relies in the capacity of having a more accurate distinction of natural vegetation and tree crops plantations in areas where optical imagery are not so efficient.

Sentinel-1 data are accomplished with the transmission of vertically polarized microwave signal, and then the reflection is detected by the satellite both in the Vertical Plane (VV) and in the Horizontal Plane (VH) (Lazecky, Lhota, Penaz, & Klushina, 2018). Sentinel-1 has single polarization, VV or HH for the Wave Mode and dual polarization VV+VH or HH+HV for all other modes. (Davidson, et al., 2010). In Tropical Areas the changes related to the reflection of VV and VH are relevant because they are key in distinguishing vegetation. The intensity of VV reflection increases with the size of reflecting objects while in the Vertical Plane (VH) it occurs when there is scattering within objects of size, similar to or smaller than the radiation wavelength regarding their orientation towards the inbound electromagnetic wave. Because Sentinel-1 uses signal of a carrier wavelength 5.55 cm, the VH backscatter is maximized by reflection from tiny and dense leaves rather than from larger leaves. So, with these features it is possible to separate types of vegetation.

Moreover, SAR imagery has several scattering mechanisms that contribute to offering information about crop properties related to its biomass, architecture and height. Likewise the SAR imagery is sensitive to the geometry of objects like roughness, texture and internal structure, and therefore it allows a better recognition pattern that can help identify the location and extension of specific crops tree plantations (Mercier, et al., 2018). For this reason, in recent years it has been carried out in different tropical locations, studies that test the usability of Sentinel-1 data for mapping palm oil plantations.

Palm oil plantations are replacing important Tropical forests of the world, and to better comprehend their overall impact worldwide, it is important to have accurate land use maps that

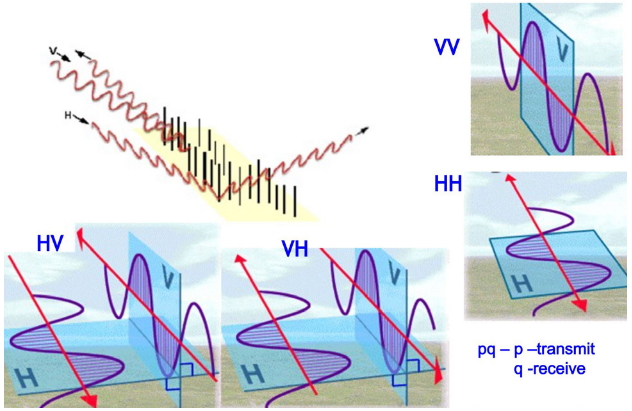


Figure 33 Polarization Combinations (VV, HH, VH, HV). [Source: (Lakshmi, 2012)]

allow to have available knowledge of its distribution and expansion. With the abovementioned attributes of Sentinel-1 data it is possible to create land use maps that are overall more accurate than optical imagery maps, and some studies have proven to be able to monitor the stage of their lifecycle (age). For this reason, it has been studied an innovative methodology that can assess the potential of Sentinel-1 available data for the creation of land cover maps of the Northwestern Chocó in Ecuador, and to carry out further analyses for understanding the main drivers of these crop trees plantations.

2.4 Climate Change: Global Warming and Disaster Risk Mitigation

Climate change, that is also known as Global Warming is the result of the effects of human action. The new post-ecological era known as the Anthropocene has transformed the world in many ways, from loss of natural environment, coastal reduction, pollution, global warming, among many others. Moreover, these changes not only have had an effect in the availability of resources to sustain live, but also has resulted in tremendous natural disasters around the globe that have taken many lives, left people homeless and left a huge loss in infrastructure and economy. It is necessary to take action into finding ways to give a halt to global warming and to prevent disasters worldwide. These actions should be addressed with strategies in which planning is developed from a wide knowledge of the hazards being endured, and it is only possible to do it with tools the right tools. Remotely sense data tools, real-time digital data, and the application of geospatial information tools and techniques are key to understand how to mitigate the climate change effects, in the long term (Atta-ur & Fang, 2019).

2.4.1 Group on Earth Observations

Group on Earth Observations (GEO) is an Intergovernmental Organization of more than 100 member governments and 100 Participating Organizations, of which are included national governments and the European Commission, intergovernmental, international, and regional organizations with a mandate in, and/or use of, Earth observations and related activities This group has been created in a response of climate change crisis to address and help mitigate its consequences. The importance of this initiative is that decisions and actions are enhanced by coordinated, comprehensive and sustained earth observations and information, for the benefit the world. GEOs work is focused on improving and coordinating global Earth observation (EO) systems, to promote the generation of EO products and tools for decision making; to promote broad, open data sharing and to build capacity and promote collaboration. The main global priority engagement areas in which GEO is concentrated on are the United Nations 2030 Agenda for Sustainable Development, the Paris Agreement, and the Sendai Framework for Disaster

Risk Reduction. But GEO also works across eight societal benefit areas, where Earth observations play a key role in decision making that are Biodiversity and Ecosystem Sustainability, Disaster Resilience, Energy and Mineral Resource Management, Food Security and Sustainable Agriculture, Public Health Surveillance, Infrastructure and Transport Management, Sustainable Urban Development and Water Resources Management (West, et al., 2018).

The purpose GEO is to make decisions and take actions for the benefit of humankind with information coordinated, understood, and sustained by Earth observations to address global environmental change, and its resulting impacts on all aspects of society. Earth observations are imperative for helping countries accomplish the UN 2030 Agenda for Sustainable Development and also, the associated Sustainable Development Goals (SDGs). Assessments by GEO and the Committee on Earth Observation Satellites (CEOS) have identified nine goals where Earth observations are most important from the SDGs: zero hunger, good health and well-being, clean water and sanitation, affordable and clean energy, sustainable cities and communities, sustainable consumption and production, climate action, life below water and life on land. Earth observations are used for monitoring and reporting on the SDG targets and indicators, and help countries develop policies, track progress and make decisions and adjustments (West, et al., 2018).

2.4.2 GEO and The Sendai Framework for Disaster Risk Reduction

Open Earth observation data and information are a major component in the reduction of disaster risk. The United Nations Sendai Framework for Disaster Risk Reduction commits governments to the creation and implementation of national and local disaster risk reduction strategies. The aim of these strategies is to significantly reduce the impact of disaster risk and the loss of lives, livelihoods, and health. Also, the economic, physical, social, cultural, and environmental assets of the whole world (West, et al., 2018).

In the Anthropocene era, humanity is dealing with various inherent hazards in the context of climate change. The events in the last few decades like, hurricane Katrina and hurricane Sandy, have enlightened scientists and planners that the actions to manage these disasters is not enough. It is needed a disaster risk management, to prevent further damage and death in the most vulnerable areas of the World. For this reason, many countries and institutions are looking for an approach that can help mitigate human driven, natural driven and global warming related disasters. One of these efforts is being carried out with the initiative of the UN that has been improving its UN Sustainable Development Goals to include a framework that can help prevent and mitigate the effects of climate change. This is the Sendai Framework for Disaster Risk Reduction (SFDRR) that is an agreement of which the member countries agree to reduce and prevent disaster risks globally. Its purpose is to reinforce social and economic resilience to mitigate the effects of climate change, man-made disasters, and natural hazards (UNISDR, 1015).

2.4.3 GEO and the Paris Agreement

The Parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached an agreement to strengthen efforts to address the threat of climate change. EO are required for responding to various specific provisions of the Paris Agreement such as the inclusion of national reporting, mitigation measures, adaptation, technology transfer and capacity building.

With workshop on the Paris Agreement in 2018 was marked a significant milestone in GEO's hard work to engage important and key organizations that have explicit mandates in the climate policy process. The international agenda goal was to improve climate data access; supporting actions on mitigation, adaptation and loss and damage; to integrate climate with SDGs, Sendai Framework and other Rio Conventions; engage with national stakeholders; enhancing the use of climate data records for a variety of application areas, including drought monitoring, renewable energy assessments and health early warning systems, among others (West, et al., 2018).

The Paris Agreement

Tropical forests preservation and climate change are inextricably linked. Forests are natural carbon storehouses. They capture and store carbon at a large scale. Tropical forests comprise approximately 470 billion tons of carbon which accounts for more than half the global carbon (Interface Rainforest Initiative). From 2010 to 2015, tropical forest area declined at a rate of 5.5 M ha y-1 – only 58% of the rate in the 1990s – (Keenan, et al., 2015)

Many organizations and countries worldwide have signed-in to find ways to address global warming and climate change. In 2016 the Paris Agreement was signed as an effort to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. The EU contribution is to reduce greenhouse emissions (GHG) to 40% by the year 2030, and while carbon emissions from fossil fuel use are very well quantified, emissions from land-use change in tropical regions—that contribute to 20% of annual greenhouse gas emissions globally—are the most uncertain thing of the global carbon cycle (Harris, et al., 2012).

Reducing emissions from deforestation of Tropical Forests can contribute to stop or slow down climate change. If tropical countries manage to reduce deforestation in an unprecedented rate, emissions allowances from reduced deforestation could help developed countries and their industries control costs and take steeper reduction targets. Carbon market credits for reduced deforestation can also help communities in tropical countries benefit financially and this could become a real incentive to help preserve the Tropical Forests. For this Carbon markets to work, the UNFCC included the Reducing Emissions from Deforestation and Forest Degradation (REDD) concept that has involved many countries in the attempt to globally reduce carbon emissions. For this concept to work it is needed to measure and monitor deforestation in Tropical countries (Asner).

Tropical Rain Forests are also recognized as the most biodiverse terrestrial ecosystem in the world, that beyond storing carbon sinks, also provide important ecosystem services. The importance of the preservation of these forests is also linked with the importance of preserving wildlife and biodiversity because they are currently hosting two thirds of the world-wide biodiversity (Gardner, et al., 2009). Preserving biodiversity provides various benefits regionally and globally by providing economic goods, environmental structure and balance, and habitat transformation and fragmentation (Raffaelli & Frid, 2010). Moreover, besides sustaining the biodiversity and sustain a reservoir of carbon sinks, Tropical forests provide various additional benefits globally, that are related to climate. They help maintain the moisture in soils and in surface air, they reduce the radiation exposure of the soil, it weekends the wind in the near surface and overall maintain the productivity of tropical ecosystems (Pielke, et al., 2013). For these reasons, efforts to mitigate climate change need to deepen in the preservation of Tropical forest, reforestation, and afforestation.

As an incentive for long-term funding for the preservation of Tropical Foreststhere exists an alternative: the market approach that can trade rights and needs of local communities to protect biodiversity and reduce greenhouse gas emissions. As stated by Swingland in Capturing Carbon and Conserving biodiversity (Pielke, et al., 2013), GHG mitigation markets exist and have a great potential in developing countries.

In 1990 the United Nations Framework on Climate Change Convention took place in response to 'stabilize the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (Blobel, Ohlendorf, Schlosser-Allera, & Steel , 2006) Consequently, in 1997 the revision of the convention created the a plan to reduce the main Green House Gases (GHG) emissions (CO_2, CH_4 N_2O, HFCs, PFCs and SF_6) called the Kyoto Protocol (Justicia, 2007)

The Kyoto Protocol was provided as an instrument to assist Parties included in Annex I to the United Nations Framework Convention (Annex I Parties) in the implementation of their commitments related to the accounting of emissions. The policy instruments include the accountability on reporting the GHG emissions in national system inventories, the accounting of assigned amount, specifically national registries and transactions, tradable emission credits or 'emission trading' (ET) and procedure for accounting for Land Use, Land Use Change and forestry (LULUCF) activities (UNFCCC, 2008)

Governments of tropical & subtropical developing countries and donor organizations who participate in the Kyoto Protocol for CO_2 reduction use as a primary source for baseline estimation optical sensors. Nevertheless, due to frequent cloud cover it can be challenging. With the availability of multi-temporal Sentinel-1 data products land cover classification and soil moisture estimation are expected to dramatically increase (Davidson, et al., 2010). The methodology proposed in the next Chapter can be an opportunity to be used as part of greenhouse gas concentrations and emissions inventories and monitoring.

CHAPTER 3: RESEARCH METHODOLOGY AND RESULTS OF DATA ANALYSIS

3.1 Research methodology

There is a lack of availability of shape files (geospatial vector data format for Geographic Information System (GIS)) of land-use/land-cover changes of Ecuador in the past decades. Although many governmental platforms allow free access to some data, it is currently inaccessible the download of multitemporal shape files. Hence, the main objective of this research is to find a feasible methodology that allows to identify the drivers and the most vulnerable areas to change and therefore, it has been implemented an innovative method of land cover, land use maps. The methodology used for creating the land use and land cover maps uses data and software that is available in the public domain.

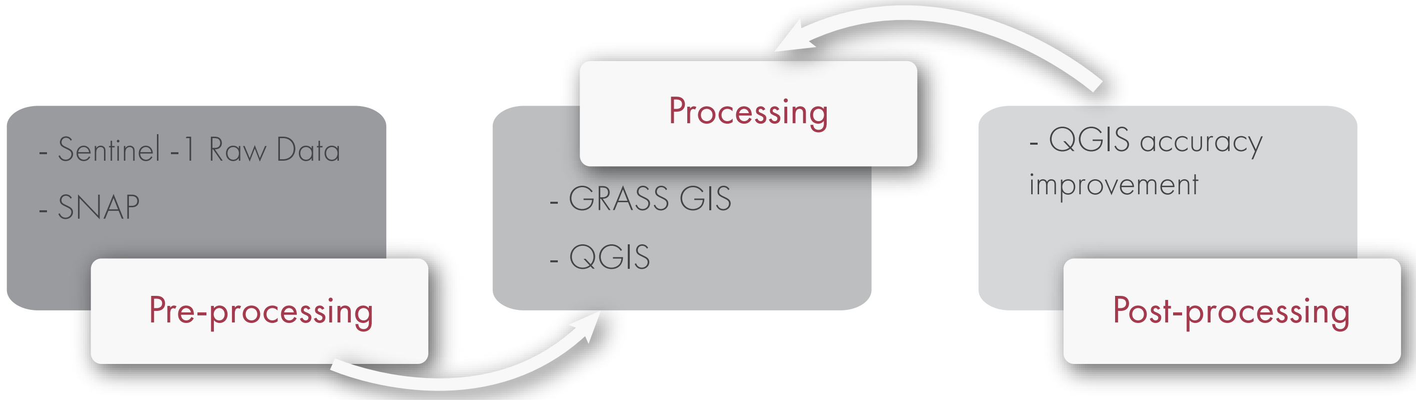
3.1.1 Objectives

After attempting to carry out multi-temporal land use maps of the region of the Chocó in Ecuador, from public available satellite data, such as Landsat and Sentinel-2 imagery, it was decided to find a new methodology for the creation of these maps. Although the processing of these images is lengthy, and the size of the digital files is significant, it was possible, through different platforms, to obtain Random Forest classification of two time-periods, May of 2015 and May of 2019.

The objective of this new methodology is to find a way that allows to determine what has been the expansion of palm of plantations in a 4 year time period (2015-2019) and if the changes have been significant in a short year range. Moreover, this methodology allows to compare the land use maps created from the Sentinel-1 imagery to have a better knowledge on the patterns of change of the land use and what are the main drivers and threats for deforestation. Additionally, it was possible to compare these maps with historical digitalized maps, to have a broader understanding of the trends of land use and a further quantification of the deforestation rate. And, by using remote sensing, GIS techniques and this innovative method to create land use maps, it is also possible to define the boundaries of habitat patches that are the most vulnerable and determine the expected expansion and hotspots for palm oil plantations in the future. All this information is then analyzed in conjunction of interviews carried out on experts of the region to determine what and where should efforts be concentrated in order to ensure the conservancy of this region.

The methodology was carried out following several papers that describe how it is possible to use Sentinel-1 data to create land use maps. All this information was tested and improved to work with the tools available for studying the Chocó Region, because not all studies describe all the processing parameters to achieve a good result. The most important studies that use similar methods were carried out by Fatwa Ramdani (Ramdani, 2019) and Miguel Castro (Castro G., 2018), but these were combined with others. Ramdani (Ramdani, 2019) states that because of speckle noise produced in SAR images it is imperative to perform pre-processing steps pre-processing steps before it could be used for any interpretation or classification. So, with all the information of these references the processing steps and its sequence where chosen as it described in the following figure.

Figure 34 Processing steps for Creating Classification Map from Sentinel-1 Data.



Methods

- Apply Orbit File
- Radiometric Calibration
- Radiometric Terrain Flattening
- Thermal Noise Removal
- Speckle Filter 1: Lee Sigma
- Speckle Filter 2: IDAN
- Range Doppler Terrain Correction
- Convert Data Type
- Grey Level Co-occurrence Matrix

- Segmentation using object based geospatial feature extraction algorithm
- Export as Geotiff
- Polygonization of Segmented image in QGIS
- Sampling with Google Earth and xyz tiles
- Image classification tool with plug-in dzetsaka

- SAGA in QGIS with Majority Filter for implementing accuracy in classification
- Zonal Statistics to translate data as a vector file and meliorate results

3.1.2 Data Accessibility

The Sentinel-1 data is available using the ESA (European Space Agency) CREODIAS website. CREODIAS is a cloud platform infrastructure adapted to process big amounts data, and contains Sentinel-1, 2, 3 and 5-P, Landsat-5, 7, 8, Envisat and many Copernicus Services data (CREODIAS, 2020).

The Sentinel-1 datasets that used in this study were downloaded on May 2020. And for two-time ranges 2015 and 2019. For which it was only needed two images for each year to cover the entire region of Northwestern Chocó Region. The SAR data used have VV (Vertical-Vertical) and VH (Vertical-Horizontal) of dual polarization modes.

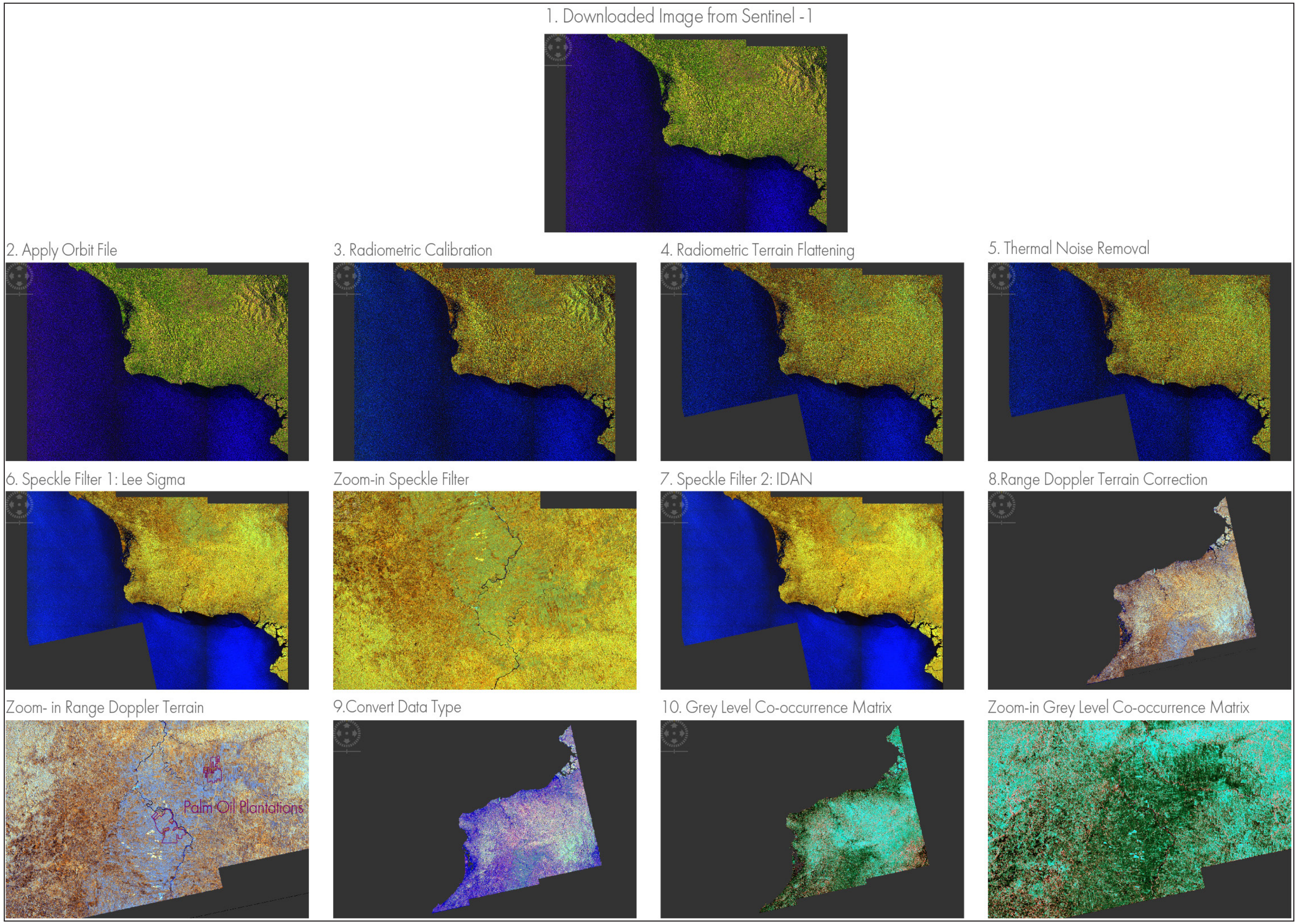
3.1.3 Pre-processing using SNAP

For a better classification process, it is necessary to preprocess the images to remove thermal noise, for radiometric and geometric correction, and for filtering. For this was used a free software offered by the ESA called SNAP. There are as series of steps that were tested in order to have a resulting image that is smooth for better understanding, eliminates features that can become a confusing when classifying, like topography, and that at the end facilitate a more accurate classification to create the land use maps. With SNAP it's not only possible to improve the quality of the SAR, but also visualize what this calibration techniques results are. In Figure 33 it is possible to visualize these changes.

1. Download Sentinel-1 data

There are several online services that provide and allow the download for free of Sentinel-1 data, CREODIAS has an online data base that allows immediate access, free of charge, earth observation data from the European Union Earth Observation data. Sentinel -1 products can be GRD, OCN, RAW or SLC, all of these are extracted from a C-BAND instrument but each of them has different detailed information that can be relevant in different studies. For the classification matters, the data acquired is a Level-1 processing level called Ground Range Detected (GRD) that are sampled n a resolution of 20x22cm (Lazecky, Lhota, Penaz, & Klushina, 2018). It is also necessary to acquire C-band dual-polarization data of vertical-vertical (VV) and vertical-horizontal (VH).

Figure 35 Difference in visual perception when processing in SNAP. After filtering with Lee Sigma and IDAN the palm oil plantations become evident. To visualize the result in RGB preview it was used a combination of Red: VV, Green: VH and Blue: VV/VH



2. *Apply Orbit File*

There are several online services that provide and allow the download for free of Sentinel-1 data, CREODIAS has an online data base that allows immediate access, free of charge, earth observation data from the European Union Earth Observation data. Sentinel -1 products can be GRD, OCN, RAW or SLC, all of these are extracted from a C-BAND instrument but each of them has different detailed information that can be relevant in different studies. For the classification matters, the data acquired is a Level-1 processing level called Ground Range Detected (GRD) that are sampled n a resolution of 20x22cm (Lazecky, Lhota, Penaz, & Klushina, 2018). It is also necessary to acquire C-band dual-polarization data of vertical-vertical (VV) and vertical-horizontal (VH).

3. *Radiometric Calibration*

Calibration is a very important step in SAR analysis. To provide imagery in which the pixel values can be directly related to the radar backscatter of the scene it is necessary to do radiometric calibration. The amount of data received by the radar signal accounts for many factors such as antenna gain, system laws, and etc, and this introduces a significant volumetric predisposition in the SAR image (Castro G., 2018).

4. *Radiometric terrain flattening*

Topography can have an impact in the contrast on certain areas in the SAR images, having shaded areas can be identified by classification programs as a different category to what the area belongs to. For this reason, terrain flattening is an imperative step to do in SAR analysis, without this step it will be reduced the accuracy of the classification process. It can be visually understood by looking at Figure 33, looking a the difference of the image from step 3 to 4.

5. *Thermal Noise Removal*

In SAR imagery, Thermal noise is the background energy that has been produced by the receiver itself. When this energy that is generated uses radar reflectivity with higher values, it obstructs the precision of radar reflectivity estimates. So, Level-1 products provide a noise lookout table for each measurement dataset provided in linear power which can be used to remove the noise from the product (Castro G., 2018). This step is important because the noise in the image interferes with the classification later, it reduces the quality of the information and, basically by doing this processing it is possible to remove part of the inherent noise that is present in the data. This specific alteration in the imagery is normally done after the B step of Apply Orbit File, nevertheless, it was found that the terrain flattening was imperative for a more precise classification and couldn't be done right after the thermal noise removal because the bands are converted to gamma type.

6. *Speckle Filter1: Lee Sigma*

Depending on the application and the objective of a study, Speckle filtering can be necessary, or not. In this analysis, with the objective of doing a classification map of the area, it is important to do it because it fixes the common problem of SAR imagery of the salt and pepper effect. Generally, SAR images have a granular aspect and random spatial variation and may decrease the utility of SAR imagery by reducing the ability to detect ground targets and obscuring the recognition of spatial patterns. The source of this noise is attributed to random interference between the coherent returns. The principle of Speckle filtering is to recue the variance of the complex of the takeoff scattering and improve the estimate speckle scattering coefficient (Castro G., 2018). It is common that when zooming-in in the SAR images it is possible to se areas that are characterized by a specific land cover, especially in agricultural fields, that the covers can be mostly homogenous. But the SAR images show them as almost homogenous by the exception of scattered pixels with a different color or characteristic. This is the salt and pepper effect. And with the Lee Sigma speckle filtering it is possible to remove is the most part.

7. *Speckle Filter 2: IDAN*

IDAN is the Intensity-Driven Adaptive Neighborhood filter. This filtering is not necessary if the image is already been filtered once with the Lee Sigma speckle filtering. This filter has the same objective, but after running different tests, it was found that applying also the IDAN filter helps smooth out the image more.

7. *Speckle Filter 2: IDAN*

IDAN is the Intensity-Driven Adaptive Neighborhood filter. This filtering is not necessary if the image is already been filtered once with the Lee Sigma speckle filtering. This filter has the same objective, but after running different tests, it was found that applying also the IDAN filter helps smooth out the image more.

8. *Range Doppler Terrain Correction*

From a visual perspective this step is evidently important, and thi is because the image is re-projected to the coordinates, and so it is possible to see the image in the actual position on the earths' surface. This step is very important because it allows to have a critical and visual recognition of the areas that are being analyzed, and although SAR images do not look like traditional satellite images like Google Earth, it allows to have an understanding of the spatial area in study. The radar information is mapped onto an angle range domain and so it has a side looking geometry of a source system. Moreover, SAR images are likely to be affected by geometric distortions, such as for shortening by shadows, because of the topographical variations of the scene. So, the terrain correction is the process by which SAR data is converted from slant range to ground range geometry and into a defined cartographic system. So, for this process we take advantage of a digital elevation model and at the same time we can also project our data into a specific map projection (Castro G., 2018). This can be better understood by the image above (Figure 33) in which from step 7 to 8 the image is re-projected to the coordinates of general cartographic system, and so it is possible to see the image in the accustomed position of the earths' surface. This step is very important because it allows to have a critical and visual recognition of the areas that are being analyzed, and although SAR images do not look like traditional satellite images like Google Earth, it allows to have an understanding of the spatial area in study.

9. Convert Data Type

This step is only done because of software requirements. It is needed to convert the products into bytes inputs because the GLCM operator that is going to be used next only uses this as input data type. This step in addition will allow us to have both bands in a common scale, while converting the data into the int8 target data type (Castro G., 2018).

10. Grey Level Co-Occurrence Matrix

The importance of this step is to manage the textures of the image. To accomplish an accurate result, the parameters in this step can be adjusted. Spatial information in the form of texture features can be useful for image classification. Texture measures can produce new images by making use of spatial information inherent in the image. It considers the information from neighboring pixels that is important to characterize the identified objects or regions of interest in an image. The Grey Level Co-occurrence matrix is a widely used method to compute second order textural measures. Each feature models' different properties of statistical relation of pixels co-occurrence estimates within a given moving window and along predefined directions and interpixel distances. The GLCM is a measure of the probability of occurrence of two grey levels separated by a given distance in a given direction. So, by deriving the textural information of the sentinel imagery the amount of inputs is increased so the classifier later on the land use of an area (Castro G., 2018).

11. Export image as Geotiff

Finally, we export the image as a Geotiff that is data that has georeferencing information to be embedded within a TIFF file , so when it is imported into different software it has additional information that includes map projection and the coordinate system.

3.1.4 Processing

Processing the processed image consists in using the Sentinel-1 data for classification of the land cover to create land use maps. This land sue maps main goal is to identify the trends in land cover changes with the analysis of multi-temporal maps created from data of May 2015 and May 2019. For the processing it is very important to have already pre-processed all the images that are going to be used for the multi-temporal analysis so they can be analyzed together before the classification process. There have been processed 5 images in total to cover the entire study area. Two images for the 2015 land use map, and 3 for the 2019 land use map. Then they were cropped accordingly to the area of interest so they can fit together, and then merged to have only one image for each year. Subsequently, each image needed to be cropped again in 5 smaller images, so the processing and testing time of the images is more manageable. These smaller images have been called subsets, which means they are a portion of the original image, but contain all the same information of the bigger one, such as bands, coordinates etc. These subsets were done directly on SNAP so it was possible to work simultaneously on the segmentation and classification on QGIS. Nevertheless, it can also be done in QGIS. Then, it was chosen a subset that was possible to easily identify the palm oil plantations for testing, this one was locate in the Quinindé region.

1. Sampling and choosing the classifier

For classifying the image, it is important to have samples that are used for training data for supervised classification. As mentioned hereabove, for testing the first image used was in the region of Quinindé where the palm oil plantation cover is very extensive. In Figure 36 it is possible to see how visible the palm oil plantations are in this area. Using this image and understanding what the colors are more likely to represent, it is possible to do the sampling. In the two upper corners there is a light greenish color that is forested areas, the dark blue is water, and the cyan color artificial cover or settlements.

Identifying the classes visually by colors is not precise and does not consider texture or other information in the image, and so it is only

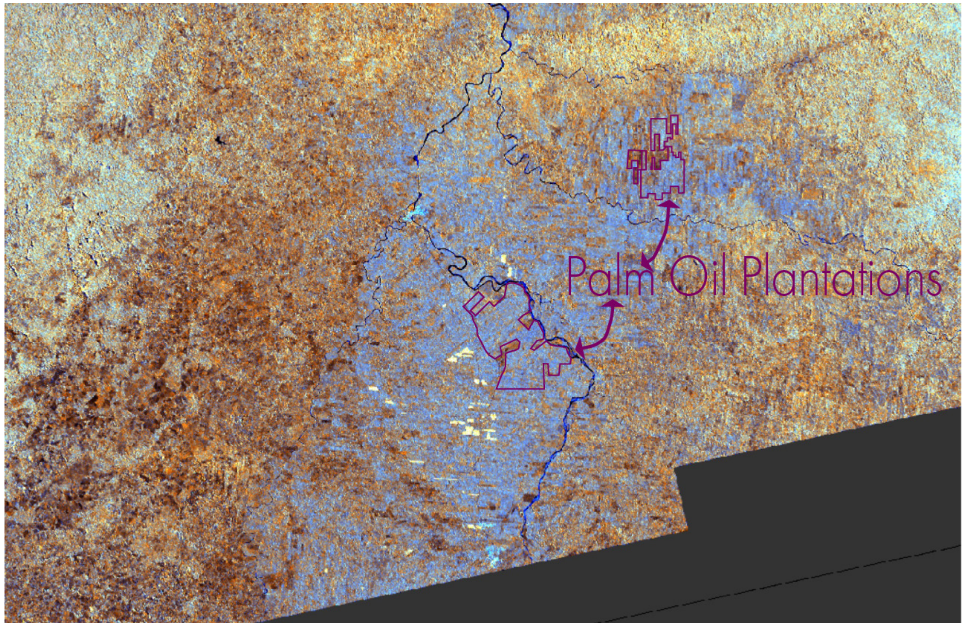


Figure 36 Quinindé area covered with Palm Oil Plantations in blue tone or framed as indicated in the image.

used as a reference to know where to sample. The sampling is done in QGIS with a point vector file, each subset contains around 100 to 150 samples, all distributes well along the image and making sure to have many samples of each class and that the samples are taken in areas of different conditions for each class. For example, palm oil plantations' soil usually covered with grass or low plants, but in some areas the plantations can be slightly flooded or have bare soil.

Google Earth tile was used in QGIS to zoom-in and have a better visual interpretation of the land use. Google Earth tiles are of a very high-quality that allows for a good interpretation of the land use. However, there are some areas in which the png images from Google Earth have gaps that have been filled poorly, and so it is impossible to understand what the land use is. For this it was necessary to use different tiles available online. Once the sampling is done, each image is tested with the classifier individually.

Number	Class	Description	Samples
1	Settlement	Urban areas and areas where infrastructure is established.	65
2	Water bodies	Areas covered by continental waters, including rivers and lakes.	250
3	Bare Areas	Areas that have been cleared for agriculture or naturally areas with bare soil due to topography.	309
4	Palm Oil Plantation	Extensive areas of the CGE have been cultivated with African palm. The productive life of this crop is about 25 yr, at which point plantations are replanted with younger palms.	680
5	Forest	Includes areas of tropical rain forest with trees taller than 30 m.	224
6	Secondary Vegetation	Formed by natural regenerations of vegetation, such as shrubs, small trees, or mosaics of both. Essentially, the difference with forests is that it has a less developed canopy structure, smaller trees, and less diversity.	189
7	Grassland	Formed by areas of introduced grass species which are used primarily for cattle grazing. Within the CGE, large areas of native grasses do not occur as natural vegetation.	234

Table 7 Differentiation of each class for Land Use Maps.

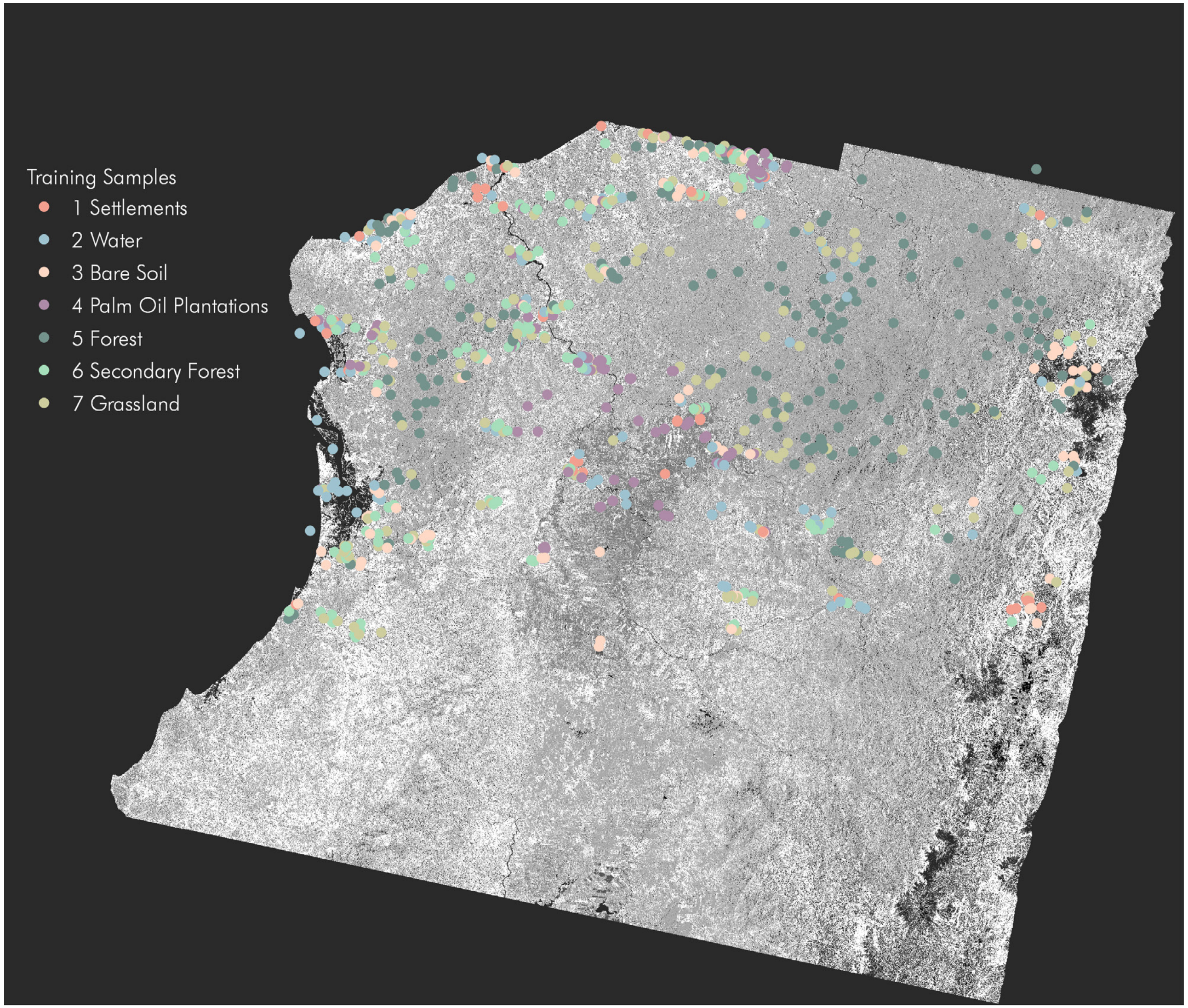


Figure 37 Training Samples in 2019 imagery.

The vector file for the sampling needs to have a column called DN that is in a number format to which each sample of each class is assigned to a number.

The Sentinel-1 data does not allow to separate into different classes the croplands from the grasslands, even if the crops are of different sizes like cacao that are medium size, or corn that are smaller. For which reason, the classification does not include the class croplands, as it is normally misclassified ad grasslands, and sometimes also as bare soil or settlements. Also, this analysis does not include different types of forest cover, as moist forest of dry forests' vegetation are different because the focus of this study was to separate palm oil plantations to understand their role in the land use change of the region.

2. *Classification with Random Forest*

The Dzetsaka plug-in in QGIS was originally created to be used for the Gaussian Mixture Model classifier developed by Mathieu Fauvel in QGIS. But its updates have allowed to have 4 different classifiers: Gaussian Mixture Model, Support Vector Machines, K-nearest Neighbors and Random Forest. Each of them offers a different precision in the classification, the latter, Random Forest, being the most accurate, but also, most time consuming, is the one it was used in this study. Random Forest (RF) classification is a statistical method in ecology to map vegetation by remote sensing techniques. Classification of trees has the potential of combining many classified trees to produce more accurate classifications. The by-products of the RF calculations include measures of variable importance and measures of similarity of data points that can be used for clustering, multidimensional scaling, and graphical representation (Cutler, et al., 2007).

This step was done repeatedly, for each image because if the sampling is not done well, many areas can be misclassified into a different one. So, cross-checking in each classification overlapping the raster result-

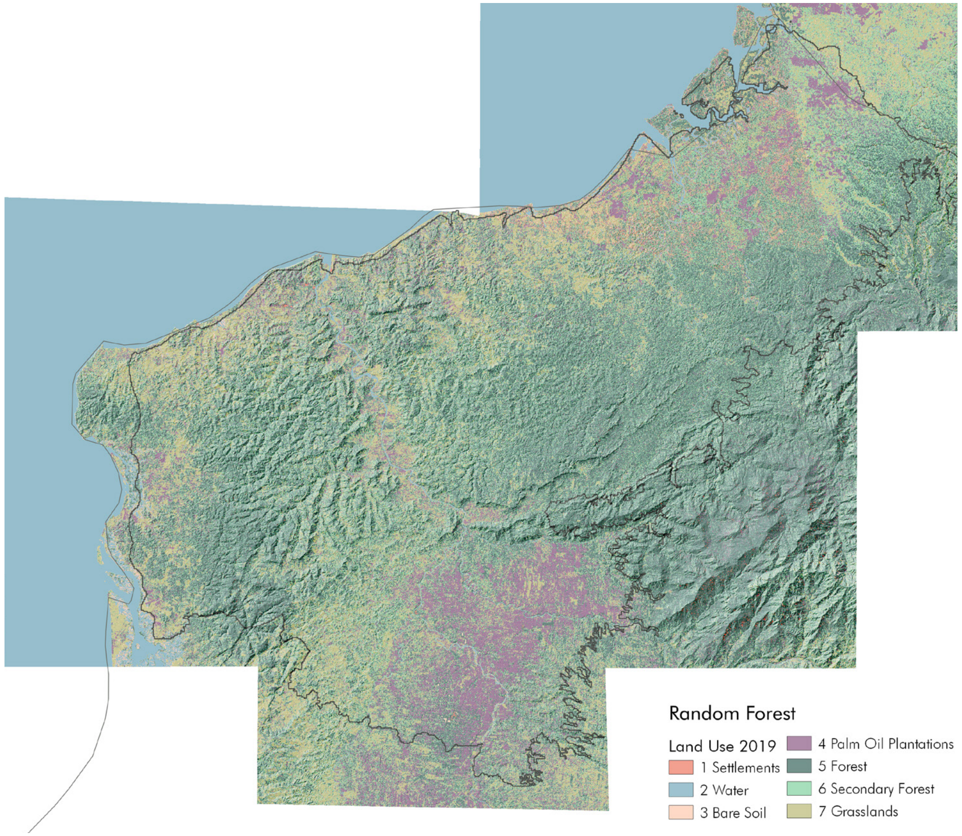


Figure 38 Result of Classification with Random Forest

ing image with the png tiles, to see what worked better. Also, another problem that was encountered is that there are two elements that can really cause a misclassification are topography and illumination. The topography was managed to be removed after several tests in SNAP on how to incorporate it into the steps of processing. But although the image was flattened in some areas some of the data that were characterized by being mountainous the misclassification continued to happen. To solve this, it was decided to use more than one images that covered the same area and see which result was better to keep.

Then, after achieving with each subset a classification that was very accurate, it was decided to perform the classification of the images as a whole, because this way the sampling would be more variate, and so the results could be improved. The time it takes to run the Random Forest of a whole processed Geotiff image is significant, for which reason it was only performed after the results with subsets were satisfying.

Finally, the having the raster image that contains the 7 classes mentioned before, they were cropped to keep the most accurate classification of each image, and then merged.

3. *Segmentation Stage*

The Segmentation stage is a key step in the classification of the images. The previous image that resulted from the classification process is noisy because the classification identifies each pixel and associates it with a class, but it does not take into consideration the nearby pixel class. So large areas characterized by a same land use, can appear to have a salt and pepper effect in which are pixels that 'don't belong'. The segmentation process works in the opposite way, the segmentation is carried out by separating shapes of similar characteristics, but these shapes are not associated to any class in specific. So, then it is important to combine both processes to have a smoother and clearer image.

It is important to import the images in GRASS so the images can be segmented into polygons as it can be seen in the image below. Although QGIS offers an extension of the GRASS tools embedded in the software, due to the heavy size of the images it was not possible to do so. Therefore, the images were processed separately in GRASS for the segmentation. The segmentation is an important process that can be done before or after the classification, as it will be used to vectorize the raster image that results from the classification process. The classification image is very detailed and to

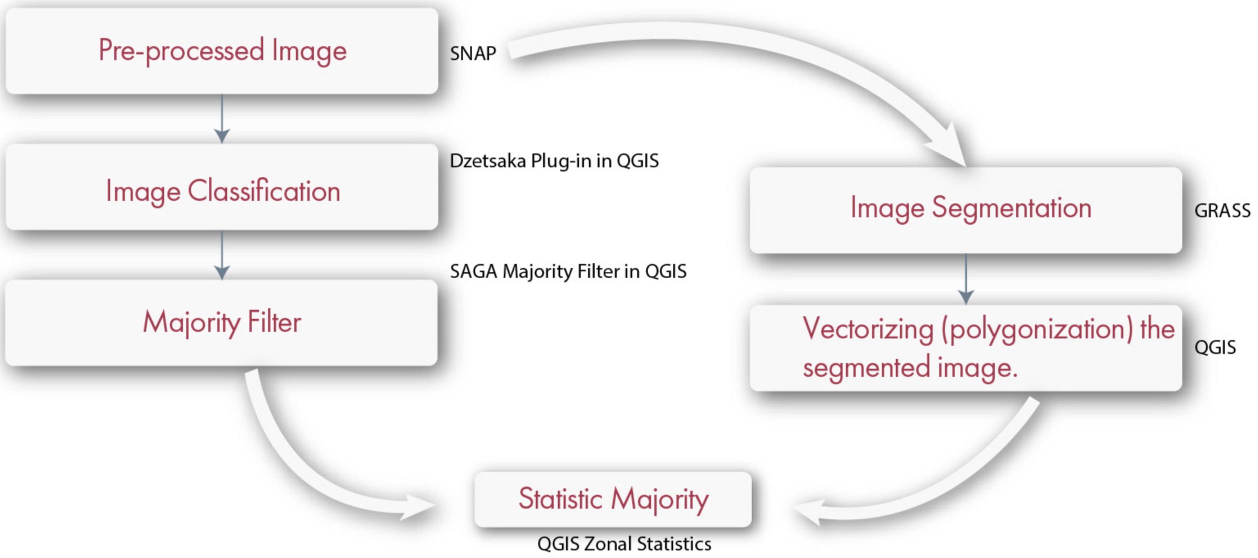


Figure 38 Result of Classification with Random Forest

vectorize it in QGIS could result in crashing the program and considering all the pixels colors that can still contain some of the salt and pepper effect from the Sentinel-1 data. Moreover, overlapping the Geotiff and the segmented image from GRASS, it is possible to see that the polygons follow the pattern of the image, this means that the colors that are visible in the image exported from SNAP correspond to the ones in GRASS.

To choose the parameters to do the segmentation it was used as a reference the data mentioned in papers that describe the classification process using Sentinel-1 data, such as the paper 'Recent expansion of oil palm plantation in the most eastern part of Indonesia: feature extraction with polarimetric SAR (Ramdani, 2019)'. But then tested to see the size of the polygons and how they match the original image. After the segmentation is done it is also exported as a Geotiff and then imported back into QGIS. Then it is vectorized and ready for the post-processing steps.

Figure 40 Segmentation Geotiff extracted from Grass and Polygonised in QGIS.

3.1.5 Post-processing

After the images have been processed, the result of the classification is very detailed, and the raster image is of a significant size. For this reason, it was necessary to perform additional filtering step in QGIS with a circular radius of 10 and a value of 0 for the threshold. This process smooths the image, so the different classes separation becomes clearer for a visual analysis. As mentioned before, the RF classification has noise, and the majority filter helps remove some of its noise or 'salt and pepper effect'.

The majority filter removes some of the noise as can be seen in the previous image, but still when looking at it closely, the shapes of the classes have a strange shape appearance. So here is when the combination of this image and the segmented one is important. Using this image to 'populate the segmented image extracted from grass is possible to do using Zonal Statistics. The result is a map with a very comprehensive an coherent land use classification that with overlapping it with Google Earth, is possible to verify that the land uses are accurate.

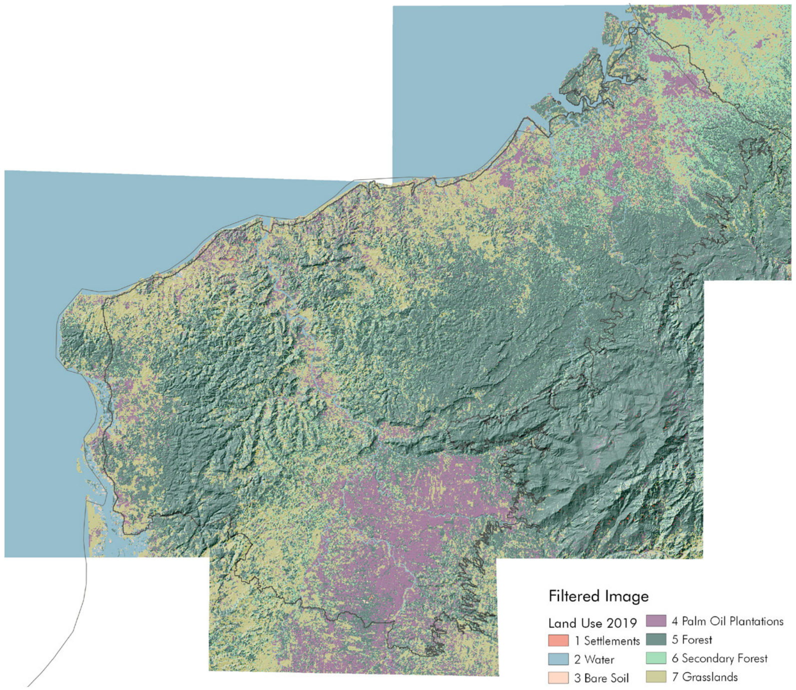


Figure 41 Majority Filtered Grid

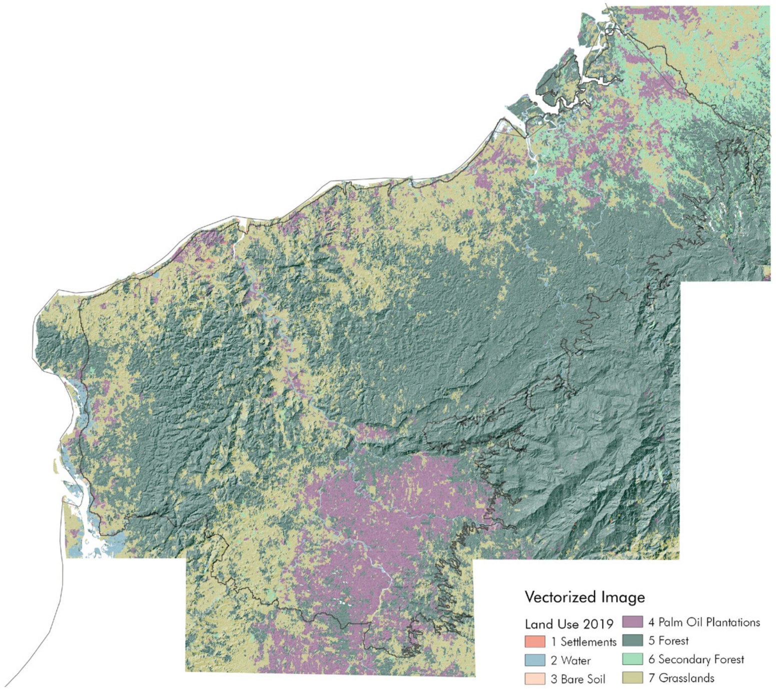
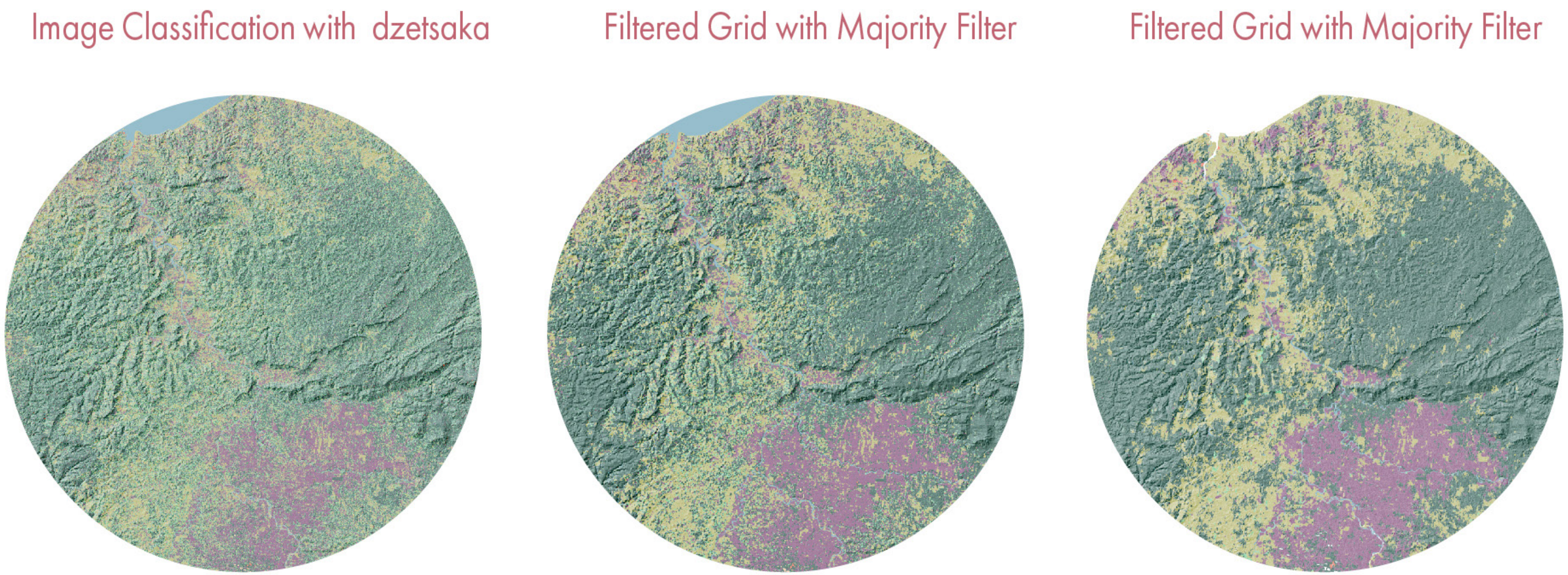


Figure 42 Vectorized Segmentation Image Classified with Zonal Statistics.

3.1.6 Multitemporal images

Finally, as it can be seen in the image hereunder, the post processing steps help clarify the image and thus, the classification result to be more accurate and coherent with the land cover of the region. These processes were done in images from 2015 and 2019 in order to be able to compare the land use change in a multitemporal analysis. The images used are the resulting ones of 2015 and 2019, and a digitalized image of 1983.

Figure 43 Comparison of Classification Maps, within ech post-processing step.



3.2 Results of Data Analysis

3.2.1 Landscape Cover and Land Use Change in the last 30 years

The study of the results of the data analysis is done by comparing the images from 1983, 2015 and 2015 to study the drivers of the changes that have occurred in this time period. First by comparing the area extent of each class to understand the land use changes, and then using climatic, topographic and proximity features to determine which features are the most deterministic for the expansion of palm oil plantations. The study of drivers is generally done with data from 2015 because it is not possible to access all data for 2019, so consequently, the main comparison of changes is done with the land use map of 2015. Finally, after determining which are the most important drivers for land use change into palm oil plantations, it was determined which are the most vulnerable areas by a process of clustering.

1. Elaborated Maps with New Methodology

With the methodology (mentioned in Chapter 3.1) were elaborated two different maps of land use with the use of Sentinel-1 data, one in 2015 and the other one in 2019. Overlapping these 2 maps and the digitalized 1983, using QGIS tools it was possible to create a transition matrix for the periods of 1983 to 2015, and from 2015 to 2019. The latter transition table isn't included because in the short time-period the changes are notable but not so easily quantified.

Additionally from the images created with Sentinel-1 data, with the digitalization of the Historical Map of 1983 it has been possible to understand better how the landscape has changed, what are its main drivers and what is the role of palm oil plantations in these changes. It can be quantified clearly that over 30 years ago the landscape was more heterogenous. It was a combination of natural extension with patches of pasture and crops. The forested areas where fragmented in the area close to the river plain, but it remained continuous, whatsoever. The main crops because of the 'golden years' of market demand were bananas, coffee and cacao. But the two latter were cultivated in combined landscapes. Currently, this has been replaced by a monoculture of palm oil plantations that result in a very homogenous landscape, that can be easily identified from an aerial view or satellite images, and by exploring the landscape in-situ.

Figure 44 Land Use Map of 2015 extracted from Sentinel-1 satellite imagery

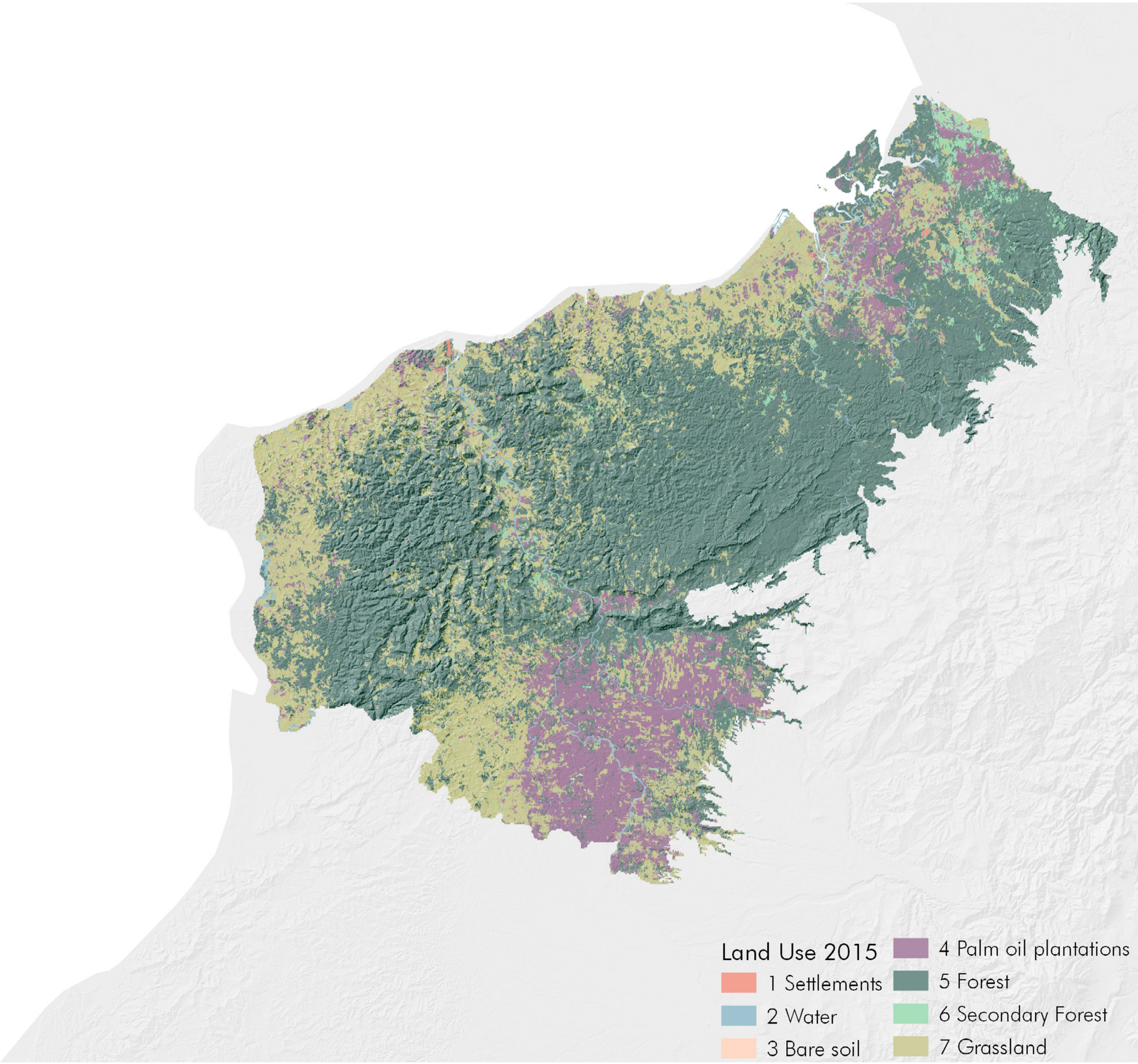


Figure 45 Land Use Map of 2019 extracted from Sentinel-1 satellite imagery.

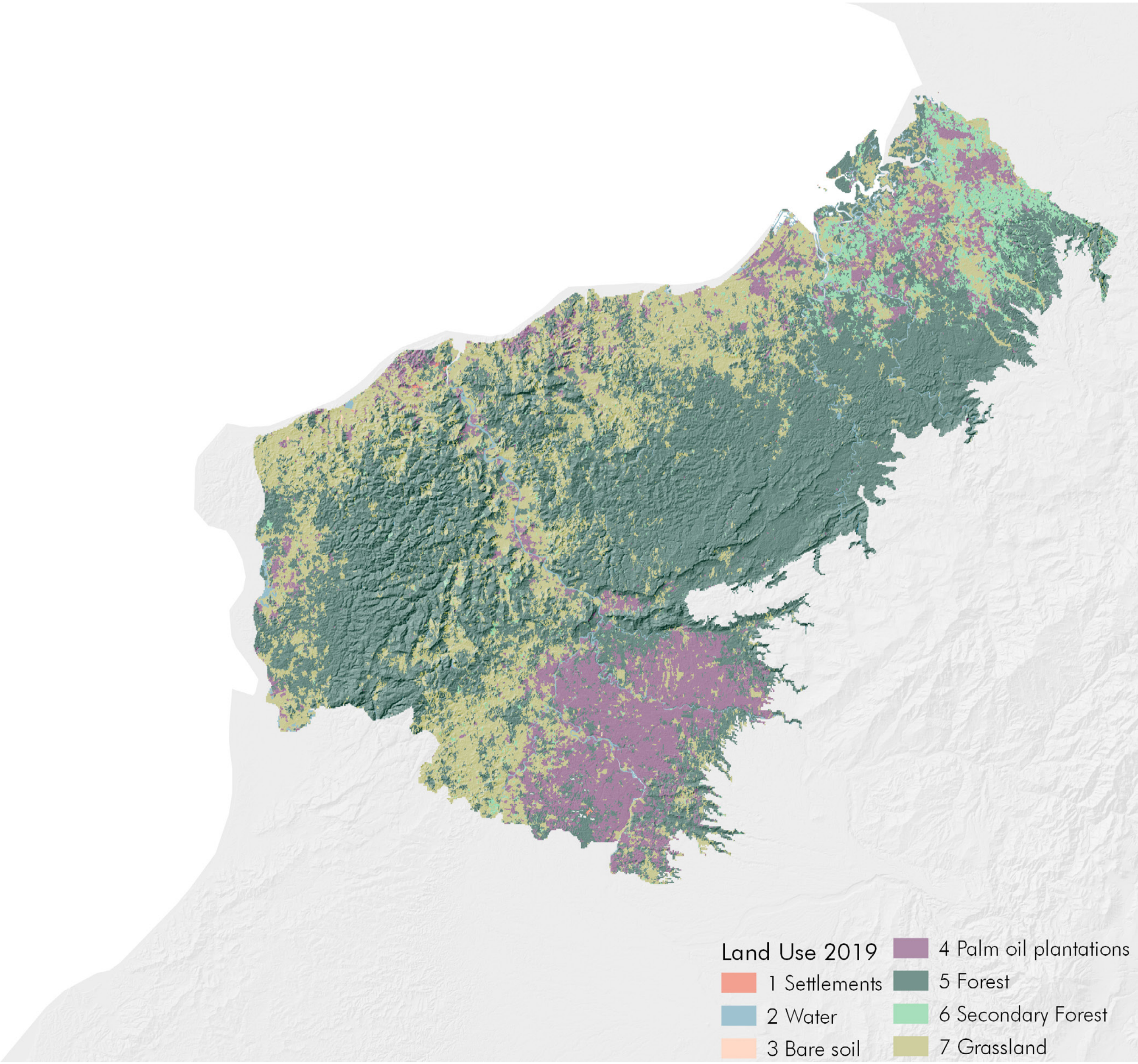


Figure 46 Digitalized Historical Land Use Map.[Source:
(De la Torre, Manrique, Trujillo, & Zuñiga, 1983)

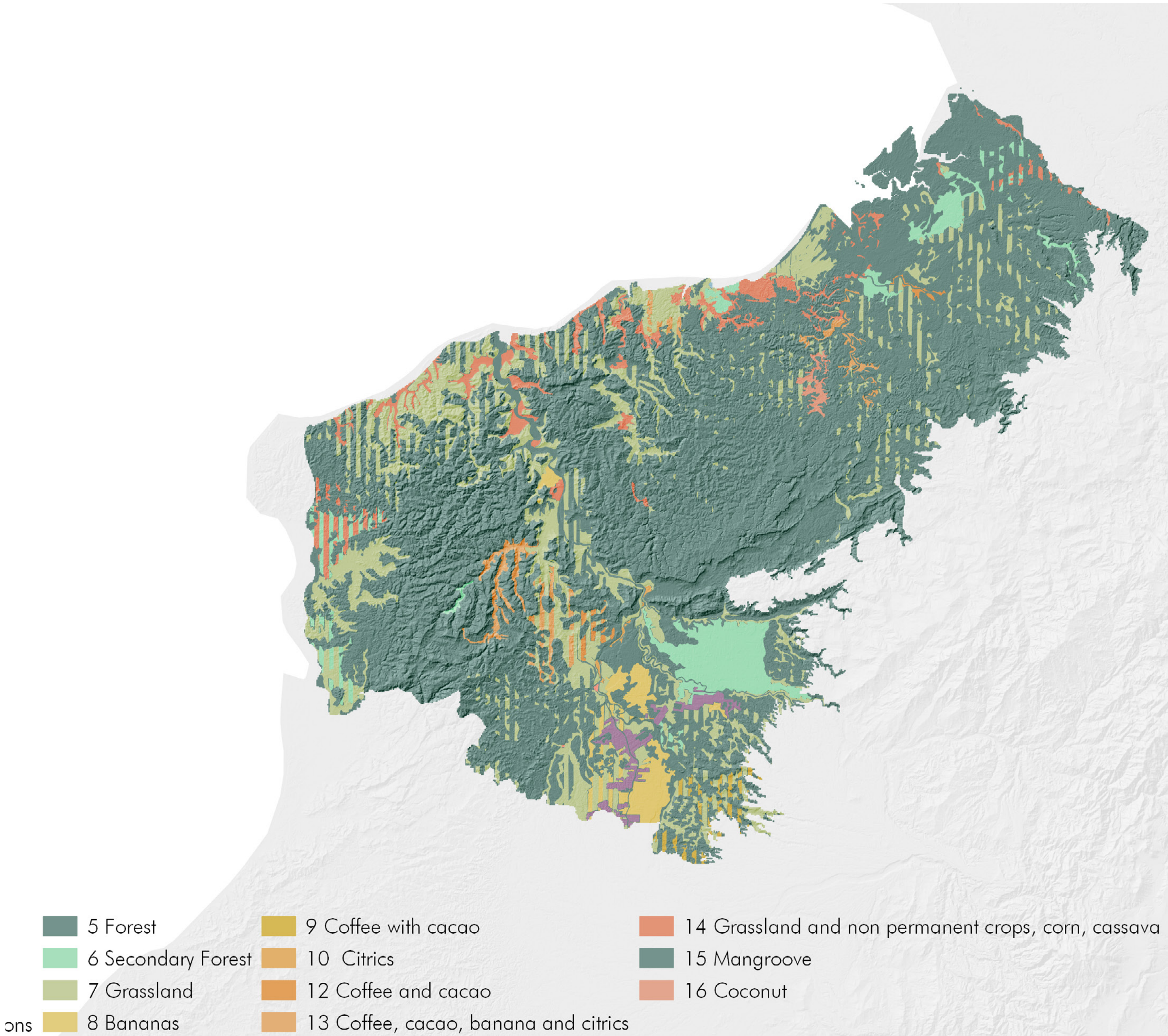


Figure 47 Palm Oil Plantations Pattern top view. [Source: (Culebras, 2019)]

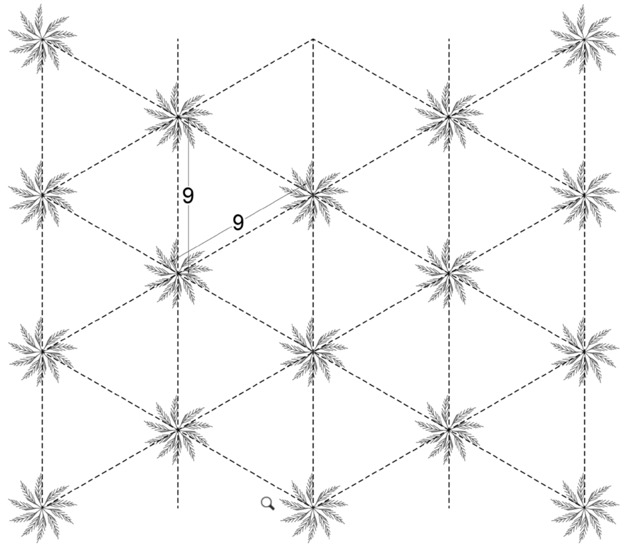


Figure 48 Palm Oil Plantation Pattern

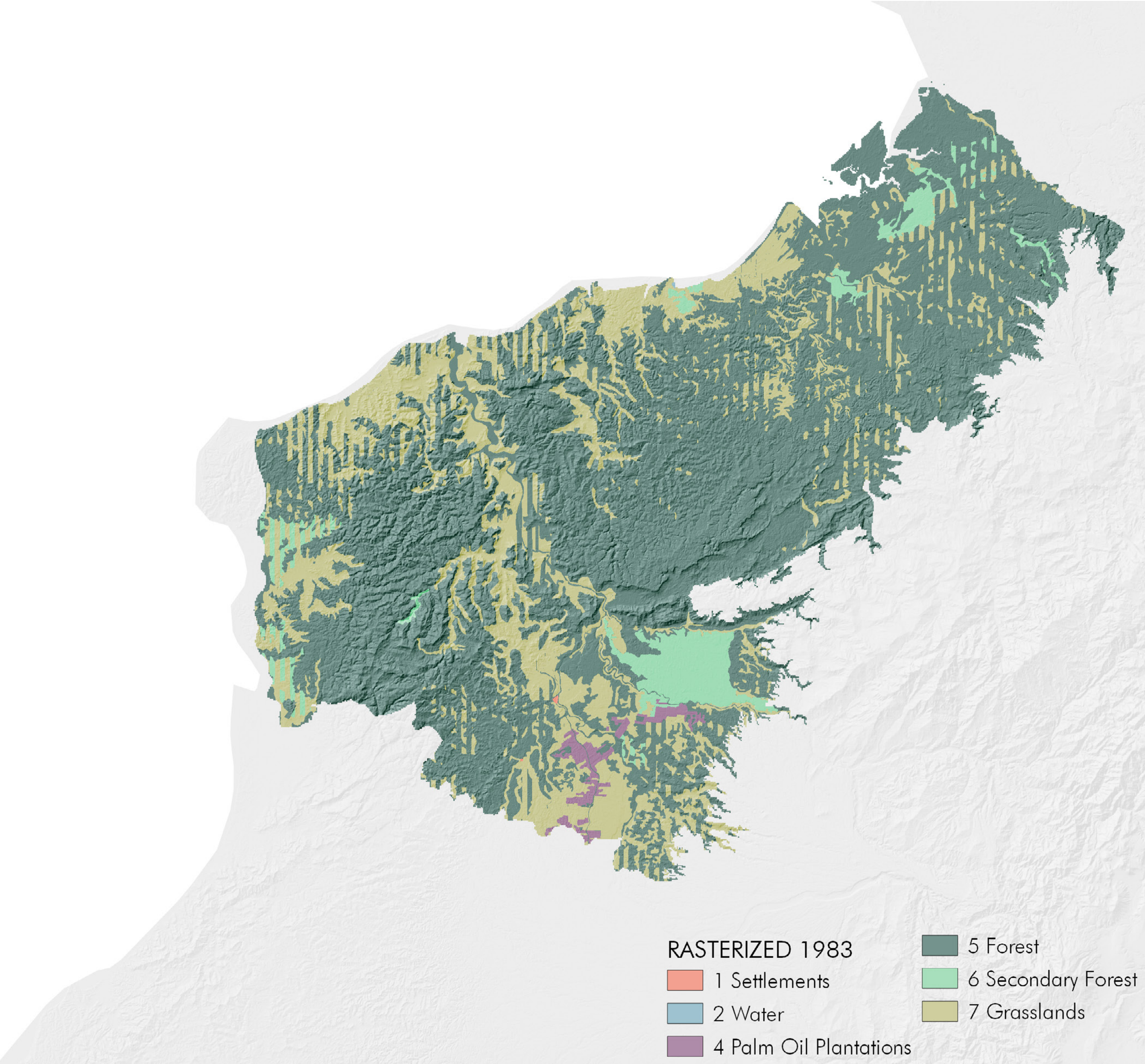
2. Comparison of Land Use in Multitemporal Maps

The methodology used to create updated maps of the region where successful with the use of Sentinel-1 because its cloud penetrating abilities allowed to have a partial classification land use cover. Nevertheless, its two bands don't allow to distinguish classes that emit similar data, like crops that can be mixed up with grassland cover, or bare soil with settlements. For this reason, the categories used for mapping are, as mentioned in 2.4, are Settlements, water, bare soil, palm oil plantations, forest, secondary forest and grasslands. The pattern used to plant palm trees can be easily distinguished to do sampling for the classification.

3. Digitalization of 1983 Map

The original map from which the data was extracted inlcuded all the different cultivation cover classes, but to match the same classes from the new elaborated maps, the classes were merged in order to obtain the same 7 classes. The interest of mapping was more to overlap the forested areas in 1983 and 2015, to have a quantified table to see how much in 2015 was still preserved, and to quantify the expansion of palm oil plantations in the same period. Also, the waterways have changed a lot during this period and for this reason they weren't mapped since this wasn't the main focus of the digitalization. So, in Figure 48 is the resulted digitalized map, with the above-mentioned classes.

Figure 49 Digitalized Historical Land Use Map.[Source: (De la Torre, Manrique, Trujillo, & Zuñiga, 1983)]



4. Expansion of Palm oil Plantations

To understand what land use cover has replaced the natural environment the maps were separated into different independent maps of each class, (e.g. one image for only forests), and then overlapped by using raster calculator on QGIS. The resulting map is a map that shows the value equal to 1 only in the areas that are overlapping by each class in the different time period. With this data, is created a Transition Matrix. So the values acquired represent what percentage of the land use in the old time (e.g. 1983) remain as the same land use in the older time (e.g. 2015) Although, croplands are not being considered, this table allows, not only to determine that there has been a great loss of forest, but what is the land use that has been replaced for Palm Oil Plantations. Secondary Forests are possible to be distinguished because they are formed by natural regenerations of vegetation, such as shrubs, small trees, or mosaics of both. Essentially, the difference with Primary Forests is that it has a less developed canopy structure, smaller trees, and less diversity. Secondary Forests have these differences with Primary Forests because they have been altered by human activity, sometimes they are cleared for pasture, roads, or any agricultural practice. And in the chart below it is possible to notice that although the main threat to Primary Forests and Secondary Forest are Grasslands (that can also be mixed up with other crops), the Secondary Forests are highly threatened by Palm Oil Plantations. The 39% of Palm Oil Plantations in 2015 used to be Secondary Forests, and only 19% of Grasslands has become Palm Oil Plantations. This matrix proves that although preservation policies and sustainability practices are looking to ensure that Palm Oil Plantations are not cultivated in areas that its previous land use was of natural character, this goal has not been met. The Ministry of Agriculture supports Palm Oil farmers by stating that new plantations are only replacing pasture and other crops, but it's not true. There exists illegal exploitation of forests that become part of this industry.

1983↓/2015→	Forest	Secondary Forest	Grasslands	Palm Oil Plantations
Forest	69%	2%	20%	7%
Secondary Forest	21%	3%	36%	39%
Grassland	35%	2%	42%	19%
Palm Oil Plantations	4%	0%	7%	88%

Table 8 Transition Matrix for the period 1983-2015 in percentage of the total study case area. Comparing digitalized Historical Land Use Map and 2015 Land Use Map extracted from Sentinel-1 satellite imagery.

LULC Type	Total Area Coverage in Hectares			Gain/Loss (%) Between Different Times	
	1983	2015	2019	1983-2015	2015-2019
Forest	881060.44	718458.97	690368.73	-18.46	-3.91
Secondary Forest	51368.94	27032.09	55559.84	-47.38	105.53
Grassland	290190.81	317052.53	310912.93	9.26	-1.94
Palm Oil Plantations	10517.64	148818.07	156795.11	1314.94	5.36

Table 9 The area in square meters approximates the relation of pixels to meters of the raster images of the maps, that have a resolution of 10m by 10m.

Additionally, to better understand how much natural environment has been lost in the period of 1983-2015 and 2015-2019 it was also created

In the period of 1983 to 2015 there has been an 18% loss of Primary Forest, 47% loss of Secondary Forests and a significant gain of Grasslands, and more importantly of Palm Oil Plantations. Likewise, although the time range of the period of 2015-2019 is short, it is possible also to distinguish some changes. There is loss of 3.91% of Forest and an increase of 105% of Secondary Forests. The Secondary Forests increase means there has been an increase of interventions in the Primary forests that have now become, secondary for this reason. And also, there is an increase of 5.36% of Palm Oil Plantations.

LULC Type	Total Area Coverage in Hectares			Gain/Loss (%) Between Different Times	
	1983	2015	2019	1983-2015	2015-2019
Forest	881060.44	718458.97	690368.73	-18.46	-3.91
Secondary Forest	51368.94	27032.09	55559.84	-47.38	105.53
Grassland	290190.81	317052.53	310912.93	9.26	-1.94
Palm Oil Plantations	10517.64	148818.07	156795.11	1314.94	5.36

Table 10 Gain and Loss Percentage in the Time Period of 1983 to 2015 and in the Time Period of 2015-2019

3.2.2 Study of drivers for change

Studies that include direct and indirect drivers in the tropical areas of South America have been determined in general standards, by literature research. The main direct drivers in the tropical areas of this region is farming expansion, logging and mining. The main indirect drivers are related to socio economic forces and demographic indicators but, also with geographical factors like soil fertility, topography, accessibility and distance to rivers, roads and settlements. (Fagua, Baggio, & Ramsey, 2019). For this reason, to have a more accurate and specific approach that suggests the main vulnerable areas in the Chocó-Andino, I have carried a series of data analyses to determine the 'hotspots' for land use change in the region.

1. Drivers of Land Use Change in the region

The drivers of land use change in tropical areas can be divided into two different classes: indirect and direct drivers. Indirect drivers are underlying or indirect causes that include social and cultural interactions, economic, political or any other cause that affects indirectly the land use change. Direct drivers are more immediate actions that directly happen when replacing forests into another land use or the opposite, turning areas into forests. In the tropical regions in South America the main cause of land cover change and deforestation is farming expansion, but also logging and mining (Fagua, Baggio, & Ramsey, 2019).

As mentioned before, the main direct driver for deforestation is large scale and small-scale agriculture that is estimated to cause 90% of the deforestation in Ecuador. Likewise, mining contributes to deforestation, from the period of 1992 to 2011 there have been 1092 mining contracts, many of them still active today. The largest files taking place in northwestern Ecuador in the province of Esmeraldas and Carchi (WWF Colombia, 2014). Finally, unsustainable logging because of the high demand of timber.

Although demographic growth could be categorized as another direct driver in which forested areas are replaced by settlements, demographic growth triggers an increase in the demand for food and ecosystem products and services resulting in one of the primary indirect drivers of deforestation. Another important indirect driver is infrastructure density, more specifically road density. Climatic drivers like precipitation, or limited access drivers like topography or distance to rivers also play an important role in deforestation.

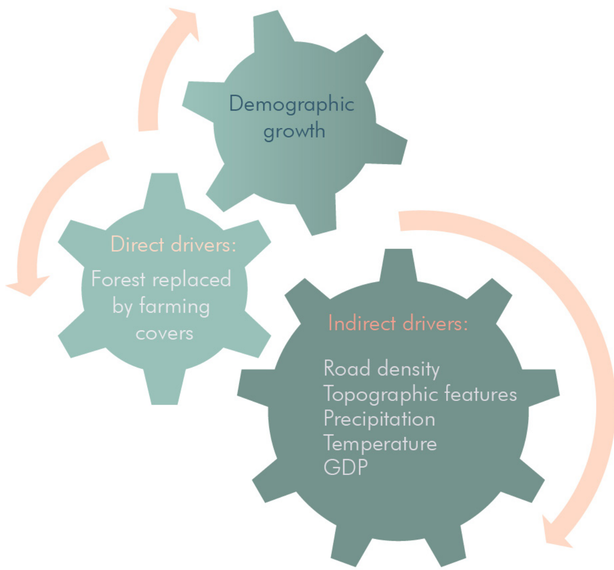


Figure 50 Direct and Indirect drivers of deforestation

2. *Study Area features that are considered for new palm oil plantations*

The drivers identified hereabove have been computerized in GIS to be able to have a co-relation between them and the land use. And then from this it were created histograms. The histograms are a useful tool to understand and determine which are, among the drivers already recognized, the most important when deciding to plant new palm oil crops. For this reason, it has been decided to compare the features that are present in the area with the ones present in the palm oil plantations.

Tropical areas are ideal for agriculture because of the high precipitation rates present. The Chocó region according to the information acquired in 2015 has a range from 887mm and 3097mm, but most common precipitation is between 2149.9mm and 2465.6mm. As for palm oil plantations these are mostly found in areas

Climatic Features

Precipitation

Figure 51 Precipitation Patterns (mm) in Case Study Area

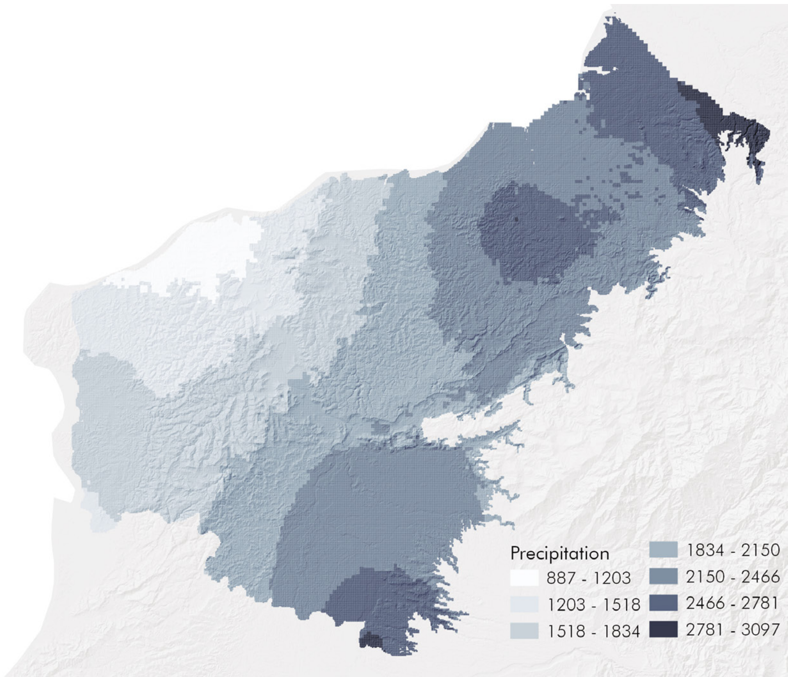


Table 11 Palm oil plantations Extension Most common precipitation patterns

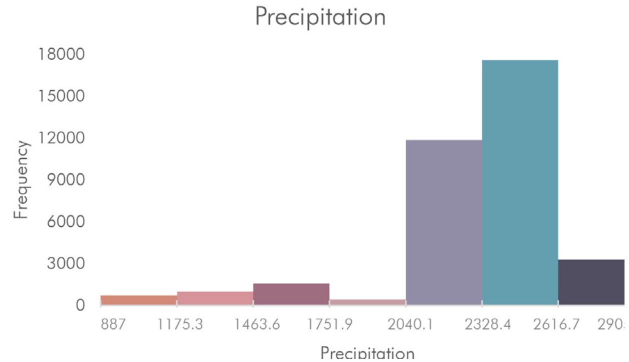
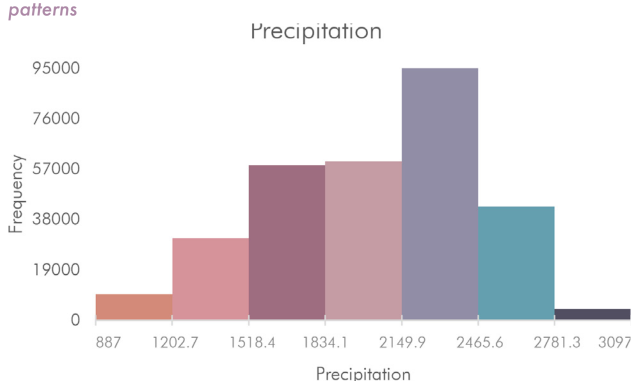


Table 12 Whole Study Area Extension Most common precipitation patterns



where the precipitation that are between 2328.4 and 2616.7mm per year. Therefore, although palm oil plantations are located in areas with an specific range, this changes every year and most of the region is characterized by high precipitation rate. For this reason, although it is an important driver, it isn't the most essential one.

Temperature

Temperature patterns are quite similar to precipitation patterns. Most of the region is characterized by having an average temperature between 22.4oC to 25.9oC. But palm oil plantations are resistant and prefer the higher average temperatures of 25oC.

Figure 52 Temperature Patterns in Case Study Area

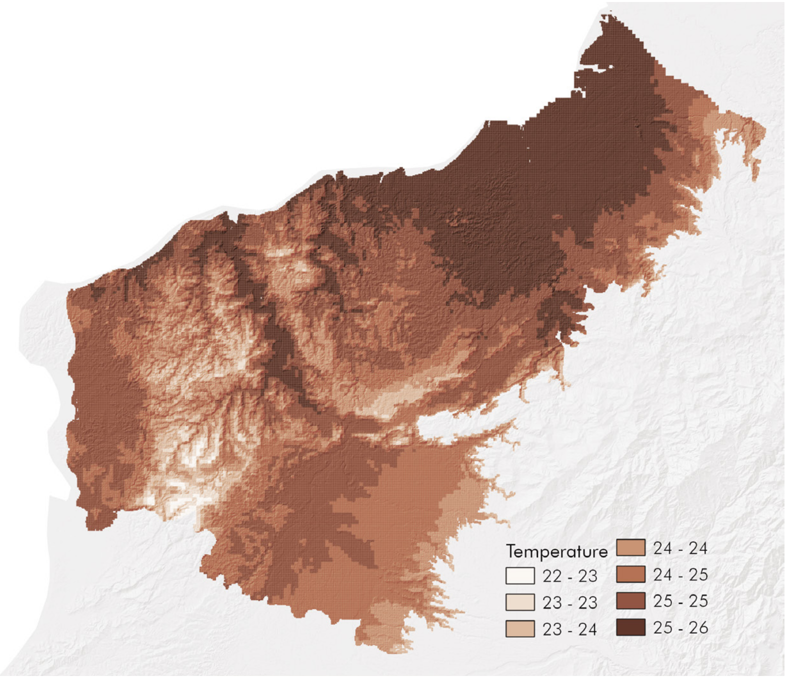


Table 13 Palm oil plantations Extension Most common temperature patterns

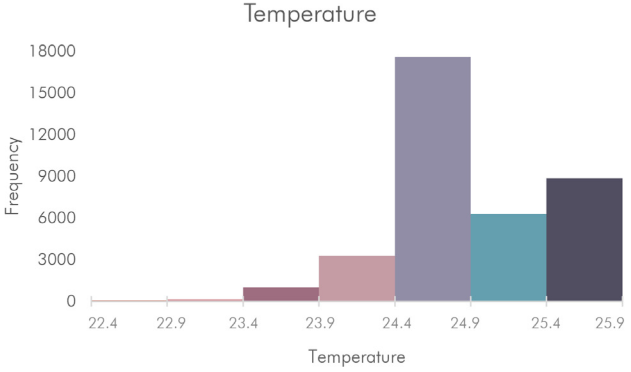
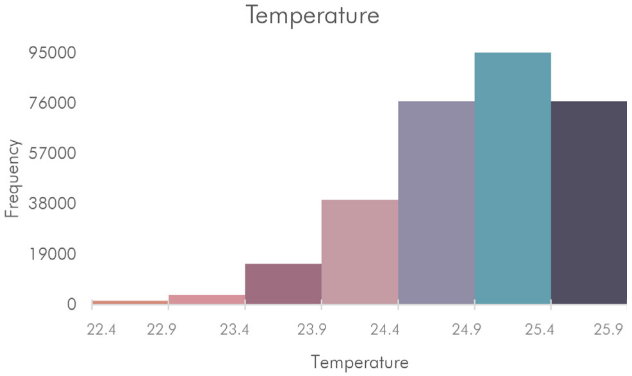


Table 14 Whole Study Area extension most common temperature patterns



Height

The height in the region is from -7 to 6820m above sea level. And palm oil plantations are located between 108m and 797m.This means that height is important when choosing a new site, and that the areas that are characterized of being below 108m high are more suitable for these crops.

Figure 53 Height in Case Study Area

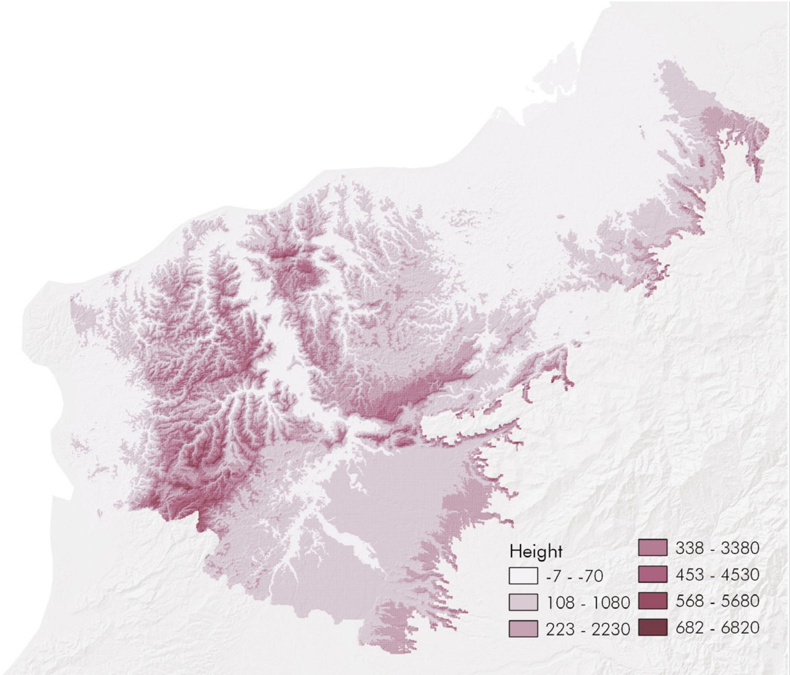


Table 15 Palm oil plantations Extension Most common height patterns

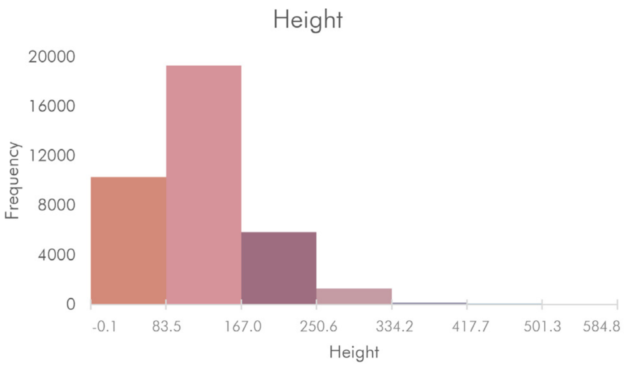
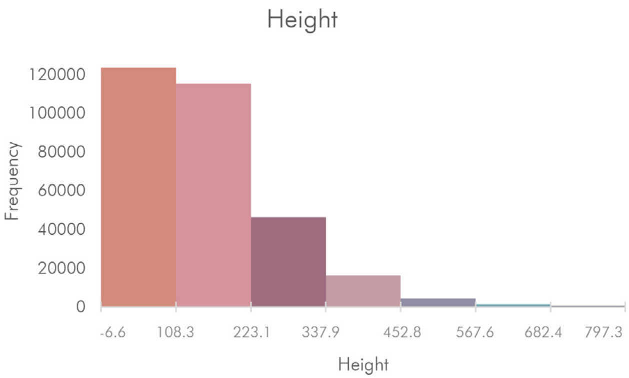


Table 16 Whole Study Area Extension Most common height patterns



Distance to Major Roads

Proximity is also a limitation when choosing a new area when planning the extension of palm oil plantations. The area is characterized by being well connected and although on Figure 54 it can be seen that the distances to major roads are only between 0-400m, palm oil plantations are normally located very close to them, as it can be seen in Table 17. This is an important driver, in the last decade there has been a huge investment in the country in infrastructure and the construction of new road, leads to further exploitation of the land. Farmers need this connectivity to transport the products to be either processed or sold.

Figure 54 Proximity feature, Distance to Major Roads

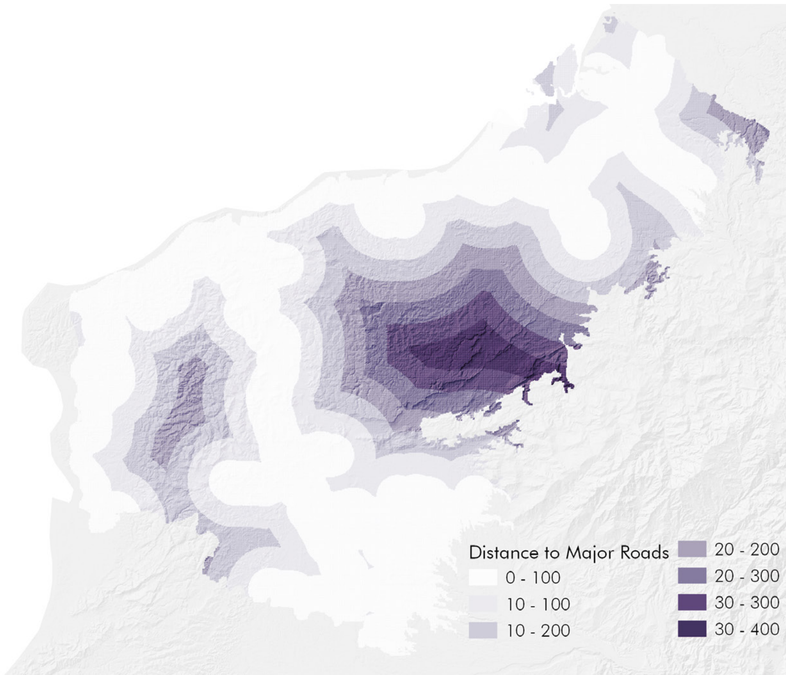


Table 17 Palm oil plantation extension in proximity with major roads

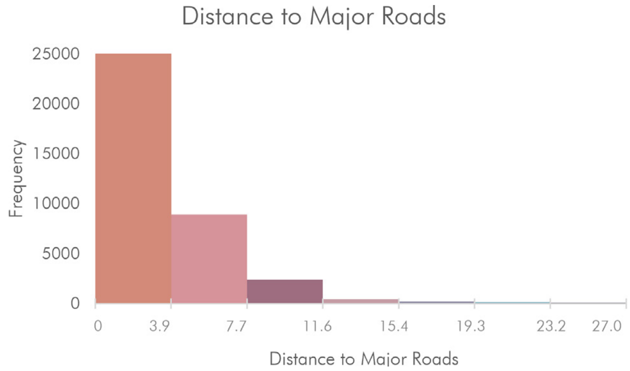
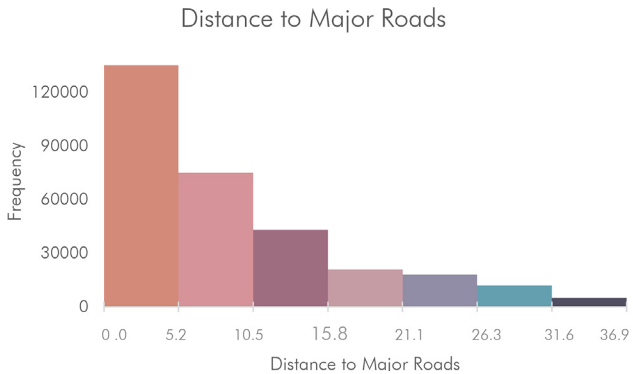


Table 18 Whole Study Area extension in proximity with major roads



Distance to Waterways

The region is also characterized by having many waterways descending from the Andes towards the coast. The main river in the region is Río Esmeraldas and along this river and its tributaries are located most palm oil plantations. The closer the distance to the rivers, the better, because besides the importance of precipitation, these rivers are used for artificial irrigation when needed.

Figure 55 Proximity feature, Distance to Waterways

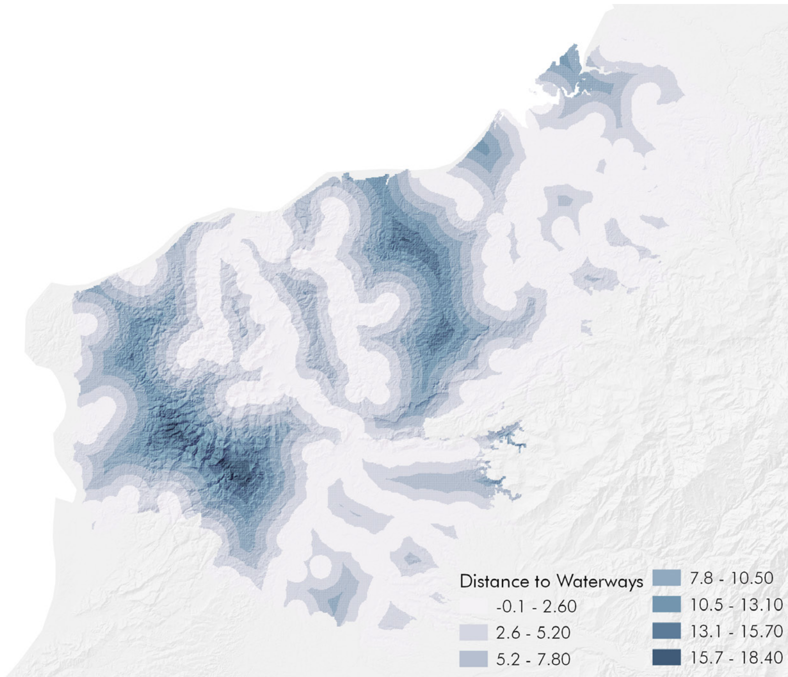


Table 19 Palm oil plantations in proximity with waterways

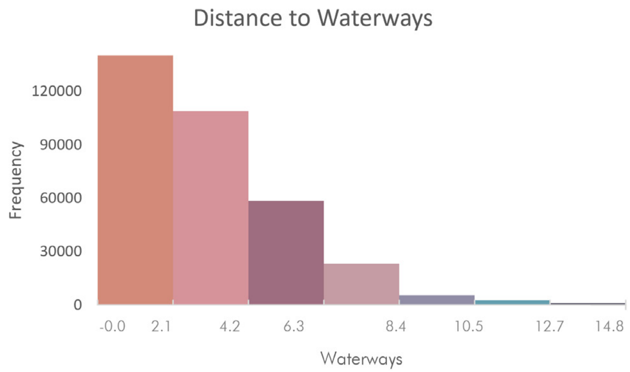
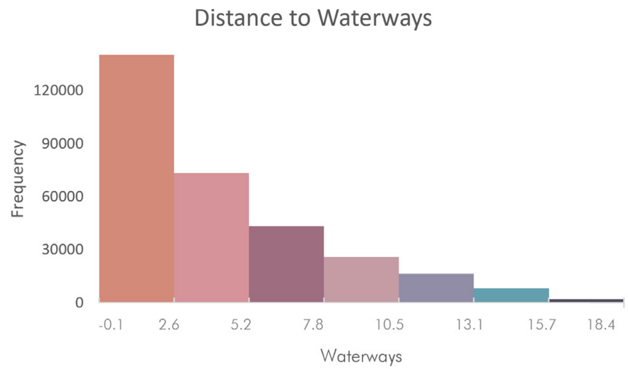


Table 20 Whole Study Area in proximity with waterways.



Distance to Mills

Finally, the distance to mills appears to be that the most frequent condition is that the palm oil plantations are located farther from them, than closer. This means that the distance to means is not so important to choose a site for new plantations.

Table 21 Palm oil plantations in proximity with mills

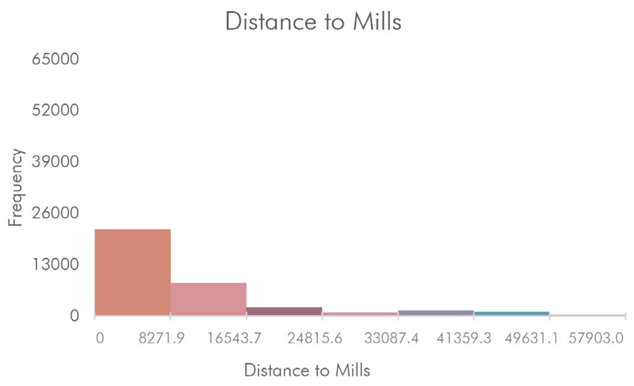
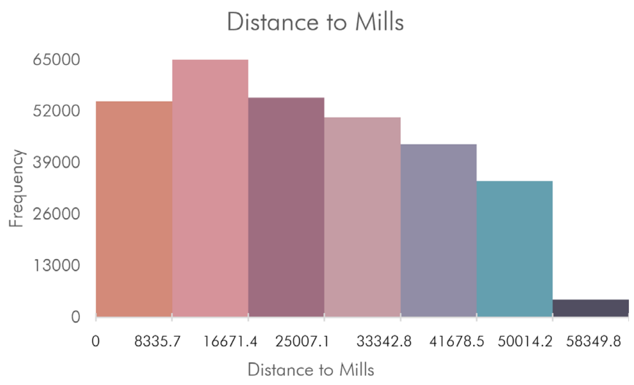


Table 22 Whole Study Area in proximity with mills



Conclusions on Drivers

In this analysis where considered 9 possible drivers that could lead to further expansion of the palm oil plantations. These where:

1. **Distance to Mills**
2. **Distance to Major Waterways**
3. **Distance to Main Roads**
4. **Height**
5. **Average Precipitation**
6. **Average Temperature**
7. Proximity to Settlements
8. Slope
9. And population growth from 2000-2015

But the clustering analysis carried out in Chapter 3.2.4 highlighted the features that are mostly considered when choosing an area for these plantations. So, it was decided to limit this analysis of drivers to those characteristics that are the most relevant. The Histograms analysis revealed a more detailed information that allows to understand which are the ranges of each feature that are considered for the expansion of this crop. For this crop it is preferred to have a high average precipitation per year of 2300 and 2600mm. Average temperature higher than 25oC. The proximity to waterways and roads is very important because of connectivity and distribution of the product. And finally, it is preferred to choose areas in flatter areas in which the height is below 200m, which is normally in the river banks and nearby areas.

3.2.3 Identification of vulnerable areas

The analysis of these transition matrices and of the Maps individually, have demonstrated that two main Cantons have experienced a significant increase in Palm Oil Plantations. First is Quinindé, that had already been exploited before but in a much-reduced extension. And the second canton is San Lorenzo that in 1983 had not been exploited at all. For this reason hereunder are analyzed these two areas deeper.

1. Quinindé Region

Quinindé was one of the areas in which historically, first appeared the palm oil plantations. Initially these plantations were replacing other crops because of its high profitability and low maintenance cost. But it is evident that that palm oil plantations have expanded exponentially in this area as it can be seen in Table 9 (790%) and that most of the plantations replaced secondary forests.

Table 23 Transition Matrix for the period 1983-2015 in percentage of the area of Quinindé. Comparing digitalized Historical Land Use Map and 2015 Land Use Map extracted from Sentinel-1 satellite imagery.

1983↓/2015→	Forest	Secondary Forest	Grasslands	Palm Oil Plantations
Forest	58%	1%	30%	10%
Secondary Forest	19%	3%	25%	52%
Grassland	32%	2%	28%	36%
Palm Oil Plantations	3%	0%	7%	89%

Table 24 Table 17 Gain and Loss Percentage in the Time Period of 1983 to 2015 of the area of Quinindé.

LULC Type	Total Area in Hectares		Gain/Loss (%)
	1983	2015	1983-2015
Forest	206420.82	151376.22	-27%
Secondary Forest	23771.69	4967.74	-79%
Grassland	86343.73	92149.58	7%
Palm Oil Plantations	8352.72	74344.23	790%

2. *San Lorenzo Region*

The transition Matrix for San Lorenzo in the period of 1983 to 2015 shows that this area 30 years ago was covered by forests and mangroves. Mangroves are considered as a part of the Protected Areas national system because of its unique ecosystem features and because these areas were disappearing due to the expansion of the aquaculture or agriculture industry. And there were no Palm Oil Plantations in this area in 1983, which shows that here the palm oil plantations replaced the natural habitat. Moreover, in Table 25 it shows that Primary Forests have been lost in a rate of 28% and mostly to grasslands. As seen in the whole area analysis, in San Lorenzo most palm oil plantations replace secondary forests, this means that it is important to protect any human disturbance to primary forests, because once they have been altered they can be considered secondary, and therefore vulnerable to become palm oil plantations.

Table 25 Transition Matrix for the period 1983-2015 in percentage of the area of San Lorenzo. Comparing digitalized Historical Land Use Map and 2015 Land Use Map extracted from Sentinel-1 satellite imagery.

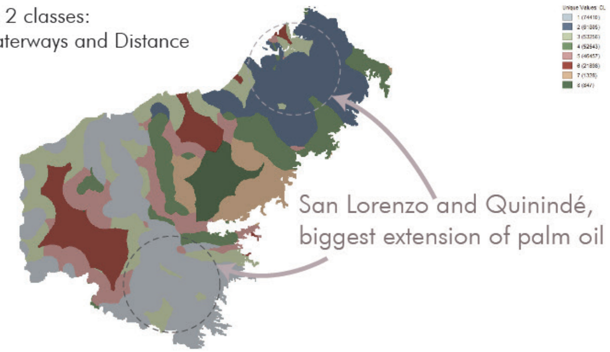
1983↓/2015→	Forest	Secondary Forest	Grasslands	Palm Oil Plantations
Forest	64%	9%	12%	13%
Secondary Forest	28%	7%	35%	29%
Grassland	46%	10%	23%	19%
Palm Oil Plantations	0	0	0	0

Table 26 Gain and Loss Percentage in the Time Period of 1983 to 2015 of the area of San l.orenzo (The value of palm oil plantations in San Lorenzo in 1983 is 0 but for calculation purposes it was set to 1).

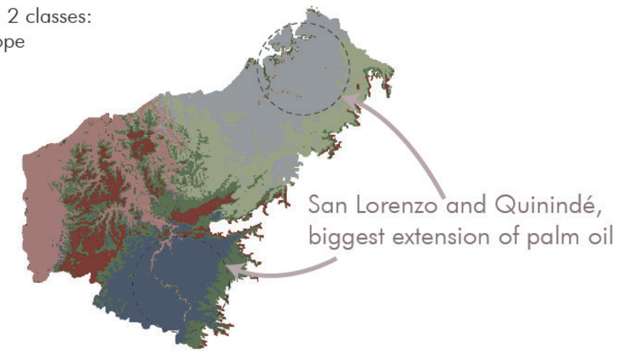
	Total Area in Hectares		Gain/Loss (%)
LULC Type	1983	2015	1983-2015
Forest	146313.68	104975.14	-28%
Secondary Forest	10685.59	14881.47	39%
Grassland	16559.86	25379.67	53%
Palm Oil Plantations	N/A	N/A	N/A

3.2.4 Projection of areas that can become Palm Oil Plantations

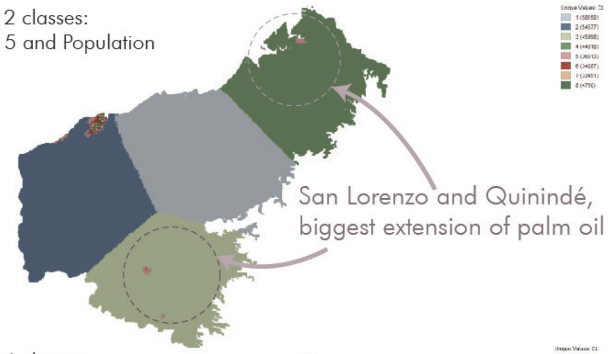
8 Clusters with 2 classes:
Distance to Waterways and Distance to Roads



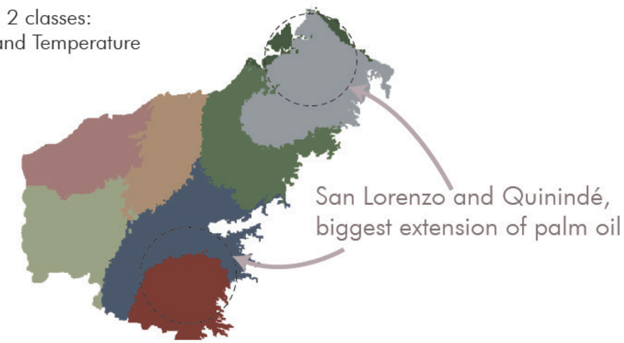
8 Clusters with 2 classes:
Height and Slope



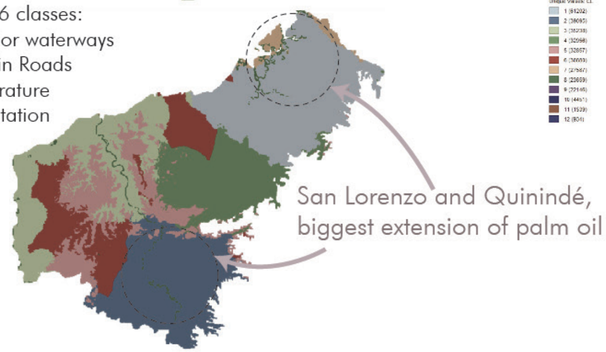
8 Clusters with 2 classes:
Population 2015 and Population Growth



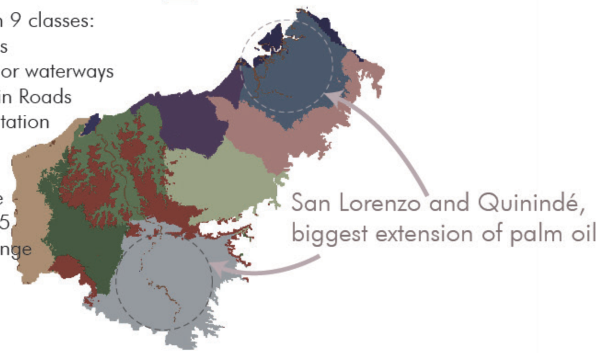
8 Clusters with 2 classes:
Precipotation and Temperature



8 Clusters with 6 classes:
Distance to major waterways
Distance to Main Roads
Average Temperature
Average precipitation
Height
Slope



12 Clusters with 9 classes:
Distance to Mills
Distance to major waterways
Distance to Main Roads
Average precipitation
Height
Slope
Av. Temperature
Population 2015
Population Change

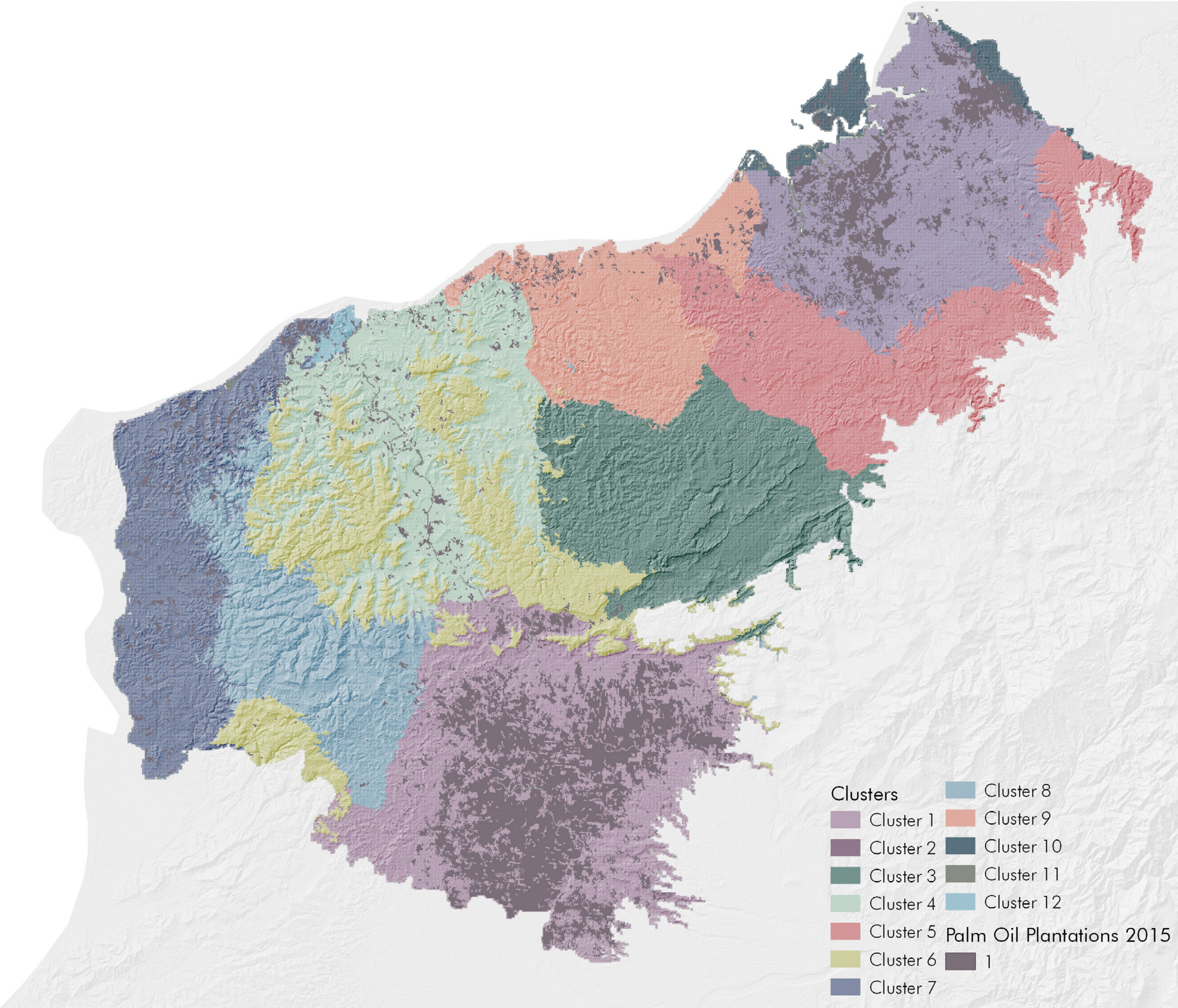


In order to identify, which are the most vulnerable areas, a series of processing methods have been carried out. First, after the first interview and the information found on palm oil requirements, it has been stablished that physical and climatic patterns and their co-relation determine the location of new palm oil plantations. The physical patterns are the site's height and slope, the population location and growth, the distance to major roads and waterways and the distance to mills. The climatic patterns that are highly recommended are related to precipitation, and temperature. Although the main drivers for deforestation have already been determined, in order to quantify them better analyzing these requirements were necessary.

The region has been divided into a different set of clusters for analysis, they are divided accordingly to the most similarities found according to the characteristics mentioned. For this was used K-mean Clustering in GeoDa software. What this software does is to reduce the dimensionality of the variables to rescue the clustering. The clustering method group different characteristics into a number of clusters (determined by the user) in which each cluster's similarity is maximized. The final goal of this method is to separate in each group maximum similarities but also having maximized dissimilarities between each group (GeoDa Center, 2020).

Several tests of clustering where made to see what are the most common characteristics that are grouped together in each cluster, and which dissimilarities are the ones that separate them apart. First, to reduce the vulnerable areas to a comprehensible extension it was tested to cluster in 6 and 8 clusters with 6 classes. Comparing the resulted images to the maps of the whole area of each feature or driver, it was hard to tell what was the main characteristic that was driving the grouping of this clusters. Secondly, it was tested to cluster only using specific features to see how much the clustering changed accordingly to each group of features. It was tested gathering climatic patterns: precipitation and temperature; topographic features: height and slope; population patterns: location of population in 2015 and population growth from 2000 to 2015; and proximity features: distance to roads, to waterways and to mills. A key element in the k-means method is the choice of the number of clusters, that is the variable k. Several tests were done to consider the correct k value accordingly to the visual delimitation of these cluster maps (GeoDa Center, 2020). Then, clustering in 12 clusters showed similarities to clustering by climatic patterns and clustering by topographic features, for which reason it was chosen to analyze deeper the clustering in 12 map. Finally, overlapping the clustering with the location of palm oil plantations it was identified that clusters 1 and 2 have most of the palm oil plantations as it can be seen hereunder.

Figure 57 K-Means Clustering in 12 clusters with the 9 characteristics listed in Table 26.



The center of each cluster is the mean of each characteristic inside the cluster. GeoDa assigns a number to this center that is in the table below.

With this information it is possible to have the distance between each cluster in a transition matrix. The highlighted cells are the numbers that indicate a shorter distance between cluster 1 and the other clusters. The two closest clusters are cluster 1 and 2 which are also the clusters in which more palm oil plantations are located. The distances are also smaller between cluster 1andclusters 4,6 and 10. Which graphically in the map it is possible to see that cluster 1is close to cluster 4 and 6, and cluster 2 to 10.

Table 27 Cluster center with all considered drivers.

Clusters/ Classes	Distance to Mills	Distance to major waterways	Distance to Main Roads	Height	Average precipitation	Average Temperature	Population 2015	Slope	Population Change
Cluster 1	8071.73	2.58	3.80	162.31	2287.77	24.74	48.52	89.76	1.31
Cluster 2	12257.10	2.13	4.33	49.02	2499.40	25.61	34.28	89.62	0.95
Cluster 3	32820.70	5.01	26.62	162.14	2146.06	24.95	4.39	89.97	0.13
Cluster 4	19956.60	2.15	6.46	126.71	1502.23	25.11	31.83	89.80	0.79
Cluster 5	30589.30	1.40	11.36	132.57	2497.82	25.14	8.36	89.95	0.26
Cluster 6	17678.30	3.96	10.95	334.63	1716.06	24.09	11.22	89.99	0.35
Cluster 7	43443.00	5.32	3.27	78.20	1476.93	25.08	56.89	89.83	1.76
Cluster 8	26913.20	11.29	9.13	265.95	1712.71	24.21	11.14	89.98	0.38
Cluster 9	40531.20	8.43	6.39	84.25	2024.17	25.51	21.54	89.92	0.64
Cluster 10	15973.40	4.21	6.75	39.18	6.03	0.00	24.62	88.53	0.62
Cluster 11	18782.60	2.08	4.36	14.62	1573.88	20.72	87.69	29.71	0.62
Cluster 12	32278.70	1.41	0.33	58.38	1048.62	25.32	3605.71	89.35	104.35

Table 28 Transition Matrix of the Distance between each cluster.

Clusters	CL 1	CL 2	CL 3	CL 4	CL 5	CL 6	CL 7	CL 8	CL 9	CL 10	CL 11	CL 12
CL 1	0	4192	24749	11911	22519	9625	35381	18851	32461	8226	10736	24499
CL 2	4192	0	20567	7764	18332	5485	31203	14679	28278	4475	6591	20390
CL 3	24749	20567	0	12880	2259	15149	10644	5924	7712	16983	14051	3807
CL 4	11911	7764	12880	0	10679	2298	23486	6961	20581	4256	1184	12839
CL 5	22519	18332	2259	10679	0	12936	12894	3761	9953	14827	11844	4232
CL 6	9625	5485	15149	2298	12936	0	25767	9235	22856	2433	1163	15054
CL 7	35381	31203	10644	23486	12894	25767	0	16533	2963	27509	24661	11723
CL 8	18851	14679	5924	6961	3761	9235	16533	0	13623	11074	8136	6497
CL 9	32461	28278	7712	20581	9953	22856	2963	13623	0	24641	21754	9051
CL 10	8226	4475	16983	4256	14827	2433	27509	11074	24641	0	3218	16727
CL 11	10736	6591	14051	1184	11844	1163	24661	8136	21754	3218	0	13958
CL 12	24499	20390	3807	12839	4232	15054	11723	6497	9051	16727	13958	0

Finally, the clusters have been imported to GIS to see what land uses are in these areas. Cluster 1 shows a large extension of grassland. As seen in prevously, grasslands are very likely to become palm oil plantations. And in Cluster 2 there is a large extension of primary forests and secondary forests.

To conclude, the vulnerable areas revealed in this analysis contain different land uses that should be preserved to maintain the cultural landscape of the Chocó. It is important that the relevant authorities understand that the vulnerave areas are most likely to be locate din areas close to existing palm oil plantations, and that preventing any human action in the natural areas is imperative to preserve these areas. Moreover, the resulting land us maps extracted from Sentinel-1 data, don't allow a differenciation between crops and grassland for which reason they appear as grassland combined. Grasslands are mostly artificial pastures for cattle, but crops have a huge variety. It is also important to protect agriculture fields from further expansion of palm oil plantations, as they constitute an important part of the culcutural landscape of the Ecuadorian Northwestern Chocó Region.

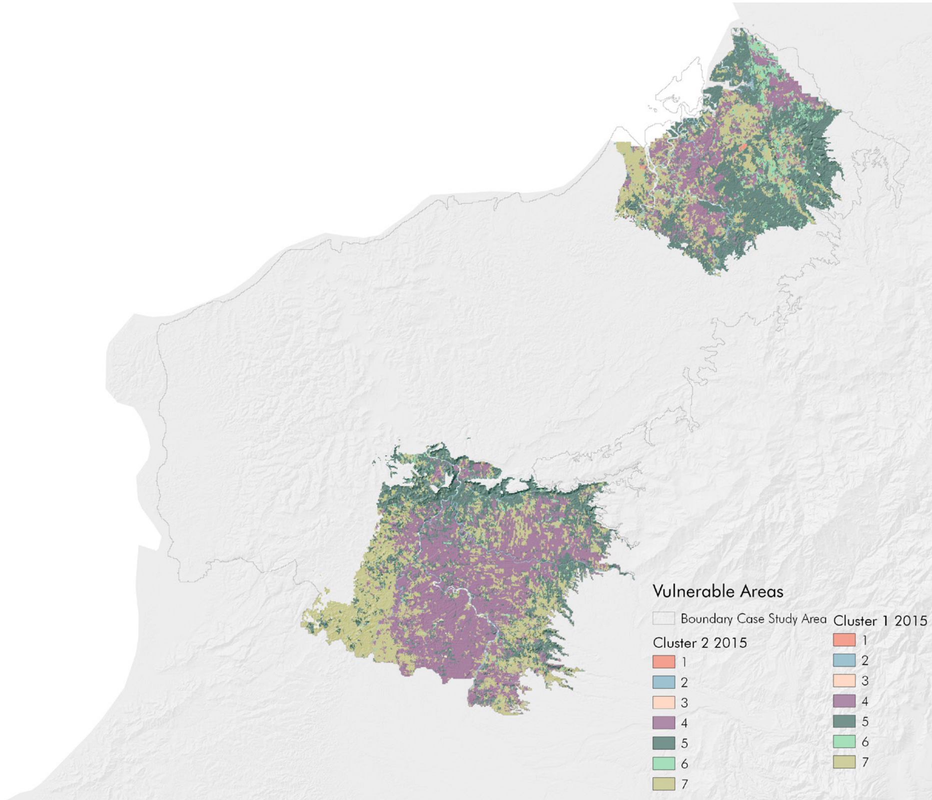


Figure 58 Vulnerable Areas. (The classes correspond to each number as follows: 1. Settlements; 2. Water; 3. Bare soil; 4. Palm oil plantations; 5. Forest; 6. Secondary forest; 7. Grassland)

3.3 Future Scenarios: New Directions for the Preservation of Cultural Landscapes of the Chocó Region

3.3.1 SWOT Analysis

A SWOT analysis that stands for Strengths, Weaknesses, Opportunities and Threats is an analysis that is used to identify resources, capabilities, core competencies, and competitive advantages inherent to a subject which are normally intended for an internal perspective, in this case, as a point of view of the current characteristics of a problem. The external analysis identifies opportunities and threats by looking at possible scenarios if the variables change or can be changed. The objective of a SWOT analysis is to use the knowledge about an specific subject to formulate its strategy accordingly (Sammut-Bonnici & Galea, 2008). The SWOT Analysis has been done as summary of the characteristics that define the Northwestern Chocó region and what are the weaknesses and problems found there, as well as the strengths, and therefore, the opportunities of this region to be preserved and valued as a Cultural Landscape. This SWOT analysis has then been used to formulate a strategy or a set of guidelines that can be addressed for the preservation of this landscape.

Strengths

S

Environmental

- Climate and soil quality are great for many crops, specifically for palm oil groves.
- The Government has ecosystem restoration goals that has triggered restoration targets in development plans on forests, agriculture, biodiversity, climate, and water.
- NGO's like Proyecto Washu and Jocotoco are already encouraging to protect native species.
- Currently, there are measures and efforts to use more sustainable practices because of market demands.
- The Clustering Analysis can help local authorities protect most vulnerable areas.
- Monitoring can prevent deforestation.

Socioeconomic

- It is one of the main work sources in the region of Northwestern Choco of Ecuador
- Most palm oil plantations are close to roads which allows an easy transportation to mill, ports and markets.
- Palm oil is by area the most productive vegetable oil; it takes much less land to produce a ton of palm oil than any other oil.
- ANCUPA and big palm companies are helping small farmers to get sustainable certifications on their farms.
- Monitoring practices can encourage to abandon unprofitable areas for oil palm growing and convert such areas into wildlife reserves.
- Indigenous communities are in charge of National Reserves.
- Despite price fluctuations in the last 5 years, investment on palm oil has a very good revenue.
- Small farmers already have a strong link with mill owners.

Cultural/Agricultural

- Palm oil production has many characteristics of sustainable crops, because the residue is as biofuel and biological fertilizers. For which reason it is auto sustainable, as the mills don't need power from other sources.
- The Government has ecosystem restoration goals that has triggered restoration targets in development plans on forests, agriculture, biodiversity, climate, and water.
- Cultural Heritage's definition by the Ministry of Culture includes elements landscapes that constitute references of identity for the peoples or that have historical, artistic value.
- The innovative methodology for land use maps when improved can identify palm oil groves age for monitoring sources.
- Because of the bud rot plague, farmers are already changing farms to mixed use.
- The landscape, besides its ecological value, has an evident distinctiveness and authenticity that should be preserved in conjunction as a Cultural Landscape.

Weaknesses

W

Environmental

- Cultivating palm oil requires high amounts of water which consequently reduces the availability of freshwater and the quality of the soil.
- Deforestation has generated an issue of fragmentation of natural ecosystems and landscape degradation.
- Logging and plantain farms are also important drivers of deforestation.
- The need to expand the palm oil plantations or to move them to an area that has not been affected by the bud rot plague can lead to deforestation.
- Deforestation leads to land degradation because forest ecosystems, with all their important cultural, regulating and provisioning services, are depleted and eroded.
- The deforestation quickens soil erosion and the modification of soil functioning. This can incite a decrease in carbon, nutrient and water storage, and cycling limits.
- The deterioration of areas that link the ecosystems of the Andes and the Amazon, or the Pacific ecosystems with the Andean ecosystems is highly pressuring the biodiversity.
- Best practices guides do not include design tools with examples and graphics on how to create a sustainable palm oil farm.

Socio-economic

- Workforce in the plantations of big farmers are most likely to be from immigrants of other regions of the country, because inhabitants of the region are not qualified workers.
- Local communities are not qualified to work on the agricultural field.
- Expansion of palm oil plantations are relocating indigenous networks from their customary grounds.
- Supply chain has intermediaries, so farmers don't necessarily get a decent price.
- The rising need of providing food to a growing population involves an expansion of agricultural practices.
- Lack of knowledge on sustainable palm oil practices
- A big portion of the population lives in extreme poverty.
- There is a lack of forest keepers to protect forest and forest buffer zones because of lack of proper management and economic resources.
- Certified Sustainable Palm Oil (CSPO) is not possible to be achieved by small farmers
- The life cycle of this crop dictates that it starts being productive starting from the 3rd year reaching full maturity at the age of 20-25 years old in which it needs to be replaced.

Cultural/ Agricultural

- Possible lack of identity from the inhabitants that don't belong to afro-Ecuadorian or indigenous groups.
- Ecuador's agricultural technology is one of the least developed in South America.
- The current methodology to measure the extent of plantations is with the use a GPS system to physically measure the boundaries of the farms. But it is time consuming.
- The use of satellite imagery tools to measure the extent of plantations is very expensive and affordable.

- The innovative methodology for land use maps still needs improving for more precise maps.
- Because of the bud rot plague, palm oil plantations are expanding to other areas in the country.
- The lack of knowledge, appreciation, appropriation, and respect for cultural heritage from Ecuadorians, in general, has resulted in illicit actions, illegal, anti-technical interventions and loss of authenticity and originality.

Opportunities

O

Environmental

- Standardization to promote the sustainable palm production
- Raise awareness of the RSPO and CSPO globally
- Incorporating Landscape Ecology principles can improve natural resources quality, which can increase yield.
- Restoration and responsible management of primary forests and forests future, contributing to carbon absorption.
- Promoting biodiversity to create resistance to future invasion of non-native species.
- Remove invasive plant species to encourage native ecological wildlife to remain in their native areas and promote growth of native flora.
- The opportunity in this gap of management of isolated or dispersed protected areas is mapping vulnerable areas that can help managers of protected areas to reformulate its zoning integrating new 'hotspots' and buffer zones in the form of gradients, to avoid direct or indirect land use changes that affect biodiversity inside their limits

Socio-economic

- Poverty eradication by providing employment and job opportunities to the surrounding community
- Food security for the inhabitants of this region.
- Eco-tourism can be an economical incentive to change to more sustainable practices.
- Landscape design in farms can attract tourists and have an additional economic injection in the area.
- Provide educational initiatives that tackle local social issues.
- Fair employment conditions and training to enhance competency of the workers. Engagement with and training of smallholders.
- Creation of national green stamps can become a mean to which small farmers can have access to.
- The exploration of the new methodology for land use maps can reduce costs of certification.
- Sustainable agriculture visitor centers can help to educate employees and the local community about the importance of sustainable growing practices.

Cultural/ Agricultural

- Planning and policy initiatives can increase the resilience of food systems.
- Prioritizing native agriculture over alien species can help preserve the culture and traditions of the region.
- Introduction of native shade tolerant between palm grove columns can increase productivity of the lands.
- Introduction of shade-tolerant legumes can reduce Nitrogen fixation on soils.
- Traditional practices of agriculture like the use of native bamboo, coffee, cacao and tagua.
- Farms affected by bud rot can replace the palm groves with forestry practices.
- Tourism activity can be extended from the farms to the essential knowledge of rural traditions, culture and, history.
- Promoting traditional agriculture can enhance the link between the land and the identity of the people, and so encourage them to preserve it.
- Acknowledging the culture and traditions this multi-cultural region that hosts various indigenous groups, afro-descendent communities, and mestizo (mixed-raced) population, can result in a culturally rich landscape.
- Preservation of architectural building techniques like the 'techo de bijao'

Threats

Environmental

- Deforestation for clearing land for new plantations
- The spread of pesticides poison wildlife as well and conclude in entering rivers polluting and spreading further.
- Overuse of inorganic fertilizer results in a decline in soil condition and structure, including reduced soil carbon content, soil water holding capacity and porosity.
- Monoculture leaves soil exposed, and overall generates a low-stability microclimate.
- Bud rot disease is killing large extension of land in Ecuador, and these are being left abandoned.
- RSPO Principles and Criteria demand use of best practices in existing and new plantings but the guide does not include specific measures on the design of a sustainable farm.

Socio-economic

- Producers do not respect the rights of indigenous people and the community surrounding premises.
- Challenging to certify the small farmers that do not have the interest or the economic resources to go through the process of certification.
- Certified Sustainable Palm Oil (CSPO)needs a lot of resources to be achieved by small farmers.
- This region is considered dangerous outside of the cities because of criminal activity; this can repel investment.
- The recent economic crisis and the power of big companies can put pressure on the government to allow further exploitation of the region.

Cultural/ Agricultural

- Mixed use farming is being lost to Monoculture.
- Loss of traditional agricultural practices that are being substituted with more productive crops that can be more harmful to the environment.
- People from surrounding communities might not be interested in selling their properties to become protected reserves.
- Heritage can be threatened by the idea of a modernity embodied in new adopted traditions.
- Funding and planning for maintenance of heritage and natural areas can be more difficult to achieve than for starting a new project.

T

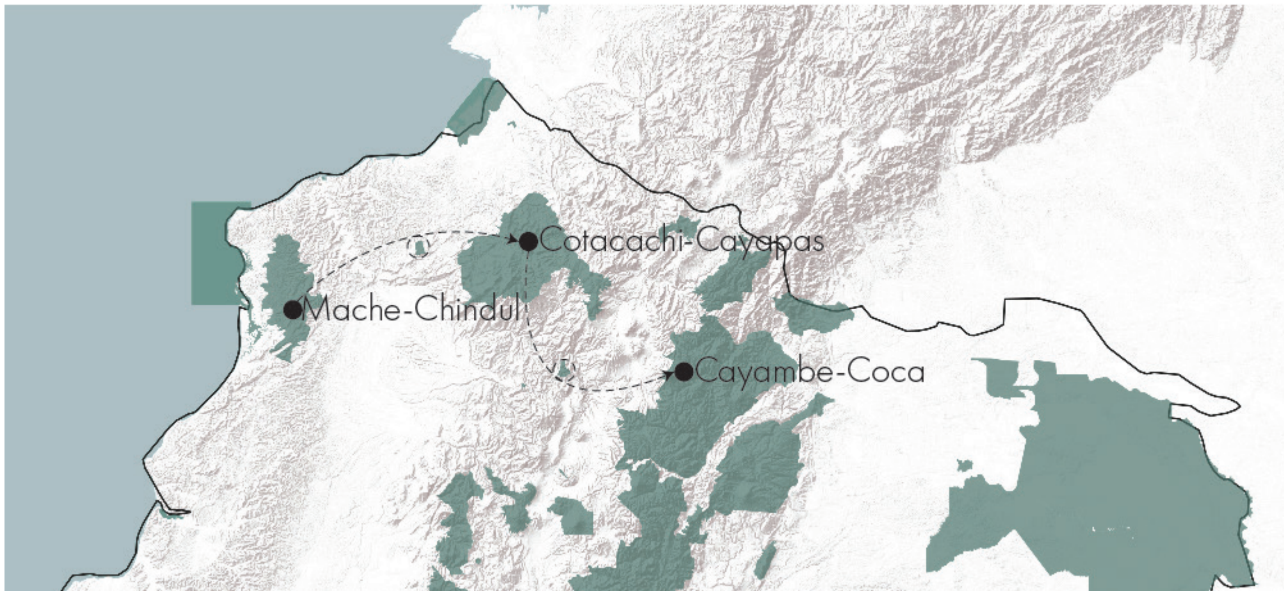
3.3.2 Guidelines for Sustainable Development and Practices for Preserving the Cultural Landscape

Climate change effects across the globe have managed to get more attention from organizations around the world, about how to preserve the earth, and by doing so also ensure food security for everyone. The United Nations has developed the Sustainable Development Goals in 2015 to put an ending on poverty and for preserving a healthy planet. To reach these goals it is necessary to have a transformation worldwide of financial, economic, and political systems that currently manage societies to assure human rights for all (United Nations, 2020). Many goals align with the concept of Cultural Landscapes in which ecological problems are strictly connected to exploitation and poverty issues (Álvarez M., 2011). Preservation of the cultural landscape is not only be about preserving the landscape heritage of the Northwestern Chocó Region of Ecuador but use it as a tool to enhance the living circumstances in which its inhabitants live.

Introducing sustainable development can play a major role in the eradication of poverty by providing employment and job opportunities to the inhabitants. Preserving the environmental resources of the region can give a better quality of live to the people, better water quality and better soil properties for more efficient production. As most rural areas of Ecuador, this region has very high illiteracy levels, it is important to encourage the government and the big palm oil companies to invest in social programs that can enhance literacy, health, safety, and environmental awareness. Additionally, another problem, stated by Venegas (Venegas, 2020), that is important to address, is the resentment against the palm companies, "since they say that these companies do not take them into account when hiring". A great percentage of the workers come from different regions of the country or from Colombia because the people from this region are not qualified workers for agricultural practices besides logging. For this reason, it is important to demand from companies to have programs to train workers and also make re-training a permanent feature of employment. It is also essential to incentivize the creation of other farmer groups because as stated by Davila (Nápoles, 2020) the existing ANCUPA group that helps palm growers in general has become somewhat politicized and the decisions of this association can be biased. New groups and partnership can best address shared threats and support public services. And it could be interesting to have an internal/regional compensation for sustainable farmers, a prize winning competition that can help encourage local growers to adopt more sustainable practices through award schemes (Unilever, 2003). Another important social impact that sustainable palm oil can have is gender equality. In communities like the Awá, both women and men are hunters and gatherers, nevertheless, this equality aspect needs to be reinforced. It is important to also encourage women to follow educational programs and training to work in agricultural practices or craftmanship. Making their role as important as men can help to acquire an empowering perspective that in the long term can help reduce gender violence and also increase the income resources of families.

Sustainable development also needs to be accompanied with environmental responsibility, which includes clean water, sanitation, and affordable and clean energy. First of all, it is important to identify the main threats that palm oil plantations have on the environment. Palm oil plantations are a monoculture crop, which has an impact on the biodiversity of the region. Biodiversity plays an important role in the preservation of the soil's quality because it influences in the microbial community and, the latter, are imperative for the maintenance of the soils condition. So, according to Agronomist Venegas, (more details in Chapter 2.2.1) rotating crops with the combination of forest plantation can have a positive impact in the preservation of the natural resources. It can provide a chance to renew and improve the soils nutrients and quality. Besides rotating crops, it can also be an introduction of native shade tolerant crops that can grow between palm grove rows and this can increase productivity of the lands, and an introduction of shade-tolerant legumes that can reduce the nitrogen fixation in soils. Also, the removal of invasive plant species can encourage native ecological wildlife to remain in their native areas and promote growth of native flora. Promoting biodiversity can create resistance to future invasion of non-native species and helps rebalance the ecosystem services of the area. Currently, biodiversity protection is limited to the National Protected Areas and the communities and organizations that manage them, but these are isolated or dispersed protected areas. This gap that doesn't allow connection between them can be recognized through mapping tools, and mapping vulnerable areas can help managers of protected areas to reformulate its zoning integrating new 'hotspots' in the form of gradients, to avoid direct or indirect land use changes that affect biodiversity inside their limits. Moreover, Dr. Moens (Moens D. M., 2020) also suggests protecting buffer zones of Protected Areas by increasing the number of forest keepers in the region. For these measures the new methodology proposed in this study can be

Figure 59 Connection of Protected reserves of different altitudes.



very useful, as many vulnerable areas have already been identified and it can help identify others.

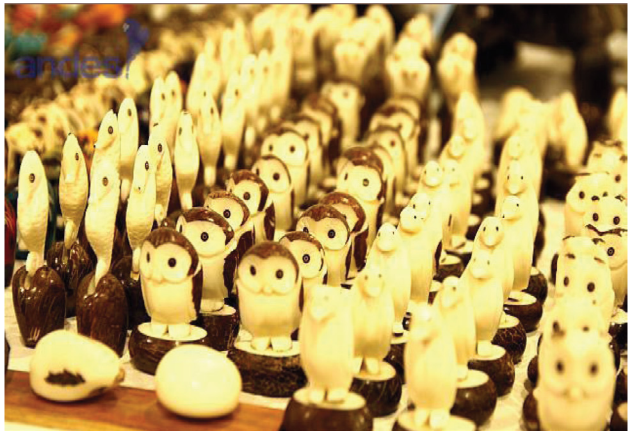
Climate change can be diminished or slowed down by preserving Tropical Rain Forests, as the Chocó. The restoration and responsible management of primary forests and future forests can contribute to carbon absorption. There is an important need of the use of more tools for protecting the natural heritage. One of them can be a standardization guide of the principles of sustainability that are understandable for all stakeholders and can promote the sustainable palm production and raise awareness of the RSPO and CSPO globally (an example of such is proposed further on). Another tool can be to use Landscape Ecology principles which can improve natural resources quality. The importance of the preservation of the natural environments can also help to increase yield, and this can also be an incentive for farmers to use more sustainable practices. Lastly, an important tool to preserve this region is the creation of new protected areas that can link Mache Chindul, with Cotacachi-Cayapas Reserve and Cayambe-Coca National Park. According to Dr. Moens (Moens D. M., 2020) climate change has modified the limits of the bioclimatic floors, which are driving species to climb towards higher altitudes, this means that creating a corridor that connects the coastal plain with the pre montane forests of the Andes is crucial for ensuring the survival of the most vulnerable species.

Architectural traditions should be encouraged, like the use of native palm trees from which the leaves are harvested to use them on the roofs of indigenous building techniques. In Esmeraldas historically the type of construction consisted on elevated houses of medium to high heights, using wood or cane for pillars, the whole construction was made with light materials: wood, cane, leaves, etc, and the roofs were either gable or hopped roofs made of palm tree leaves or other ecological materials. The reason why this particular type of housing should still be used is because it is of an ecological nature, at the same time that it already constitutes a cultural tradition. Moreover, in a hot and extremely humid climate, the elevated hous-

Figure 60 Tagua Palm trees. [Source: (Montúfar, Brokamp, & Jácome, 2013)]

Figure 61 Fruit from which is extracted the nut. Source: (Montúfar, Brokamp, & Jácome, 2013)

Figure 62 Tagua Arts and crafts. [Source: (Montúfar, Brokamp, & Jácome, 2013)]



ing provides a better aeration and isolation from soil and flooding (Camino Solórzano, 1998).

Moreover, the harvest of wood from coconut palms and balsa forests, that were used to make canoes and boats, should also be encouraged that are practices that are part of the tradition specially from afro-Ecuadorians. Prioritizing native agriculture over alien species can help preserve the culture and traditions of the region. Moreover, the traditional agriculture in the region was of multi-crop farms, so besides the crop rotation and forestry, it is important to reintroduce along the palm groves rows traditional shade-tolerant legumes that can also reduce Nitrogen fixation on soils. Strengthening the preservation of these traditions with planning and policy initiatives can increase the resilience of food systems. And, finally, Acknowledging the culture and traditions this multi-cultural region that hosts various indigenous groups, afro-descendent communities, and mestizo (mixed-raced) population, can result in a culturally rich landscape.

Finally. maintaining all these sustainable goals and principles can result in a stronger and improved cultural landscape that can attract tourists. Tropical Forests already attract a lot of tourists in other parts of the country, the Chocó forests are as important as the Amazonia but much more accessible. For example, The Mashpi Lodge named National Geographic's Unique Lodges of the World offers a unique approach to biological research and a set of adventure activities like hiking trails, sky bike, jungle swing trail, among others, but most importantly it is research station that is at the forefront of rainforest protection, the Mashpi Reserve. This lodge attracts tourists from around the world for its extraordinary location, in the middle of the cloud forest mountains. Although, this is a 5-star hotel, its incentives local communities to preserve the forests in the reserve, and training on techniques of preservation. Sustainable tourism can be a good way to increase awareness of the importance of this region, both regionally and nationally.

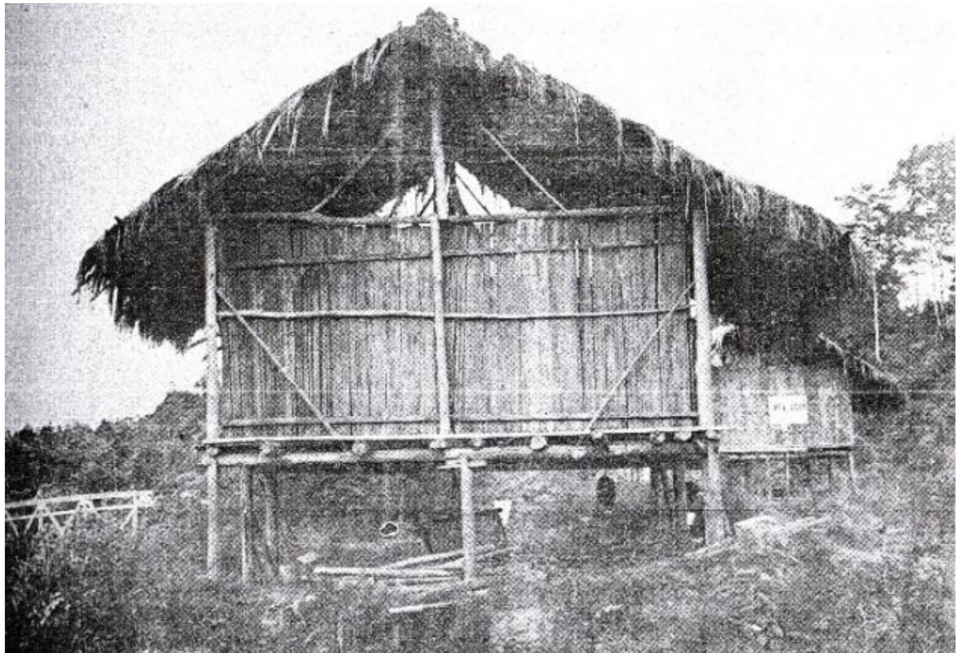


Figure 63 Palm leaves roof. [Source: (Montúfar, Brokamp, & Jácome, 2013)]

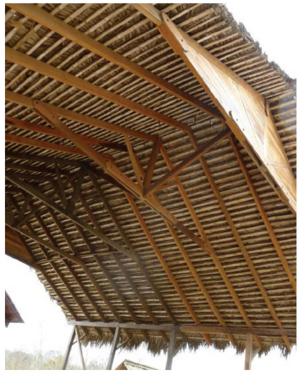


Figure 64 Vernacular Architecture of Esmeraldas with tagua roof. [Source: (Holm, Estrada Ycaza, & Nurnberg, 1982)]

Design Guidelines for sustainable farms

As a part of the possible future outcomes of this study, one is to have a simple design guide that can help farmers introduce more sustainable practices into their farms. Nevertheless, with the information provided by the interviewed experts, there have been identified some measures that can be taken in consideration to improve yield and to guarantee, in the long term, that the land remains productive.

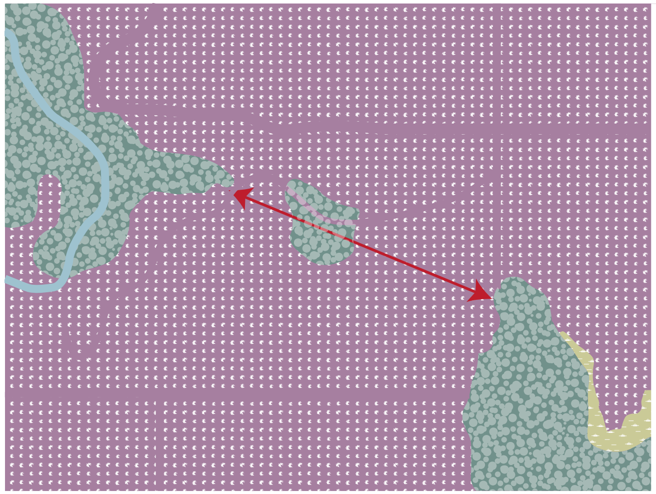
The first measure is to protect small fragments of forested areas that can be connected to the existing larger fragments of Ecological Reserves for the preservation biodiversity and create a corridor that connects the bigger patches of the region. This measure is important for the regional scale, but also in a much wider perspective, because if it done in key areas it can help connect the National reserves, but also, the different ecosystems between the coast and the Andes. Besides being important for connectivity, patches support significant populations of interior species, they offer a core habitat and escape cover for most vertebrates, and allow a near-natural disturbance regimes (Forman, 1995).

The third measure can only be applied to big farms that need to have pest management done by aircrafts. For aircraft spraying fumigation, there needs to be a buffer zone to ensure the chemicals do not damage natural areas or are spilled in waterways. This "non-spray's" barrier width depends on the technique used and the products, nevertheless, it is important to consider the type of plants that can help prevent the spread of the chemicals to natural areas. In addition, nowadays, there are precision thrones that can also help avoid the spilling from aircrafts.

The fourth give space to steppingstones between large patches to provide alternative routes for species and allow connectivity between patches. As in measure number one small patches are being connected to bigger patches, are not fragments of forests, it can be isolate vegetation, or individual trees that work as steppingstones for the fauna to move in the area safely. An example are trees that can be used by primates to move in the search of food without getting exposed by predators on the ground.

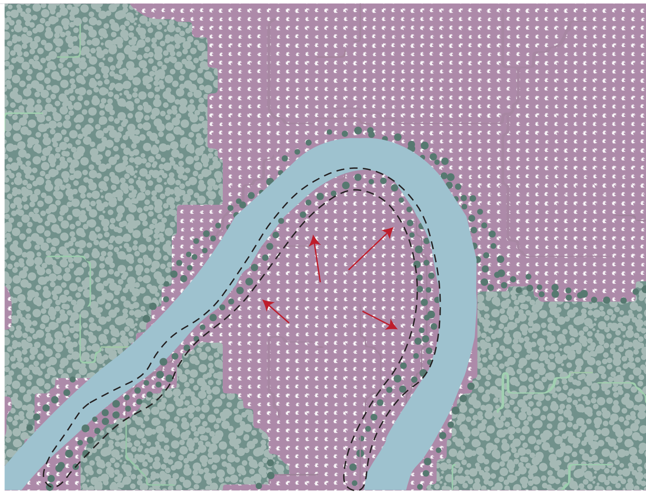
The fifth measure is to pay attention to the edges of the plantations, these edges need to allow structural diversity within its vegetation. Edges cannot be abrupt; they need to have a gradient in tree size and horizontally they need to be heterogeneous.

The sixth measure is that in addition to the 15% of forest that is required to leave for every 50 hectares of planation, there are also riparian strips within the plantations. These can provide hydrological and erosion prevention benefits because support biodiversity (Edwards, Edwards, Sloan, & Hamer, 2014). These strips are called corridors and have been highly encouraged to preserve and create by landscape ecologists' experts because they connect isolated patches of habitat with each other or with bigger fragments of forests. These can ensure the preservation of biodiversity because they can function as habitat or as a part of a habitat for some species. They are also important for large animals that have migration patterns on which they depend on for food and other needs. There are other measures that have been taken from the guide of sustainable palm oil of Unilever (Unilever, 2003), that are more specific to in-situ measures.



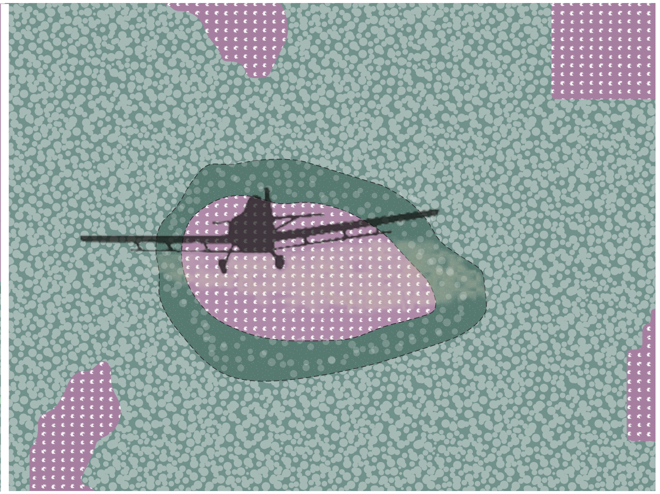
Patches

Protect small fragments of forested areas that can be connected to the existing larger fragments of protected areas to protect biodiversity and create a corridor that connects the bigger patches of the region.



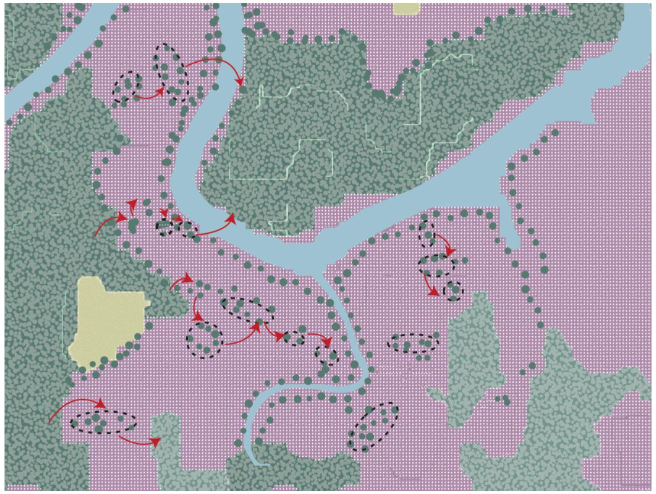
Shelterbelts

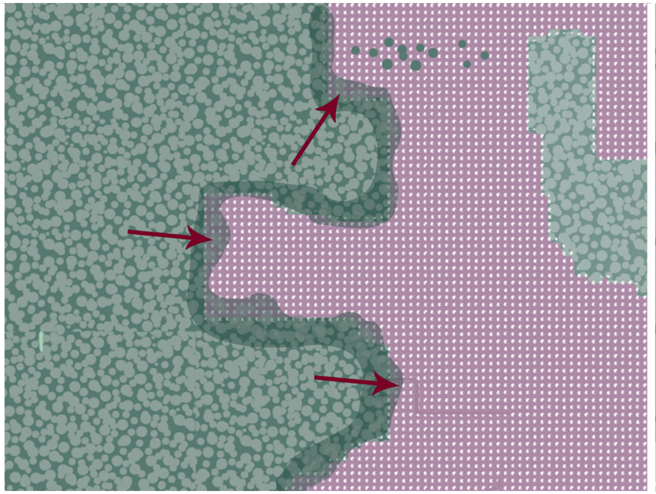
Ensure to have shelterbelts of vegetation, to protect the waterways pollution with vegetation that absorbs chemicals, and also for protecting riverbanks from erosion.

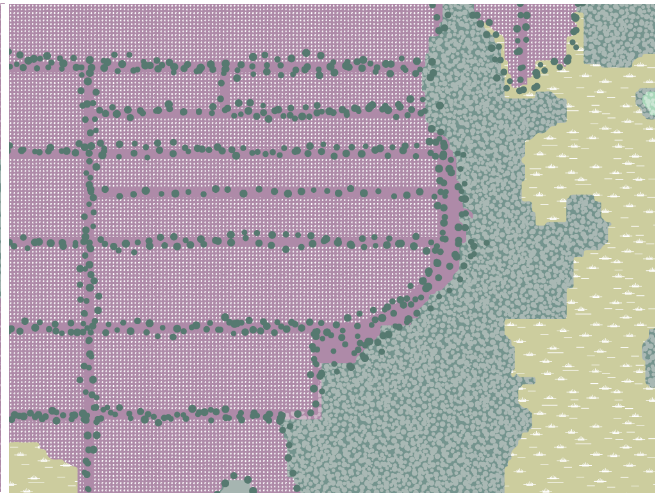


Buffer

For aircraft spraying fumigation, there needs to be a buffer zone to ensure the chemicals do not damage natural areas or are spilled in waterways. It is important to consider the type of plants that can help prevent the spread of the chemicals to natural areas. In addition, Nowadays, there are precision thrones that can also help avoid the spilling from aircrafts.







Steppingstones

Create 'steppingstones' between large patches to provide alternative routes for species and allow connectivity between patches.

Edges

Edges need to allow structural diversity within its vegetation. Edges cannot be abrupt; they need to have a gradient in tree size and horizontally they need to be heterogeneous.

Riparian Strips

Consider having riparian strips within the plantations. These can provide hydrological and erosion prevention benefits because support biodiversity (Edwards, Edwards, Sloan, & Hamer, 2014). These strips are called corridors and have been highly encouraged to preserve and create by landscape ecologists' experts because they connect isolated patches of habitat with each other or with bigger fragments of forests.

Design Guide 4-6




Pest Control

Minimum use of pesticides can be managed by having host plants of predatory insects are frequently planted on the edge of plots and receive particular attention.

Interrow Crops

Allow
woody regrowth (like cacao) to develop in interrow
not used for transport, also to encourage
beneficial insect life.

Fruit Bunches

Empty fruit bunches (bunches stripped of their fruit) should be returned
to the soil to recycle nutrients and organic matter (Unilever, 2003).

Terracing

Soil conservation by terracing steep land and using creeping legume ground cover crops (Unilever, 2003).

Best Practices 1-4

3.3.3 Strengthening of National and Regional planning tools to protect Landscape Heritage

It is important to implement a Network of Cultural Landscapes in the Chocó Region, because this has not been established in the Organic Law of Culture (Ley Orgánica de Cultura). This network should make up all the sites and landscapes that have been previously identified as vulnerable. These vulnerable areas are located in San Lorenzo and Quinindé, both cantons which contain natural reserves. But as mentioned previously, these are now working as isolated elements or dispersed, and this is a threat for the preservation of biodiversity in the area. This isolation of natural areas is also turning into a weaker connection the different ecosystems of the Andes and the Amazon, or the Pacific ecosystems with the Andean ecosystems which is already highly pressuring the biodiversity in the country. Regional authorities and relevant managers of the protected areas should re-delimitate the zoning of such areas and integrate new 'hotspots' in the form of gradients, to avoid direct or indirect land use changes that affect biodiversity inside their limits. Protecting the areas in the periphery (buffer zones) of the protected areas can help to create a corridor for connecting the variety of ecosystems integration of a network of smaller reserves that can be arranged along environmental gradients that can guarantee the displacement of the species along the bigger-scaled reserves. Additionally, it should be implemented outreach, training, and enhancement programs for the prevention of illegal exploitation of African Palm as part of the protection of the country's heritage assets.

Heritage can become an element of strengthening and social unity, and the preservation of antique techniques for agricultural practices can become allies for the conservation of the cultural landscape heritage. This can be achieved also by a framework that has the planning vision to enhance existing capacities and resources to be integrated to achieve tangible, pragmatic objectives that can allow projecting landscape heritage as a new and encouraging conservation processes. Agriculture needs to be considered as Cultural Heritage of the country. The only agricultural element that is considered as cultural heritage is the archaeological heritage, but although other agricultural traditions are not ancient, they have been practiced for decades and are already part of the people's identity. Heritage is currently threated by the idea of a modernity embodied in new adopted traditions, the Ministry of Culture needs to educate people about the importance of traditions and culture, emphasize that new techniques of building or agricultural practices are nit necessarily fit for every region, and that endurance can only be achieved by the use of sustainable practices.

Cross-scale planning is needed for accomplishing the national and local objectives. Funding and planning for maintenance of heritage and natural areas can be more difficult to achieve than for starting a new project after local elections or government change. Further exploitation of forests can be prevented by planning in advance. Planning in advance within the vulnerable areas (from chapter 3.2.3) forest keepers ensure the preservation of protected areas buffer zones and primary forests buffer zones as well. Also, there needs to be clear guidelines that transcend time governments, and that indifferently of the political situations of the country, these activities can be maintained. There have been many programs of reforestation, but many of this fail to reach all stages of planification because there is not continuity in governmental policies. Reforestation needs to be privatized, by paying private companies to fulfill these activities and so, ensure that with the contract, the reforestation activities fulfill their objectives. In 2001, the MAE coordinated a process with different groups from the private sector and to develop a system independent for forest control called Tertiary National System as an instrument to support the forestry authority, aimed at promoting the participation of civil society and private initiative in forest management. Due to lack of effectiveness in 2007 the MAE starts a new strategy for the management of sustainable forests called Forest Administration System (SAF). So currently, the management of forests is still in hands of the MAE, and not in the private sector (Ministerio del Ambiente Ecuador, SENPLADES, 2013).

National planning also needs to strengthen the water safety measures in agricultural practices, companies are required to have assessment on water quality for green seals, but this kind of measurements is challenging in big farms. It is important to verify that not only waterways meet the standards, but also there needs to be testing of underground water.

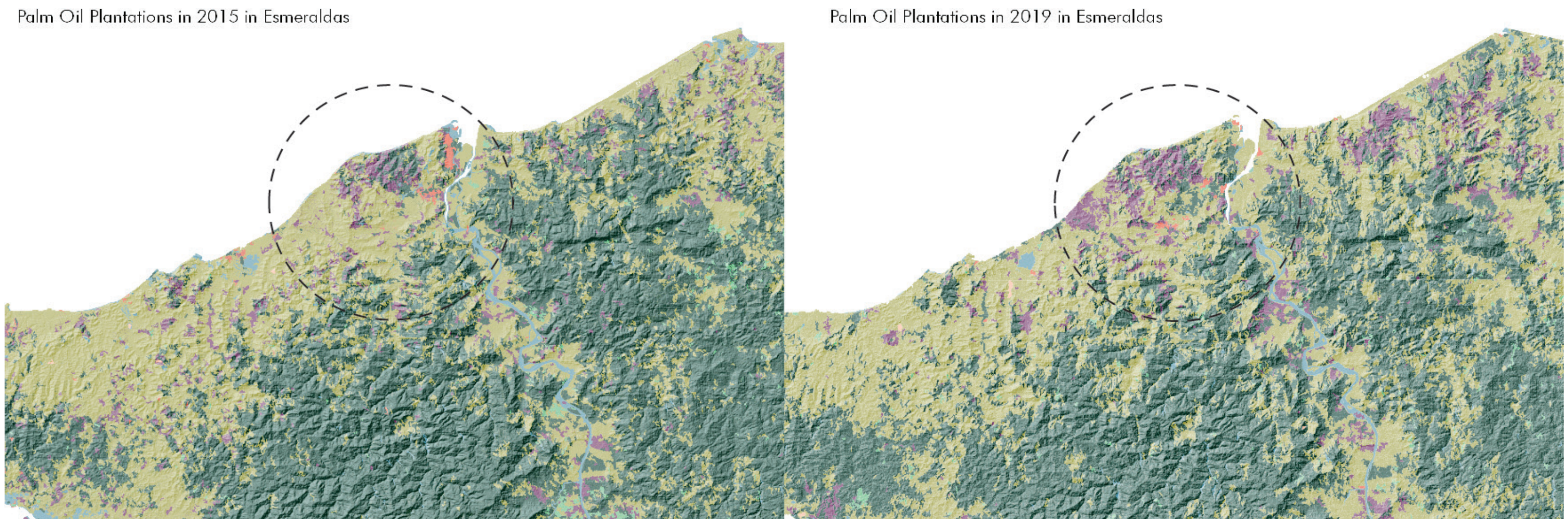
Finally, it is imperative for the Ministry of Agriculture to create new national green stamps and seals of sustainable practices. This can be an incentive for small farmers to adopt sustainable practice if these national seals are more accessible by providing training and assessment on best practices. And, mill owners have to guarantee that the product they sell, either if it comes from internal sources or from small farmers, within a certain period of time this will ensure that all the product they sell, eventually will always come from sustainable farms.

3.3.4 Implementation of monitoring and using Radar Imaging

As it has been mentioned previously, currently it is not possible for all farmers to access the green seals that are available in the country. There are many limitations starting with the bureaucratic laborious paperwork that is needed, then the cost for implementing monitoring and mapping of the land that not affordable, and finally, as long as the product continues to be sold, there is not sufficient incentive to do so. Nonetheless, there are some possible measures that could assure that the natural resources can be better preserved.

This study provides many benefits in relation of remote sensing to monitor the extent of plantations. Mapping palm oil plantations in the region using synthetic aperture radar (SAR) makes the task easier to be managed because this methodology can penetrate the cloud cover present in Tropical Areas. Monitoring can be done in many levels using this technology; it can be used in a regional level for structured planning and careful monitoring for environmental impacts. Also, at regional level monitoring can be done to keep track of the age of the palm oil plantations. Old palm oil plantations should be replaced when they are no longer productive, and when they have reached this matured age it is important to replace them with other crops to rebalance the soils properties, or just remove them so nature can return. But monitoring can also be done in the farm level, having the monitoring done constantly can help the farmer keep track of the rate at which the palm trees are growing, and so

Figure 65 Comparison of Palm Oil Plantations from 2015 to 2019.



make decisions on the needs of the crops.

Monitoring using this methodology can be key to include comparison of imagery in hotspots or most vulnerable areas. Sentinel-1 imagery has new images available every week and developing further this methodology can result in the development of an automated system that can identify significant changes. An example in the image below, although the images are 4 years apart in which the changes should be more visible, but they could still be possible to track, especially in areas that are not close to settlements in which illegal activities are hard to keep track of. This can help monitor not only the expansion of the palm oil plantations but also illegal logging and deforestation in general. This automated system can help develop planning strategies to monitor the most vulnerable areas that are located inside or in the buffer zones of protected areas.

Finally, International policy initiatives, such as the United Nations Framework Convention of Climate Change Reducing Emissions from Deforestation and forest Degradation (REDD) program have encouraged countries like Ecuador to track and map the densities of carbon densities in order to trade them worldwide for the reduction of GHG emissions. Currently this approach is being used in Ecuador with the 'Protocol For Map Processing Carbon Densities For Forest Layers Of The Continental Ecuador With Modis And Landsat Images' that uses MODIS and LANDSAT imagery that is processed to generate Ecuador's mosaic with the tiles of the MODIS images previously filled in. Nevertheless, although this process is approved by the United Nations that collaborated with this protocol, Ecuador's methodology to track carbons densities lacks the inclusion of a methodology that allows separability between palm oil plantations and forests. Optical imagery in not optimal in tropical countries because of cloud and fog cover, but also because, as mentioned before, MODIS is not efficient in distinguishing types of vegetation, as palm oil plantations. Therefore, the estimation of above ground biomass (AGB) that provides a glimpse of the amount of carbon that resides in an ecosystem can be useful as an indicator of an effective carbon sink. AGB of oil palms can be estimated to assess its ability to retain carbon stock and biomass accumulation. Radar remote sensing could benefit from the penetrative nature to derive structural information to estimate AGB. As palm oil trunks and its primary branches compose most of its biomass, L-band data are considered the most significant source of data in estimating AGB (Chong, Kanniah , Pohl , & Tan, 2017). So, exploring further the use of satellite radar data can be a key to map carbon densities to be sold in international markets.

Furthermore, another important use for remote sensing in palm oil plantations monitoring is pest and disease detection. Early detection of pest and disease could help to plan intervention strategies to prevent outbreak, especially if it's possible to identify bud rot. Depending on the disease, the infected palms can show symptoms at a later stage. To prevent the spreading of the disease, the infected oil palms have to be quarantined and removed. The use of remote sensing for monitoring the status can be done with the development of this methodology using Sentinel-1 data because there are already studies that suggest that with a statistical approach applied to classify diseased plants based on the hyperspectral reflectance data can point out the diseased ones (Chong, Kanniah , Pohl , & Tan, 2017).

CHAPTER 4: CONCLUSIONS

The conclusions chapter is being presented as personal considerations about the results and the work carried out in the thesis. Scientific results and outcomes are presented in Chapter 3.3 Future Scenarios: New Directions for the Preservation of Cultural Landscapes of the Chocó Region in which the reader is addressed with a summary of the findings of this study and as of possible scenarios for the Preservation of the Cultural Landscape of the Chocó region.

Ecuador is a country that can be worldwide referred to as a developing country, but we, Ecuadorians, refer to it a poor country but at the same time a rich country. Poor country in terms of socioeconomic problems, extreme poverty in which people live with less than a dollar a day and experience hunger, illiteracy, discrimination, and poor working conditions. But rich in culture, in nature, in ethnicity, in biodiversity, rich in diversity of landscapes that go from the depths of the Amazon to the top of volcano Cotopaxi, to the Pacific Ocean into the Galapagos Islands. "ALL YOU NEED IS ECUADOR". But the rivalry and division of the people because of their race, their socioeconomic situation, the region from where they come, and political views weakens any effort to grow. This division becomes stronger any time the country experiences an economic crisis which in my lifetime have been so many, I can say that they happen every 5 to 10 years. The only way to develop Ecuador is starting by strengthening our identity as Ecuadorians, not as the poor, the rich, 'los serranos' (from the highlands), 'los monos' (from the coast), 'los indigenas' (indigenous), 'los blancos' (the white), and so on. So many titles for the same people, from the same country. I'm not sure of why so much division, is it possible that 500 years after the colonization this division between the 'colonos' and the 'mano de obra' still remains? But whatever it is, it needs to stop. And in my opinion the only way to do so is by retrieving all the important values of our culture, of what makes us Ecuadorian. Cultural heritage profits and benefits remain in the hands of the investors, the big touristic companies, and so the obtained resources are centralized and do not reach the people, the actual owners of certain natural or cultural heritage, this rich authentical communities.

So, it is needed a new approach, a cultural approach that educates Ecuadorians to value Ecuador, to be proud of their culture, and to protect this culture. The introduction of Cultural Landscape concept can do that in my country. A concept that protects a certain landscape combining all the unique characteristics of our country and of our culture, might they be geographical, natural, historical but at the same time incentivizes economic development, of which the communities can benefit from, not only economically but as a mean of inclusion into the society, to give a halt to segregation.

The most vulnerable people in the country are the people that live in the rural areas, the poverty and illiteracy in these parts of the country are greater than in urban areas. Agriculture is expanding at an accelerated rate in coastal areas of the country, especially in areas that are rich in natural resources. The need of expansion overlaps with the need to protect the natural resources, resources of which this people need and depend on to survive. At the same time, one of the most biodiverse regions of the world that is highly threatened by economic pressures is the Chocó region of Ecuador. The combination of these two problematics, poverty, and hunger in agricultural areas, with outstanding ecological values, can be addressed together with a cultural landscape approach. The inhabitants of this region come from multiple ethnic groups, each of which are losing their cultural heritage to modernity and to migration. Therefore, preserving the landscape of the Chocó region can be beneficial for the people, but also for the environment.

As this is a new concept in Ecuador, how can it be addressed and introduced? The study carried out showed the importance of implementing a thoroughly cultural mapping methodology to capture all the outstanding, but also everyday aspects of this region that characterize it. Starting with a literature review that explores the biophysical values, agro-historical values and socioeconomical values, as well as its threats, then to mapping the extension of this territory, to narrowing it down to the delimitation of a landscape that is worth preserving.

The challenge to map a cultural landscape in Ecuador, not only relies in the exploration of a concept that hasn't been explored before. But in the challenge to do it remotely, finding relevant information about culture, traditions, history of a 'neglected' area is not easy. Historical documents of large cities, or archaeological sites can be less challenging. But finding information about 'everyday landscape features' that are constituted as part of the culture is much more challenging. After carrying out interviews to deepen the understanding of the region, it was also found that there are many aspects of this region that are worth preserving, it is just a matter of giving value to historical characteristics, that aren't necessarily ancient, but are historical. Moreover, finding multi-temporal imagery of Ecuador that can help keep track of the changes the landscape has endured in history, is a much more challenging task. The new methodology implemented for this study, was key to understanding the landscape as a whole. It pointed out the dependence of the people of this region on the price of the markets for primary goods, how these prices drive the changes not only in land use and land cover, but also in socio-economic aspects.

And although, palm oil plantations have played a major role in the land-use land cover changes of the region, I believe that they should be addressed more of as an opportunity than a threat. They are threat to the environment and to the culture of the landscape but removing them is not going to solve all the problems the region is enduring. But, tracking them, monitoring them, and encouraging its owners to have sustainable practices can have a huge positive impact. All these opportunities are deeply explained in Chapter 3.3, but in my opinion, the most important one is to take the advantage of the high productivity the extraction of palm oil has, and combine it with the production of traditional crops. Besides the environmental and economic benefits this can bring to the region, it can be an opportunity to preserve the traditions that are getting lost with time. Cacao, although it is not a native species, is developing in recent years in Ecuador as national brands of chocolate like Washu Chocolate Orgánico, or República del Cacao, promote sustainable practices that include good working ethics and that involve communities in its production while offering training programs to have a more qualified workforce. Native crops like tagua for craftsmanship can be very useful also to teach new generations how to use this 'marble nut' for arts and crafts.

Conclusively, as a landscape architect, I'm confident that landscape architecture is a tool that goes beyond its aesthetical capacity but that can offer a broader perspective for planning, for finding strategies to address large-scale projects, and more importantly that answers to the need of engaging communities to a more environmentally friendly way of living. The world is enduring climate change and global warming, and finding tools to address this is important, doing so while ensuring food security and ending hunger and poverty, is fundamental in this century. And finally, I believe that in the future the design of farms that include a resilient approach of ecological systems is going to make a great difference in the preservation of landscapes, but also in preserving the Earth. It is possible to have farm designs that include restoration operations to repair soil degradation, and that also includes cultural and natural features that can help re-shape a cultural landscape, with outstanding, but also, everyday value.

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CHAPTER 6: APPENDIX

6.1 Interview to Andres Dávila, stakeholder of palm oil plantations in the region.

1. **How big is the farm in hectares and do you consider it to be small, medium, or large?**

Currently we have 2250 he which is considered a large farm.

2. **How big was the extension of the farm when you started working there, who owned it?**

Originally the farm started with 35 he of palm oil plantations, but when I started to work there the extension of the farm was of 250he. We have incorporated more chain productive processes, not only the cultivation of the palm.

3. **What kind of production did your company have before having palm oil plantations?**

The company belongs to my family for two generations, starting with my grandfather that introduced the see of the palm oil in the country. It has always been a monoculture farm with palm oil plantations exclusively.

4. **What kind of modifications was it necessary to carry out to plant the palm trees?**

It is important to understand first how this cultivation has developed in the country. This industry developed after the Agrarian reforms in the 60s in Ecuador, at which time most of the land was essentially artificial pasture. The properties were big farms or latifundios that had already affected primary forests in the region. So, when the palm oil is introduced to the country it was planted in areas that had already been exploited, this wasn't crop that lead to deforestation in the region. So, to start the plantation of the palm it is important to first do soil testing to know the type of soil and more importantly, the minerals that are present in the soil, so further in the cultivation, the recipe for the growth can incorporate the nutrients that are lacking. Generally, the soil has to be loamy with a black colorization, and it's important that the land doesn't have floodable risk because the palm tree doesn't tolerate flooding. Then it is required to do a planimetry planification that is called '3 bolillos' that means a triangulation of 3 points of 3m of distance accordingly to the topographic conditions where the palm trees will be planted. The next step is to have a greenhouse process because the seed can't be planted directly on the soil. The greenhouse growth takes about 12 months to develop the palm tree enough, so it can be planted directly on the land. If the structure is strong enough, the palm tree is contained in biodegradable bags that are then planted on the designated area. Generally, there isn't a modification done in the land with the exception of areas that might not have sufficient precipitation, and therefore, it is required to install an irrigation system that can achieve the requirements of the crops development. Additionally, the topography most suitable for the plantations in a relatively flat terrain, but in sloped terrains, it is still possible to have cultivations, by terraced platforms that allow the structure of the palms have stability. Nonetheless, it adds an additional cost to the plantations that is normally considered to be avoided. Then, the other climatic requirements that are needed is precipitation of 1800 to 2300mm yearly, these conditions are found in the subtropical areas of which this region is part of. Also, the temperature range must be between 26 to 28 C, the highest the temperature, the more productive the crop becomes, and if the precipitation is higher it also becomes more productive because it develops faster. Finally, there is the luminosity condition that is required, the palm oil trees need minimum 1500 of sun a year. With more light it also increases the oil production, so generally, the temperature and the luminosity are the conditions that increase the oil content on each palm, and the water availability is linked to the development of the palm tree itself.

5. When the conditions are not met in terms of water availability, what is the process that needs to be carried out for irrigation?

For the oil palm cultivation there are a few methods that can be used for irrigation, but the most common one is the furrow irrigation called riego por surcos. This method consists on having a system that allows the channels along the field length that then can be absorbed by the crops. There is also the sprinkler irrigation that isn't used too much because the system is very expensive, and then the other method that is also used more often is the drip irrigation, that has also proven to be effective. The drip irrigation consists on water that arrives to the root of the crop in a system that delivers it drop by drop. This type of irrigation has to be done by companies that offer this service, and then the maintenance of this system needs to be monitored constantly for its effectiveness.

6. How does the industry work, after extracting the fruit of the palm trees?

The palm fruit is very similar to grapes, but much denser. So, each 'grape' is can be considered the fruit, which allows the extraction of several different products. The palm fruit is transpoted to an oil mill, to an extraction process that is generally mechanic, where the fruit is sterilized, so the rotting process is halted. Then to separate the fruits from the string it is used the mill that presses the fruits to be extracted, but the pressure needs to be adjusted so the seed isn't destroyed. The main product extracted from the fruit is the red oil or crude palm oil, and from the seed it is extracted a different oil that is called palm kernel oil. Then, after the oil has been extracted the oil needs to be taken under a process of purification, in which it is needed to remove remaining water, because during the process it is used heat and steam in cauldrons of high and low pressure. After that, once the oil is clean and dry the crude palm oil is sent to to refinery industries so it can be clarified, so remove the color and smell. The process is called RBD (for refinery, whitening and deodorization for its abbreviation in Spanish). The refined oil is then bottled and sold to the public. Sometimes there are done some mixtures with other oils like soy oil, but it is more related to the public's demand that might have some requirements like that one.

Then, for the seeds there is a different process with an additional mill, where the oil from the seed is extracted. This is a more exclusive oil that is used for cosmetic industry, like lip balm. This is the palm kernel oil, that is also used as a replacement of cacao oil in many products, like kit-kat chocolates and others. Then the residue called 'raquis' that is the fruit bunch and the palm kernel shell. This one is used as a fertilizer and also as biofuel that generates electricity that is used during the processing of the palm oil and other fuels are used (like diesel), for which reason, the production of palm oil can be considered a sustainable practice, that is auto-sustainable. Also, this residue is 20% that is a considerable amount, and it replaces somewhat the chemical fertilizers. Moreover, now, we are working on a certification that will allow the oil extractor companies to be considered a zero-emission industry.

7. How long have you had the certification of Roundtable of Sustainable Palm Oil?

In the palm oil it is important to mention that only recently this certification became viable, before there were only The Green Seal or The Rainforest Alliance, but these weren't so applicable for the palm oil production. From this premises, the Round Table of Sustainable Palm Oil was created by countries like Ecuador or Malaysia that are the biggest producers worldwide. As a company we have been certified with the RSPO, but only in the extraction process and in only in an extension of 250he of the cultivated land. The big challenge nationwide, is to certify the small farmers, because the 89% of palm oil farmers are small farmers, with less than 50he. These people do not have the interest or the economic resources to go through this process of certification. So, we are working with the RSPO so the certification is done nationwide, or at least in many areas of cultivation that have an important value, like the area of Los Rios or the Amazon or San Lorenzo. The goal of this certification is efficiency, so the farmer uses the resources like a law enforcement were resources in a sustainable way. But most importantly, it is focused in the preservation of the natural environment and in the social aspects, where people that work isn't illegal, like making sure there aren't any underage workers. So, it takes care of all these aspects that make the business efficiency and the sustainable practices. Additionally, this certification is interested on protecting forests from deforestation and making sure that were the new plantations will take place or already are planted, the previous land use has to be other croplands, plantations that replace forests cannot access this certification. This is an important aspect, because any hectare that is planted needs to be in a land that was not forest since the year 2015. If the new plantation is located in a place where in 2015 it was a primary forest, the farmer needs to compensate this to the local authorities with $600 per hectare or participate in reforestation programs, which makes the cultivation unprofitable. This has become a very important tool to protect the forested landscapes, so that they do not become palm oil plantations. Finally, it is important to mention that before 2015 it was not possible to apply to this certification either, if there was land use change involved, but after 2015 this has become very strict, in terms that, it is possible to access this certificate if any kind of land use change has happened.

8. What percentage of farmers have this certification and what are its requirements and limitations?

This is very interesting question. In the RSPO website there are published 8 main principles that need to be met to apply to this certification, but the most difficult to accomplish are the ones related to nature and natural environment. The RSPO isn't really the problem here, because it absolutely comprehensible that they would ask for an environmental license, but it's more related to local authorities, that to apply and receive an environmental license but takes up to 2 years and the cost is quite high for a small farmer for whom $10.000 is a considerable cost that with a small farm it would mean reaching its equilibrium point or have no profit at all. With the addition of all the administrative baggage that means that it is needed to hire an environmental expert, do all the paperwork with The Ministry of Environment, all the certifications that are needed, all the planimetry required, and so on. So, it's all these limitations that are administrative and economic that are very limiting for the small farmer.

9. What percentage of the plantations have this certification?

In Ecuador, only big companies have access to the RSPO certification, and the percentage ranges from 15% in relation to the hectares of the country that have this certification. Now, the importance of this certification, besides the sustainable practices that it promotes, is that now the market asks for this certification in order to purchase the oil, and eventually, any product that doesn't have this certification will not be bought.

10. What kind of methods do you use to track the plantations, and is it available and reliable for all farmers?

This has been one of the most difficult problems to assess in order to get the RSPO certification. There is basically just one company that was created by my company and other farmers that were promoting the RSPO, the resources to even have an adequate census was having the satellite images that would allow to access this data. After a lot of trouble and time, it was finally possible to have a private company to start this initiative 5 years ago. So, there is a tool to access satellite images by which it is possible to have an accurate planimetry of the extension of the plantations. Previously, it is important to mention that, the methodology used to measure the extent of plantations it was necessary to hire an engineer that would use a gps system to physically measure the boundaries of the farms. But it was very messy, it was not accurate, and it was very time consuming. When the satellite imagery tool became available it became much easier to track and measure the extension of the farm, nevertheless, the cost of using this tool is very high. So, at the moment, there are efforts to have worldwide investments so that there become available other tools that can be used in this matter. This tools not only provide a measurement of the farms, but most importantly, they allow to have information of the land use cover that is key for the RSPO that requires to have data confirming that the plantations are located in areas that were not natural environments, and that want to track the change of the area over the years.

11. Have you experienced problems with the bud rot plague? What are the solutions to combat this problem?

This is a huge problem that we have experienced for the last 5 years. To understand better this disease, it's important to know that its first appearance in the Country was in the 1980's in the Amazon in the plantations of a group called Grupo Morisaenz. But then it didn't expand until 10 years ago, it reactivated in Colombia in Tumaco, spreading it towards the boundary of Ecuador to the area of San Lorenzo. From here, the bud rot spread towards the south, to the areas of Quinindé and Santo Domingo, From Santo Domingo to Esmeraldas, and now from Santo Domingo to Esmeraldas. The first thing that we did when this started to happen, was to migrate to other areas of the country like Quevedo and Guayaquil. With the help of specialists from France and Costa Rica and agronomists, it was determined that towards the southern coast there is a physical barrier that halts the spread of the plague to these areas. Where there are dry areas, this natural barrier exists because the plague, more specifically the Phytophthora that is fungus, cannot survive in dryer areas. This Phytophthora can be understood as cancer for the plant, that what it does to the palm trees is that it rots the center of the palm tree and after losing its leaves, it starts to weaken its structure and falls and ends up dying. So, with a higher investment in irrigation, the plantations in the dryer areas are not affected by this plague, and currently these dryer areas are completely free of this disease.

Additionally, what has been done to combat this disease, in collaboration with bigger companies of the area, like La Fabril, Danec, Ales, is to collective support with different resources, to develop new genetic variations of the palm oil. Even with the collaboration of the Government, to develop different variations of the palm oil trees that are immune to the bud rot disease. With this technology it is possible to re-plant the affected areas.

Finally, the main solution has been to develop new hybrid species of palm oil trees, that are resistant to the plague and that can be replanted. Currently, unfortunately, with the pandemic of Covid-19 emergency, this process of replantation has slowed down because there isn't full access to all the commodities that would have allowed us to attack this plague with the aggressiveness we wanted.

12. Is this solution of hybrid species replacing affected trees with the plague affecting the productivity of the farms?

Yes, absolutely. It's pretty much starting from zero. Although, with this new species it has been possible to reduce the time of reaching the full growth of the palm trees, it has been reduced by 1 to 1,5 years, so now it takes 2 years to have a palm tree that can produce the fruit to be extracted. Although, it is two whole years in which it is necessary to put a lot of resources, without having any revenue. And the efforts aren't only to help the big farmers, on the contrary, it's focused in helping the small farmers as well. Because it's impossible for big companies to invest in the replacement of the plantations because it requires too much concentration of resources. So, with the government it has been possible to get founding with 5 years of grace, nevertheless, the prices of the palm oil have lowered, and small farmers prefer to wait instead of investing in the palm oil plantations.

13. How are other farmers dealing with his plague?

Some have gone bankrupt, and some are replacing the palm oil plantations to other crops. For example, the new alternatives are Cacao and passion fruit (maracuyá). But this condition has led this industry into a very demotivating situation. Nevertheless, the lowered production of this product influences the market, so the lower the offer the higher the prices. And the country is very well linked to the market values.

14. Where would you expand the cultivation of palm oil in the future and why?

What is happening currently is that the palm oil plantations are expanding towards the south. From Santo Domingo to Guayaquil, and even to Santa Elena. It was imaginable to expect the plantations to be take place in the coast, near the beach, but now it has developed in theses areas with different technologies for irrigation. So, now the focus is not really to expand further the plantations, but to make the current ones more efficient. With this new hybrid it is extracted more oil in less units of palm trees because it is really hard to have the cultivation expand at the moment. This what farmers are doing and the transformation that they are seeking.

15. What is happening with the farmers that weren't able to replace the affected palm trees or expand to unaffected areas? Are these farms being abandoned?

To answer this question, it's important to mention that the palm oil had its golden years between 2008 and 2014. Between these years, to have an idea of the productivity, the cost was of $70-$80 for one ton of the palm oil fruit, but the selling price reached at some point $200 per ton. So at this time, many people from the cities with resources but with different profession, military, economists, doctors, and so on, invested in this production that could be managed like with a remote control, they hired someone at the site to be in charge, and didn't need to be checking the plantations with too much regularity. So, these people that started in the business in this way, but have never been true farmers, are abandoning the plantations, because they don't know how to deal with these problems. In contrast, the farmers that have experience in this, are first replacing the species of the palm trees but also having an alternative crop. They do want to remain palm farmers, but they also want to diversify the production to have safety with other incomes. The abandonment exists, but it's not really massive.

To give an example on how the diversification takes place, there are more or less two options. So first, where there are palm trees rows, they alternate it with rows of passion fruit. Because these trees don't compete with the palms, they do not affect the luminosity needed for the palm trees. Other farmers have divided the plot with, for example cacao that cannot share the site with the palm trees.

16. How has the landscape changed in the last years and what is the projection in the future for this crop?

This question is very interesting so I will answer it in two parts. The first one, I that I have experienced the landscape for more than the 15 years that I am part of the company, but since I was a kid I have seen the landscape change in the palm oil areas or where the company has settled. So, many years ago, more than 15, it was possible to see monkeys in the area, also some specific types of native fish, the landscape in general was a lot more natural in that sense. But mainly it has been an introduction to the technology in the area that has changed the landscape. Before, the harvest of the palm oil fruit was carried out with a 'machete' or cutlass, that is a manual way for harvesting. Also, it was previously used small hydraulic trucks that was used to harvest. And this changes with the use of technology has been changing the forested areas.

The second relevant change is better understood nationwide. Before the palm oil plantations were very concentrated in specific areas, more specifically in Santo Domingo. And it was possible to see that everything looked green, not only palm oil plantations, but also pasture and forestry. But what mostly changed the landscape has been logging. Additionally, the population in the region has grown, so the cities like Quinindé have expanded a lot. Also, the expansion of palm oil that has a strong economic pressure that has turned the landscape into a more civilized environment. It used to be a lot more natural and this has changed a lot.

Finally, I wanted to point out that the pandemic has brought back the wildness to the region. In the area where we had the original 250 he, it has been possible to see for the first time the new home of large white egrets (garzas blancas), they have located near a natural lagoon that has never been altered, and walking around the area it's possible to see hundreds of them in the same seven trees. It is quite impressive, with the pandemic there was been a reduction of workers working at the same time, and the harvest is being done manually, and this has allowed nature to return to the area. Just recently, after spending some days at the farm, we realized how impressive nature is, when human activity stops in returns so fast. The resilience is impressive. I have some amazing videos that are worthy to see how these egrets leave in the morning, only the chicks and the moms stay in the trees, but then in the afternoon they all return at the same time, quite loudly, and then they sleep there. So, although nature can return so fast, also humans have to realize how small changes can have such a positive impact in the landscape.

So, finalize, I'm able to notice this change because my company has always cared about preserving nature. It is necessary to preserve the environment because if it lost then it is not possible to produce. So, we have been promotors of sustainability in the area and also have put effort into helping people. We were actually, since the beginning leading the National Association of Palm Oil Farmers (ANCUPA) for 8 years. This is an iconic association in the country that was founded by my grandfather and Fidel Egas from the Banco de Pichincha. It became so important in terms of supporting palm farmers, that it turned into more of a political interest in the area. For this reason, we have lost interest in continuing to lead it but we are still liked to them and we still support it.

17. Can you please explain a little bit more why do you think this area of the farm with the original 250 he has been able to recover its natural value with the pandemic?

With the reduction of the access of the workers, that was a measure to ensure social distancing, it was allowed to have a separation of shifts. This resulted in having the harvest done manually, for which reason the use of the agricultural tractor has stopped. Coincidentally, also, because of the plague, a while before the pandemic, we had already stopped using technological methods in the production to halt the spread of the bud rot, but in addition to this, the limitation of access of workers has positively affected the environment.

6.2 Agronomist Diego Cordovez Interview

1. Do you have experience in agriculture in the coastal areas of the country?

Yes, for 15 years.

2. What crops were traditionally grown in the northern coastal area of the country?

The crops that were traditionally grown in the region are African palm, cocoa, and livestock pasture.

3. What are the current trends in agriculture in the Northwest Region of the Ecuadorian Chocó? More specifically, in the province of Esmeraldas?

They are putting commercial forest plantations of Gmelina arborea and teak in addition to African palm, cocoa, and livestock pasture.

4. Why is the Esmeraldas area characterized by a preeminence of oil palm plantations? Do the climate and soil play a role?

Because the climate and soil are optimal for your cultivation.

5. What has been used historically as technological techniques in the production of crops in the area?

There hasn't been any other crops in the last 30 years, only palm oil plantations because it is a very poor province.

6. What native crops are grown in this area?

There are not any native crops.

7. What crops are exotic species that could be replaced by native crops?

There are no crops that can be used to replace palm oil plnatations.

8. How has the agricultural landscape changed in recent decades?

There is an important change in recent years because palm oil plantations have died from a disease called bud rot and people have not replanted.

9. What was the landscape like in Esmeraldas 15 years ago? And now?

There is an illegal logging of native wood in primary forests and illegal mining that are destroying the banks of the rivers and polluting their channels due to the illegal exploitation of gold.

10. What traditions or cultural characteristics are being lost with modern production techniques and technology?

There aren't any traditions that are being lost because afro-Ecuadorians have historically lived from logging and they continue to do so.

11. What traditions should be preserved in the production of traditional crops?

The tradition that should be preserved is care of primary forests that local people depend on. There needs to be training to cultivate in permitted areas that are in places outside of reserves or protective forests. This can improve the standard of living and it can encourage the planting of commercial forest plantations to avoid illegal logging of these ecosystems.

12. What are the main threats to palm oil plantations?

Monoculture

13. What are the effects of palm oil plantations?

In Esmeraldas, more than 100,000 hectares of palm have died

14. What are the effects of its expansion?

It has decreased in the last 5 years

15. What are the areas characterized by the greatest expansion of palm oil plantations?

It was the canton Rosa Zarate, Biche and San Lorenzo.

16. What is the role of palm oil producers in the loss of forested areas in the region and the degradation of the soil and the loss of ecosystem services?

Currently, palm oil plantations require to have only 15% of the area for cultivating palm oil trees, the rest needs to be left as a reserve. In my opinion the main problem is not the palm, it is illegal logging and illegal mining of protected areas.

17. What is the social impact of these plantations? What kinds of conflicts or problems of injustice are being dealt with in this industry?

With the loss of palm oil plantations to bud rot, people have lost one of the only sources of employment that existed in the area.

18. What kinds of sustainable practices can have a positive impact on the landscape and natural resources?

Allow palm, cocoa and forestry crops in areas destined for agriculture and delimit reserves for their preservation.

19. What are the limitations of sustainable practices in the country and in the region?

There is no control of the Ministry of the Environment.

20. What sustainable measures can be applied at all levels of production, despite the size of the palm oil plantations, that can help preserve the cultural and natural environment?

The measures are already in place from 50 hectares of cultivation, you leave 15%. The problem in the north is illegal logging, the depredation of wild animals and illegal mining.

21. What crops can replace palm plantations in the future?

There are not any other crops that can replace palm oil trees because the area is characterized by a very high precipitation.

22. What other crop would be suitable in Esmeraldas?

The best option would be to invest in forestry.

6.3 Agronomist Fausto Venegas Interview

1. Do you have experience in agriculture in the coastal areas of the country?

I worked at Monsanto and Syngenta who are agrochemical vendors and laboratories and part of the strategic crops for both companies was African palm and bananas, so I visited those areas, Esmeraldas visited it in greater quantity between 2001 and 2006 when I worked with Monsanto.

These companies are manufacturers of agrochemicals that serve to control weeds, insects and diseases. Palm and bananas are part of the country's strategic crops.

2. What crops were traditionally produced in the northern coastal area of the country?

Traditional crops can be divided into two different circumstances:

The years 1930s - 1940s, in Esmeraldas the main crops were tagua, a type of palm that serves for the elaboration of buttons and crafts. It was a harvesting and subsistence crop, native, but there were also palm trees, to which the leaves are harvested for use on the roofs of the housing types of the coastal area. There were also coconut palms and balsa forests, used to make canoes and boats. Around World War II a lot of rubber was exported, which was considered indigenous to the province of Esmeraldas.

Since the mid-1940s and early 1950s, the "boom" of cocoa exports in the mid-1950s has entered, which is additionally added to that of bananas, which begins to drastically change the landscape due to the growing presence of intensive banana crops, many of which replaced cocoa crops. At this time, banana exporting multinationals entered, buying hundreds of hectares and establishing a monoculture, changing the landscape.

The crops introduced more than 60 years ago that are representative are cocoa, bananas, and coffee (about 10 or 15 years ago).

3. What are the current trends in agriculture in the Northwestern Region of Ecuadorian Chocó? More specifically, in the province of Esmeraldas?

The area where the provinces of Esmeraldas, Santo Domingo de Tsáchilas and Pichincha converge are quite a few areas of cocoa and palm, however what is most observed (if you could have a satellite view) and has a greater impact are the sembríos of African palm, oil palm. African palm, cocoa and bananas have the most impacted on the landscape, with trends around 15 years ago you have the strong income of African palm, bananas start a decline of sembríos and cocoa is maintained with slight variations of expansion.

In the coastal areas of the north of the province of Esmeraldas, such as San Lorenzo, Camarones, etc. you can see coconut palm, tagua, forestry, banana and banana again. Bananas and bananas also increase in the southern part of the province of Esmeraldas, in the area bordering Manabí.

This area where the provinces of Pichincha, Santo Domingo de Tsáchilas and Esmeraldas converge, following the road that connects Santo Domingo with Quinindé you can see diversified crops such as fruit farms (such as passion fruit, export pineapple, papaya) and concentration of banana areas.

The expansion of African palm crops can be talked about two epochs in the province of Esmeraldas:

The old areas, the areas around Quinindé, La Unión and Santo Domingo. These are the areas that first came the palm.

The new palm crops: around 2000, large palm growers such as Ales Palma, Agrícola del Pacífico, Hidalgo-Hidalgo, Palmeras del Oriente, Palmeras del Ecuador, among others, began to arrive on the route of the crossing of Mataje to San Lorenzo (crossing the north of the province from the border with Colombia, towards Imbabura).

Although the old areas have a greater area than the new ones, in the area around Mataje, it is where the expansion of palm crops had the greatest impact, since only palm is found in this area, giving a desolate landscape, only intensive palm cultivation is observed. In the old area due to being further away from the border with Colombia, which made it safer due to issues of military conflicts with various Colombian insurgent groups (the ELN and farC), allowed for greater farming, greater number of farmers, and with them various crops.

4. Why is the Emeralds area characterized by a pre-eminence of oil palm plantations? Do climate and soil play a role?

Economic power groups

It is considered that the quality of labor in the province of Esmeraldas was not very good in the 1950s, people had a habit of taking long naps and not having an intense work activity, which does not combine with agricultural activity. Many companies that are located in this province, exporters of cocoa, rubber, bananas and palm. Due to this low-intensity labor issue and insecurity about the proximity to the Colombian border, they reduce the presence of agricultural crops that could have diversified what became practically an African palm monoculture. It also influenced that large palm growers found large areas of land at very low costs, as these lands belonged to commoners who sold them at a low price.

In bananas 8 workers are needed for each hectare, while with the African palm a single worker can work 8 hectares of cultivation. Therefore, you can have large areas of crops with few workers, if the quality of these is low the problem is minimized. These areas began to grow a lot, and companies began importing labor from the provinces of Imbabura and mainly Manabí. This created a social discontent, there is a resentment in the population of the province of Esmeraldas against these palm companies, since they say that these companies do not take them into account to hire them, companies instead say that when they settled they hired the people of the nearby towns but that people did not want to work, they carried out many protests and strikes. The contracting conditions that have been generated in these extensive crops are very informal, precarious and that have been given around the whole of Ecuador also in the history of bananas.

I worked around the country a lot for my work, I went from Guayaquil to Esmeraldas, on this route in the coastal towns (e.g. San Mateo, Shrimps, Timbre, etc.) people are seen a lot in the hammocks, playing football, drinking, chatting in working hours, and they are things that are not seen in any other province and therefore attract attention. When you enter a farm you find that the butlers, the workers, and the workers are from other areas, such as Manabí, san Antonio de Ibarra but not Esmeraldas. In Esmeraldas it is observed that indigenous people from provinces near Esmeraldas have moved to this province for work, the problem is the insecurity of this province since there is a lot of crime, but Afro-Ecuadorian is not known to be a worker, and this causes him to be displaced and this causes this resentment with these companies. When visiting agricultural industries and companies, it is observed that the capital and owners do not belong to Esmeraldas, but to Pichincha or Santo Domingo or Manabí or Guayas.

The province of Esmeraldas is characterized by a prominence of oil palm by the quality of the soil, which is good, and that the price of the land is quite economic - since this price is tied with the insecurity present in the province - but after acquiring these lands companies to be able to operate them must settle in the place, delimit the territory and have a security management system , type guards, due to the intrusion of armed people and criminal organizations, that is why those who really took advantage of these lands and the situation were really large companies with the capital of acquiring large areas of land and to establish their armed security systems to ensure their safe operation. This greatly influences economic power groups to be established in this province. The situation in the early 2000s was such that agrochemical companies did not deliver their products to farms directly, but maintained business in nearby cities, such as Quinindé, and it was the companies themselves that owned the land that were responsible for the custody and transport to their farms, even sometimes hiring armored cars for the transfer of high-cost products for transfer.

5. What has historically been used as technological techniques in crop production in the area?

Every agricultural production system has an impact on the ecosystem, probably the most sustainable is subsistence agricultural production, i.e. family production. The impact is much greater when the crop is intensive, large areas, and even worse monoculture.

In addition, the introduction of foreign species in the middle, introducing a new variety, is an intrusion, the technology for the production and cultivation of this plant also generates an impact. The greatest impact generated in Esmeraldas would be the introduction of the Gros Michel banana variety, for intensive production in place of other crops or other forests. The great deforestation of the province first occurred on a small scale with cocoa farms, then intensified deforestation when the areas ' banana farms (around the 60s) were established, and then another stage of high deforestation 'more visible to our generation - of the African palm came.

From crop production technology, I think it would be the implementation of post-harvest patios for bananas and bananas, which are areas that are fed in full cultivation to make fruit washing tubs, packaging, drying areas for tendons, for coffee and cocoa.

With bananas and cocoa the production technique has been maintained, but it was the introduction of these species that generated an impact.

The cultivation of the tagua was indigenous, and was a labour that belonged to women and men and allowed a microenterprise, through handicrafts. It was a hand-pick-up system.

Rubber was also manual, collected through people, an incision is made in the bark and collected in a container that is then collected by workers.

With the new crops introduced, these historical crops of tagua and rubber are being lost. It is very important to note that Ecuador in agricultural technology issues has approximately a delay compared to Colombia of at least 50 years, but it is the reality, we are the main exporter of bananas in the world, but the crops in which we have developed some kind of technology is bananas, roses and perhaps broccoli. In all other crops, the application of the technology is virtually zero.

6. What crops are exotic species that could be replaced by native crops?

Exotic species that could be replaced by native crops would tell you that they are African palm, banana, cocoa and palm, which was the natural replacement that occurred.

The success experiences at Esmeraldas are just of these four types.

An agricultural production that could help not lose the native ecosystem, you could cultivate almost any crop, but you face deficiencies in labor issues, unhealthy access roads, insecurity. The native crops that could replace these exotic species would be mainly tagua, forest plantations, rubber not because like the African palm requires intensive cultivation and that on the floor there is no other vegetation, generating an application of herbicides or methods of control of weeds by means of tractors, which in the long run contribute to the compaction and deterioration of soils. Wild grazing areas could also be encouraged as a native crop, which are options that help recover soil quality and do not generate a high impact on the flora and fauna of the area.

Another option could be the Guadua cane, in the surroundings of Santo Domingo are guadua cane fields, since one of its uses is to shore up banana plants, which by the weight of the banana cluster the plants begin to fall and the cane is used to support them straight. This is practiced by low-tech banana trees. Guadua cane contributes a lot to soil conservation.

7. How has the agricultural landscape changed in recent decades?

As a summary, since the 1950s Esmeraldas has suffered deforestation by the banana boom, even cocoa beans were replaced with bananas, the areas of mass production acquired by large companies that I already mentioned. Esmeraldas had a particular promoter of this crop that was Folk Anderson, he collaborated with the expansion of banana areas in the north of the country, and is well known for it. Large transnationals such as Dole also participated. In the last 20 years, for my work and travels in the area I have witnessed, the very noticeable loss of forests, by intensive African palm crops that are now of average age of production in the area near Mataje (crops of approximately 15-18 years of age).

The agricultural landscape is desolate, by the main palm oil extractors, which in many cases import labour from other parts of the country, leaving the local community unemployment and generating poverty, that is what I mean with desolate.

The main road connects the port of Esmeraldas with Santo Domingo, making it easy to witness logging traffic late at night.

On the Ecuadorian coast, their houses are all built of wood, fires that occurred in major cities such as Guayaquil led to the change of houses to be a combination of wood and cement. Deforestation cannot be accused only of African palm, as it began with banana areas, cocoa areas but nevertheless in new palm areas (in Mataje) there is deforestation of both businesses and communities, as they are not motivated by agricultural work, Afro-Ecuadorian has preferred fishing, or cultural recreational activities , then these areas were not farmed, and foreign people came to the province looking to do land business and native settlers felled trees to sell wood or coal. Changing the landscape to dry forest by deforestation. Plants that were generated in shade no longer survive, giving soils that already begin to have limitations to recept any type of crop, and only allows crops resistant to high luminosity.

African palm is a crop that adapts quite a bit to these conditions and was the opportunity to sow it in these areas.

A very personal experience. The first time I went to an African palm crop in Mataje was in 2002. I was 24 years old, I had an impressive experience, driving along the road of La Unión that leads to the province of Esmeraldas, close to the town of San Mateo, very close to the Emerald River. It looks like all vegetation from the interior of the province following the riverbed towards the mouth in the Pacific Ocean and shows the change of vegetation, where the union of the river in the ocean is observed, and very rich and diverse vegetation is observed. What with a better system of responsible and sustainable management to the whole province, this province would have wonderful vegetation conditions.

Crops and products that have changed the ecosystem of Ecuador's coastal area were bananas, shrimp and African palms. Considering that in many of these areas they were banana trees are now African palm.

8. What are the main threats to African palm plantations?

The main threat of any plantation in an intensive production is monoculture. The impact is the change in the native plants, which live in the surroundings since the flora and fauna are affected. By clearing an area - cleaning an area, taking out everything that are plants and trees and leaving directly soil - to sow a crop, flora and fauna are moved. 5 palm oil extraction companies own more than 50000 hectares of monoculture palm areas in the area you are studying. This causes the displacement of wild flora and native plants, which become considered weeds. If you sow palm, you only want to see palm, so that all nutrients and water are used only by the palm and not by other plants. Getting rid of the other plants makes selection pressure, eliminating one type of individuals and leaving another type of individual predominant. The biological risk of making an individual predominantly introduced is that this individual has no genetic vigor in that environment, e.g. an undergrowth such as achiotillo, Momor di Ca Charantia, which is a common plant in Esmeraldas, when observing its life cycle, versus another introduced species, it is observed that in the case of a drought, while the introduced plant dies, the Momor di Ca Charantia no; in a rainy season, the Momor di Ca Charantia survives while the introduced plant (e.g. the oil palm) drowns and dies, this is because of the adaptation of the native plant to the middle the introduced plant does not have that generational adaptation, then it is a weak plant. Having a selection pressure are removing strong, indigenous individuals, and introducing a plant, it is practically causing competition control over the crop to be very strong, i.e. plants that remain as weeds are the ones that bear the most mechanical or chemical control, so you will have to invest in stronger chemical or mechanical techniques that most affect the environment.

In addition, in addition to the introduction as monoculture of the African palm, other practices were introduced, such as oxen (African buffaloes, an introduced species), which is a form of transport for the harvest very common in Esmeraldas, Santo Domingo and in the northern part of Los Ríos. The oxen drag large wagons where the acorns, the fruit, part of the threats of the introduction of the oil palm in such an intensive system are.

It would add the displacement of the local population, and the introduction of external populations, these people traveling for work, if they do not get inserted in this medium, their money and investments will be outside this province.

9. What is the role of palm oil producers in the loss of forested areas in the region and soil degradation and loss of ecosystem services?

The previous government had the Reforesta Plan, where forest planting was encouraged, where logging was allowed as long as they were reforested. It also proposed that areas equivalent to areas planted by oil palm be reforested with forest plantations, including with subsidies in plants, technologies, and techniques to do so.

10. What is the social impact of these plantations? What kind of conflicts or problems of injustice are being addressed in this industry?

In the case of displacement of native populations, Afro-Ecuadorians were displaced by workers from other provinces.

Cases of social pressure on the part of these large business groups on the commoners to sell their land.

Informality on procurement issues in this industry, with unfair payments and informal contracts.

11. What kind of sustainable practices can have a positive impact on the landscape and natural resources?

Mainly diversify crops, do not allow the monoculture of oil palm. In addition, the state body is required to provide technology that integrates the local population into non-intensive agricultural activity.

- Diversifying crops - non-monoculture
- State body provides technology, integrates local population
- Create national stamps, national certification

- BPA - Good agricultural practices – do not contaminate water.
- Aerial buffer zones- for fertilization aircraft application – buffering areas –
- Demand crop rotation, old palms. Cultivate crops to renovate the soil properties.
- Integrated crop practices – between the rows of banana, cocoa is planted.
- Integrate cocoa with corn, beans with corn. Better use of soil, do not generate monoculture.

12. What are the limitations of sustainable practices in the country and in the region? What sustainable measures can be applied at all levels of production, despite the size of the palm oil plantation farm, which can help preserve the cultural and natural environment?

Sustainability I have seen that only large companies comply and meet them in the interest of stamps and certifications of export markets. As for example: Roundtable of sustainable palm oil (RSPO), Rainforest, Tesco and others. Smallholder farmers do not follow these sustainable practices as the acquisition of these stamps is costly. For these smallholder farmers, who can access these certifications and sustainable practices, they could follow in the footsteps of the cocoa industry where there are many NGCs or multinationals mainly those related to chocolate cocoa, where they group smallholder farmers and train them, certify them and have them added to sell locally to these companies that then export them.

The Ecuadorian state could generate its own national seals, a certification where to have it demand and condition you to a type of exploitation, where the community is integrated, local research is developed, the participation of the academy is conditioned, but all this requires economic resources and incentives. These stamps could be used like the one launched by the previous government, "Made in Ecuador", that of the tricolor hand. There were many taxes on imported products, which it sought in conjunction with this seal to promote consumption of domestic products. The implementation of Good Agricultural Practices (BPAs) could be a certification by the Ministry of Agriculture on a mandatory level. BPAs are: do not contaminate water resources, avoid contact between meat or milk cattle and farm fields where agrochemicals are used.

The implementation of buffering areas for aerial applications, buffering areas are large crops that are applied by airway, and wind drags some of these products to surrounding, damping areas, which are not for human consumption but trees that trap and help recycle this product. Damping areas are very important as they prevent this product from reaching room areas, water footprints, watercourses, communication routes, school areas, urban and rural areas. It is very important because agricultural production areas are immersed in rural areas, with a lot of population activity, so it means that there is a lot of pollution. And unreasonable control in planting areas, such as banana, oil palm crops, should no longer grow. And government laws that require crop rotation, changing or reforesting for soil to regenerate.

Crop diversification and integrated crop practice.

13. What crops can replace palm plantations in the future? What other crops would be suitable in Esmeraldas?

The recommendation is the recovery of forest areas, for soil recovery.

Agriculture to take advantage of the soil must either put a lot of fertilizer on it or let the soil rest - a sustainable recommendation - by sowing oilseed plants such as soy, cuchut, which help to start a forest, and if forest trees are added to this, without the aim of drilling them by wood, but to create shade and allow the proliferation of flora and insects allows the recovery of the soil. Companies that have already used soil could pay communities to plant such plants or forest trees. The farmer would invest his money in having a land recovered in a couple of years so that he could sow his palm again. In the event that the trees are used to be sold as wood there is a double economic benefit that allows an additional income to the recovery of the soil.

Other crops could be fruity, vegetable grains, tropical flowers, or even cannabis seeds - as an adaptable, non-native species.

14. What has been the Governmental transformation that has had a role in the expansion of palm oil plantations?

Since 2007 there has been a transformation in political management with respect to agriculture and the environment, focused more on the environment. Ecuador is a country that lives off agriculture, more is the second item after oil. All governments have not boosted agriculture, only farmers, banana farmers, ranchers and cocoaiers have been made according to the power groups. Domestic crops, such as rice, tomato and maize, technology are precarious. The crops that have technology are the ones that are exported. The political agenda of the Ministry of Agriculture moves according to these power groups. Compared to banana production technology, Ecuador is much more advanced than the Santa Marta banana area in Colombia, we are well above the Philippines, Honduras and El Salvador and you could be talking about being in a technological situation very similar to that of Costa Rica and Guatemala. But when you compare the technology of rice cultivation, seed use, irrigation systems, planning management systems, genetics, etc. Ecuador is about 50 years late.

This shows an overview in which the political agenda is handled only around these power groups. In Ecuador there is inIAP (National Agricultural Research Institute), which is an institute dedicated to researching technologies for national crops. It is the institute that must generate research, technology and academia in the national agricultural field. Universities on the coast cities of Ecuador should be directly linked to this institute, to be on par with these agricultural issues, and so it was in the 1950s to the 1970s, but in the 1980s this was lost. INIAP has had very little economic support, more than that, the governments that have supported it were one in the 80s and one between 2006 and 2017. Some of the policies implemented by the previous government around 2010 were: there was a law that prevented sowing more hectares of bananas (the current government does not implement this mitigation law, at least not formally, I know a person in the government who three years ago had 80 hectares of bananas now in 2020 has more than 1000 hectares); promote the use of biological resources for pest and disease control in crops, prioritized the registration and certification of these products, which transformed the industry because many biopesticides and other biological products could be introduced, and not only use chemicals, which also pollute. In terms of state policy, agriculture has always been forgotten, it is preferred to support large companies rather than smallholder farmers.

The previous government allowed the association of small businesses to access export quotas (which until 2008 only 14 families from Ecuador could export bananas). In addition, the previous government also agreed on a forest planting commitment equivalent to sown oil palm hectares, and the government subsidized plants, technology and means for reforestation.

6.4 Parameters and values for the processing of data in each step of the methodology

6.4.1 SNAP

1. **Download Sentinel-1 data and open in SNAP**

   i. Open web page CREODIAS (https://creodias.eu/) and select Tools, then Select EO Finder.
   ii. Search the area of interest and select, then the dates and in collection, select Sentinel-1. Then make sure to check the boxes that say product type: GRD and in Polarization: VV+VH.
   iii. Then, select a product that covers the area and download it.
   iv. The downloaded product is a zip file and there is no need to extract the information in it.
   v. Open SNAP and select File, Open product. And then select the zap folder.

2. **Apply Orbit File**

   i. When the product is open go to Radar, and then click Apply Orbit file.
   ii. Chose a name for the file, and then in the Parameters section, check the box that says: "Do not fail if new orbit is not found'.

3. **Radiometric terrain flattening**

   i. Go to Radar, then to Radiometric, then select Radiometric terrain flattening. Leave all the default parameters as they are.

4. **Thermal Noise Removal**

   i. Go to Radar, then select radiometric, and then select S-1 Thermal Noise Removal.
   ii. The, in processing parameters check the box that says Remove thermal noise removal

5. **Speckle Filter: Lee Sigma**

   i. Go to Radar, then to Speckle Filtering, and then Single Product Speckle Filter
   ii. Then, in Processing parameters select the options hereunder:

Filter	Lee Sigma
Number of looks	4
Window size	17 x 17
Sigma	0.9
Target window size	5 x 5

6. **Speckle Filter: IDAN**

i. Go to Radar, then to Speckle Filtering, and then Single Product Speckle Filter

ii. Then, in Processing parameters select the options hereunder:

Filter	IDAN
Number of Looks	1
Adaptive Neighbor Size	20

7. **Range Doppler Terrain Correction**

i. Go to Radar, then select Geometric, and then select Terrain Correction. Then, select Range Doppler Terrain Correction.

ii. In the processing parameters options, leave all parameters to default, except the Map Projection in which VTM 84 Automatic should be chosen.

8. **Convert Data Type**

i. Go to Raster, then to Data Conversion. Then select: Convert Data type

ii. Here choose INT 8

9. **Grey Level Co-Occurrence Matrix**

i. Go to Raster, then select Image Analysis. Then choose Grey Level Co-occurrence Matrix

ii. Choose in the parameters options to have the Window Size of 11 x 11.

10. **Export Image as Geotiff**

6.4.2 Grass Steps

1. Launch GRASS and create new location
2. File   import raster data   Simplified raster import with reprojection
3. Imagery   Classify image   Object Segmentation [i.segment]

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