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Analyzing the inclusion of nature in an oil palm plantation: a landscape ecological case study in Mapiripán, Meta, Colombia

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List of Acronyms

DNP	Departamento Nacional de Planeación - in Spanish / National Planning Department
ES	Ecosystem Services
Fedepalma	Federación Nacional de Cultivadores de Palma de aceite – in Spanish / National Federation of Oil palm Growers
Gt	Gigatonnes
ha	Hectares
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales in Spanish / Institute of Hydrology, Meteorology and Environmental Studies
IPM	Integrated Pest Management
LST	Landscape Structural Types
MDG	Millennium Development Goals
RA	Rainforest Alliance
RSPO	Roundtable on Sustainable Palm Oil
S2E	Services to Ecosystems
SAS	Sociedad por Acciones Simplificada – in Spanish / Simplified Stock Company
SDG	Sustainable Development Goals
SLV	Social Landscape Values
UN	United Nations

Abstract

Oil palm plantations are known for their adverse effects on biodiversity and human well-being. Such industrial agricultural landscapes are homogeneous and oversimplify biodiversity and convey little or no human well-being. Yet, an oil palm plantation design implementing land sharing and land sparing simultaneously can provide a place for biodiversity conservation, generate social landscape values and provide human well-being. Also, local biodiversity controls agricultural pests.

An Integration of nature in an oil palm plantation can foresee benefits and risks to the oil palm and workers. First, a heterogeneous agricultural landscape can provide habitat to local species, which can act as a biological control in agricultural systems. Second, it can provide social landscape values and change and shape humans' perception of the plantation. Third, workers are positively or negatively affected by interacting with nature inside the plantation.

Intensive large-scale agricultural landscapes such as plantations are often considered and designed as sole production areas. They can also exhibit a complex spatial pattern of vegetation types, implementing land sparing and land sharing approaches. The company, Poligrow Colombia SAS, has implemented these approaches in the Macondo plantation for a decade. The company followed the principles and criteria of the RSPO and the Rainforest Alliance plus the national laws to design the oil palm plantation. As a result, the plantation has different vegetation types besides oil palms, namely compositional and configuration heterogeneity. The Macondo plantation has gained a

nature-enhanced agricultural landscape that can create different habitats for local flora and fauna and provide ecological and social values. For instance, biological control service for oil palms pests of *Opsiphanes cassina* and *Rhynchophorus palmarum.* Also, workers can perceive social landscape values such as shade and water provision. A nature-enhanced plantation design is possible to implement and maintain, though it generates costs. Yet, implementing both approaches provides a framework to make large-scale farming systems more sustainable. It is possible to argue that nature-enhanced plantation design is more sustainable as compared to monocultures. Other oil palm plantations and other large-agricultural systems can see the Macondo plantation design as viable. Production areas and conservation areas, with native flora and fauna, are intertwined. However, it is still unknown whether implementing both approaches simultaneously in an oil palm plantation can bring any benefits to the agricultural landscape structure, provision of social landscape values and human well-being.

This interdisciplinary study explores the role of nature in oil palm plantations. Specifically, to analyze the landscape characteristics of the Macondo plantation for two purposes: a) ecologically, the landscape composition and configuration of the plantation enhance landscape connectivity and pest control service, 2) socially, owing to the landscape characteristics, plantation workers perceive social landscape values, well-being and better working conditions in the plantation. Chapter 1 is the general introduction describing the oil palm plantations worldwide. Chapter 1 summarizes the ecological and social effects of rapid oil palm expansion in tropical regions. Chapter 2 is a description of the study area. The chapter begins with a description of the Meta department and the municipality of Mapiripán to understand the general context of the eastern region. Following is a description of the company Poligrow Colombia SAS and the Macondo plantation where the case study was performed. Chapter 3 is the theoretical framework of the project. Chapter 4 is the research design and research questions.

In Chapter 5, the landscape analysis of the Macondo plantation is related to pest occurrence. To show relationships among the landscape structural types, land cover, and pest occurrence, a landscape analysis by multivariate cluster analysis and an NMDS ordination were performed. The results show that a heterogeneous plantation improves landscape connectivity and control pest populations.

In Chapter 6, the specific nature-enhanced plantation design can provide social landscape values, SLV, to workers is examined. The results on the structural landscape analysis of the plantation, in Chapter 5, were analyzed jointly with the results from the participatory mapping with plantation workers. The correspondence between landscape analysis and the location of the perceived values is analyzed, revealing socio-ecological hotspots (e.g., *epiphytarium*). It highlights the relationship between the landscape characteristics of the plantation and the social landscape values perceived by workers. Workers perceive most social landscape values in the prevalence of landscape connectivity and heterogeneity.

Chapter 7 addresses whether plantation workers relate to and perceive nature (e.g., gallery and riparian forests) and non-natural areas (e.g., crops such as oil palm) in the plantation. Using qualitative content analysis from focus group discussion and in-depth interviews with workers, I infer they derive a great variety of values and also experience ambivalent relationships towards nature in the plantation. Through the perceived benefits to humans and other species, a possible naturalization process might happen on such a nature-enhanced plantation.

Finally, Chapter 8 is the general discussion and conclusions.

Zusammenfassung

Ölpalmenplantagen sind für ihre negativen Auswirkungen auf die biologische Vielfalt und das menschliche Wohlbefinden bekannt. Solche industriellen Agrarlandschaften sind homogen, vereinfachen die biologische Vielfalt und vermitteln wenig oder gar kein menschliches Wohlbefinden. Eine Ölpalmenplantage, bei der gleichzeitig Land geteilt und Land gespart wird, kann jedoch einen Platz für die Erhaltung der biologischen Vielfalt bieten, soziale Landschaftswerte schaffen und für das menschliche Wohlbefinden sorgen. Außerdem kontrolliert die lokale biologische Vielfalt landwirtschaftliche Schädlinge.

Die Integration der Natur in eine Ölpalmenplantage kann Vorteile und Risiken für die Ölpalme und die Arbeiter mit sich bringen. Erstens kann eine heterogene Agrarlandschaft Lebensraum für lokale Arten bieten, die als biologische Kontrolle in landwirtschaftlichen Systemen fungieren können. Zweitens kann sie soziale Landschaftswerte schaffen und die Wahrnehmung der Plantage durch die Menschen verändern und prägen. Drittens werden die Arbeitnehmer durch die Interaktion mit der Natur auf der Plantage positiv oder negativ beeinflusst.

Intensive, großflächige Agrarlandschaften wie Plantagen werden oft als reine Produktionsgebiete betrachtet und gestaltet. Sie können auch ein komplexes räumliches Muster von Vegetationstypen aufweisen, wobei Ansätze zur sparsamen Nutzung von Land und zur gemeinsamen Nutzung von Land umgesetzt werden. Das Unternehmen Poligrow Colombia SAS hat diese Ansätze in der Macondo-Plantage ein

Jahrzehnt lang umgesetzt. Bei der Gestaltung der Ölpalmenplantage befolgte das Unternehmen die Grundsätze und Kriterien des RSPO und der Rainforest Alliance sowie die nationalen Gesetze. Infolgedessen weist die Plantage neben den Ölpalmen auch andere Vegetationstypen auf, d. h. eine Heterogenität in der Zusammensetzung und Konfiguration. Die Macondo-Plantage hat eine naturnahe Agrarlandschaft erhalten, die verschiedene Lebensräume für die örtliche Flora und Fauna schaffen kann und ökologische und soziale Werte bietet. Zum Beispiel die biologische Bekämpfung von Ölpalmenschädlingen wie *Opsiphanes cassina* und *Rhynchophorus palmarum*. Außerdem können die Arbeiter soziale Landschaftswerte wie Schatten und Wasserversorgung wahrnehmen. Eine naturnahe Gestaltung der Plantagen ist möglich, auch wenn sie Kosten verursacht. Dennoch bietet die Umsetzung beider Ansätze einen Rahmen, um großflächige Anbausysteme nachhaltiger zu gestalten. Es kann argumentiert werden, dass die naturnahe Gestaltung von Plantagen im Vergleich zu Monokulturen nachhaltiger ist. Andere Ölpalmenplantagen und andere großflächige landwirtschaftliche Systeme können das Macondo-Plantagendesign als tragfähig ansehen. Produktionsflächen und Schutzgebiete mit einheimischer Flora und Fauna sind miteinander verflochten. Es ist jedoch noch nicht bekannt, ob die gleichzeitige Umsetzung beider Ansätze in einer Ölpalmenplantage Vorteile für die Struktur der Agrarlandschaft, die Bereitstellung sozialer Landschaftswerte und das menschliche Wohlergehen bringen kann.

In dieser interdisziplinären Studie wird die Rolle der Natur in Ölpalmenplantagen untersucht. Konkret werden die Landschaftsmerkmale der Macondo-Plantage für zwei

Zwecke analysiert: a) ökologisch gesehen verbessern die Landschaftszusammensetzung und die Konfiguration der Plantage die Landschaftsvernetzung und die Schädlingsbekämpfung, 2) sozial gesehen nehmen die Plantagenarbeiter aufgrund der Landschaftsmerkmale soziale Landschaftswerte, Wohlbefinden und bessere Arbeitsbedingungen auf der Plantage wahr. Kapitel 1 ist eine allgemeine Einführung, in der die Ölpalmenplantagen weltweit beschrieben werden. Kapitel 1 fasst die ökologischen und sozialen Auswirkungen der raschen Ausbreitung von Ölpalmen in tropischen Regionen zusammen. Kapitel 2 ist eine Beschreibung des Untersuchungsgebiets. Das Kapitel beginnt mit einer Beschreibung des Departements Meta und der Gemeinde Mapiripán, um den allgemeinen Kontext der östlichen Region zu verstehen. Es folgt eine Beschreibung des Unternehmens Poligrow Colombia SAS und der Plantage Macondo, auf der die Fallstudie durchgeführt wurde. Kapitel 3 stellt den theoretischen Rahmen des Projekts dar. Kapitel 4 beschreibt das Forschungsdesign und die Forschungsfragen.

In Kapitel 5 wird die Landschaftsanalyse der Macondo-Plantage auf das Auftreten von Schädlingen bezogen. Um die Beziehungen zwischen den Landschaftsstrukturtypen, der Bodenbedeckung und dem Auftreten von Schädlingen aufzuzeigen, wurden eine Landschaftsanalyse mittels multivariater Clusteranalyse und eine NMDS-Ordination durchgeführt. Die Ergebnisse zeigen, dass eine heterogene Bepflanzung die Vernetzung der Landschaft verbessert und die Schädlingspopulationen kontrolliert.

In Kapitel 6 wird untersucht, inwieweit die naturnahe Gestaltung der Plantage den

Arbeitern soziale Landschaftswerte (*Social Landscape Values* - SLV) bieten kann. Die Ergebnisse der strukturellen Landschaftsanalyse der Plantage in Kapitel 5 wurden zusammen mit den Ergebnissen der partizipativen Kartierung mit den Plantagenarbeitern analysiert. Die Korrespondenz zwischen der Landschaftsanalyse und der Lage der wahrgenommenen Werte wird analysiert, wobei sozio-ökologische Hotspots (z. B. *Epiphytarium*) aufgedeckt werden. Es wird die Beziehung zwischen den Landschaftsmerkmalen der Plantage und den von den Arbeitern wahrgenommenen sozialen Landschaftswerten deutlich. Die meisten sozialen Landschaftswerte werden von den Arbeitern im Hinblick auf die Konnektivität und Heterogenität der Landschaft wahrgenommen.

Kapitel 7 befasst sich mit der Frage, wie die Plantagenarbeiter die Natur (z. B. Galerien und Auwälder) und nicht natürliche Gebiete (z. B. Nutzpflanzen wie Ölpalmen) auf der Plantage wahrnehmen. Aus der qualitativen Inhaltsanalyse von Fokusgruppendiskussionen und Tiefeninterviews mit den Arbeitern schließe ich, dass sie eine große Vielfalt an Werten ableiten und auch ambivalente Beziehungen zur Natur in der Plantage erleben. Durch die wahrgenommenen Vorteile für Menschen und andere Arten könnte ein möglicher Naturalisierungsprozess auf einer solchen naturnahen Plantage stattfinden.

Kapitel 8 schließlich enthält die allgemeine Diskussion und die Schlussfolgerungen.

1. Chapter 1: General Introduction

1.1. Motivation

Palm oil has become, in the last 50 years, a key ingredient for manufacturing a wide range of products we use every day (e.g., Azhar et al., 2017; Goh, 2016; Mba et al., 2015; Qaim et al., 2020). Oil palm plantations have expanded across tropical regions to cover the palm oil demand (Ritchie & Roser, 2021). Additionally, oil palm plantations: generate several jobs across the value chain, and increase income and GDP in tropical countries (Goh, 2016; Qaim et al., 2020; Ritchie & Roser, 2021). Oil palm plantations are usually monocultures to facilitate harvesting (Azhar et al., 2015). Yet, monocultures use the land intensively (exploitatively) (Green et al., 2005). Oil palm monoculture expansion has been associated with massive deforestation and biodiversity loss (Qaim et al., 2020).

Now, as Goh (2016: 950) asked “Can We Get Rid of Palm Oil from A Bio-Based Economy?”. It is not a simple question to answer but is almost impossible to get rid of palm oil completely. Palm oil has a major role in the global market (Goh, 2016). Economic incentives will increase palm oil production, as is the case in Colombia. In Colombia laws, decrees and other governmental documents support the use and production of palm oil (e.g. Law 693 2001, Law 939 2004, Law 788 of 2002, 939 of 2004, Decree 383 of 2007) (Conpes 3477, 2007). Furthermore, the global “interconnected socioeconomic interests among the various land use stakeholders make things even more complicated” (Goh, 2016: 950). The major problem is the unsustainable land-use practices in oil palm plantations (Goh, 2016). Therefore, we should make efforts to provide information on sustainable land-use strategies. In a case study from an oil palm plantation, the Macondo plantation in Mapiripán (Colombia), we integrate the landscape assessment of the plantation (ecological) and the spatial representation of social landscape values perceive by workers (social). The study integrates a socio-ecological landscape perspective of the Macondo plantation. In this sense, the study provides insightful evidence that an oil palm plantation integrating land sparing and land sharing approaches, as a sustainable land-use strategy, generates benefits to the agricultural system (landscape heterogeneity and pest control) and to workers (provision of social landscape values, a sense of well-being and better working conditions).

1.2. Problem statement: oil palm expansion, ecological and social effects

Palm oil is versatile, has low production costs and gives the highest yield per hectare compared to other vegetable oils (Khatun et al., 2017; Mba et al., 2015) (Figure 1). Until 1980, palm oil was primarily for human consumption (Qaim et al., 2020). Since the mid-1980s, palm oil is used for chemical, pharmaceutical, cosmetics and energy industries (Qaim et al., 2020). Palm oil is used in several products: in food from margarine to chocolate and cooking oils (68%), in industrial applications (27%) and bioenergy (5%) (Ritchie & Roser, 2021). Global palm oil demand and production have increased steadily over 50 years: in 1970 worldwide oil production was proximately 2 million tonnes by 2018 the oil production was 35 times higher (71 million tonnes) (Ritchie & Roser, 2021) (Figure 2).

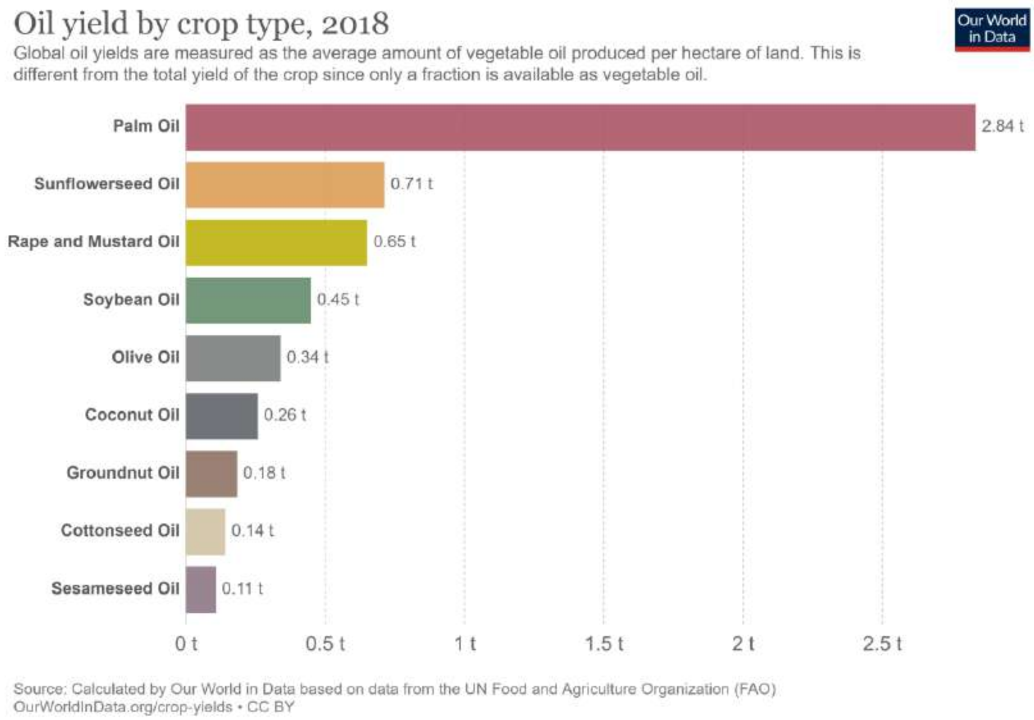


Figure 1 Estimated yield of various vegetable oils (ton/ha) worldwide (source: Ritchie & Roser (2021))

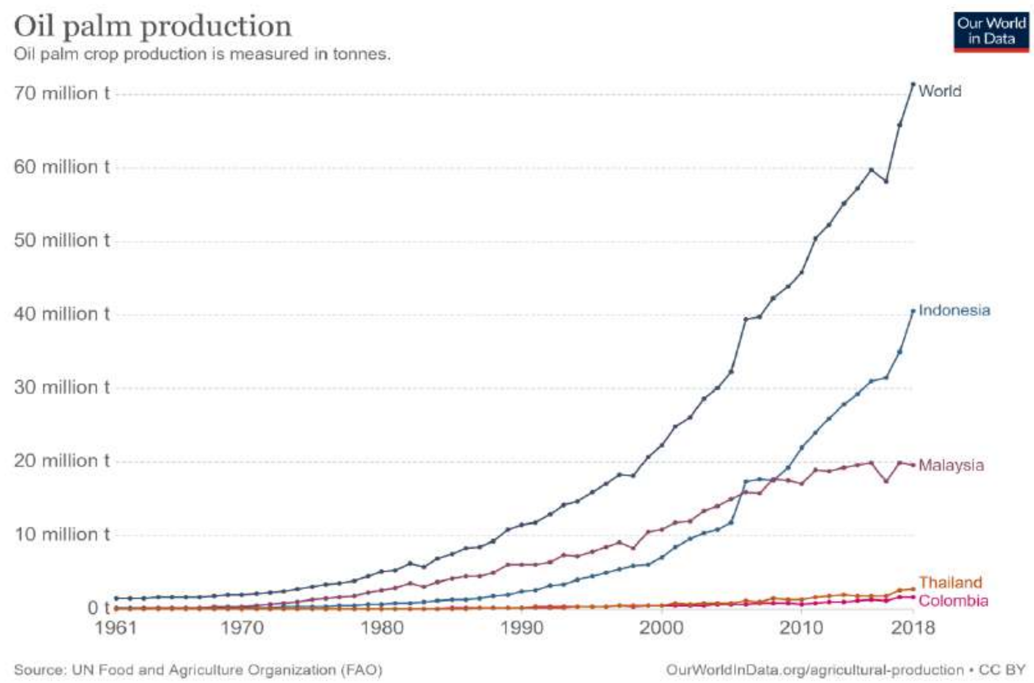


Figure 2 Total palm oil production worldwide (measured in tonnes), showing the largest palm oil producers worldwide- Indonesia, Malaysia, Thailand, Colombia - (measured in tonnes) (source: Ritchie & Roser (2021))

Palm oil alternatives do not provide a better solution. The land needed to cover vegetable oil demand worldwide is lower for oil palm crop as compared to other crops (Ritchie & Roser, 2021) (Figure 3). For instance, 8.6% of the land under oil palm produces 36% of oil as compared to soybean, of which 39% of land produces 25.5% of oil (Ritchie & Roser, 2021) (Figure 3). Using other vegetable oils to cover the rising global demand will entail more land use change, biodiversity loss, deforestation and more conflicts over land (Qaim et al., 2020). Consequently, oil palm plantations have been expanding rapidly across tropical regions in Asia, Africa, and Latin America (Indexmundi, 2020; Taheripour et al., 2019) (Figure 2, Figure 4). The rapid expansion has had adverse ecological and social effects in tropical countries (Azhar et al., 2017; Qaim et al., 2020; Ritchie & Roser, 2021).

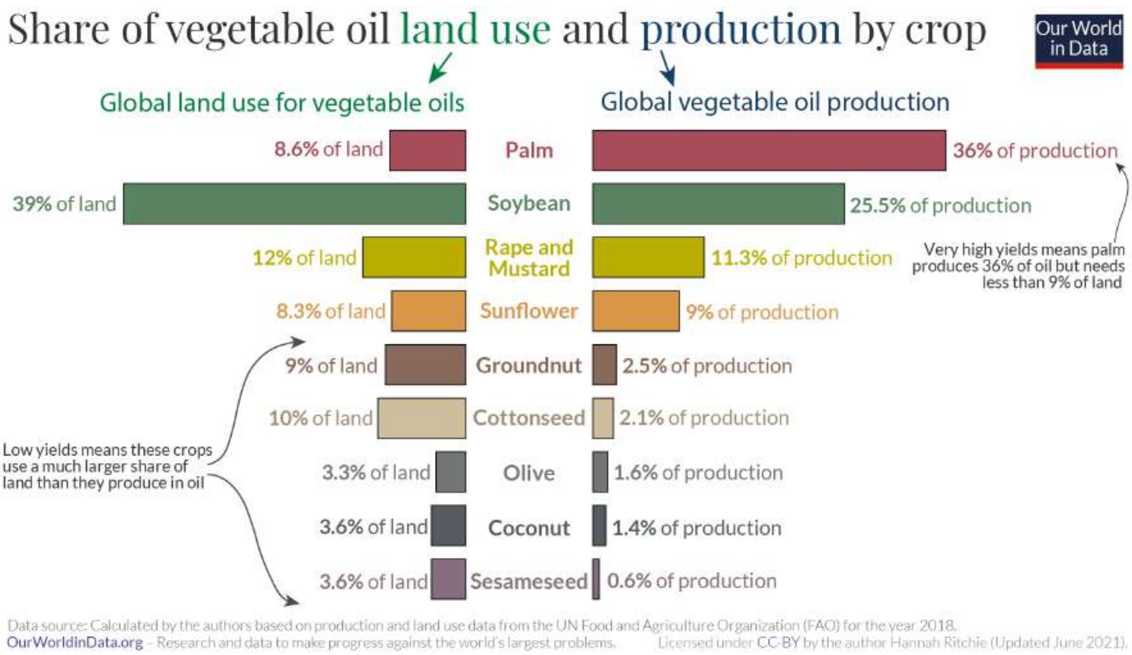


Figure 3 Comparison of vegetable oil production versus land use(source: Ritchie & Roser (2021))

Oil palm plantations are usually designed as a monoculture to facilitate harvesting and maximize palm oil yield (Azhar et al., 2015). Monocultures, thus, are prone to deforestation, biodiversity loss, pest outbreak, and can reduce nutrients in the soil (Gray et al., 2016). Additionally, the expansion of plantations at the expense of smallholders and local communities generates social conflicts over land access and ownership (Oosterveer, 2015). Present and future oil palm plantations must minimize adverse ecological and social effects. Oil palm plantations can be dynamic and have diverse landscapes. Biodiverse and heterogeneous oil palm landscapes are key to maintain palm oil production and biodiversity conservation (Foster et al., 2011). Interdisciplinary research provides information on agricultural landscape complexity to support ecosystem functions (Foster et al., 2011). Research encourages policymakers and industry to design complex oil palm plantations (Foster et al., 2011).

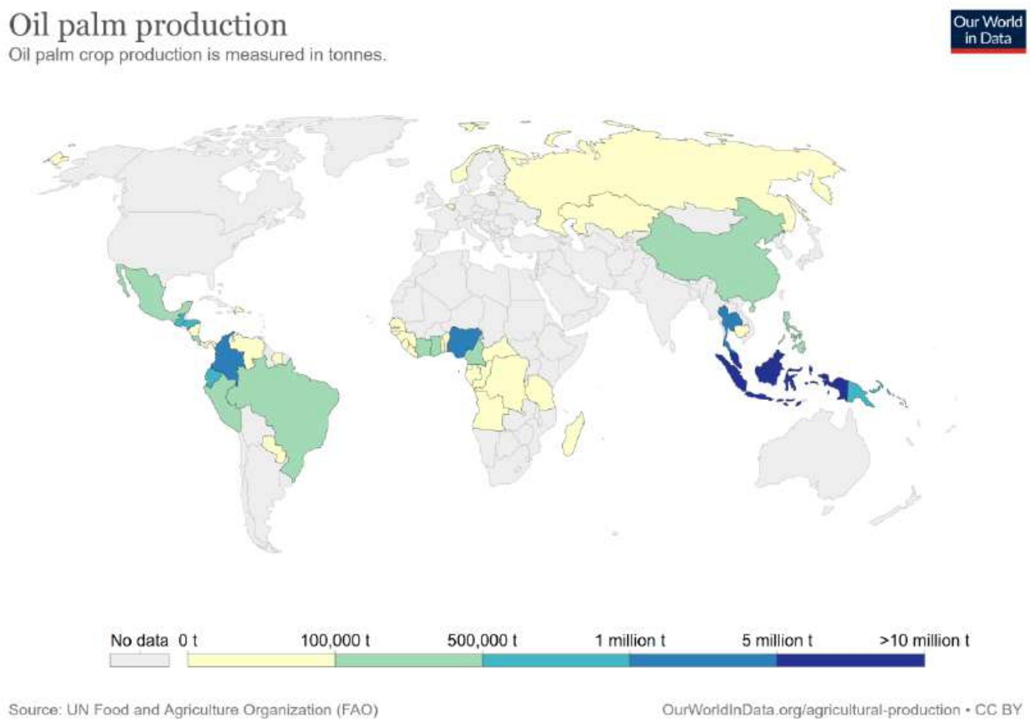


Figure 4 Map of oil palm production worldwide (source: Ritchie & Roser (2021))

1.2.1. Oil palm plantations: ecological effects

Several studies show that species richness is lower in oil palm plantations as compared to forests, including fungi, plants, invertebrates, dung beetles, ants, amphibians, lizards, birds, and mammals (Danielsen et al., 2009; Dislich et al., 2017; Fitzherbert et al., 2008; Foster et al., 2011). Plantations are also structurally simpler than forests comprising fewer vegetation layers (Foster et al., 2011). Oil palm plantations can affect the local and regional climate due to air pollution from land-clearing fires and increase emissions of volatile organic compounds (VOCs) (Dislich et al., 2017). As a result of forests clearing, large amounts of nutrients are lost and increase soil erosion (Dislich et al., 2017). For instance, Rulli et al. (2019) estimated in Indonesia a carbon loss of 2.43–4.37 gigatonnes (Gt) because of deforestation and nutrient runoff. Additionally, CO2 emissions are higher when oil palms are over peatlands, where large amounts of CO2 are stored (Rulli et al., 2019). Oil palm plantations contain less carbon than forests. An estimated 163 tonnes/hectares (t/ha) are emitted into the atmosphere when forests are converted into oil palm (Danielsen et al., 2009). Danielsen et al. (2009: 355) showed that "it would take between 75 and 93 years for the carbon emissions saved through use of biofuel to compensate for the carbon lost through initial forest conversion, depending on how the forest was cleared. If the original habitat was peatland, carbon balance would take more than 600 years. Conversely, planting oil palms on *Imperata* grassland, which often takes over as the dominant habitat after deforestation, would lead to a net removal of carbon within 10 years".

In Indonesia, after 2000 over 20 million hectares (ha) have been deforested for agricultural production, of which 30% (~5.8 million ha) is attributed to oil palm plantations (Rulli et al., 2019). In South America (Ecuador, Perú, and Brazil) and Asia (Indonesia, Malaysia and Papua New Guinea) deforestation occurs in areas with oil palm expansion (Vijay et al., 2016). In other countries in Latin America, recent oil palm plantations have replaced previously degraded lands, resulting in low levels of deforestation (Furumo & Aide, 2017; Vijay et al., 2016). In Colombia usually, the oil palm plantations are in areas that have previously been used for other agricultural production (Meijaard et al., 2018).

1.2.2. Oil palm plantations: the socio-economic effects

Oil palm plantations are contributors to the gross national product and foreign exchange earnings in many tropical countries (Qaim et al., 2020). For instance, in 2018 the international trade was approximately US $30 billion in Indonesia and Malaysia (Qaim et al., 2020). Palm oil accounts for 10% of national exports in Indonesia, and 5% for other palm oil producers (e.g., Honduras, Papua New Guinea, and Guatemala). Also, oil palm crops contribute to increasing the income of smallholders and workers, for example, in Malaysia, Indonesia and Colombia (Castiblanco et al., 2015; Dharmawan et al., 2020). The rural economy has grown because of investments from oil palm plantations (Dharmawan et al., 2020). Oil palm expansion in the tropical regions "has brought about significant income gains for farmers, laborers, and other people involved in the supply chains, including traders, intermediaries, and small-scale processors" (Qaim et al., 2020: 330). In Colombia, Castiblanco et al. (2015: 38) found that "oil palm municipalities have lower unmet basic needs indicators and have bigger fiscal income when compared to other municipalities where oil palm is not produced". However, in Colombia, oil palm municipalities tend to have higher land concentration as compared to other municipalities (Castiblanco et al., 2015). Although oil palm plantations contribute to rural development and increase income for workers and smallholders, they do not improve food security in rural areas because many smallholders have changed cash crops to cultivate oil palm (Qaim et al., 2020).

1.3. Oil palm plantations: the possibilities for sustainable production

1.3.1. Sustainable Development Goals (SDGs)

In 2015, the General Assembly of the United Nations (UN) adopted the SDG as a follow-up to the Millennium Development Goals (MDG) (Sachs, 2012). The MDG helped "to promote global awareness, political accountability, improved metrics, social feedback, and public pressures" (Sachs, 2012: 2206). Following the MDG, where countries have made remarkable progress, the SDGs are complementary goals applicable to every United-Nations member to foster sustainable development globally is a 15-year (United Nations, 2015). The Sustainable Development Goals (SDG) are a measurable framework to reach the well-being of people, wealth and conservation of biodiversity (Conpes 3918, 2018). In Colombia, the document Conpes 3918 considers strategies to implement and monitor the SDGs in the country. Monitoring the SGD oil palm sector brings an opportunity to the sector to improve the agricultural process and the quality of life of the workers and inhabitants.

The present project will attend to the objectives of SDGs, specifically, alleviate poverty, hunger and human well-being (SDG 2), responsible consumption and production (SDG 12), life on earth (SDG 15). The efforts for implementing and monitoring the Sustainable Development Goals (SDG) bring an opportunity to the oil palm sector to improve the agricultural process and the quality of life of the workers and inhabitants. SGDs in the oil palm sector will bring a significant contribution to support the achievement of the SDGs at the regional and national levels. Colombia has also committed to the SDG to improve education, human well-fare and environmental conservation (Conpes 3918, 2018). Oil palm plantations play an important role to improve the economy, take part in biodiversity conservation and human well-fare in rural areas and the country (Meijaard et al., 2018).

1.3.2. Land sharing and land sparing approaches in oil palm plantations

Two farming strategies for biodiversity conservation and agricultural production have been put forward: land sparing and land sharing. As argued by Loconto et al. (2020) the underlying debate lays in the "best farming method" to balance agricultural production and biodiversity in a geographical area. Land sparing refers to the setting aside of land for conservation, while the rest of the land is used intensively (exploitatively), such as on conventionally designed plantations (Green et al., 2005). Land sharing, on the contrary, attempts to fulfill both production and conservation aims within one land unit (Perfecto & Vandermeer, 2012). This implies that production practices under a land sharing scenario allow biodiversity within agricultural systems. Practicing land sharing and land sparing simultaneously can have synergic or additive effects on species richness (Egan & Mortensen, 2012), maintain and conserve local biodiversity and generate highly productive agricultural systems (Perfecto & Vandermeer, 2012).

Implementing land sparing and land sharing approaches in oil palm plantations favor biodiversity conservation, landscape connectivity and human well-being, following Abdullah & Nakagoshi, (2008), Azhar et al. (2013; 2015), Denmead et al. (2017), Gray et al. (2016), Koh (2008a), Koh et al. (2009), Lucey et al. (2014), Meijaard et al. (2018), Nurdiansyah et al. (2016), Pardo et al. (2019; 2018), Pardo-Vargas & Payán-Garrido (2015), and Perfecto & Vandermeer (2008, 2010). Schroth et al. (2004b) argued that forest-like agroforestry systems have also displaced natural ecosystems. However, agroecological systems do have the potential for biodiversity conservation while attaining production goals (Schroth et al., 2004b). Agroecological practices influence the movement of native flora and fauna, nutrient fluxes, pest-predator dynamics, microclimate and water (Schroth et al., 2004b). Biodiversity conservation and agroecological practices generate costs to farmers: biodiversity management (e.g. live fences, buffer zones), can threaten crops, property and even lives (Schroth et al., 2004a). Yet, biodiversity in agricultural systems comprises useful products (e.g. timber, fruit, game animal) and services (e.g. pollination, pest control) (Schroth et al., 2004a).

Several studies conclude that integrating forest (local ecosystems) in oil palm plantations can promote biodiversity conservation in a heterogeneous landscape (Abdullah & Nakagoshi, 2008; Azhar et al., 2013; Gray et al., 2014; Koh, 2008a; Lucey & Hill, 2012; Nurdiansyah et al., 2016; Pardo et al., 2018). The heterogeneous landscape has two components: compositions heterogeneity with a great variety of land cover types, and configurational heterogeneity is the spatial pattern of the land covers (Fahrig & Nuttle, 2005). Natural fragments within oil palm plantations can act as corridors, habitats, food sources, and refuge for local fauna and contribute to biodiversity conservation and landscape connectivity (e.g., Lynch, 2015; Pardo-Vargas & Payán-Garrido, 2015). Fauna uses natural fragments in oil palm plantations which act as biocontrol agents (e.g. parasitoids, predators, insectivorous birds) and pollinators (Tscharntke et al., 2007).

1.3.3. Certification schemes and biodiversity conservation projects

According to Meijaard et al. (2018: 46) “certification of more sustainable production is a leading environmental governance initiative in the palm oil sector. It aims to engage stakeholders in the supply chain, in particular producers and mills, in the implementation of standards that set a minimum level of best practices for the industry. Certified producers may receive premium prices or secure access to particular markets”.

Overall, oil palm expansion has created environmental problems, land concentration, as well as economic growth (Qaim et al., 2020). Also, vegetable oils demand worldwide will continue to grow, and oil palm is an option given its high yield (Azhar et al., 2015). The trade-offs between economic growth, vegetable oils demand and biodiversity conservation must be managed and balanced (Azhar et al., 2017; Qaim et al., 2020).

Such concerns upraised criticism from stakeholders on oil palm projects. In response, governments, NGOs, and the oil palm industry created the Roundtable for Sustainable Palm Oil (RSPO) in 2004 (Oosterveer, 2015). Then the RSPO became a non-profit organization that addresses the concerns that arise within the palm oil plantations (Cattau et al., 2016). The RSPO is one of the first certification schemes focused on sustainability for the palm oil sector involving multi-stakeholders globally across the supply chain (Cattau et al., 2016; Vis et al., 2012). The major goal of the certification scheme is to define environmental, social and economic best practices (Furumo et al., 2020). The roundtable was done "by actors from various parts of the international palm oil chain that see the development of effective sustainability criteria and certification schemes for palm oil as a way to improve the legitimacy of palm oil" (Boons & Mendoza, 2010: 1690). Major palm oil producer countries have a national interpretation of the RSPO principles and criteria as a mechanism to bring the international certification translated for the local situation (RSPO, 2018; Schouten & Glasbergen, 2011; Vis et al., 2012).

Another certification scheme for palm oil is the Rainforest Alliance. Rainforest Alliance (RA) is part of the Sustainable Agriculture Network (SAN) (Koreniushkina et al., 2019). RA is a global non-profit organization, founded in 1987, and developed a third-party certification to fight deforestation, improve agricultural practices, biodiversity conservation and ensure rural livelihoods (Koreniushkina et al., 2019; Milder & Newsom, 2015). The certification scheme ensures sustainable manufacturing practices for over 100 different crops, with coffee, cocoa, tea, bananas and oil palm comprising the largest land areas and numbers of producers (Milder & Newsom, 2015).

Implementing the certification requires commitment from all stakeholders in the value chain to improve management and business practices, and land management (Koreniushkina et al., 2019).

Beyond the certification schemes as RSPO and RA, in Colombia, the National Association of Oil Palm Growers (Fedepalma–*Federación Nacional de Cultivadores de Palma de Aceite*) generates projects towards conservation and maintenance of biodiversity in oil palm plantations. A nationwide project "Biodiverse Oil Palm Landscape" (*Paisaje Palmero Biodiverso*) aims at biodiversity conservation and sustainability of the oil palm sector in the long term (Espinosa et al., 2018). The principles and criteria of international certifications, conservation projects, and national regulations are the blueprints of the management practices of the oil palm plantations. The management practices will shape the plantation's spatial characteristics of existent oil palm plantations and will influence future plantations. The spatial characteristics of a plantation could enhance biodiversity conservation while safeguarding socio-economic development and producing palm oil (Vis et al., 2012). The spatial characteristics of the plantations will generate: 1) services and disservices, 2) landscape heterogeneity, 3) perception of social landscape values in oil palm plantations.

1.4. A brief history of oil palm production in Colombia

In Colombia, the first commercial oil palm plantations started in 1960. However, since 2002, oil palm plantations have rapidly expanded following the government's support and incentives to produce palm oil for export and to meet domestic demands (Conpes 3510, 2008) (Figure 5). Currently, Colombia is the largest palm oil producer in Latin America and fourth worldwide (FAO, 2020; Indexmundi, 2020). By 2019, Colombia had a total area of 559.582 hectares of oil palm, of these, 41% in the Eastern Zone, 31.4% in the Central Zone, 23.19% in the Northern Zone, and 4% in the Southwestern Zone (Girón-Amaya et al., 2020) (Figure 5, Figure 6). The eastern zone has the largest number of plantations compared to the other zones (Castiblanco et al., 2013) and is targeted for future oil palm expansion (DNP, 2019) (Figure 5).

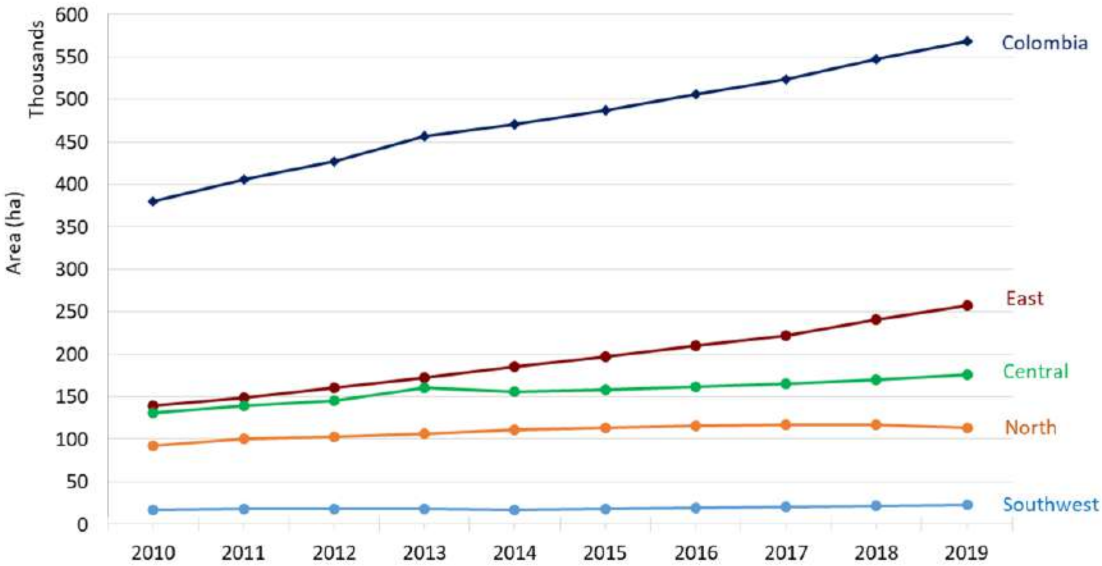


Figure 5 Distribution of oil palm planted in Colombia (total planted area) and by zone (East, Central, North, and Southwest). Based on data from the Fedepalma database (Fedepalma, 2020).

Oil palm plantations are also labor-intensive. In rural areas, they are the major source of employment (Vis et al., 2012). In Colombia, by 2016, oil palm plantations generated 67,672 direct jobs, of which 92.4% were in oil palm plantations (e.g. harvesting, pruning, nursery), and 7.6% in palm oil mills (Daza Alfonzo, 2018). Besides, the economic development plan in Colombia prioritizes oil palm plantations (DNP, 2019) and is selected as a replacement crop in post-conflict regions (Colombian National Government & FARC-EP, 2016). Castiblanco et al. (2013) suggested an increase of 647,687 ha by 2020 in Colombia. The National Association of Oil Palm Growers (Fedepalma–*Federación Nacional de cultivadores de Palma de aceite*) foresees an increase of 1,600,000 ha by 2032 (Pardo Vargas et al., 2015). As a result, oil palm plantations will expand. However, land available is limited (Ocampo-Penuela et al., 2018). Future agricultural expansion in the tropics will affect biodiversity, increase deforestation rates, and habitat loss and degradation (Gray et al., 2016; Meijaard et al., 2018; Ocampo-Penuela et al., 2018). The eastern savannas are most suitable for oil palm cultivation (Pardo Vargas et al., 2015). Natural savannas and gallery and riparian forests have an important diversity of fauna, flora and landscape, besides having soil carbon reservoirs (Ocampo-Penuela et al., 2018). Pardo Vargas et al. (2015) and Ocampo-Penuela et al. (2018) have suggested further oil palm expansion in degraded lands or in cattle lands dominated by pastures to mitigate biodiversity loss and avoid deforestation.

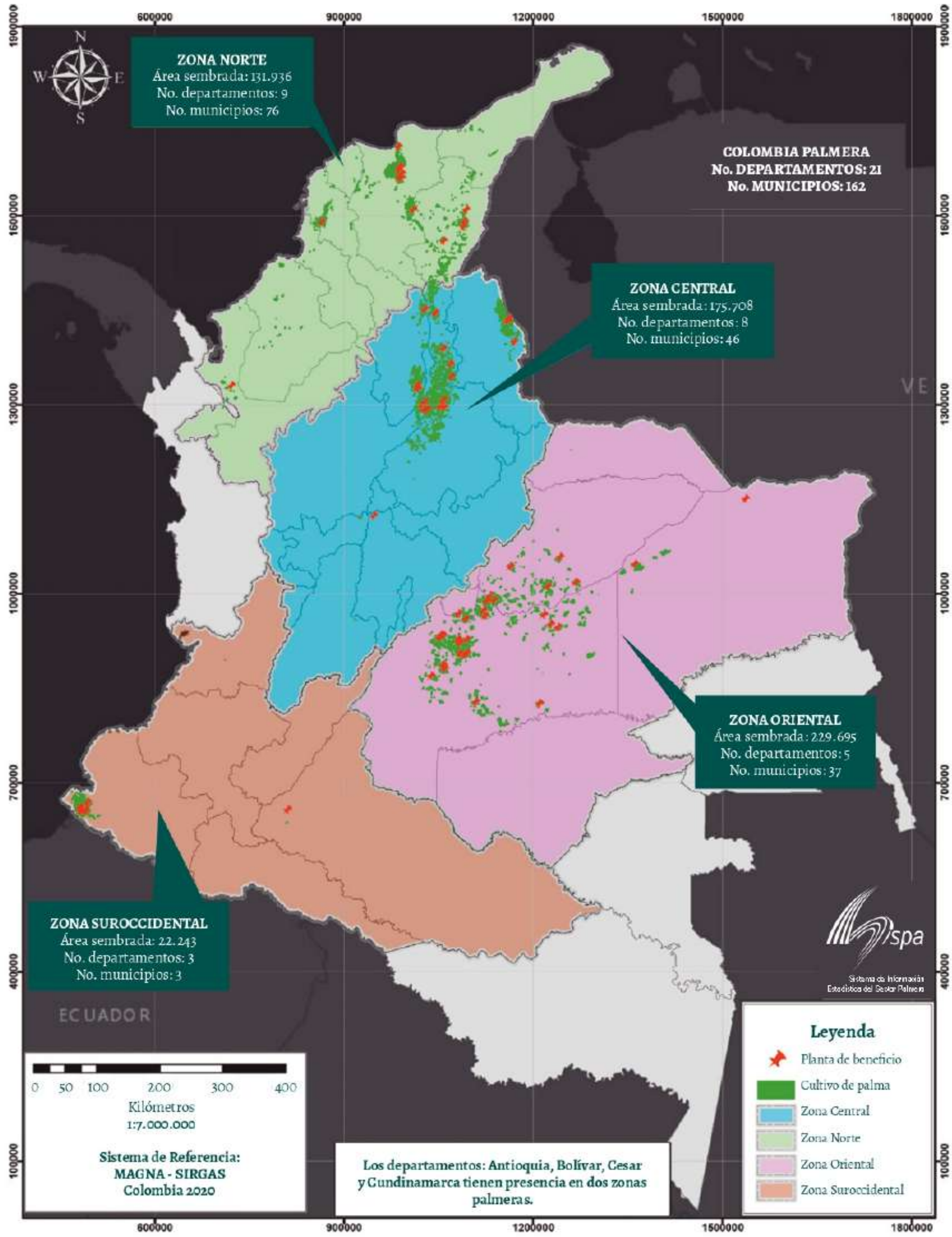


Figure 6 Oil palm plantations in Colombia divided in regions (2019) (source: Girón-Amaya et al.(2020: 40))

2. Chapter 2: General description of the study area: The Macondo oil palm plantation, Mapiripán, Meta, Colombia

2.1. The Department of Meta

The department of Meta is in the Orinoquia region, with an area of 85,635 km^2. Geographical limits of Meta are: in the north with rivers Cundinamarca, Upía and Meta, to the east with the department of Vichada, to the south with the Department of Caquetá and the river Guaviare, and to the west with the departments of Huila and Cundinamarca (Trujillo et al., 2018). Orinoquia region is divided into six districts: 1) Piedmont Casanare District–Arauca, 2) Arauca District–Apure, 3) Casanare District, 4) Piedmont Meta District, 5) High savannas District, and 6) Maipures District (Hernández-Camacho et al., 1992).

The water supply of the Orinoquia region is characterized by shallow rivers. Specifically, the department of Meta is surrounded by three hydrographic sub-areas for the rivers Meta, Orinoco and Amazonas (Correa et al., 2006). The tributaries of the great basin of the river Orinoco come from the territory are the Vichada, Tomo, Meta and Guaviare rivers (Correa et al., 2006). The soils in the Orinoquia region have low fertility. Fertility levels decrease in the eastern direction, with lower levels in the areas of influence of the Guyanese Shield (Correa et al., 2006).

The Orinoquia region is characterized by a tropical climate and a constant temperature throughout the year. The average annual precipitation amounts to 2,200 mm, the dry season starts in October and ends in April, whereas the rainy season is from May to

September. The annual average temperature ranges between 24 °C and 30 °C (Instituto de Hidrología Metereología y Estudios Ambientales -IDEAM, n.d.).

2.2. The municipality of Mapiripán

The municipality of Mapiripán is in the transition zone between the Piedmont Meta District and the northern edge of the Amazon. The location of Mapiripán between savanna and slope transition ecosystems favors the development of gallery or riparian forests, which are the main refuge for fauna in this region (Rodríguez, 2010). The surface of Mapiripán municipality has two types of topography: one flat and the other strongly undulating, and the other presenting terraces, meadows and hills ranging from 150 to 300 meters, with slopes between 0% and 25% (Alcaldía de Mapiripán, 2000). There is an alternating set of savannas and mountains delimited by gallery forests and streams through the municipality (Alcaldía de Mapiripán, 2000). The soils in the municipality have low fertility, high acidity, high susceptibility to stagnation, especially in the flat areas with poor water drainage (Alcaldía de Mapiripán, 2000).

In Mapiripán, the average annual rainfall is 2,657.6 mm. There are two seasons: rainy from April to November, where rain increases from May to June, and the dry season from December to March (Alcaldía de Mapiripán, 2000).

2.2.1. Demographic description of the municipality of Mapiripán

Spaniards, American, European and African migrants became part of the socio-cultural scene of the Orinoquia region, after a historical process of pre-Hispanic occupation, colonization, demographic growth and urban expansion (Correa et al., 2006). The mixture of cultures resulted in the current conformation of the Colombian-Venezuelan population of the Orinoquia region (Correa et al., 2006). According to the National Planning Department (*Departamento Nacional de Planeación* - DNP) in 2020, the total population of Mapiripán is 7,156, comprising 54.1% men and 45.9% women, from which the indigenous population accounts for 23.80%, afro Colombian and mestizo 1.10%, and rom 0.01%. Urban population is 34.78% and rural population is 65.22% (Figure 7) (DNP, n.d.). Ethnic groups are organized in nuclei belonging to the hitnú people: macaguán-, betoye, kuiba -wamone-, sikuani -guahibo- and saliva, they represent the 14% of the country's total indigenous population (Correa et al., 2006).

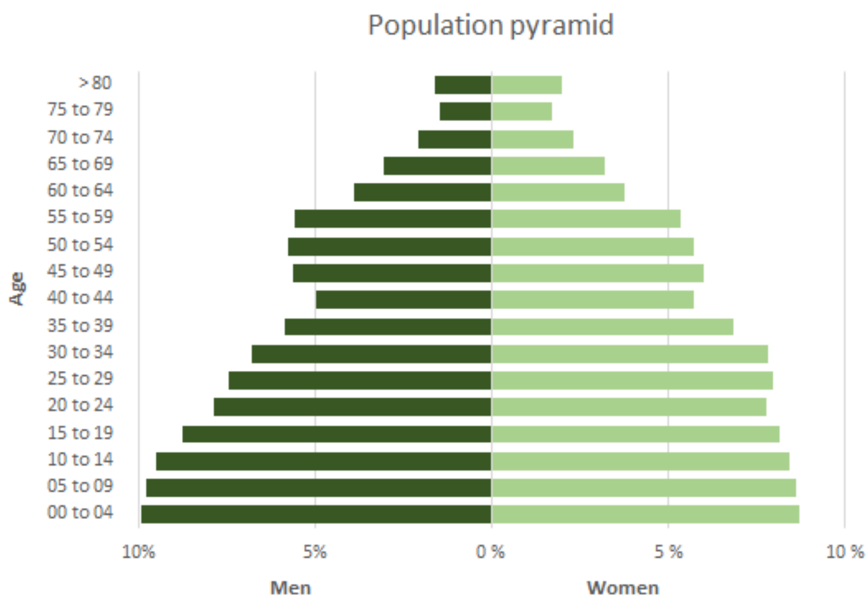


Figure 7 Population pyramid for Mapiripán (source: DNP, n.d)

2.2.2. Land use change in the municipality of Mapiripán

In Mapiripán, land use changed occurred from crop and livestock production to oil palm in the present (Mejía-Buitrago, 2016). In the colonial period, the cattle industry expanded in the Orinoco regions, following by open range grazing and burning of natural grasslands to favor grass regrowth (Etter et al., 2008). Livestock determined the population of the territory, forms of social organization proper to the region, and the growth of the economy (Correa et al., 2006). In the region, nomadic and sedentary indigenous groups were present, they were dedicated to the extraction of hydro biological and natural resources from gallery and riparian forests and natural grasslands (Correa et al., 2006). In Mapiripán, livestock and agriculture were the main economic activity, that even without proper road infrastructure, there was an important market (Alcaldía de Mapiripán, 2000). The Guaviare River became an alternative transportations canal to market wood, agricultural, livestock and hydro biological products (Alcaldía de Mapiripán, 2000). By 1970 there was an intense colonization movement that led to conflicts in land tenure, rising unemployment, violence generated by political parties and finally the cultivation of illicit crops (Alcaldía de Mapiripán, 2000).

Since the late 70s and until the 90s, Mapiripán was a center for coca cultivation (Castro-Garzón et al., 2020). The geographic, social, and economic isolation favored cultivation in the region. The expansion of the coca industry brought with it environmental deterioration (Castro-Garzón et al., 2020; García-Ruíz et al., 2003). By the mid-90s, Mapiripán had the largest area planted with coca and the highest level of production and laboratories establishment (Castro-Garzón et al., 2020). Under this situation, since 1994 the national Government launched a program for eradication of illicit crops that combined forms of forced and voluntary eradication, denominated the National Alternative Development Plan (PLANTE) (García-Ruíz et al., 2003). The program complemented forced eradication campaigns through social investments to prevent and avoid illicit crops production, limited to areas of peasant and indigenous economy (García-Ruíz et al., 2003).

Since 2008, oil palm cultivation has allowed a change in the municipality: the cultivation of licit crops generated employment and ensured social security for workers (Castro-Garzón et al., 2020). The Macondo plantation has been part of the land use changes that have happened in the Orinoco region since colonial times. Currently, the crop production is mainly oil palm, banana, corn, and yucca (Figure 8) (DNP, n.d.).

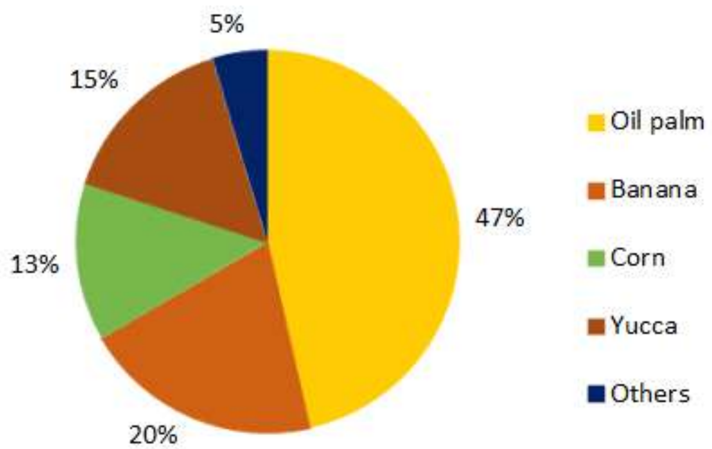


Figure 8 Crop production in Mapiripán (source: DNP, n.d)

2.3. Description of Poligrow Colombia SAS

The present project is done in the facilities of the company Poligrow Colombia SAS. Poligrow Colombia was founded in 2008 and established in Mapiripán, Meta, dedicated to agricultural development; profitable, sustainable, inclusive and beneficial, promoting municipality's improvement (Trujillo et al., 2018). Poligrow aims to have a productive project, thus it makes efforts in human and financial resources to integrate the social and environmental aspects, to maintain the oil palm project over time (Trujillo et al., 2018).

Poligrow Colombia SAS is divided into seven administrative offices: General management, sales, integrated management systems, environment, finance, plantation management and human resources management (Fandiño, 2021, personal communication, June 22, 2021). The plantation management office is subdivided into plant health management, machinery and mechanical workshop, and industrial area. The hierarchical organization is: the highest level is the general director, followed by leaders, coordinators, supervisors, assistants and fieldworkers. The plantation management, with staff from agronomy studies, administers the sowing, maintenance and health of the crop. The environment office includes professionals from biology, environmental engineering and ecology. The responsible of the environmental office in 2009 created the environmental management practices. The environmental management practices aim at controlling the agro-industrial activities to eliminate, reduce and mitigate the adverse impacts (Trujillo et al., 2018). The general management office, jointly with the integrated management systems and environment offices, contemplated the plantation design based on international standards such as RSPO and Rainforest Alliance, as well as national regulations (Trujillo et al., 2018). Besides, integrated management systems and environment offices, together with general management and plantation management offices, create and maintain research projects for conservation and environmental education as the *epiphytarium* (Trujillo et al., 2018).

The company has three oil palm plantations, Macondo, Barandales and Toninas. The present project is based on the Macondo plantation, which is the largest oil palm plantation (5,853 ha) compared with the other two (Barandales: 2,590 ha; Toninas: 1,500 ha). The plantations are the biggest administrative units, followed by sectors and lots.

By 2021, 429 people work at Poligrow Colombia SAS (Departamento de Gestión Humana, 2021). 76% of the workers are employed at the plantation management office, 13% in the industrial area, 4% in the human resources office, 2% logistics in sales and logistics, 2% finance, 2% environment. Integrated management systems, IT systems, infrastructure and general management each has 0,23%. Most of the workers are men (74%) and 26% are women. The ethical description of the staff is: 70,6% mestizo, 23,8 indigenous, and 5,6 afro Colombian. 30% of the workers were born in Mapiripán, 69% come from other municipalities of Colombia (Departamento de Gestión Humana, 2021). 0.5% of workers come from outside the country (Departamento de Gestión Humana, 2021). 95% of the total staff currently working in the Macondo plantation has had experience working in larger oil palm plantations or any other agro-industrial plantation in the country (Fandiño, 2021, personal communication, June 22, 2021). 5% of the staff born in Mapiripán had no experience working in an oil palm plantation, but they had working experience in small farms (Fandiño, 2021, personal communication, June 22, 2021).

2.3.1. Description of the Macondo plantation

The study area comprises the grounds of the Macondo plantation (5,853 ha) in the eastern lowland savannas of Colombia, in Mapiripán, Meta, in the village of Morro Pelado, at a distance of 23 km from the urban area (Trujillo et al., 2018) (Figure 9). The Macondo plantation is in the Orinoco River basin and near the Guaviare River, at altitudes between 163 and 226 m.a.s.l. (Trujillo et al., 2018). The plantation has access to three river basins in the region, which are Jabón, Yamú, and Evaristo (Trujillo et al., 2018). The average annual precipitation amounts to 2,400 mm: 600 mm more than the basic palm requirement, although there are three months of water deficit in which the palm suffers from water stress (Trujillo et al., 2018). The soils present at the Macondo plantation, according to the taxonomic classification are: *Oxic dystrudepts*, *Petroferric hapludox*, *Typic humaquepts*, *Typic dystrudepts*, followed by *Typic inceptisols humaquepts, Aquic humaquepts*, and to a lesser extent the *entisols Typic tropofluvens* (Trujillo et al., 2018).

The Macondo oil palm plantation, Mapiripán, Colombia, is a case of plantation designed after the principles and criteria of the Roundtable for Sustainable Oil Palm (RSPO), Rainforest Alliance (Poligrow Colombia SAS, 2016) and national regulations. Here, the nature-enhanced Macondo plantation is considered as a heterogeneous landscape with human-made areas as oil palms and natural areas such as gallery and riparian forests are intertwined. Following Erikstad et al. (2015: 5), the landscape is "a geographical area, characterized by its content of observable, natural and human-induced, landscape elements". The Macondo plantation is an example of an oil palm plantation applying concomitantly the land sparing and land sharing approaches for conservation and sustainable land use. However, implementing and maintaining the plantation design generates costs, but it also provides benefits for the oil palms (e.g., biological control) and workers. First, the plantation design of the Macondo plantation generates a heterogeneous agricultural landscape that favors pest control populations of *O. cassina* and *R. palmarum.* Second, the spatial characteristics of the plantation will affect the distribution of goods and services, and human well-being (Mitchell et al., 2013). Therefore, the plantation workers might perceive social landscape services inside the plantation.

2.3.2. Management practices in the Macondo plantation

The general management, integrated management systems and plantation management offices created the management practices (Trujillo et al., 2018). The management practices follow the RSPO and Rainforest Alliance, as well as national regulations (Trujillo et al., 2018). They are (Poligrow Colombia SAS, 2016): 1) design of lots, 2) installment of living fences and buffer areas, 3) soil management, 4) implementation of Integrated Pest Management (IPM), 5) Wood production areas, 6) establishment of conservation areas, 7) biodiversity management plant, 8) Training programs (Table 1). According to the biodiversity management plan, inside the plantation, the staff may not hunt, fish, take any type of animal for selling, burn any type of vegetation, or cutting down trees. However, indigenous people may hunt to satisfy their basic needs. The staff can, however, eat fruits and vegetables that they sporadically find on the plantation.

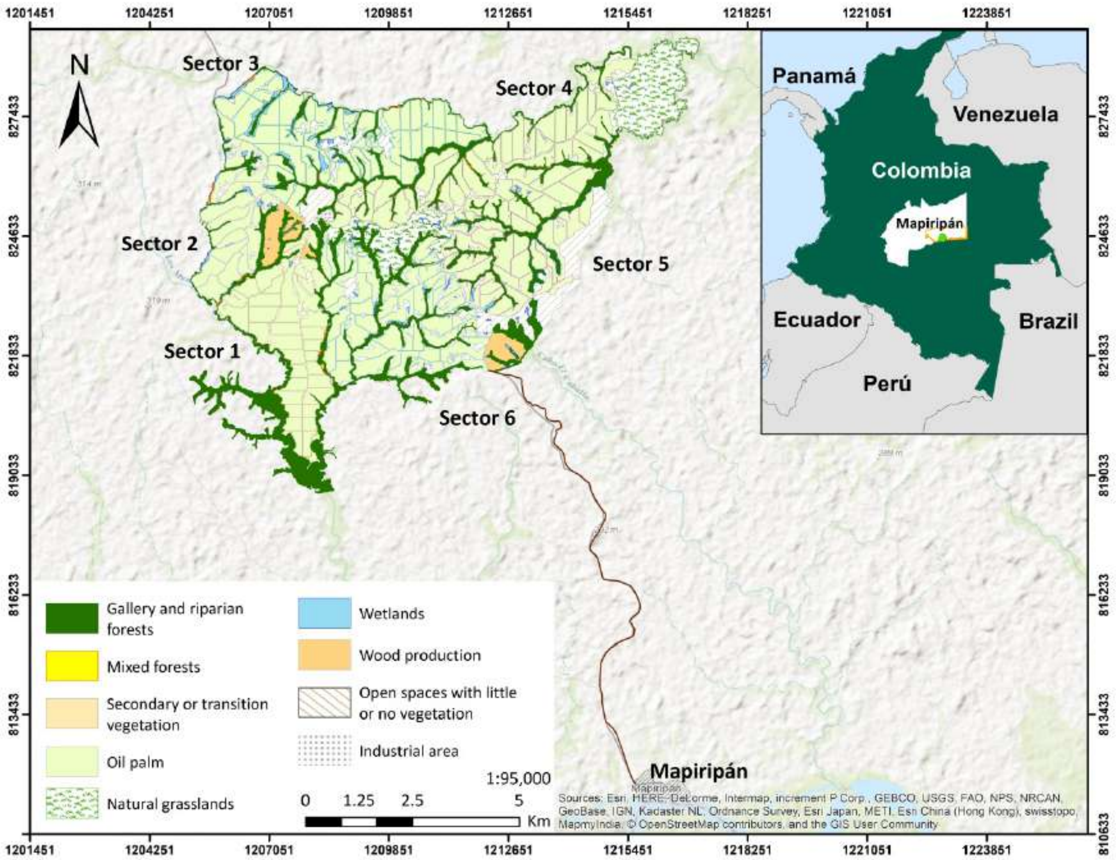


Figure 9 Macondo plantation map representing the land covers and six sectors with oil palms (source: author)

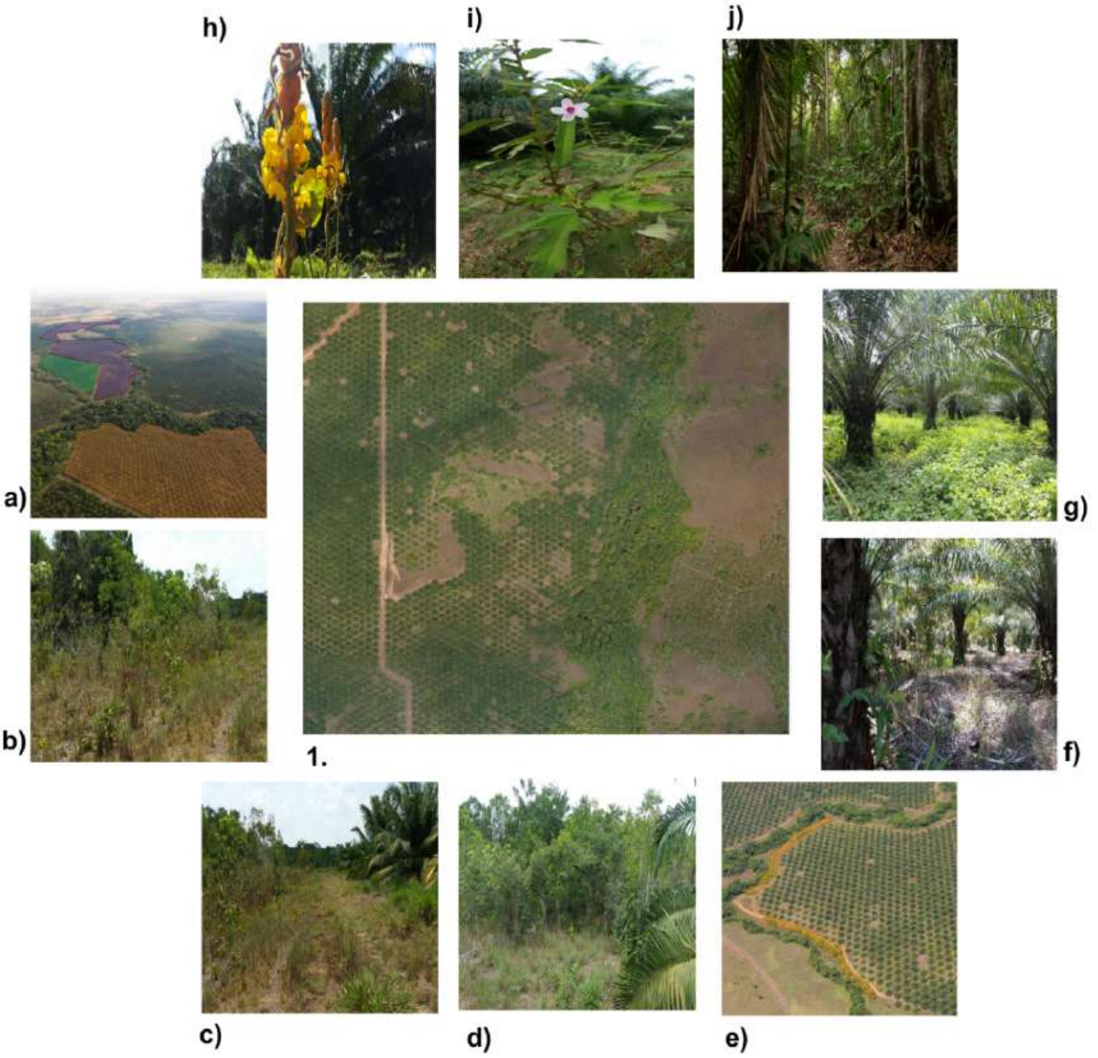
Table 1 Description of the management practices implemented in the Macondo plantation (source: Poligrow Colombia SAS, 2016, Trujillo et al., 2018)

No	Management practices	Description
1	Designing sectors and lots	The design of the sectors and lots is based on background information on land covers (e.g., gallery

		and riparian forests, water bodies), soil conditions (i.e. type and characteristics of the soil) and local fauna and flora. The background information will determine the size, shape and location of the oil palm lots (Figure 10, a). The information is collected by third parties (e.g., consultants) or by the environmental office of the company. Office responsible: General management, environmental management and plantation management.
2	Implementing the living fences and buffer areas	The living fences and buffer areas mark a boundary between natural land covers and oil palms (Figure 10, b, c, d, e). Office responsible: General management, environmental management and plantation management.
3	Soil management	The soil management includes: a) the establishment of soil cover vegetation (e.g., *Pueraria phaseoloide*), b) place biomass (e.g., leaves and trunk pieces form the oil palms) on the ground. These practices avoid erosion, maintain moisture, and add organic matter and nutrients to the soil (Figure 10, f, g).

		Office responsible: plantation management.
4	Implementation of Integrated Pest Management (IPM)	The IPM aims at prioritizing alternative pest control over chemical control. IPM program includes establishing flowering plants (e.g., *Urena lobata* and *Cassia reticulata*) to host beneficial insects, the manual capture of pests, and placement of traps to capture pests (Figure 10, h, i). Office responsible: environmental management and plantation management.
5	Wood production	The wood production areas serve as wood source. This wood source covers the plantation's usage of wood for building and sector demarcation. Office responsible: General management, environmental management and plantation management.
6	Establishment of conservation areas	The conservation areas are reserves for fauna and local ecosystems (e.g., savannas and gallery and riparian forests) inside the plantation (Figure 10, j). Office responsible: General management, environmental management.
7	Biodiversity management plan	The plan aims at conserving and maintaining local fauna and flora at the Macondo plantation. The plan

		incorporates the following activities: research programs, monitoring of water resources, monitoring of flora and fauna, and environmental education. Office responsible: General management, environmental management.
8	Training programs	The continuous training programs for all workers on environmental awareness, certification systems, and management practices in the plantation. Training programs ensure that workers, at different hierarchical levels, are aware of the existent natural resources and their management and contribute to the continuation of the environmental projects and initiatives (Trujillo et al., 2018). Office responsible: General management, environmental management, human resources, integrated management systems, and plantation management.



Photos: Santiago Chiquito (2019- photos: 1., a, e, j), Adriana M. Gómez M. (2019–photos: b, c, d, f, g, h, i, j)

Figure 10 Examples of management practices in the Macondo plantation: 1) aerial photograph in a sector of the Macondo plantation; a) Shape of lots, b) and c) buffer areas between natural habitats and oil palm; d) and e) living fences; f) and g) soil cover; h) flowering plant – Senna reticulata; i) flowering plant – Urena lobata; j) gallery and riparian forest present in the plantation (source: author)

2.3.3. Nature inclusion on Macondo plantation

Macondo plantation design follows the landscape structures, including natural ecosystems and oil palms. Thus, both land sparing and land sharing strategies for conservation are applied. The Macondo plantation landscape comprises oil palm fields and natural ecosystems typical of the eastern lowland vegetation in Colombia, such as gallery forests along streams, secondary or transition vegetation, and natural grasslands (Rodríguez, 2010). The oil palms cover ≈ 60% of the total area. This area comprises six sectors with different varieties (16 varieties in total). The oil palms used in Colombia today are a hybrid between the west Africa *Eleanis guineensis* (male) and the Colombian palm species *Eleanis oleifera* (female) (Bastidas Pérez, 2013; Rey et al., 2004). Other hybrid species are generated in Colombia, for instance, by Corpoica (Colombian Corporation for Agricultural Research – *Corporación Colombiana de Investigación Agropecuaria*) (Bastidas Pérez, 2013). Sectors 1, 2, and 3 were planted in 2009, and the varieties are *Cirad*, *Deli x Compacta*, *Hibrido OxG Amazon*, *Bamenda x Ekona*, *Unipalma*, and *Nigeria*. For sectors 3, 4, and 5 planted between 2010 and 2011, the varieties are *Clones Titan*, *Dami las Flores*, *DxL ASD*, *DxL Cabaña*, and *Unipalma*. For sector 6 planted in 2012, the varieties are *Deli x Ghana* and *Deli x Nigeria*. The rest of the plantation area (40%) features a variety of different vegetation covers. Gallery and riparian forests (5.72%) are a vegetation type associated with streams dominated by the native palm *moriche* (*Maurita flexuosa*). Water bodies such as wetlands and streams cover approximately 2% of the area. Natural grasslands (8.37%) are a vegetation type typical of the eastern zone, they are all under conservation. Secondary and transition vegetation (4.73%) are protection buffers between the gallery and riparian forests and the oil palms. Initially, in 2009, the protection buffer was an area with little vegetation to keep distance between the oil palm and the gallery and riparian forests. This buffer area is today the secondary and transition vegetation.

Mixed forests (0.36%) are areas assigned for reforestation projects planted with native species such as *Cochlospermum orinocense, Cochlospermum vitifolium, Protium llanorum, Jacaranda obtusifolia, Zygia sp., Enterolobium schomburgkii, Himatanthus articulatus, Calophyllum lucidum, Hymenaea courbaril, Hura crepitans, Guazuma ulmifolia, Ochroma pyramidale, Enterolobium cyclocarpum, Cassia moschata, Minquartia guianensis,* and *Mauritia flexuosa.* The wood production (2.81%) comprises the species *Acacia mangium, Melina sp., Eucalyptus, Tectona grandis,* and *Cedrus*. Areas with little or no vegetation and roads cover ≈ 17% area. The industrial area (0.07%) is the extraction plant. About 38% of the plantation area features natural land covers.

Figure 11 Panoramic view of the Macondo plantation (Source: Santiago Chiquito)

3. Chapter 3: Theoretical and conceptual framework

3.1. Landscape ecology

Landscape ecology is an interdisciplinary discipline that focuses on understanding spatial heterogeneity, including social and natural perspectives (Turner et al., 2001; Wu et al., 2007). According to Turner et al. (2001: 5) "landscape ecology draws from a variety of disciplines, many of which emphasize social sciences, including geography, landscape architecture, regional planning, economics, and forestry. The role of humans in shaping and responding to landscapes […] Humans clearly create and respond to spatial heterogeneity and the importance of spatial heterogeneity in linked social–ecological systems". Landscape ecology considers a) the development and dynamics of the landscape spatial heterogeneity, b) ecological interactions and functions of landscapes, c) the influence of spatial heterogeneity of ecological processes, d) management of spatial heterogeneity, e) effects of humans shaping and changing landscapes (Turner et al., 2001; Wu et al., 2007).

The interdisciplinary of landscape ecology allows for the integration of the socio-ecological system of the Macondo plantation. The landscape assessment of the plantation delivers ecological information, landscape composition, and configuration. This information is then related to the spatial representation of social landscape values perceive by workers (social) (Figure 12).

Two fundamental theories - the island biogeography theory (MacArthur & Wilson, 2016) and the metapopulations theory (Hanski & Ovaskainen, 2003; Levins, 1969) -

describe the species ecology in fragmented landscapes (Dondina et al., 2017; Hanski & Ovaskainen, 2003). The island biogeography theory describes the effects of fragmentation, habitat fragmentation and isolation, on species richness (Debinski & Holt, 2000). The metapopulation theory describes the spatial and functional arrangements and dynamics of populations in fragmented landscapes (Petit et al., 2001). These theories support the results from the landscape assessment (landscape metrics) in terms of landscape connectivity, fragmentation, and diversity in Chapter 5. The landscape assessment characterizes the Macondo plantation. The assumption is that a connected and heterogeneous landscape will support more fauna and flora populations for pest control (Bennett, 1999; Nurdiansyah et al., 2016) (Figure 12).

3.1.1. Theory of island biogeography

The theory of island biogeography explains the relationship between species pattern occurrence and area (i.e. islands or forests patches in fragmented landscapes) (Hanski, 2010). Forests patches act as islands in a modified matrix. The matrix is a barrier for animal movement throughout the landscape, as compared to oceans described in the theory (MacArthur & Wilson, 2016). The theory can also explain the occurrence of species in fragmented landscapes (Laurance, 2010).

3.1.2. Theory of metapopulations

The metapopulation theory describes the spatial and functional arrangements and dynamics of populations in fragmented landscapes (Petit et al., 2001). Species richness is determined by the species dynamics (Dondina et al., 2017). For instance, the species dynamics with habitat remnants (interior species) are not affected by the matrix (generalist species), or species that require transitional habitats (edge species) to move between forest patches (Dondina et al., 2017).

3.2. Ecosystem services and social landscape values

In the Monography, I use both terms: ecosystem services (ES) and social landscape values (SLV). I refer specifically to the regulating ecosystem service of pest control in Chapter 5. In the following chapters (Chapter 6, Chapter 7), I will use the term social landscape values to refer to the goods and services that workers perceive and localize in the Macondo plantation (Figure 12).

Ecosystem functions become services when they are valued by humans concerning human needs and choices (Fagerholm et al., 2012). Ecosystem services (ES) are consumed or used directly or indirectly to the benefit of human welfare and to satisfy human needs (Costanza et al., 1997). In general, ES has four categories: supporting (habitat), regulating, provisioning, and cultural services (Costanza et al., 1997; MA, 2005). These ES are the ecological characteristics, functions, or processes that directly or indirectly benefit humans' well-being from ecosystem processes (Costanza et al., 1997; Costanza et al., 2017; MA, 2005).

These services are then place-based, vary in geographical space and are perceived and valued differently from individual to individual (Brown, 2004; Fagerholm et al., 2012). As argued by Fagerholm and Käyhkö (2009), SLV are socially constructed and have commonly approved meanings. In this way, the SLV relates to how humans value landscapes (Brown, 2004). They reveal the relationship between landscape and social-cultural processes and constructions with the surroundings (Brown & Weber, 2012; Fagerholm et al., 2012). Therefore, the spatial reference of landscape values discloses the relationship between landscape characteristics and humans' well-being, and how humans use and perceive landscape values (de Groot et al., 2010).

As argued by Fagerholm and Käyhkö (2012: 422), the ES "captures only partly the true value of the land and resources when the third value domain, socio-cultural, is neglected. As humans constantly modify their land and living space, which leads not only to multiple land uses, but moreover to the diversity of perceptions and values attached to the landscape […]". Although the ES concept has been important for decision making, ES concept is not explicit in landscape research to show the tangible and intangible benefits identified and valued by stakeholders (Fagerholm et al., 2012).
The social landscape values (SLV), as defined by Fagerholm and Käyhkö (2009) give a better insight into complex socio-ecological systems. In this context, SLVs materialize from constant interaction with landscapes (Brown, 2004). The SLV is a framework to link "geography of place" (localization of values) and "psychology of place" (perception of values on the Macondo plantation) (Brown, 2004). Brown and Reed (2000) distinguished thirteen landscape values: life, support, economic, scientific, recreation, aesthetic, wildlife, biotic diversity, natural, history, spiritual, intrinsic, subsistence, cultural, and therapeutic values.

3.3. Land sharing and land sparing approaches

In the Macondo plantation, the land sparing and land sharing approaches are implemented simultaneously, as a sustainable land-use strategy. In the land sparing, the agricultural lands are typically industrial, intensively managed, and usually with high inputs of chemicals (Fischer et al., 2008). Therefore, biodiversity is restricted to conservation areas or nature reserves away from agricultural production (Fischer et al., 2008). However, protected areas are insufficient to maintain and conserve biodiversity (Butchart et al., 2010). Biological reserves are immersed in intensive agriculture, with pesticides application is worse than smaller reserves into diverse agroecosystems (Perfecto & Vandermeer, 2008). The agricultural matrix can combine conservation and production aims–land sharing (Perfecto & Vandermeer, 2008).

Land sharing or wildlife-friendly farming promotes practices to benefit wildlife within the agricultural lands (Fischer et al., 2008). According to Fischer et al. (2008: 381), there are three main "differences between land sparing and wildlife-friendly farming. First, in land sparing, there is a strong contrast between land for agriculture and land for biodiversity, whereas this disparity is less pronounced in wildlife-friendly farming, and agriculture and biodiversity co-occur in the same area. Second, in land sparing, agricultural land itself is essentially homogeneous, whereas it is typically much more heterogeneous under wildlife-friendly farming. Third, variability in land cover and its value for biodiversity are at a finer spatial scale, or grain, in wildlife-friendly farming than in land sparing".

Grass et al. (2019) concluded that land sparing and land sharing can be integrated into the landscape matrix to optimize connectivity between fragments and production areas to facilitate species movement. Implementing both approaches in agricultural landscapes is relevant to "(a) promote the spillover of ecosystem services from land ‐ sharing/ ‐ sparing measures to agricultural production and rescue service ‐ providing species from hostile areas, (b) to facilitate immigration and counteract possible extinctions in spared habitats and (c) to conserve response diversity of species communities for ensuring resilience of ecosystem services in changing environments" (Grass et al., 2019: 263).

3.4. Human–nature relationship

The following theories and concepts are useful to understand how plantation workers perceive nature inside the Macondo plantation, from the results in Chapters 6 and 7. The feelings and bonds that workers develop towards the plantation are related to the landscape characteristics (Chapter 5) through social landscape values (Chapter 6) and how they perceive and use nature (Chapter 7) (Figure 12).

Exposure to nature is integral to the human developmental process and essential in physical and mental growth (Wilson, 1984). The biophilia hypothesis provides an understanding of human's tendency to relate to living organisms and nature (Wilson, 1984). It suggests that humans have an innate need to connect with nature and all forms of life because humans have evolved in nature (Wilson, 1984). According to Wilson (1984) the hypothesis "proclaims a human dependence on nature that extends far beyond the simple issues of material and physical sustenance to encompass as well the human craving for aesthetic, intellectual, cognitive, and even spiritual meaning and satisfaction" (Wilson & Kellert, 2013: 20).

Encounters with the wilderness and the threatening features of nature can evoke fears, as humans are "biologically prepared" to learn about fears that threatened the survival of the human species (Seligman, 2016; van den Berg & ter Heijne, 2005). Negative emotions towards nature or wilderness might be driven by biophobia, the inherent fear of nature, or non-man-made scenarios (van den Berg & Konijnendijk van den Bosch, 2012). Simultaneously, nature evokes an ambivalence between fascination and fear, positive and negative emotions in the face of encounters with wild animals, nature, wilderness, and the unknown (van den Berg & ter Heijne, 2005). Since openness and wilderness can mean being exposed and vulnerable (Konijnendijk van den Bosch, 2012).

3.4.1. Place-based theory

The place-based theory is based on "empirical hypotheses that place orientation is a feature of all people's experience of their environment" (Norton & Hannon, 1997: 227). The theory assumes that territoriality is universal to all human cultures, especially to those aspects relating communities to their ecological, social and cultural contexts (Brown et al., 2002; Norton & Hannon, 1997). The theory is developed on a "sense of place" in which individuals construct local values linked with myths and cultural practices (Norton & Hannon, 1997). People develop feelings and bonds for a place constructed through social interaction and recognition of places that fulfill their lives (Brown et al., 2015; Hidalgo & Hernandez, 2001). According to Brown et al. (2015), place attachment reflects identity and home range (a term borrowed from biology), an area in which people meet their functional needs. The home range for humans is influenced by the landscape values that promote the economic benefit and social identity (Brown et al., 2015).

3.4.2. Nearby nature and human well-being

Exposure to natural settings as forests and watersides have relaxation and health effects on humans, for instance, decrease blood pressure, lower cortisol levels (stress hormone) (Park et al., 2009), enhance memory, concentration and learning and decrease negative thoughts (Berman et al., 2008). Human well-being includes the absence of illness or diseases, social, physical and mental health, and personal growth (Pritchard et al., 2020). Fuller et al. (2007) demonstrated that psychological benefits and human well-being were related to green spaces with species richness of plants and birds in urban areas. Cox & Gaston (2015: 10) “found a correlation between the number of species that a respondent could correctly identify and how connected to nature they felt when they watched garden birds”. People who feel more connected to nature are more likely to have pro-social behavior (Howell & Passmore, 2013) and are psychologically healthier (Howell et al., 2013; Pritchard et al., 2020). According to Cox & Gaston (2015: 10) “being connected to nature is an important step in mediating the extinction of experience (the progressive loss of human interactions with nature), in raising people’s awareness of the nature around them”. People feel more connected to nature and their surroundings when nature is present as green spaces, gardens, or trees (Cox & Gaston, 2015; Nisbet et al., 2020).

3.4.3. Naturalization process: Nature, socio-ecological systems and naturalization of the environment

Nature and wilderness are perceived as those areas untouched, pristine, and not managed by humans (Cronon, 1996). The unnatural areas are agricultural landscapes and cities (Cronon, 1996). The word naturalness or wilderness, in the eighteenth century, had a negative connotation (Cronon, 1996). By the next century, the "wilderness" gained a picturesque (western) perception of the "perfect" nature (without humans or human influence) (Cronon, 1996). This perception allowed excluding humans from nature. Valcuende del Río J. M. & Ruiz-Ballesteros E. (2019: 185) stated that "this process is grounded in the application of the discursive nature-culture dichotomy, so that, when a protected area is created, greater distance or proximity to nature is attributed to its inhabitants". In other words, humans are completely part of nature or excluded from it.

Nature, according to Smith & O'Keefe (1980: 30) has two sides, "on one hand, nature is external, non-human reality, pure and god-given; on the other nature is more abstract, incorporating human as well as non-human spheres of reality […] "nature" is expected to be simultaneously human and non-human […]". The word nature itself is ambiguous, and it might be mistaken with ecological quality concerning different meanings and perceptions of nature (Nassauer, 2007). The perception of "good" ecological quality is the absence of human influence where “nature” is left alone, as argued by Nassauer (2007). Thus, nature is not an external part of humans, as humans depend on nature to satisfy basic needs (Smith & O'Keefe, 1980).

According to Swyngedouw (1999: 445) “natural or ecological conditions and processes do not operate separately from social processes, and that the actually existing socio-natural conditions are always the result of intricate transformations of preexisting configurations that are themselves inherently natural and social” (Swyngedouw, 1999: 445). This socio-nature, following Peluso (2012) is a hybrid between social and natural processes, and they are constantly co-created “being constructed and broken apart […]”(Peluso, 2012: 81). In this regard, social and natural processes are connected and maintain both the social life and the natural life (biodiversity) (Swyngedouw, 1999). The socio-ecological systems, according to Berkers and Folke (1998), emphasize “the integrated concept of humans-in nature and to stress that the delineation between social and ecological systems is artificial and arbitrary. They addressed the interplay and problem of fit between social and ecological systems by relating management practices based on ecological understanding to the social mechanisms […]” (Folke, 2006: 262). This leads to a co-evolution process. Fischer-Kowalski & Haberl (2007: 14) defined the co-evolution process as “societies become structurally coupled with parts of their environment, leading to a process where both mutually constrain each other's future evolutionary options”. By applying agroecological practices, the social and the natural are present in the agricultural landscape. People might perceive the new emerging agricultural landscape as their own and associate it with local biodiversity

(Peluso, 2012). Then the nature exists "on its own" and its intrinsic value is recognized by the social sphere (Achterberg, 2002).

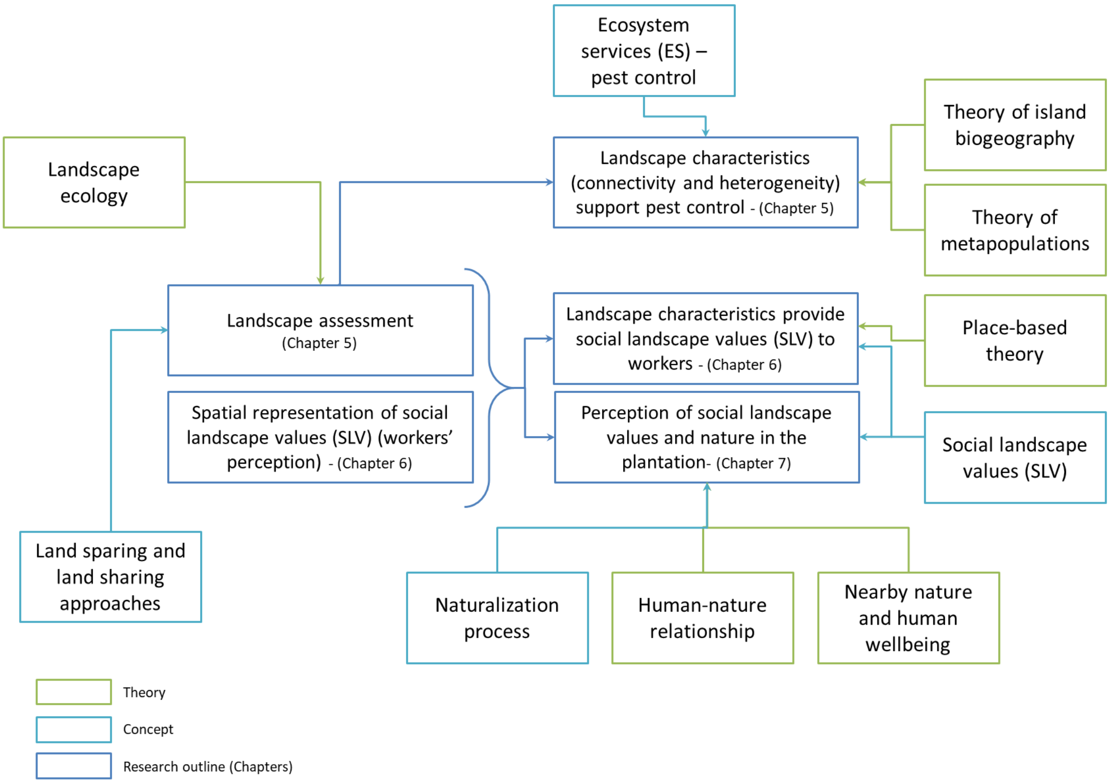


Figure 12 Theoretical and conceptual framework related to the research outline (Chapters) of the present study

4. Chapter 4: Research design and research questions

4.1. Research design

An interdisciplinary mixed-methods study was selected as the design for this research project. Landscape assessment provided ecological information on the agricultural landscape (quantitative methods). The assessment is then related to pest occurrence (quantitative methods), and the provision of social landscape values (quantitative methods). Finally, the workers' perception of nature and use and provision of social landscape values in the plantation was analyzed (qualitative analysis).

The data was collected between October 2018 and April 2019. First, to answer the questions in Chapter 5, the geographical and pest abundance data were requested directly to the company. Geographical information includes the official planning state-of-the art 2009-2012 of the Macondo plantation. Then, a land cover map was digitalized using ArcGIS Version 10.6. on a scale of 1:60,000 conforming to the Corine Land Cover nomenclature for Colombia (Ardila & García, 2010). Pest abundance on *O. cassina* and *R. palmarum* was provided by the plant health department, which organizes the IPM throughout the Macondo plantation. To classify the landscape, the land cover map was divided into a raster grid cell (500*500 meters), resulting in 296 grid cells. Then a set of selected landscape metrics was measured to perform a landscape assessment. Following, an ordination method was used to show graphically the relationships between the landscape characteristics, land cover and pest occurrences.

Second, to answer the questions in Chapter 6, three focus group discussions (FGD) and participatory mapping interviews were performed with plantation workers. First, the FGDs were performed with six to eight workers (: FGD1: 8 (women: 1; men: 7), FGD2: 7 (men: 7), FGD3: 6 (men: 6)). During the focus group discussion, a list of the social landscape values (SLV) was identified. In a second step, structured individual interviews were conducted with 35 plantation staff. The landscape analysis of the plantation, the landscape structural types (LST) and the localization of SLV were jointly analyzed; foremost represented in a map to highlight the social hotspots inside the plantation and then using an ordination method to find relationships among LSTs, land covers, and SLVs.

Third, for Chapter 7, two more focus group discussions were performed (FGD4: 7 (women: 2; men: 5), FGD5: 8 (women: 8)). The focus groups discussions from the previous chapter (Chapter 6) were also considered for the analysis, to have five focus group discussions. Additional information on the participatory mapping interviews and the description and perception of SLV were considered. The information from focus group discussions and interviews was analyzed using qualitative content analysis (Figure 13).

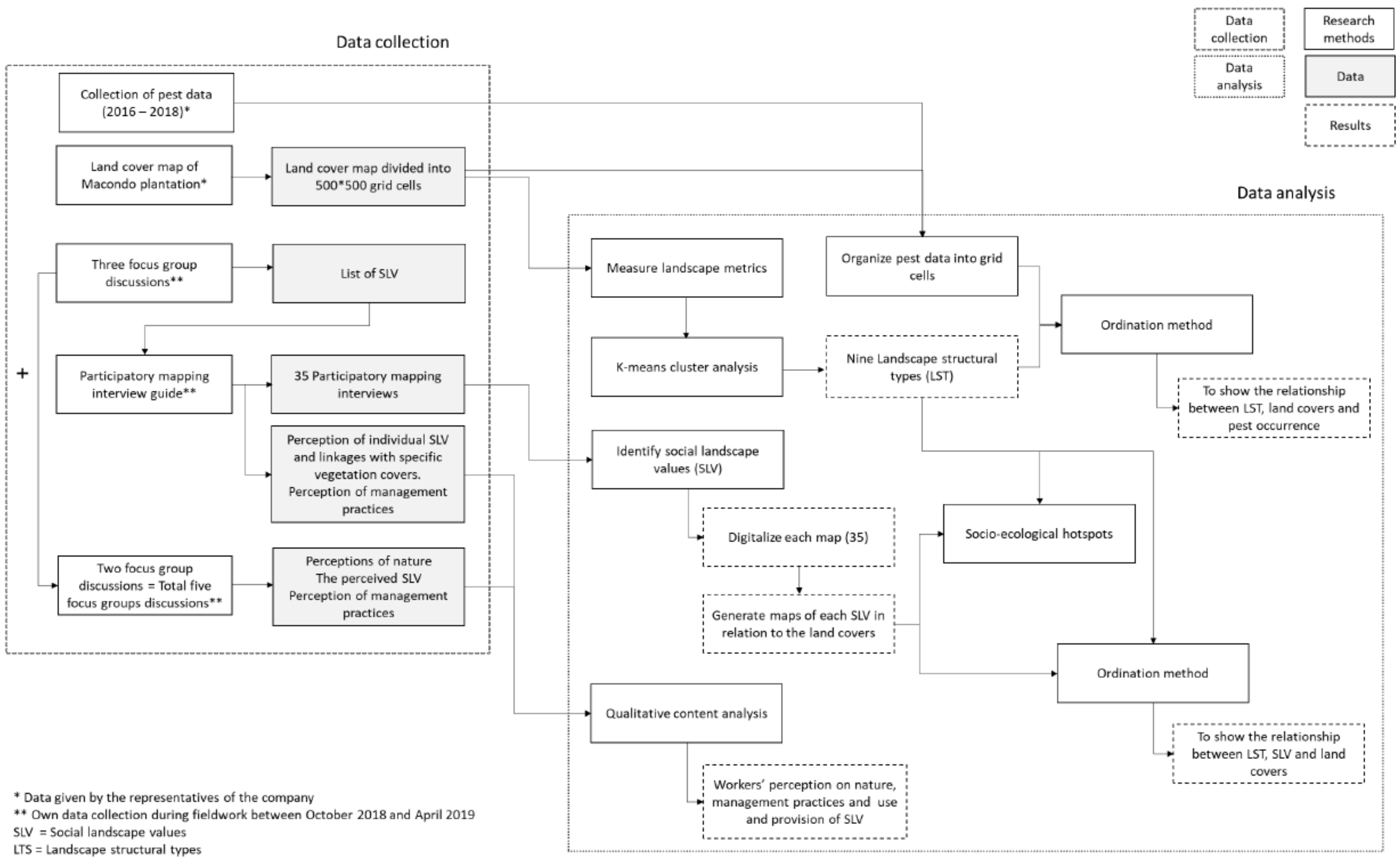


Figure 13 Flow chart of the research design including data collection tools, data analysis and results (source: author)

4.2. Research questions

The principal theme of this dissertation contributes scientifically to the sustainable land-use strategy for the oil palm sector. Here, the Macondo plantation is a heterogeneous landscape. The oil palm landscape composition and configuration create habitats for local fauna that control pest populations of the butterfly larvae (split-banded owlet *Opsiphanes cassina*) and the red weevil *(Rhynchophorus palmarum)*: two of the most significant pests in the oil palm sector in Colombia. However, little is known about how the oil palm landscape characteristics relate to the pest occurrence.

Heterogeneous agricultural landscapes bring benefits to the agricultural landscape structure and provide social landscape values and human well-being. However, oil palms as a heterogeneous landscape and as a social-ecological system are still understudied. To address this gap, a landscape assessment in a heterogeneous oil palm plantation was performed. First, the assessment shows the ecological characterization of the plantation. Second, the spatial distribution and composition of land covers in the plantation can support local fauna that acts as a biological control agent (Chapter 5). Third, workers' perceptions of nature and social landscape values can be related to the landscape characteristics (Chapter 6, Chapter 7).

Research question 1: How do landscape characteristics of the Macondo plantation relate to pest occurrence?

Sub-research question 1.1: which landscape structural properties characterize the landscape of the oil palm plantation in Mapiripán, Meta, Colombia?

Sub-research question 1.2: how are these dominant landscape structural properties related to the presence of *O. cassina* and *R. palmarum*?

Research question 2: How do these landscape characteristics provide social landscape values to workers in the Macondo plantation?

Sub-research question 2.1: Which SLVs are perceived by workers to the land covers on the plantation?

Sub-research question 2.2: How SLVs relate to landscape characteristics (LSTs) and socio-ecological hotspots?

Research question 3: How do workers perceive nature inside the Macondo plantation?

Sub-research question 3.1: How is the relationship of workers with nature-enhancements on the plantation, in tangible terms (perception of management practices, social landscape values, and risks)?

Sub-research question 3.2: How does the workers' perception of nature in the oil palm plantation reflect the naturalization process in the plantation?

5. Chapter 5: How landscape characteristics in a heterogeneous oil palm plantation relate to pest occurrence

Abstract

Heterogeneous agricultural landscapes, comprising different vegetation types in a complex spatial pattern, provide habitat to a variety of species and cause high biodiversity. Biodiversity can thus offer pest control ecosystem service to agricultural systems. However, so far it remains unclear whether landscape structure and diversity can be related to pest occurrences. The chapter poses two main questions, which landscape structural properties characterize the landscape of the oil palm plantation?, how are these landscape structural properties relates to the presence of the butterfly larvae split-banded owlet (*Opsiphanes cassina*) and the red weevil *(Rhynchophorus palmarum)*? To answer these questions, first, a landscape analysis was performed using multivariate cluster analysis to derive nine landscape structural types. The landscape structural types emphasize the landscape characteristics of the plantation. Second, NMDS ordination was performed to show similarities among the landscape structural types, land cover, and pest occurrence. The results show that the oil palm plantation is a heterogeneous agricultural landscape with high landscape connectivity, low landscape fragmentation. The plantation has high landscape diversity that can host different species, some of which can control agricultural pests. The results show the homogeneous landscapes types relate to presence of pests. This supports the argument that natural vegetation (e.g., gallery and riparian forests) and heterogeneous agricultural matrix provide biotic entities that regulate pest populations.

5.1. Introduction

In Colombia, oil palm has become an important sector to improve the economy in rural areas (Girón-Amaya et al., 2020) with multiple farms committing to international standards such as the Roundtable of Sustainable Oil Palm (RSPO) and Rainforest Alliance. These often heterogeneous oil palm plantations can contribute to biodiversity conservation by connecting habitats and offering refuge for local fauna and flora (Lucey et al., 2014). The integration and maintenance of the native flora into the plantation and its management results in unique, heterogeneous spatial patterns (i.e. compositional and configurational heterogeneity) causing a high diversity and connectivity with many options for suitable habitats for local wildlife (Fahrig et al., 2011).

Landscape spatial patterns influence the provision of ecosystem services, such as pollination and pest control, within human-modified landscapes such as oil palm plantations (Tscharntke et al., 2008). Pollination and pest control services are closely related to the production process and will positively affect yield (Denmead et al., 2017). Heterogeneous oil palm plantations can be multifunctional landscapes: oil palm production along with conservation of local ecosystems implementing land sharing and land sparing approaches simultaneously (Egan & Mortensen, 2012; Meijaard et al., 2018).

Inclusion of nature in plantations might enable species movement which facilitated the spread of pests, exotic species, wild fauna that could create conflicts among inhabitants and affect oil palms (e.g., small mammals, insects) (Meijaard et al., 2018). Therefore, assessing the positive and negative consequences of including flora and fauna within a plantation requires management practices where both nature conservation and management are necessary. The inclusion of nature favors local fauna that acts as pest predators and pollinators (Gagné et al., 2015; Meijaard et al., 2018; Nurdiansyah et al., 2016; Tscharntke et al., 2005). Other studies have focused on understanding land cover patterns and relationships between ecological processes and spatial patterns in extensive areas (Abdullah & Nakagoshi, 2008; Partington & Cardille, 2013). However, little is known about the spatial pattern of a heterogeneous oil palm plantation and its relation to the pest occurrence. The chapter aims to analyze the landscape patterns (composition and configuration) and their relation to pest occurrence across the study area. Existing and future oil palm plantation projects in Colombia could implement the outcomes of the project at hand. The landscape analysis will attend the Roundtable on Sustainable Palm Oil (RSPO) which foresee the maintenance and management of local ecosystems and landscape for the provision of ecosystem services (Meijaard et al., 2018).

In South America, the most important pests for oil palm are the butterfly larvae (split-banded owlet *Opsiphanes cassina*) and the red weevil *(Rhynchophorus palmarum).* The *O. cassina* can defoliate over 50% of the oil palm leaves, which negatively affects oil palm yield, causing economic damages (Rodríguez-González et al., 2008). *R. palmarum* damages the palm during feeding and oviposition (OEPP/EPPO, 2005). The larvae of the *R. palmarum* feed on the crown of the palm, which damages the apical growth area, causing the death of the palm (OEPP/EPPO, 2005). The larvae spread the nematode *Bursephelenchus cocophilus* that causes red ring disease (Oehlschlager et al., 2002). Red ring disease affects native palms and oil palm plantations, causing necrosis of leaflets and produce small and deformed younger leaves, affecting the production of fruit bunches, causing economic damages (Chinchilla, 1991). Several natural enemies such as predators, parasitoids, and entomo-pathogens can control the larvae abundance of *O. cassina* and *R. palmarum* (Mexzón & Chinchilla, 2011; Moura et al., 2006). The natural enemies of both species depend on the available understory plant covers and flowering plant species (Mexzón & Chinchilla, 1996; Mexzón & Chinchilla, 2011).

The Macondo plantation considers at least 30% of its total area of local ecosystems incorporating savannas, gallery and riparian forests, and secondary vegetation offering good habitat conditions for natural enemies of pests. Therefore, the study area offers ideal conditions to study the relationship between a complex oil palm plantation landscape and the presence of the most important pests in the oil palm sector, *O. cassina* and *R. palmarum.* The chapter takes the innovative approach considering the Mapiripán nature-enhanced oil palm plantation as a complex landscape itself. The diversity of landscape types within the plantation is assessed, based on classic landscape metrics and land cover. The analysis resulted in nine landscape structural types, LST, showing high landscape diversity at the level of the plantation. The key research questions are: 1) which landscape structural properties characterize the landscape of the oil palm plantation in Mapiripán, Meta, Colombia?, and 2) how are these dominant landscape structural properties related to the presence of *O. cassina* and *R. palmarum*?

5.2. Methods

The representatives of the company provided the initial digital land cover map on a scale of 1:60,000, showing the official planning state-of-the art 2009-2012. The land cover map was digitalized using ArcGIS Version 10.6. with land cover classes conforming to the Corine Land Cover nomenclature (Ardila & García, 2010). To classify the landscape, the land cover map of the plantation was divided into a raster grid cell (500*500 meters), resulting in 296 grid cells. The following landscape metrics for landscape assessment structure were calculated using vLATE version 2.0 beta (Lang and Tiede 2003) in ArcGIS Version 10.6: proximity, edge density, total edge, mean patch edge, Shannon's diversity, Shannon's evenness, and dominance and proportional area (Table 2).

Table 2 Landscape metrics used for the landscape analysis in Macondo plantation

Landscape metrics	**Description**
Proximity index	The proximity index (PX) distinguishes the distribution of small habitat patches from clusters of large patches. It calculates the index using the area (Si) and the edge-to-edge distance from patch *i* to its nearest neighbor forest patch (zi) incorporating the isolation factor (Gustafson & Parker, 1994):

	$PX = \sum_{i=1}^{n} (\frac{S_i}{z_i})$ PX is large when the patch is surrounded by large and/or closes patches. PX decreases as patches become smaller and/or sparser. The index tests the landscape context of patches at a specific scale of analysis. The downside is that the PX is insensitive to the type of boundaries of the landscape matrix (Gustafson & Parker, 1994).
Total edge Edge density Mean patch edge	Total edge **(TE)** is the total length of boundary lines within a class or the entire landscape (Lang & Tiede, 2003). Edge density **(ED)** is the length of the boundary line **(TE)** in a unit area (Lang & Tiede, 2003). The length of the edge line refers to a patch by Mean Patch Edge **(MPE)** (Lang & Tiede, 2003). Edge metrics represent the landscape configuration because the edge amount of edge in a landscape and the edge effect is important to ecological phenomena (McGarigal & Marks, 1994).
Shannon's diversity Shannon's evenness Dominance	**Diversity:** Relative **richness** is the ratio of the actual class number to the maximum possible. **Shannon's diversity** is increasing with higher richness or **evenness** (Lang & Tiede, 2003). Shannon's **Evenness** is the current diversity, standardized to the maximum (Lang & Tiede, 2003). The higher species **evenness** occurs when many species have similar

	abundance, with no single species dominating (Izsák & Papp, 2000). **Dominance** equals the deviation of one maximum diversity value (Lang & Tiede, 2003). The Shannon-Weaver index: adapted from (Izsák & Papp, 2000): $ShWI = -\sum_{i=1}^{n} x_i \log x_i$ Where *n* is the number of species and x_i is the probability of an individual that belongs to *ith* species (Izsák & Papp, 2000).

5.3. Data on pest records of *Opsiphanes cassina* and *Rhynchophorus palmarum*

The representatives of the plant health management, who organize the IPM throughout the Macondo plantation, provided the data on *O. cassina* and *R. palmarum*. Two times a month, the fieldworkers manually collect and count the larvae of the *O. cassina* per oil palm. For the study, the data on the number of larvae per lot between 2016 and 2018 was requested.

The plant health department installs baiting traps to control *R. palmarum* adults. Two times a month, the fieldworkers do a visual survey to register the number of red weevils inside the trap, change pheromone if needed, and clean the trap. The baiting trap comprises a plastic gallon with a male-produced aggregation pheromone, hanging on the top, and a sugarcane juice on the bottom to attack adults of the red weevil (Oehlschlager et al., 2002). The baiting traps are placed around the plantation, delimiting the gallery and riparian forests and oil palm. For the present study, the number of adults that fell in the batting trap on each lot between 2016 and 2018 was requested.

5.4. Data analysis

5.4.1. Detecting LST by using cluster analysis

All landscape metrics were checked for linear intercorrelation. Variables with R-values higher/lower than ±0.5 were deleted to avoid intercorrelation. Resulting in a final set of 33 landscape metrics and eight land covers used for clustering. To derive comparable landscape types from the 500*500 meters grid cells, a k-means cluster analysis using R and Vegan package version 2.5-6 was calculated. The Hubert index to visualize and determine the optimal number of clusters was used (Charrad et al., 2014). In this case, nine was the optimal number of clusters.

5.4.2. Statistical analysis of landscape structure and presence of *O. cassina* and *R. palmarum* in the oil palm plantation

NMDS was used to show graphically the relationships between the landscape characteristics, land cover and pest occurrence. In the study, the metaMDS function of the Vegan package for R 2.5-6 was used (Oksanen et al., 2019). The direction and length of the arrows in the NMDS show the gradient and correlation between the variables and the ordination (Oksanen et al., 2019). After calculating a three-dimensional NMDS, with principal component rotation, after 20 tries, two convergent solutions were found with minimum stress (0.153) (Clarke, 1993).

To visualize the abundance of *O. cassina* and *R. palmarum,* the point size to the average number of individuals for each year was adjusted. In the study, a Nemenyi test and the non-parametric Kruskal-Wallis *post hoc* test were performed to assess significant differences. Tests were completed for:

1) *O. cassina* and the years (between 2016 and 2018)

2) *R. palmarum* and the years (between 2016 and 2018)

3) *O. cassina* and the years (between 2016 and 2018) among each cluster.

4) *R. palmarum* and the years (between 2016 and 2018) among each cluster.

5.5. Results

5.5.1. Analysis of landscape structural properties of the Macondo plantation

The cluster analysis showed that the Macondo plantation has high proximity index, meaning high connectivity among the vegetation types. The landscape structure of the Macondo plantation is characterized by nine LSTs grouped according to their similarities in the landscape metrics and land cover (Figure 14, Table 3). The LSTs range from very heterogeneous and connected to homogeneous and fragmented landscape types. Macondo plantation is characterized by the following landscape structure characteristics (Figure 14, Table 3):

Table 3 Description of the LST in the Macondo plantation (source: author)

No	Name	Area (%)	Color
1	**High landscape connectivity between the gallery and riparian forests patches and water bodies:** This LST is the largest among other landscape types. It covers most of the area in the center of the plantation and has a high landscape connectivity index for gallery and riparian forests. The dominant vegetation is oil palm (70%), open areas (20%), and gallery forests (4%). Most of the water bodies present on the plantation are under this LST (Plate 1).	39,88%	
2	**Heterogeneous landscape and high connectivity with different vegetation types of forests, natural grasslands and oil palm**: This LST the oil palm (52%), open areas (30%), and gallery and riparian forests (15%) are the dominant vegetation covers. The natural grasslands and secondary vegetation are almost 2% of the land cover. Most of the grid cells that belong to this type are in the center of the plantation. Other grid cells are dispersed throughout the plantation. In this type, there is high connectivity among the vegetation covers. There is high landscape diversity because of the different vegetation covers (Plate 2).	16,74%	

3	**High landscape connectivity between forest patches and homogeneous landscape:** Secondary or transition vegetation is the dominant vegetation type (85%) in this LST. The grid cells are mainly at the border of the plantation. This landscape type has high connectivity (proximity index) in wood production area but low landscape diversity and mean patch size. The low number of vegetation types within the landscape types shows low landscape diversity (Plate 3).	1,16%	
4	**High connectivity and homogeneous landscape with natural grasslands, open areas with little vegetation, and oil palm**: This LST consists mainly of natural grasslands (60%), and to a lesser extent, oil palm (18%) and open areas (12%). The grid cells are grouped in the center of the plantation. In this landscape type, the patches of natural grasslands are closer to each other than other vegetation types (Plate 4).	4,82%	
5	**High landscape connectivity dominated with secondary or transition vegetation and oil palm**: Secondary vegetation (41%) and oil palm (18%) are the representative vegetation type. The landscape has high landscape connectivity. Grid cells are mainly at the border of the plantation (Plate 5).	8,28%	

6	**Low configurational heterogeneity with wood production and gallery and riparian forests vegetation types:** In this LST the wood production area (46%), oil palm (22%), and open areas with little vegetation (16%) are the dominant vegetation cover. Gallery and riparian forests are about 10% of the total area. Wood production patches are larger than other vegetation patches (Plate 6).	5,12%	
7	**Homogeneous landscape dominated by natural grassland vegetation**: Natural grasslands account for 72% of the total area, followed by 23% of secondary or transition vegetation. The grid cells are mainly in the center (conservation areas) of the plantation (Plate 7).	4,74%	
8	**Homogeneous landscape dominated by oil palm vegetation**: Oil palm and open areas (e.g., roads) are the dominant land cover (almost 98%). To a lesser extent, the gallery and riparian forest, mixed forests, secondary and transition vegetation and water bodies comprise 1.68% of the total land cover. In this type, the oil palm plantation has a larger edge perimeter than other vegetation types. The low landscape diversity relates to a low number of vegetation types within the grid cells (Plate 8).	12,78%	

9	**Homogeneous and fragmented landscape dominated by open areas and oil palm vegetation**: The oil palm vegetation covers almost 60% of the total area of cells categorized in this landscape type, followed by open spaces and secondary or transition vegetation. The grid cells are at the border of the plantation. Few grid cells are in the center of the plantation (Plate 9).	6,49%	

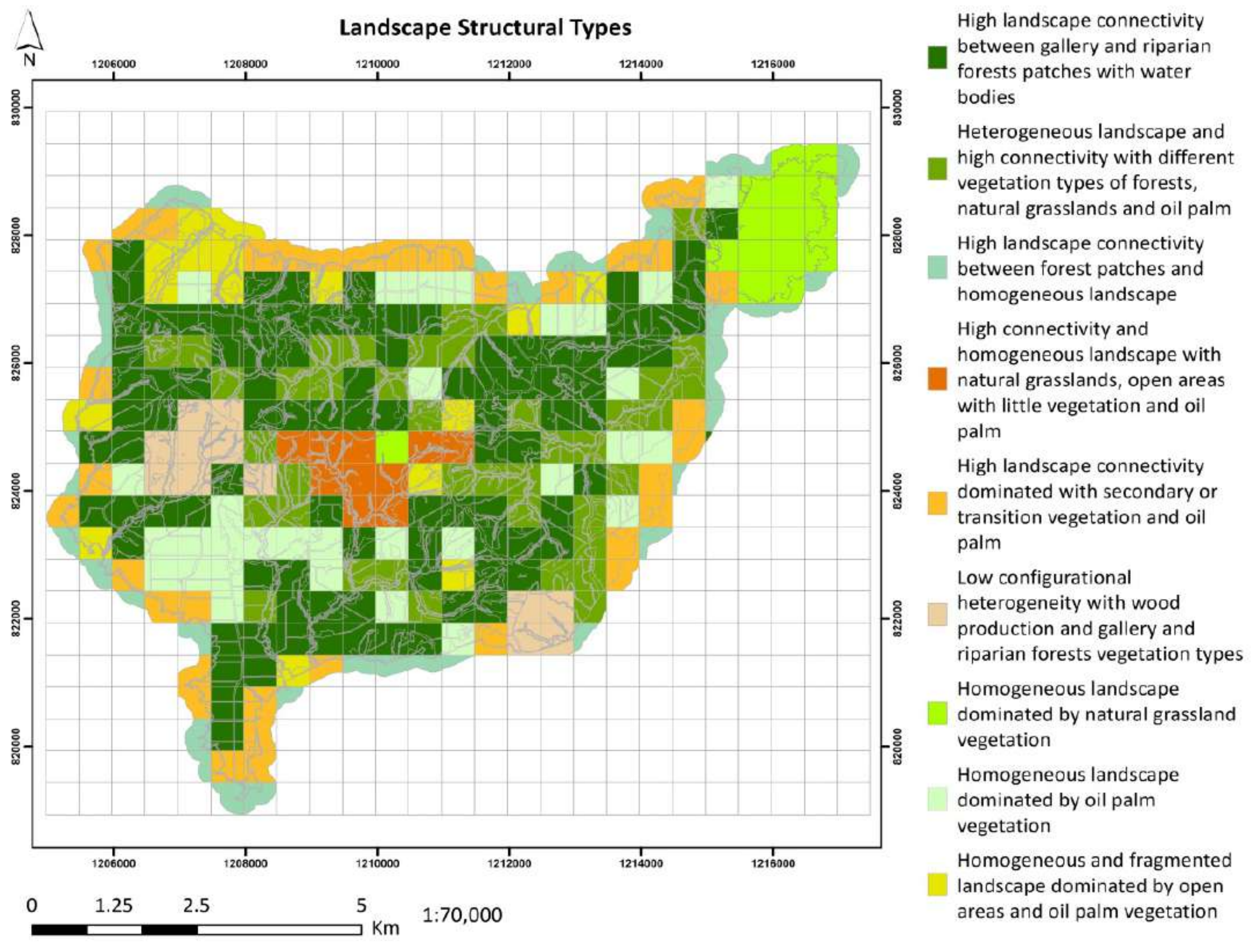


Figure 14 Cluster analysis – LST present in the plantation (source: author)

5.5.2. Landscape structural properties and pest occurrence

The NMDS ordination with a stress level of 0.153 is well fitted. The ordination graph shows a separation of the LSTs dominated by secondary or transition vegetation (STV) on the left side and oil palm plantation (OP) and gallery and riparian forest (GRF) on the right side of the first NMDS axis. The gradient displayed along the second NMDS axis depicts the change between mixed forests (MF) and natural grasslands (NG) (Figure 15). The presence of the species relates significantly ($p < 0.001$) to gallery and riparian forests, mixed forests, oil palm plantations, open space and secondary and transition vegetation (Appendix 1, Appendix 2). The presence of *O. cassina* is also significantly related to natural grasslands and water bodies (Appendix 1). In the year 2018, *O. cassina* is more closely related to oil palm plantation than in 2016 at a greater distance to each other, such as forest plantation. With *R. palmarum,* the number of individuals in 2018 relates to secondary and transition vegetation (Figure 15).

The presence of *O. cassina* relates significantly to the ordination ($p \leq 0.001$), showing a moderate and non-significant relationship to the LST 1 and 2 with high landscape connectivity between natural habitats, presence of open areas with little or no vegetation, oil palm, and fragmented landscapes (Figure 15). The presence of *R. palmarum* relates significantly to the ordination ($p \leq 0.001$), with a relationship on the second axis. The graph shows an increasing abundance of *R. palmarum* with secondary and transitional vegetation. However, the relationship between the presence of the species and the vegetation type is weak (Figure 15).

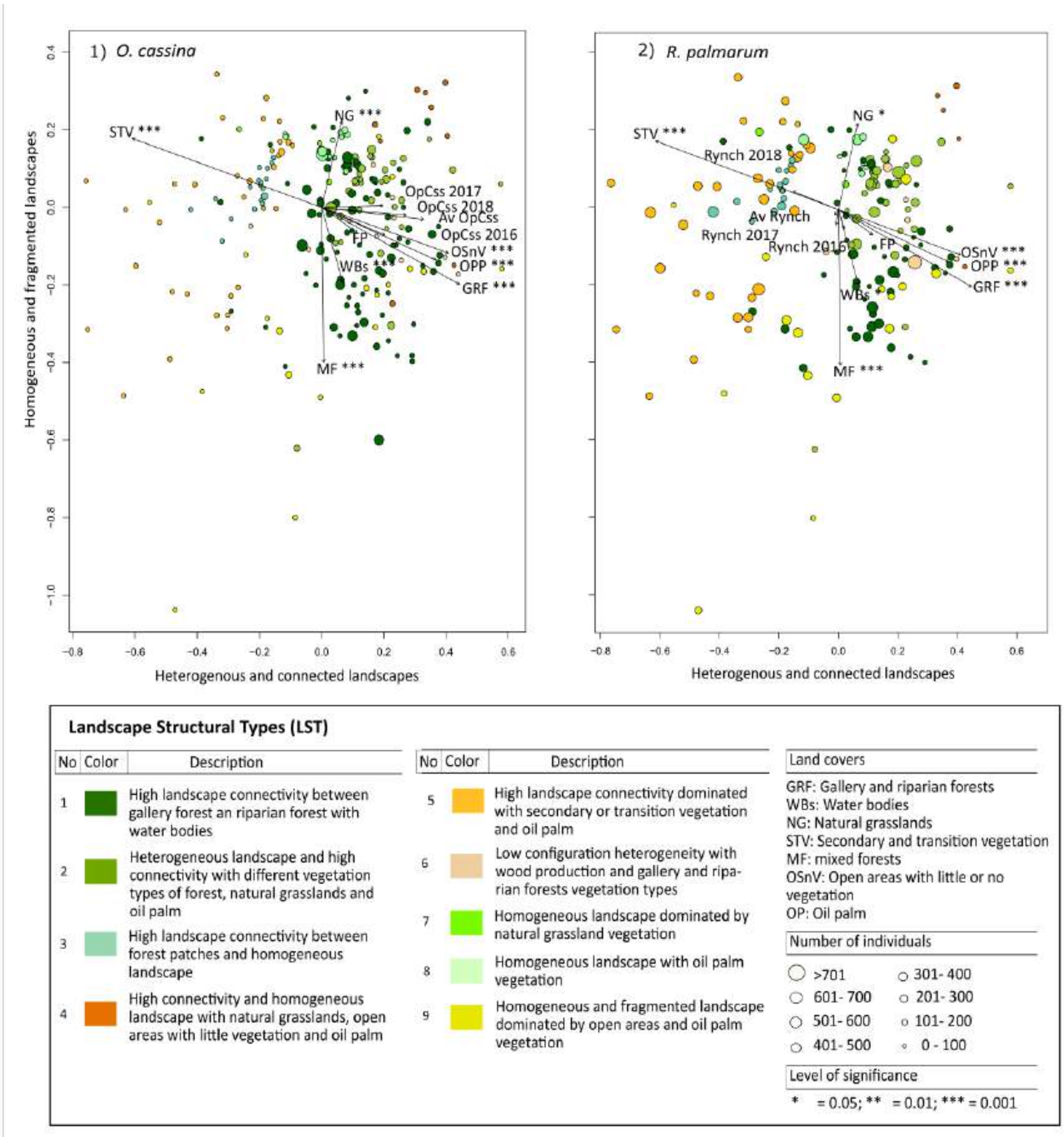


Figure 15 NMDS ordination mapping the landscape structural types, land cover and an average number of individuals. The bold letters represent the average number of individuals between 2016 and 2018. Land covers and O. cassina and R. palmarum were fitted as vectors against the NMDS ordination of the landscape structure types. The average number of individuals was used to visualize the abundance of species as point size regarding the landscape structural type into the NMDS ordination (source: author).

The number of individuals of *O. cassina* is significantly different in 2018 (median) compared to 2016 (median) and 2017 (median) (Figure 16). The number of individuals of *R. palmarum* is not significantly different in all three years (Figure 16). For *O. cassina*, 2018 and 2016 are more similar, and to a lesser extent 2017.

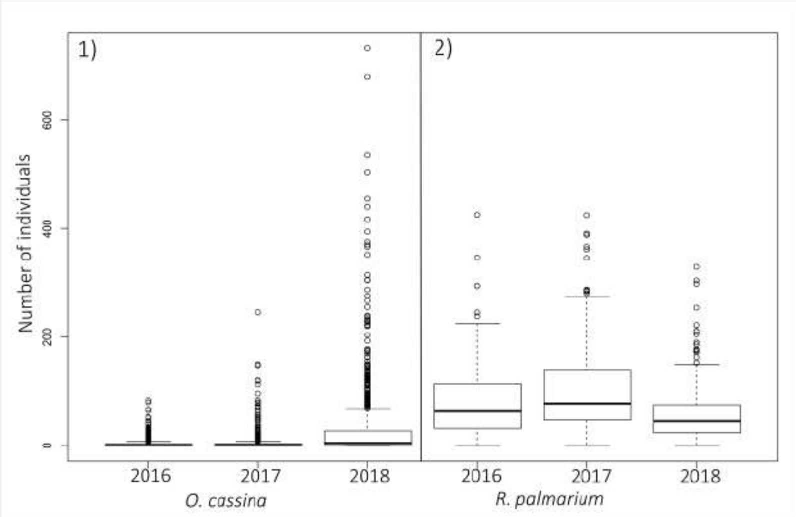


Figure 16 Box whisker plot of the abundance of the two pests 1) O. cassina and 2) R. palmarum in 2016 and 2018. Significant differences were calculated using a Kruskal–Wallis ANOVA and a Nemenyi post hoc test. Bonferroni correction was used for multiple testing. Letters show homogeneous groups (p < 0.005) (source: author)

Overall, the abundance of *O. cassina* is significantly higher in 2018 except in LST 3, 6 and 9. On the contrary, *R. palmarum* presents more changes in the number of individuals than *O. cassina* through the years and landscape structural types. The number of individuals is highest in 2017, and significantly different in LST 1, 3, and 7. In line with the results of the ordination diagram, *R. palmarum* mostly appears in LSTs 7 and 8 which have low landscape diversity and dominated by one land cover, for instance, natural grasslands or oil palm (Figure 17).

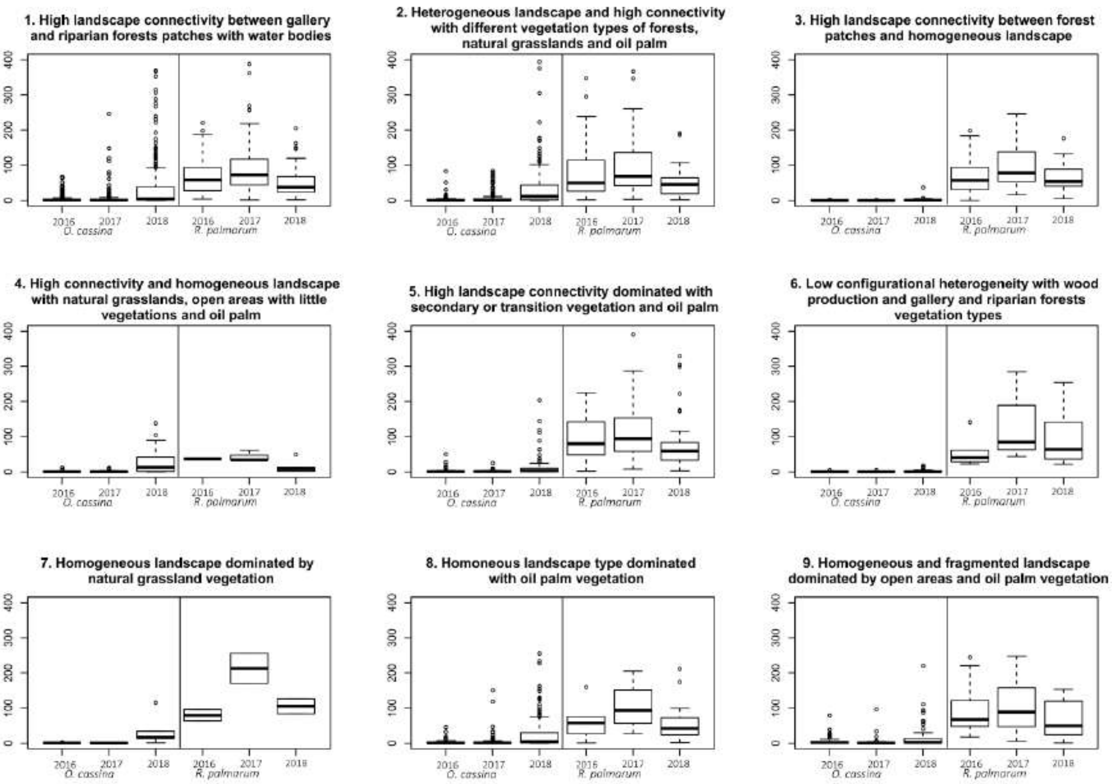


Figure 17 Box whisker plot of the landscape structural types and two pests in 2016 and 2018: a) O. cassina and b) R. palmarum. Significant differences were calculated using a Kruskal–Wallis post hoc test after Nemenyi. Bonferroni correction was used for multiple testing. Letters show homogeneous groups (p < 0.005) (source: author)

5.6. Discussion

5.6.1. LST in the Macondo plantation and the occurrence of *O. cassina* and *R. palmarum*

The LSTs divide the plantation into homogeneous, interpretable spatial units within the plantation (Celebi et al., 2013). The need for ecologically meaningful classifications or typologies has been raised in many previous landscape studies using multivariate, synergistic methods (Bryan, 2006). These methods are suitable for providing information on landscape characteristics of anthropogenic or cultural landscapes, such as oil palm plantations. Mapping the LST provides a visual classification of landscape characteristics on the plantation.

The largest area on the plantation is covered by LST 1 and LST 2, which represent high connectivity and heterogeneity. This suggests that the plantation is a heterogeneous agricultural landscape with high landscape connectivity, low landscape fragmentation (Lang & Tiede, 2003; McGarigal & Marks, 1994). The landscape composition of agricultural landscapes influences de distributions and the occurrence of flora and fauna species: vegetation diversity will affect habitat availability of fauna, some of which are parasitoid and predators of agricultural pests (Bennett et al., 2006). Species richness depends on the land mosaic and interacts with the landscape, for example, the effect of the nearby forest and oil palm, the structure complexity, the habitat diversity and connectivity (Koh, 2008b).

Additionally, the Macondo plantation has different vegetation types, ranging from natural grasslands to oil palm with diverse landscape elements (high diversity index – Shannon diversity index). These results show the relationship between diverse landscape elements and species richness, as highlighted by Bennett et al. (2006). The Shannon Diversity Index has been used to predict species richness by measuring landscape diversity at the farm level (Weibull et al., 2000; Weibull et al., 2003). Therefore, is possible to argue the Macondo plantation has high diversity landscapes that can host different species, some of which can control agricultural pests. The index can also show land use change (from heterogeneous to homogeneous or vice versa) by measuring the landscape diversity throughout time, as shown by Amaral et al. (2019). The Macondo plantation has heterogeneous (LST 1 – LST 3) and heterogeneous (LST 4 – LST 7) landscape types. Further landscape diversity measures in different years are needed to assess the land cover change in the LSTs in time in the Macondo plantation.

Heterogeneous oil palm plantations might be an option to minimize biodiversity loss in the tropics (Foster et al., 2011). For instance, shaded coffee plantations in Colombia have become a refuge for local species of flora and fauna (Somarriba et al., 2004). Several studies argue that the complex agricultural matrix of coffee plantations increases species abundance of bees, ants and fungi that control pest populations (Perfecto et al., 2003; Perfecto & Vandermeer, 2002, 2008; Somarriba et al., 2004). Also, heterogeneous and connected agricultural landscapes promote better pest control increases compared to simpler agricultural landscapes (Chaplin-Kramer & Kremen, 2012). The results show a first approach to assess landscape structure in an oil palm plantation in relation to pest abundance. The results show that homogeneous landscape types are related to pest abundance, in this sense is possible to argue that because of habitat heterogeneity and complex agricultural matrix more species control pests in the oil palm plantation, and enhancing pest control service (Gray et al., 2016; Tscharntke et al., 2005). Gallery and riparian forests in the plantation might host arthropods as potential predators of defoliating pests, as found by Gray et al. (2016). For instance, aphid populations in soybean crops were reduced by populations of coccinellids as a function of the diversity of natural habitats in the agricultural diversity landscape (Gardiner et al., 2009).

Previous research findings of Bhagwat and Willis (2008) conclude that these heterogeneous oil palm plantations host more generalist species than endemic or specialists species. However, generalist and specialists species require different landscape management strategies to maintain natural enemies for pest control and local biodiversity (Chaplin-Kramer et al., 2011). A landscape strategy might be to maintain and improve the nine LSTs in the Macondo plantation. In this regard, Bennett et al. (2006) argued that landscape connectivity and heterogeneity support viable fauna and flora, considering island biogeography (MacArthur & Wilson, 2016) and metapopulation models (Levins, 1969). In the theories, forests fragments within agricultural settings can facilitate movement and colonization of local species from and to forest patches (Laurance, 2004). Connected forest fragments increase plant diversity and species richness through the movement of species from the source to a recipient habitat (spillover effect) (Brudvig et al., 2009). Spillover effect in oil palm plantations has been documented for butterflies (Lucey & Hill, 2012), ants, birds and bats (Lucey et al., 2014; Maas et al., 2016) and dung beetles (Gray et al., 2016), all of which are important for biological control. In this sense, connected forest patches in the Macondo plantation can support flora to create habitats and enable the spillover effect for viable populations of pest predators of *O. cassina* and *R. palmarum*. Besides, connected and heterogeneous landscapes in the plantation create a complex agricultural matrix to support several local fauna for conservation perspectives.

Homogeneous landscapes and open areas with little or no vegetation relate to an abundance of pests. The results reveal that *O. cassina* is present in open areas with little or no vegetation and related landscape structural types with low heterogeneity, high connectivity, but dominance of one or two vegetation types. These results are consistent with Mexzón & Chinchilla (2011). The authors reported that the populations of the *O. cassina* increase in the open areas and move to the oil palm plantations. Populations of *R. palmarum* increased in homogeneous landscape structural types. These results are in parallel with Baguma et al. (2019). They demonstrated that plantations near natural vegetation had a lower mean incidence of the weevil. This supports the argument that natural vegetation (e.g. gallery and riparian forests) provides biotic entities that regulate pest populations (Baguma et al., 2019).

5.6.2. Using *k-means* as clustering method and the NMDS as ordination method of multivariate data

The k-means algorithm was used for several reasons. First, it is the most widely used algorithm (Celebi et al., 2013). Second, it is consistent and can detect natural groupings in the landscape (Jain & Dubes, 1988). Third, it is a method well established to find the optimal clustering of the data (Bryan, 2006). Fourth, the k-means classification is simply to examine the multidimensional structure of the data. Finally, it is used to analyze multivariate data (Jain, 2010). Additionally, non-multidimensional scaling (NMDS) is one of the most common ordination methods because: 1) can give the strongest possible fit to pair-wise dissimilarities among variables (Hui et al., 2015: 400); 2) it avoids the assumption of linear relationships among variables (McCune & Grace, 2002: 125); and 3) it allows the use of any distance measure (McCune & Grace, 2002:

125). Prior studies have tested landscape characteristics using cluster analysis to classify similar spatial patterns of forest types and using altitude and vegetation gradients (Long et al., 2010; Partington & Cardille, 2013). In the results, nine optimal LST, or clusters were obtained. The LST reveals the plantation's landscape characteristics: connectivity and heterogeneity. LST illustrates the anthropogenic influence ranging from high landscape connectivity, between gallery and riparian forests patches with water bodies, to homogeneous and fragmented landscape dominated by open areas and oil palm vegetation.

5.7. Conclusion

LSTs from the study area allow for an in-depth understanding of the relationship between the landscape, biodiversity, and management practices to support sustainable land management. The results encourage the implementation of heterogeneous oil palm plantations to support local fauna and benefit from ecosystem services. From the results, it is possible to confirm that a heterogeneous plantation, by integrating landscape connectivity and vegetation heterogeneity, enhances the role of the local diversity to control agricultural pests.

5.8. Overview of the Chapter

The results of this chapter provide information on the landscape characteristics of the Macondo plantation and its relation to the presence of the *O. cassina* and *R. palmarum*. The results prove that a heterogeneous and connected agricultural landscape enhances pest control services.

Research question: Which landscape structural properties characterize the landscape of the oil palm plantation in Mapiripán, Meta, Colombia?

Evidence:

The Macondo plantation has nine clusters or landscape structural types (LST). The LST are grouped according to their similarities in the landscape metrics (proximity, edge density, total edge, mean patch edge, Shannon's diversity, Shannon's evenness, and dominance) and land cover (proportional area). The first three LSTs have high landscape connectivity index and over two vegetation types (landscape diversity). The next three LSTs have high connectivity among forest patches but less than three vegetation types (low landscape diversity). The last three LSTs are fragmented and homogeneous landscapes mainly dominated by oil palm vegetation (Figure 14).

Research question: How are these dominant landscape structural properties related to the presence of *O. cassina* and *R. palmarum*?

Evidence:

LSTs with low configuration, homogeneous and fragmented tend to have a higher occurrence of the pests *O. cassina* and *R. palmarum*. The presence of *O. cassina* is significantly related to open areas with little or no vegetation, oil palm, and fragmented landscapes. *R. palmarum* is significantly related to secondary and transitional vegetation. However, the relationship between the presence of the species and the vegetation type is weak (Figure 15, Figure 16, Figure 17, Appendix 1, Appendix 2).

5.9. Appendix

Appendix 1. NMDS ordination r values showing significance values to the axis, land cover and O. cassina abundance for 2016 to 2018 and average.

Item	1	2	r2	r
Forest plantation	0.59575	-0.80317	0.0109	0.245
Gallery and riparian forest	0.86352	-0.50431	0.2099	0.001 ***
Mixed forests	0.11274	-0.99363	0.2237	0.001 ***
Natural grasslands	0.58911	0.80805	0.0851	0.001 ***
Oil palm plantation	0.99995	-0.00954	0.0683	0.001 ***
Open spaces with little or no vegetation	0.97511	-0.22171	0.1044	0.001 ***
Secondary or transition vegetation	-0.99574	0.09225	0.4744	0.001 ***
Water Bodies	0.27474	-0.96152	0.0926	0.001 ***
O. cassina 2016	0.72831	-0.68525	0.0132	0.186
O. cassina 2017	0.99154	0.12976	0.0131	0.189
O. cassina 2018	0.99961	0.02775	0.0342	0.012 *
O. cassina average	0.99997	-0.00764	0.0430	0.004 ***
Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Appendix 2. NMDS ordination r values showing significance values to the axis, land cover and R. palmarum abundance for 2016 to 2018 and average.

Item	1	2	r2	R
Forest plantation	0.86203	-0.50686	0.0242	0.199
Gallery and riparian forest	0.90763	-0.41977	0.3177	0.001 ***
Mixed forests	0.01789	-0.99984	0.2149	0.001 ***
Natural grasslands	0.30863	0.95118	0.0675	0.017 *
Oil palm plantation	0.92629	-0.37681	0.2051	0.001 ***
Open spaces with little or no vegetation	0.95786	-0.28725	0.2411	0.001 ***
Secondary or transition vegetation	-0.95125	0.30844	0.5160	0.001 ***
Water Bodies	0.33081	-0.94370	0.0595	0.021 *
R. palmarum 2016	0.40583	-0.91395	0.0075	0.650
R. palmarum 2017	0.05711	-0.99837	0.0038	0.812
R. palmarum 2018	-0.94336	0.33176	0.0332	0.112
R. palmarum average	-0.01771	-0.99984	0.0010	0.946
Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

6. Chapter 6: How landscape connectivity in an oil palm plantation provides social landscape values

Abstract

Specific agriculture system design could provide social values to people that work, live, and interact daily with them. In the present chapter, the results from participatory mapping with plantation workers and the results from the previous chapter on the structural landscape analysis of the plantation were jointly analyzed. First, a list of the perceived social landscape values was made through group interviews including beauty, biological control, food, freshwater, observation of flora and fauna, shade, soil formation, and taking a rest. During 35 participatory mapping interviews, the plantation workers located the perceived landscape values on a map of the plantation. Finally, the correspondence between landscape analysis from the previous chapter and the location of the perceived values are analyzed, revealing socio-ecological hotspots (e.g., *epiphytarium*). The results show a relationship between the design of the plantation, its landscape characteristics, and the social landscape values perceived by workers. Workers perceive most social landscape values in the prevalence of landscape connectivity and heterogeneity.

6.1. Introduction

While intensive large-scale agricultural landscapes such as plantations are often considered and designed as sole production areas, a certain plantation design can exhibit a complex spatial pattern of vegetation types (Najera & Simonetti, 2010). Landscape composition and configuration affect the distribution of goods and services in the landscape (Mitchell et al., 2013). Participants in the landscape perceive landscape values (Brown & Raymond, 2007), which reveal their priorities and preferences for landscape characteristics. Fagerholm and Käyhkö (2009) defined the concept of social landscape values, hereinafter SLVs, as the values that people identify, use, and appreciate in a given landscape. The social values show the benefits derived from an agricultural landscape aside from production. In a plantation, social landscape values are especially relevant for the many workers who spend a considerable amount of time managing and harvesting the plantation, and the well-being of which are seldom considered in values studies. Alessa et al. (2008) bring both ecological and social value into a spatially explicit concept and indicator in the term "socio-ecological hotspots". "Socio-ecological hotspots" are areas "that exhibit spatial coincidence of both high perceived landscape values and high rating for biophysical conditions" (Alessa et al., 2008: 28). Such hotspots are useful to identify which landscape characteristics fulfill both human and ecological needs. These hotspots are a "consequence of spatio-temporal landscape heterogeneity, interdependencies of socio-cultural, economic and biophysical variables, and cross- and multi-scale feedbacks between these variables" (Alessa et al., 2008: 28). The socio-ecological hotspots represent the interdependence between the social and the ecological domains in a specific space and time (Folke, 2006). Thus, the delineation between the social and the natural systems is artificial and arbitrary (Berkes et al., 2002).

Macondo plantation comprises oil palms and natural habitats (e.g., gallery and riparian forests, natural savannas). The plantation design and management practices have shaped a complex agricultural landscape featuring a mosaic of landscape types ranging from highly heterogeneous, connected and complex to simpler types, as shown in the previous chapter. By integrating both ecological structure and social values, the study provides clues as to the value of a concomitant application of land sharing and land sparing design to improve the socio-ecological sustainability of plantations.

The present chapter will provide answers to three empirical questions. 1) Which SLVs are perceived by workers to the land covers on the plantation? 2) How SLVs relate to landscape characteristics (LSTs) and socio-ecological hotspots? Finally, the chapter discusses the values perceived in the nature-enhanced industrial landscape and the identified socio-ecological hotspots.

6.2. Methods

The focus group interviews were used to elicit the perceived SLVs among workers of the Macondo plantation. Participatory mapping was then conducted with plantation workers to localize the perceived SLVs and their usage. After, the results were crossed with those of a landscape structure assessment (see section 5.5.1) to determine the correlation between landscape complexity and SLV, pointing to socio-ecological hotspots. Most of the interviewees worked in the agronomic department; the largest department in the company. Men and women of the focus group discussions and the participatory mapping had various job positions (from field worker to leaders) and time working in the oil palm plantation (less than a year to more than a decade). The focus group discussions and interviews took place outside the company's facilities to avoid biases and keep the anonymity of the interviewees.

6.2.1. Focus group discussions

Three focus group discussions (FGD) were conducted with six to eight workers each: FGD1: 8 (women: 1; men: 7), FGD2: 7 (men: 7), FGD3: 6 (men: 6). During the FGD, we identified the SLVs perceived by workers on the Macondo plantation. The participants were recruited randomly, to have a heterogeneous group considering job positions and diverse periods (in months) working there, between two and 120 months. The data was collected and transcribed in Spanish. Then the SLVs were listed as an input for the structured interview guide applied for the participatory mapping.

6.2.2. Participatory mapping and localization of social hotspots

In a second step, structured individual interviews were conducted with 35 plantation staff. The interview guide was designed after collecting the list of SLV from the focus group discussions. The mapping interviews added to the results of the focus group discussions, especially by providing spatial information on SLVs and specific explanations for their location. A random sampling of workers for mapping failed because of a lack of interest of several potential respondents. The mapping was indeed conducted outside working hours and required a certain commitment from the respondents. As a result, the 35 participants were recruited opportunistically and spontaneously after they visited the administrative office. The sample represents staff from different hierarchical positions, such as leaders, coordinators, supervisors and fieldworkers on the plantation. Possibly, the sample also includes staff that are more sensitive to nature, as their participation was based on interest in the mapping. Yet, recruiting workers was done until data saturation, a time at which no new locations or new experiences for the provision of SLVs were mapped. The frequencies and locations resulting from the mapping do highlight accurately the social value hotspots of the plantation.

The interview began with a brief description of the project, reading the consent form, and explaining the map and the process of the interview. A land cover of the Macondo plantation (size: 35 cm x 25 cm, scale: 1:60,000) was the central element as a boundary object in the interviews and, also, the mean used to locate spatially the perceived values. It was important for the interviewees first to identify or mark the major roads of the plantation to ensure orientation and recognize the sectors and other land covers. The interview guide was structured and required the participants to map a set of nine pre-identified values with specific color markers on the map and to comment (Table 4). The localization and description of a value on the map were recorded and transcribed. Participants could link their knowledge of the landscape with values at certain spots inside the plantation. The interviews lasted from 26 min to 1 h and 28 min. Each SLVs marked for the land covers (color-coded) was counted and digitized to depict their location and frequency in digital maps. The frequency is the number of times the participants mentioned the SLVs on a land cover map. The land covers and places with high frequencies were then identified as hotspots inside the plantation.

Table 4 Participatory mapping interview guide (source: author)

Interview guide	
Beauty	Where do you experience beauty?
Biological control	Where do you find biological pest control (animals or insects that can control the oil palm pests)?
Food	Where do you find food?
Fresh water	Where do you obtain fresh water (for refreshing or drinking)?
Observation of fauna	Where do you observe fauna? Which fauna have you seen in the plantation?
Observation of flora	Where do you observe flora? Which flora have you seen in the plantation?
Shade	Where do you find shade?
Soil formation	Where do you see soil formation?
Take a rest	Where do you take a rest?

6.2.3. Landscape structural assessment and landscape structural types

The information on landscape structure used in this chapter was acquired from the previous chapter (see Section 5.5.1). Then the LSTs were intersected with the social hotspots – perception of social landscape values (see Section 6.2.2) highlighting the socio-ecological hotspots inside the plantation.

6.2.4. Statistical analysis of social landscape values and landscape structural types

The landscape analysis (LSTs) and the localization of the SLVs for each land cover were jointly analyzed. A non-multidimensional scaling (NMDS) as an ordination method and the metaMDS function of the Vegan package for R 2.5-6 (Oksanen et al., 2019) was used to show in a three-dimensional graph the relationships between the land cover proportions, landscape metrics, and perceived SLVs. After calculating a three-dimensional NMDS with principal component rotation and after 52 attempts, two convergent solutions were found with minimum stress (0.153) (Clarke, 1993).

6.3. Results

6.3.1. Identifying SLVs in the Macondo plantation

The first result is the identification of social landscape values (SLVs) perceived by workers through the analysis of the focus group and interview transcriptions. Here, it is impressive to realize that workers, despite the plantation being a largely agricultural landscape and the existence of many natural areas in the region, have identified and used SLVs on the plantation. The SLVs are, in alphabetical order: beauty, biological control, food, freshwater, observation of flora and fauna, shade, soil formation, and taking a rest. Here it is notable that oil palms planted in 2009 in sectors 1, 2, and 3, as well as gallery and riparian forests, *epiphytarium*, and water bodies, share over two SLVs compared to mixed forests and open areas (Table 5).

Table 5 Description of SLVs (source: author)

SLV	Description	Localization
Beauty	Appreciate the landscape or where people can experience a sense of well-being **Quote:** “*In the epiphytarium […] it is beautiful because there you can find trails and there are many plants. It is a beautiful place, the panorama changes […]*” (supervisor, working on the Macondo plantation for 10 years, code: 20).	Oil palms in sector 1, *epiphytarium*, and open areas.
Biological control	Biological control is the process by which insects, small mammals and other beneficial organisms can reproduce in the plantation’s ecosystem and thereby control the pests that affect the oil palms. **Quote:** “*Inside the lots, there are nectariferous plants that attract beneficial insects for the palm*” (coordinator, working on the Macondo plantation for 9 years, code: 6).	Oil palms in sectors 1, 2, and 3, mixed forests.
Food	The workers bring their food to the workplace and discard the seeds, which germinate. Later they can sporadically find fruits and vegetables grown from these seeds within the oil palms. Wild fruits can be found within the gallery and riparian forest.	Natural grasslands, near the office, *epiphytarium*, gallery, and riparian forests, between

	Examples: Natural grasslands: wild passion fruit, wild grapes, guava. Near the office: Mango, soursop, avocado. *Epiphytarium*: Lemon, mango, wild grapes. Gallery and riparian forests: Carob tree, wild grapes, *coyol* nut, and *moriche* palm fruit. Between the oil palms in sectors 5 and 6: cashews, lemon. Sector 1: wild granadilla. Between oil palms: papaya, watermelon, pumpkins, banana. Along with the roads: pumpkins, wild granadilla. *Industrial area:* lemon, pineapple. Nursery: pineapples. **Quote:** "*There are pumpkins that anyone can take. One can take them [home] to make juice or stew*." (field worker, working on the Macondo plantation for 4 years, code: 12).	the oil palms sector 1, 5 and, along the roads, nursery.
Freshwater	Water bodies are present in the plantation where is possible to drink water.	Wetlands and streams present on the plantation (Jabón and Yamú) and *epiphytarium.*
Observation of fauna	Appreciate the local fauna inside the plantation. **Examples:** deer, tapir, crab-eating fox, eagle, anaconda, mountain lion, wild pig, monkeys, armadillo (the five species), black agouti, red deer (rare species) anteater, giant anteater,	Oil palms, *epiphytarium*, water bodies, and open areas.

	crocodile, leopard, capybara, lowland paca, snake, bird, squirrel, turtle, several insect species, weasel, and otter. **Quote:** *"[Many] animals can be found almost throughout the plantation"* (coordinator, working on the Macondo plantation for 9 years, code: 2).	
Observation of flora	Interviewees localized areas where they could see local flora (e.g., *Mauritia flexuosa*), and wood production (e.g., *Acacia mangium, Melina sp., Tectona grandis, Cedru*s).	Gallery and riparian forests, wood production, *epiphytarium*, and natural grassland.
Shade	They could find shelter from the sun.	Under oil palms in sectors 1, 2, and 3 and gallery and riparian forests.
Soil	They saw more organic matter and dark brown soil.	Under oil palms in sectors 1, 2,

formation	**Quote:** "*The crop is always being pruned, compost is applied, there are nitrifying soil covers, and all of this cover—this organic matter—decomposes, and the formation of soil is evident, because even before, the layer of organic matter was very little or nonexistent, some consolidated soil layer was already visible*" (coordinator, working on the Macondo plantation for 9 years, code: 6).	and 3.
Taking a rest	Take a break to drink water, eat, or refresh.	Oil palms in sectors 1, 2, and 3 and *epiphytarium*.

6.3.2. Spatial representation of SLVs on the Macondo plantation

The maps provide a detailed spatial representation of the SLV identified by the interviewees (Figure 18). Figure 18 features the frequencies in which given SLVs were mentioned in total during the 35 interviews. All land cover types except mixed forests featured over two SLVs. On the maps, one can see that sectors 1, 2, and 3 with oil palms planted in 2009 provide the most services, as shown by the arrows.

Observation of fauna was generalized on the plantation, observed primarily in natural land covers as gallery and riparian forests. Also, oil palms throughout the plantation are part of a viable, though not natural, an ecosystem to observe fauna (Figure 18).

Interviews related **biological control** to the gallery and riparian forests in Sector 1 - emphasizing in 15 lots (they are surrounded by forests)-, and Sectors 3, 4, 5, and 6 (Figure 18). Local fauna has controlled pests' outbreaks in previous years in the plantation, such as small mammals, wasps, flies, and entomopathogenic fungus. Also, biological control was related to the flowering plants (*Senna reticulata* and *Urena lobata)* along the road between Sectors 1 and 2. The flowering plants are part of the IPM to host predators and parasitoids.

Shade and **taking a rest** tend to co-occur under old-grown oil palms in sectors 1, 2, and 3 (planted in 2009) and mixed forests (Figure 18). In this regard, one interviewee mentioned the following:

> *"[taking a rest] inside the lots. The advantage is that the palm is already tall and*

*provides shade for us and […] [there is] a good breeze" (*coordinator, working on the Macondo plantation for 9 years, code: 2).

Biological control, **shade**, **observation of fauna** and **water provision** SLVs were related to gallery and riparian forests, natural grasslands, and wetlands (Figure 18). These values tend to co-occur, as resting in the shade and drinking water provide time and an opportunity to observe nature:

> *"There are many forests in the plantation, and people go there to look for water. Frequently, there are gallery and riparian forests at the end of the lots. These forests are very pleasant places to go and drink water or find shade. They are good places to see birds"* (coordinator, working on the Macondo plantation for 4 years, code: 25).

For interviewees, **soil formation** occurs primarily under oil palms, especially sectors 1, 2, and 3, planted in 2009. In these sectors, since 2009, the biomass (e.g., oil palm leaves) is left on the ground to add organic matter to the soil, as part of the soil management practices (Figure 18). Workers observed newly formed dark brown soil. They see this as the result of the soil-friendly management practices, especially the regular pruning of the palms. Leaves are left on the ground to add organic matter to the soil.

It is interesting to observe that **beauty** was mainly in the *epiphytarium* and the oldest oil palms in sector 1. Sector 1 is surrounded by gallery and riparian forests, streams and wetlands. The epiphytarium is a conservation area, where the environmental office implements research projects towards biodiversity conservation. Interviewees related **beauty** in these areas that exhibit features of local fauna, flora, and oil palms (their working place) and where they could observe and hear fauna, while working (Figure 18).

Only **food** was in specific areas of the plantation compared to other SLVs. For instance, mangos were planted for ornamental purposes near the office, and workers pick their fruits. Other fruit trees and vegetables grow spontaneously where people regularly meet to eat. Wild fruits, proper to the local flora diversity (e.g., wild grapes) can be found in natural grasslands and gallery and riparian forests (Figure 18).

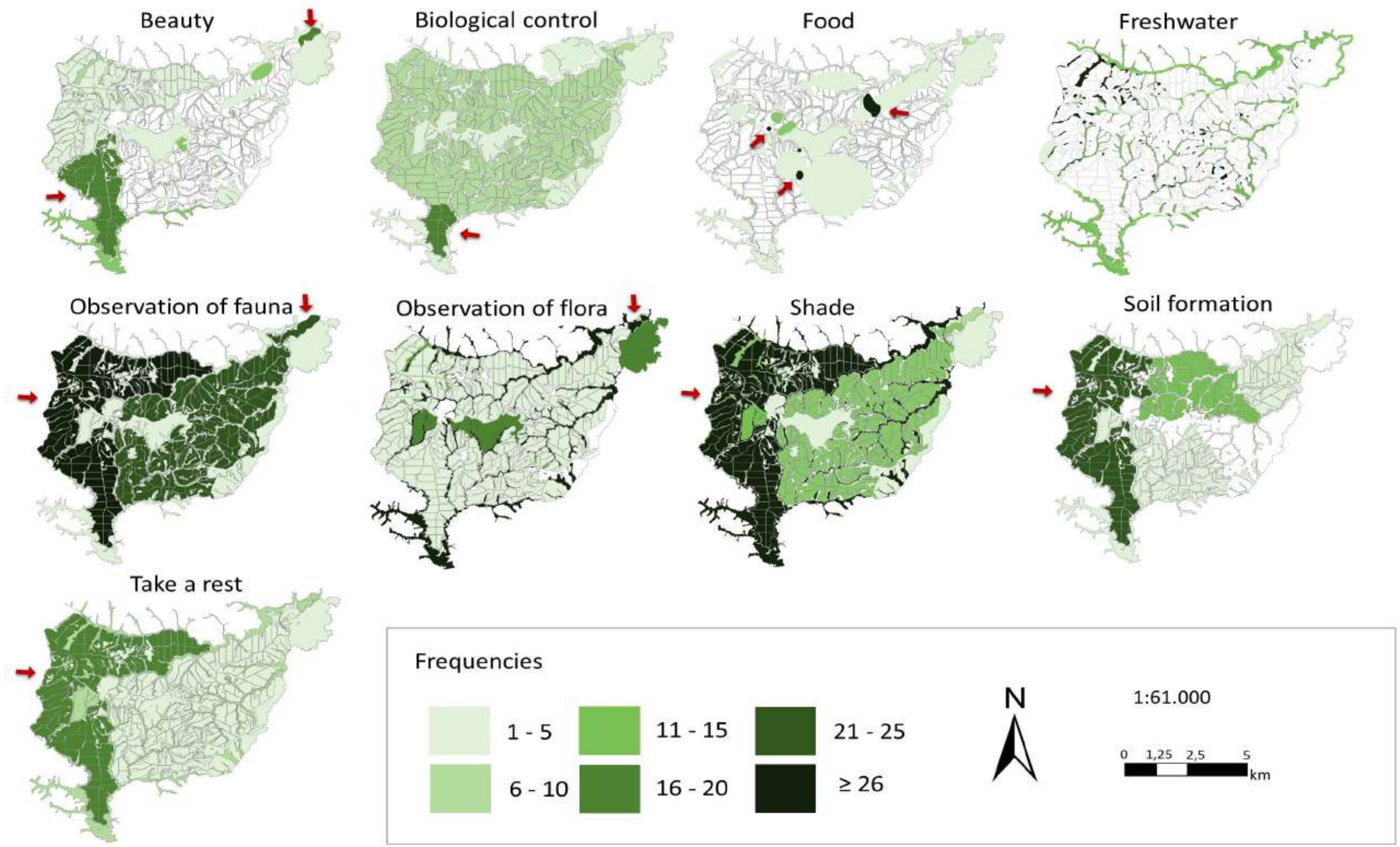


Figure 18 Localization of the SLV in the Macondo plantation (source: author)

6.3.3. SLVs relate to landscape characteristics (LSTs) and socio-ecological hotspots

Macondo plantation is characterized by connectivity (high/low), heterogeneity, and homogeneity with a dominance of vegetation types (see section 5.5.1). The nine LSTs are grouped according to their similarities in landscape metrics and proportional area of land covers (see Section 5.5.1).

Interviewees identified more SLVs associated with gallery and riparian forests, the *epiphytarium*, and oil palms, especially oil palms planted in 2009. Additionally, the LSTs with landscape connectivity and heterogeneity, which are also related to the socio-ecological hotspots, have higher frequencies than LSTs with homogeneous landscapes (Figure 19).

The interviewees identified biological control, shade, and soil formation across all LSTs, emphasizing the land cover of oil palms planted in 2009. For those SLVs, the LSTs with high connectivity and homogeneous landscape have the highest overall frequencies. The *epiphytarium* was frequently selected under the SLV beauty in the LST of "Homogeneous landscape dominated by natural grassland vegetation" (Figure 19). Observation of fauna was selected for LSTs containing gallery and riparian forests, water bodies, and oil palms, for example, for LSTs with high landscape connectivity and heterogeneity with the presence of different vegetation types such as forests, natural grasslands, and oil palms.

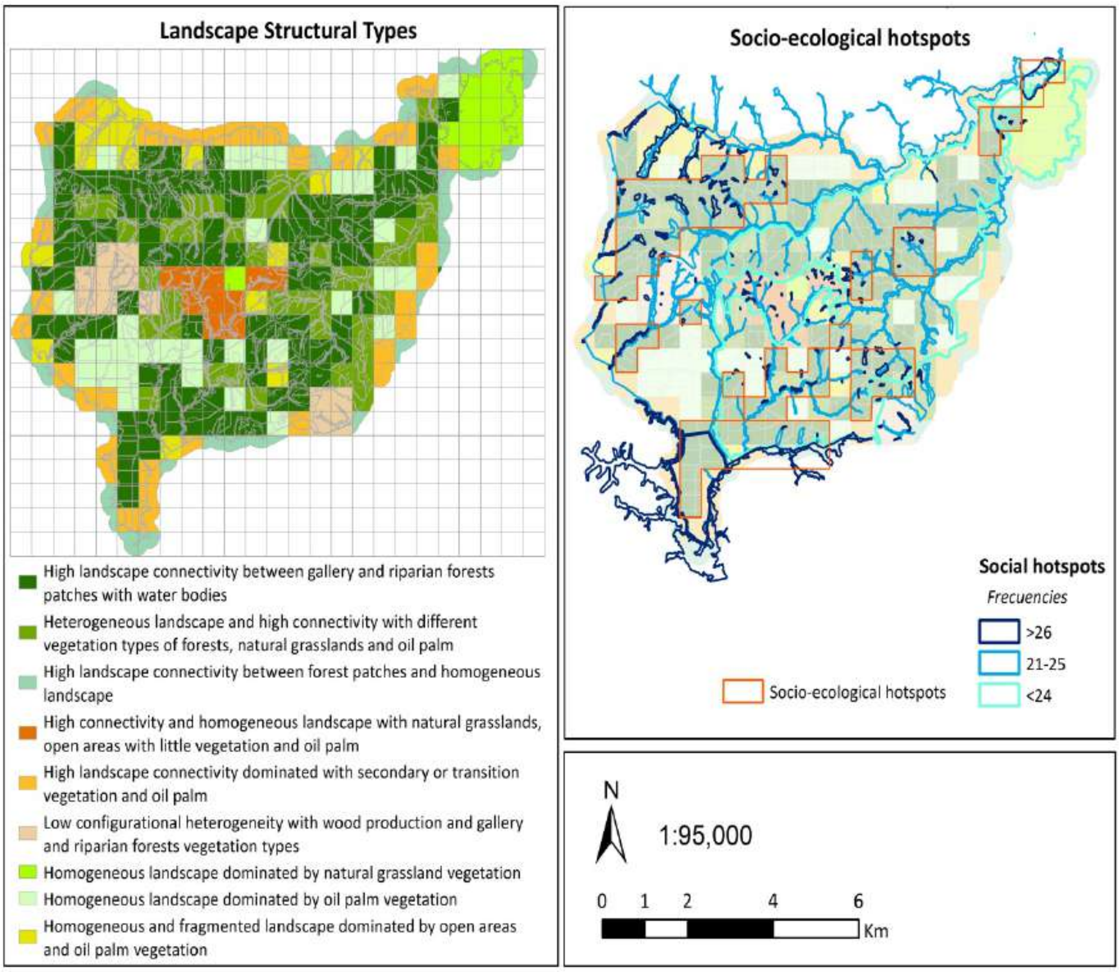


Figure 19 Identification of socio-ecological hotspots and the LSTs on the Macondo plantation (source: author)

The NMDS ordination graph illustrates the relationship of landscape characteristics (LSTs), land covers and perception of SLV in the Macondo plantation. The graph represents how the plantation's landscape characteristics (LSTs) influence the provision of SLV perceived by workers. NMDS ordination graph shows the gradient of LSTs dominated by high landscape connectivity and heterogeneity along the first axis (Figure 20). Along the second axis are the LSTs dominated by homogeneous, low configuration, and fragmented landscapes. All SLVs except beauty and food show a close relationship to LSTs that have high landscape connectivity, with the presence of gallery and riparian forests, open areas, oil palms, mixed forests, wood production, and water bodies. The arrows show similarities among the data. For instance, the results show high similarities among the SLVs as freshwater, shade, observation of flora, soil formation, and taking a rest, and the LSTs with high connectivity and heterogeneity. The SLVs showed close similarities among biological control and observation of fauna related to the LSTs with a higher presence of oil palms, gallery and riparian forests, and open areas with little vegetation. The analysis shows that workers understand and comprehend the landscape assessment and the LST structure is appreciated for values, such as observations of flora and fauna, shade, and soil formation. In the socio-ecological hotspots is possible to identify and localize almost all SLV and are related mainly to gallery and riparian forests, oil palm, and water bodies.

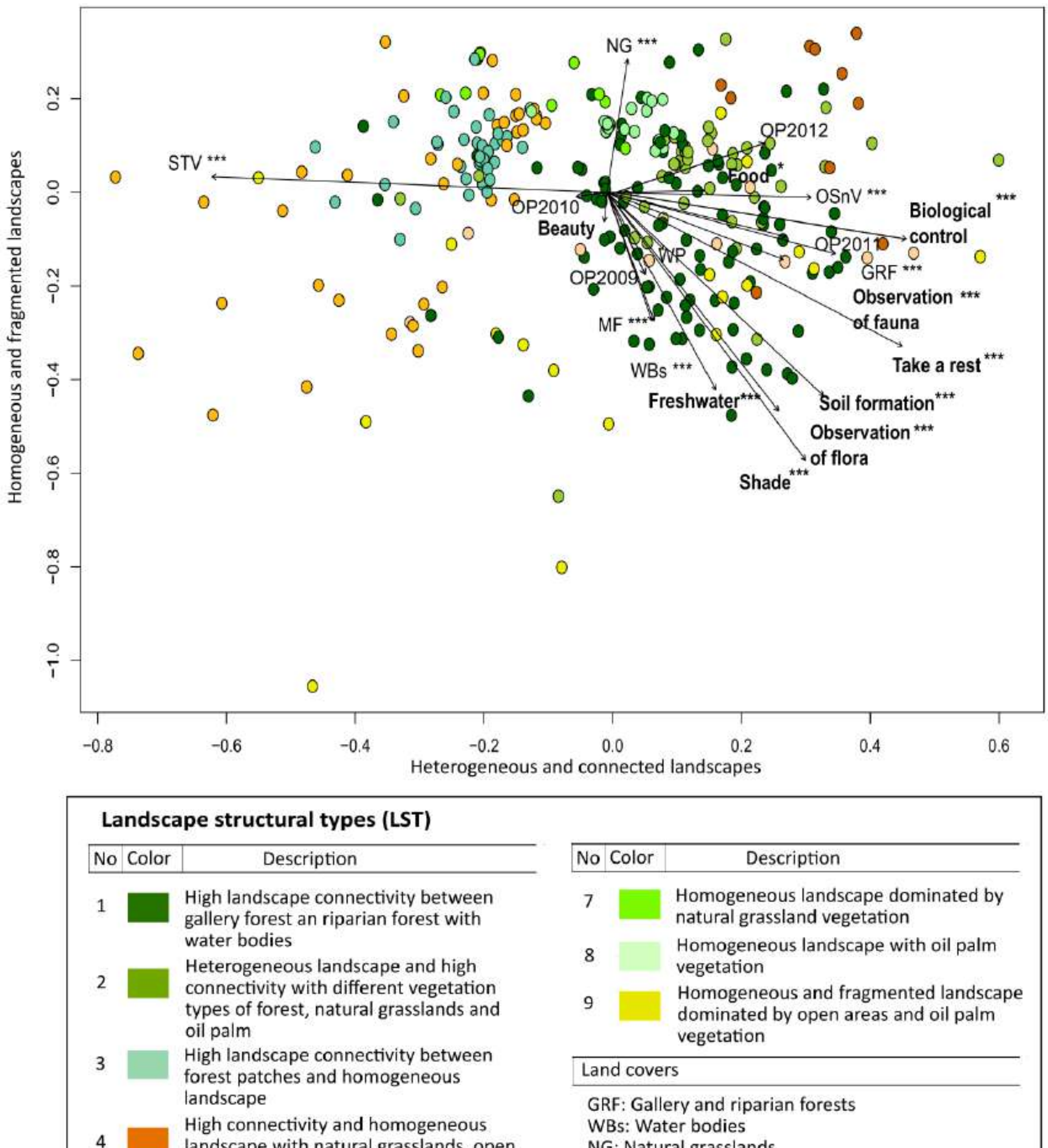


Figure 20 NMDS ordination mapping between the LSTs, land covers, and SLVs. The colors represent the LST. The bold letters are the identified SLV (source: author)

6.4. Discussion

The population included in nature-related research as participatory mapping is people living in a specific area (Brown, 2004; Rieprich & Schnegg, 2015), rather than working in it, as it is this case, plantation workers. Yet the well-being of workers on plantations, and in fact those involved in agriculture, is seldom addressed, contrary to the ecological sustainability of the production landscape.

From a theoretical perspective, the intense integration of workers and plantation employees with oil palm plantations is expected to bond with the landscape. According to Brown et al. (2015), people generate feelings and bonds for a place through social interaction and recognition of places that fulfill their lives (e.g. work). Despite the Macondo plantation being an industrial, agricultural landscape, workers do perceive material and immaterial SLV. The workers value the Macondo plantation for its design and landscape characteristics, which shows that workers have feelings and bonds with this industrial landscape, where they work and interact. Also, Fagerholm et al. (2012) argued that stakeholders can perceive multiple values on the landscapes where they interact and work daily. The identification and localization of SLVs on the Macondo plantation revealed workers do perceive, identify, and use SLVs in the landscape they work in.

According to Zube (1987), humans are active participants in the landscape through observation, thoughts, and feelings. The spatial arrangement of the landscape influence how people interact with the landscape they are active in (Zube, 1999). The spatial location of SLVs reflects the social acceptability of the land use, according to Brown et al. (2020). Plantation workers have accepted the oil palm plantation as current land use, where they benefit from those SLVs that occur because of the landscape configuration and composition of the Macondo oil palm plantation, as shown in Figure 20.

Industrial agricultural systems are perceived as homogeneous landscapes with low diversity, reducing biodiversity and oversimplifying landscapes (e.g., Foster et al., 2011). Yet, the results show workers do identify multiple SLVs, even in the industrial-agricultural system investigated. Importantly, the values are largely linked to the management practices as soil management (i.e., soil formation) and IPM (i.e., biological control) applied to the plantation and its nature-enhanced design. The particularity of this plantation's design and its landscape characteristics allows workers to perceive, identify, and use SLVs.

Previous studies have used participatory mapping mainly for the valuation of landscape values in rural communities (Fagerholm & Käyhkö, 2009; Plieninger et al., 2013; Rieprich & Schnegg, 2015) or land use planning of natural areas (Brown, 2004; Klain & Chan, 2012; Ramirez-Gomez et al., 2015; Ricaurte et al., 2014). More recently, Braslow et al. (2016) developed a guide to conduct participatory mapping of ecosystem services in agricultural landscapes in Latin America. However, participatory mapping has not been used to locate perceived SLV by workers. The results of the study relate to previous studies when participants perceive more SLV in heterogeneous and connected landscapes.

6.4.1. Landscape connectivity and heterogeneity as key properties that provide landscape values

Brown et al. (2020) and Brown & Weber (2012) suggest that landscape structure motivates a human–nature (landscape) relationship and the identification of values. First, landscape structure influences how humans perceive the landscape (Mitchell et al., 2013). Second, it can also change human behavior towards a landscape (i.e., the Macondo plantation) concerning future land use or a change in the provision of SLVs (Brown et al., 2015; Brown & Weber, 2012).

Socio-ecological hotspots reflect the valuable areas or "hotspots" to the social and ecological aspects (Karimi et al., 2015). Previous studies mapping socio-ecological hotspots in peninsula Alaska (Alessa et al., 2008) and Great Barrier Reef Australia (Karimi et al., 2015) have shown valuable areas for the inhabitants in terms of resources (for extraction, consumption, and commercial purposes) and biodiversity conservation. Mapping of socio-ecological hotspots has not been done in oil palm plantations. This study was the first to convey socio-ecological hotspots in an oil palm plantation. In the Macondo plantation, SLVs are more frequently perceived in locations with complex landscape structures (Figure 18, Figure 19). Workers identified and perceive more SLVs in areas of the plantation with higher amounts of landscape connectivity and diversity, for instance, in the oldest section of the plantation planted in 2009. The results show the hotspots are found in the gallery and riparian forests, the oldest oil palms (planted in 2009), and the *epiphytarium* (Figure 19). Thus, the social hotspots of SLVs corroborate with ecological hotspots and translate socioecological hotspots on the Macondo plantation.

The socio-ecological hotspots identified on the Macondo plantation disclose the effect of the management practices that enhance landscape connectivity (e.g., Alessa et al., 2008). For example, implementing the conservation areas (e.g., gallery and riparian forests, natural grassland) since 2009 has helped to reduce the negative impact of savanna fires -a common practice in rangelands of eastern Colombia (see Etter et al., 2008) as compared to other sectors. Inside the plantation, participants recognized that the burning can affect them. First, the fire can cause accidents and burn the gallery and riparian forests and animals inside the plantation. Second, the plantation might be severely damaged that the participants were afraid they might lose their job. Consequently, sectors 1, 2, and 3 are among the LSTs with high landscape connectivity and heterogeneity that presented higher frequencies of SLVs. Therefore, it was expected an increase in perceived SLVs in other sectors (e.g., 4, 5, and 6) over time.

The socio-ecological hotspots present in the Macondo plantation deserve special attention from a management perspective, as argued by Alessa et al. (2008). The general management, integrated systems and the environment offices should consider the socio-ecological hotspot in the plantation to improve both the ecological value and the well-being of workers, as measured through SLVs on the Macondo plantation.

However, workers also perceive values in homogeneous and fragmented parts of the plantation, yet to a lesser extent. For instance, food and shade were mentioned in low diversity LST. It is not surprising to find these material items to be valued where they can be at hand, right at the place of work. Thus, connectivity and heterogeneity are not the only determinants for a landscape to provide values: rate in interaction, time spent to observe and experience, and access surely obviously also play a role.

According to the results, the interviewees also mentioned the oil palm as a provider of SLV. Here is possible to argue, as interviewees spend more time inside the oil palm areas (e.g., working) than in other land covers, they have generated “stronger” feelings and bonds with such areas (Hidalgo & Hernandez, 2001). Therefore, oil palm land cover showed higher frequencies. However, it is the landscape heterogeneity that delivers the SLV for workers. For example, observation of fauna was related, more often, to oil palms and not natural land covers, but is the presence of the gallery forests, or the combination of land covers that support the diversity of species (Pardo-Vargas & Payán-Garrido, 2015). In the results, the observation of fauna was selected in the LST with high connectivity (e.g., high landscape connectivity between gallery and riparian forests patches with water bodies) as well as homogeneous and fragmented landscape (e.g., homogeneous and fragmented landscape dominated by open areas and oil palm vegetation). In the same line, and according to the literature, the wildlife uses oil palms as habitat, biological corridors, refuge and food provider (Höbinger et al., 2012).

6.4.2. Participatory mapping as a tool to identify and localize SLVs on the Macondo plantation

In participatory mapping research, people frequently mentioned what they can use or extract from the landscape, for example, food, fibers, areas for cultivation, or grazing areas (e.g., Fagerholm & Käyhkö, 2009; Rieprich & Schnegg, 2015). Workers in the Macondo plantation also mentioned material values, such as food or water, shade, and a place for resting. According to the biodiversity conservation management policy, staff may not hunt, fish, or burn any type of vegetation (see section 2.3.2). The staff can eat fruits and vegetables to vegetables or fruits having grown serendipitously on the plantation after seeds were spitted out in prior working seasons and could be especially found around working and resting areas. Of course, the extraction of plantation material, vegetation, and fauna is not allowed on the plantation. This explains in part why, in the study, material values were not dominating the list of SLVs. Rather, other values, such as observation of fauna or beauty, are more abstract and non-material, but equally frequently mentioned as material values.

The results confirm people localized beauty frequently in natural, highly connected and heterogeneous habitats such as forests, as found by Kaltenborn & Bjerke (2002). According to Brady and Prior (2020), the forests and the natural areas are appreciated as a complex ecosystem and give the observer opportunities for multisensory appreciation. Human perception of landscape aesthetics is complex and cultural background plays a role (Tribot et al., 2018). The results show that beauty is linked with the appreciation of fauna, flora, and older oil palms. These results confirm that beauty exists when people interact and experience nature, as stated by Rieprich & Schnegg (2015). Beauty represents the intrinsic or non-instrumental value of the natural ecosystems (Brady & Prior, 2020) present in the plantation.

Surprisingly, interviewees mentioned biological control as an SLV. The identification and precise mapping of biological control as an SLV reveal that plantation workers appreciate IPM is implemented. They could retrieve some health benefits from the IPM practices because it suggests less use of chemicals and enhances biological control service of local fauna (e.g., parasitoids, predators). Workers also mentioned soil formation as an SLV, which can appear even more surprising. Yet, soil management is central in Macondo plantation: cover crops and pruning material are left for composting. Mapping these values reveals workers understand both the management methods as the ecological background of it: they observe natural enemies and value the capacity of the local habitats to produce them.

The awareness and enjoyment of observing fauna, beauty, and ecological processes such as soil formation and pest predation may be fostered by the conservation and training programs implemented in the Macondo plantation. The reforestation, conservation, and awareness-raising on biodiversity programs may influence, direct, shape, or constrain the peoples' experience on the landscape and, in turn, their perception of SLVs (e.g., Beery & Wolf-Watz, 2014).

Places where people perceived SLVs reveal their collective importance within a landscape (Brown et al., 2020). These places represent where people spend most of the time working (e.g., oil palms), places of use, such as shade, or places that struck them for a particular reason, such as where they experience beauty. These can be named social hotspots. The natural areas present in the Macondo plantation provide several values, which fulfilled our expectations because it has been largely documented (e.g., Brown & Reed, 2000; Fagerholm et al., 2012; Kaltenborn & Bjerke, 2002). However, oil palms, especially the oldest palms (planted in 2009), also provide value to workers. The management practices, integrating nature within oil palms, and the complex landscape composition and structure of the plantation play a role in providing SLV to workers.

6.5. Conclusion

The Macondo oil palm plantation, despite being a monoculture, has been designed with land sharing and land sparing conservation effort and thus constitutes a heterogeneous agricultural landscape with a mosaic of local ecosystems (e.g., savannas, gallery, and riparian forests) and oil palms.

This study aimed to investigate whether a nature-enhanced design enabled workers of the plantation to perceive social landscape values in the place they work and to show how the landscape characteristics, more explicitly landscape connectivity and heterogeneity, provide these SLV. We found workers perceive, identify, and use the SLVs present in each land cover of the Macondo plantation. The landscape composition and configuration of the plantation are strong determinants of SLVs and may guide plantation design.

6.6. Overview of the Chapter

The results of this chapter show that landscape characteristics in an industrial agricultural landscape are important providers of SLVs for workers.

Research question: Which SLVs are perceived by workers to the land covers on the plantation?

Evidence:

The SLVs perceived by workers are, in alphabetical order: beauty, biological control, food, freshwater, observation of flora and fauna, shade, soil formation, and taking a rest.

Observation of fauna was generalized on the plantation, observed in natural land covers as gallery and riparian forests. Biological control was located mainly in the gallery and riparian forests in Sector 1. The SLV was also located in small patches of mixed forests with flowering plants (*Senna reticulata* and *Urena lobata*) in sectors 3, 4, 5, and 6. Those plants can host several pest predators. Shade, observation of fauna, take a rest, beauty and water provision tend to co-occur in old-grown oil palms in sectors 1, 2, and 3 (planted in 2009) and mixed forests. Soil formation occurs primarily under oil palms, especially sectors 1, 2, and 3, planted in 2009. Only food was in specific areas of the plantation compared to other SLVs (Figure 18).

Research question: How SLVs relate to landscape characteristics (LSTs) and socio-ecological hotspots?

Evidence:

Participants located more SLVs in the LSTs comprising landscape connectivity and heterogeneity (socio-ecological hotspots) as compared to homogeneous LST (Figure 19). In areas with high landscape diversity, participants located more than two SLVs. The landscape diversity is related to vegetation diversity and complex landscape heterogeneity. These landscape characteristics enhance the quality and quantity of SLVs perceived by workers. The reason behind, is that landscape structure motivates the human-nature relationship and the identification of values (Brown et al., 2020; Brown & Weber, 2012).

Almost all SLV show a significant relationship with landscape connectivity and with diverse vegetation types, such as gallery and riparian forests, open areas, oil palms, mixed forests, wood production, and water bodies (Figure 20).

7. Chapter 7: Which nature does nature-enhanced plantation create: a workers' perspective

Abstract

The nature-enhanced design of the Macondo plantation shall generate human well-being that creates a better working place. Little research has been done on how workers relate to and perceive nature (e.g., gallery and riparian forests) and non-natural areas (e.g., crops such as oil palm) in industrial agricultural landscapes. This gap is addressed by analyzing workers' perceptions of nature in the Macondo plantation. Workers are a key local population interacting with nature inside the plantation. This chapter aims to qualify the relationship of workers with the nature-enhancements on the plantation. The chapter claims that the values generated by the nature-enhancements legitimize the plantation both on the human and ecological dimensions.

The content analysis of transcripts from interviews and focus groups with workers depicting their perception of nature shows that workers derive a great variety of values from the nature integrated into the plantation. Workers experience an ambivalent relationship to nature on the plantation; they perceive benefits, fascination, risks, and fear. Workers perceive benefits for themselves and for other species because of the plantation design.

7.1. Introduction

The human-nature relationship is complex and reciprocal (Comberti et al., 2015). According to Comberti et al. (2015), human actions modify ecosystems to enhance the quality and quantity of goods and services that ecosystems provide. These actions can also maintain ecosystems' functioning (Comberti et al., 2015). Land sparing and land sharing in the agricultural landscape can integrate natural ecosystems and production areas (Grass et al., 2019; Perfecto & Vandermeer, 2010). Then, it is possible to argue that land sparing and land sharing approaches enhance the social landscape values to the agricultural system and human welfare (e.g., Comberti et al., 2015; Nisbet et al., 2020; Perfecto & Vandermeer, 2012).

Nature and wilderness are perceived as those areas untouched, pristine, and not managed by humans (Cronon, 1996). The unnatural areas are agricultural landscapes and cities and areas with little human intervention (e.g., parks, tree plantations) (Cronon, 1996; Jorgensen et al., 2007). Several studies show humans prefer managed areas and natural areas with some human intervention (Jorgensen et al., 2007). Natural and wilderness areas are also appreciated but evoke negative feelings such as insecurity and vulnerability (Jorgensen et al., 2007; Konijnendijk van den Bosch, 2012). However, natural areas, such as parks and areas with little human intervention, can offer mental health and a sense of belonging that might outweigh the negative feelings of these natural areas (Konijnendijk van den Bosch, 2012). Past experiences influence the positive or negative emotional affinity toward nature (Kals et al., 1999). Evidence shows that fear and fascination for natural areas are interlinked and influence how humans relate to nature and the level of environmental concern (e.g., Cronon, 1996; Jorgensen et al., 2007; Konijnendijk van den Bosch, 2012). Studies showed that nearby trees in urban areas have psychological and physical benefits for humans (Fuller et al., 2007; Nisbet et al., 2020). Agricultural landscapes usually comprise non-natural and natural areas. However, how these natural areas are perceived by workers in agricultural landscapes is poorly studied. Therefore, little research has been done on how people that interact, live, and work in an industrial-agricultural landscape, such as the oil palm plantation, relate to nature (e.g., gallery and riparian forests) and human-made areas (e.g., oil palm). In the project at hand, this gap is addressed by analyzing workers' perception of nature in an oil palm plantation in Mapiripán, Meta, Colombia.

The Macondo plantation design integrates natural areas (e.g., gallery and riparian forests) and non-natural areas (e.g., oil palms). Workers interact with the non-natural areas when they perform their daily tasks (e.g., pruning, harvesting) in the oil palm plantation. Also, workers observe and use the natural areas when they eat wild fruit and contemplate native fauna and flora inside the oil palm plantation. Therefore, the particular design of the Macondo plantation allows exploring the human-nature and the natural-non-natural (human-made) relationships.

The present chapter claims that the nature-enhanced plantation design generates human well-being that favors a better working place and biodiversity conservation. Plantation workers perceive the features of the oil palm and nature. The current management practices and plantation design implemented in the Macondo plantation have promoted the ecological processes translated into social landscape values (SLV) perceived by workers. In the previous chapter (Chapter 6) the SLVs perceived by workers were analyzed in view of the oil palm plantation landscape characteristics (for further information on landscape characteristics, see section 5.5.1)–the socio-ecological hotspots are spatially represented (Figure 19). This chapter aims at understanding how workers perceive nature inside the plantation and if they relate SLVs to management practices. The paper will provide the answer to the following empirical questions: 1) how is the relationship of workers with nature-enhancements on the plantation, in tangible terms (perception of management practices, social landscape values, and risks)? 2) how does the workers' perception of nature in the oil palm plantation reflect the naturalization process in the plantation?

7.2. Theoretical and conceptual considerations

For a complete theoretical and conceptual framework, please refer to section 3.

- Encounters with threatening aspects of nature may evoke strong fears (van den Berg & Konijnendijk van den Bosch, 2012; van den Berg & ter Heijne, 2005).
- Personality, past experiences, and gender is a significant variable if a person has a positive or negative experience in the wilderness (van den Berg & ter Heijne, 2005).
- Modern humans remain ''biologically prepared'' (Seligman, 2016) "through natural selection to learn fears of natural objects and situations that threatened the survival of the human species during evolution" (van den Berg & ter Heijne, 2005: 262).

- Nature must have the opportunity to survive in human-dominated areas (Achterberg, 2002; Schlosberg, 2009). This leads to a co-evolution process between the social and the nature spheres (socio-ecological system) (Fischer-Kowalski & Haberl, 2007). People interacting with the landscape perceive it as their own and associate it with the local landscape (i.e. naturalization process) (Peluso, 2012).

7.3. Methods

7.3.1. Data collection: focus group discussions and in-depth interview

Five focus group discussions (FGD) were conducted with 11 women and 25 men: FGD1: 8 (women: 1; men: 7), FGD2: 7 (men: 7), FGD3: 6 (men: 6), FGD4: 7 (women: 2; men: 5), FGD5: 8 (women: 8). During the FGD, we discussed on the following topics: perception of nature, perception integrating nature in the Macondo plantation, the perceived benefits and disadvantages.

Following, 35 in-depth interviews were performed. The interview comprised thirteen questions about the plantation. The first section of the interview included open questions about general description and perception of the planation design, perceived benefits and risks, and working conditions. The second section of the interview comprised describing and localizing the SLV. The localization of the SLV was analyzed in Chapter 6.

7.3.2. Definition of the content analytical units

Data collected from FGD and in-depth interviews were analyzed using qualitative content analysis following Mayring (2015) and Schreier (2012). FGD and interviews were recorded and subsequently transcribed. Then, interview transcripts were read several times to get an overview of the data. After transcription, texts were segmented and condensed into units of analysis as sentences or paragraphs that contained an idea. The codes were created using a data-driven strategy (inductive coding) and are mutually exclusive (Schreier, 2012). The coding process comprised reading the units of analysis and assigning code to the material using all dimensions of the code frame simultaneously. Each subcategory was used at least once (saturation) and none of them remained empty (exhaustiveness) (Schreier, 2012).

The codebook has five categories and 24 sub-codes (see Appendix 1). The first three categories aim to prove the existence of a link between the nature-enhancements practices and the values and risks perceived by workers at the plantation. They comprise: management practices, social landscape values, and risks. The management practices category has eight codes and five sub-codes and refers to those practices implemented in the plantation perceived by workers. They are: hunting and fishing ban, training programs, soil management as the application of organic matter and soil cover vegetation, implementation of integrated pest management (IPM), wood production, reforestation, implementation of buffer areas and conservation projects. The social landscape values category has nine codes and comprises the perceived values such as beauty, biological control, food provision, observation of fauna, observation of flora, shade, soil formation, take a rest, water provision. The risk category refers to the risks that workers perceived that are related to nature in the plantation. They are: risks of animal attack and the nature affects labor.

The following category, oil palm plantation as nature, proves that the management practices enhance the local ecosystems and species of flora and fauna and workers co-habit the oil palm plantations between conservation and production areas (land sparing and land sharing). They are: oil palm as a new agroecosystem, and oil palm as part of the local ecosystem.

A further category, the emotions category, comprises the positive and negative feelings. The emotions category reflects the human-nature relationship. The positive feelings are the joy and happiness when looking at or hearing flora and fauna in the plantation. Under negative emotions are fear towards wild animals and feeling vulnerable.

7.4. Results

7.4.1. Perception of nature-related management practices implemented in the Macondo plantation: towards a naturalized oil palm plantation

Workers understand the management practices can support the local ecosystem and give better working conditions for them. For the participants, the management practices maintain and conserve local ecosystems which bring benefits for them such as water and food provision, shade, contemplation of flora and fauna. Even they could find some health benefits because of less use of chemicals and well-being when observing or hearing birds. Training programs are constant to bring information on current research projects, health and safety programs, no deforestation and reinforce management practices. In this sense, the training programs could direct how workers perceive and understand the management practices.

Hunting and fishing ban and implementing conservation areas aim at biodiversity conservation. Workers observed that the plantation has become a refuge for many local species, but also a place where external people come to hunt either as a sport or as a food source. It is “easier” to hunt inside the plantation than in the savannas or forests.

Workers described buffer areas and conservation areas to maintain water bodies, contribute to soil formation and oxygen. Participants related soil formation to soil management practices that include the establishment of soil cover vegetation (e.g., *Pueraria phaseoloide*) to avoid erosion, maintain moisture, and add organic matter and nutrients to the soil. In addition, the implementations of IPM and soil cover create several habitats for local insects that can control agricultural pests.

Implementing conservation areas comprises local ecosystems, such as savannas and forests inside the plantation. As observed by workers, the plantation differs from a monoculture because it includes these conservation areas. In the conservation areas, workers can appreciate native flora and fauna. Also, fauna finds food and refuge and workers find water and food as wild berries. In addition, the participants called the conservation areas as “living laboratories”. Participants expressed that “living laboratories” could be a place for future projects on successional processes, ecological dynamics and local fauna, because for over a decade those ecosystems have not been burned.

The conservation areas and reforestation projects are practices for nature restoration in areas of the plantation where deforestation occurred in the past (i.e., before 2008). For instance, many “chagras” [1] were done for coca cultivation. Coca cultivation in Mapiripán implied burning and cutting down forests. Participants perceived less deforestation once the company established the conservation areas and the reforestation projects in the plantation. The *epiphytarium* was a previous “chagra”, and currently is a conservations area where conservation projects and fauna and flora monitoring take place. Here, is possible to argue that the *epiphytarium* is a clear example that the plantation, through management practices, supports the local ecosystems (natural areas) and thus enhances the ecological functions. These areas provide also habitat for fauna besides other SLVs such as shade. One participant expressed:

> *“The conservation issue has been very favorable in the plantation’s area. Because here there were chagras in the forest (what today is the epiphytarium)… good almost everywhere in the forests. And one could see a lot of deforestation back*

[1] Small areas for coca cultivation

then" (fieldworker, working on the Macondo plantation for 5 years, code: 9).

Management practices shape the agricultural landscape; influence how the plantation is perceived while implementing land sharing and land sparing approaches concomitantly. Management practices, such as conservation areas, provide a place for nature. The workers perceive the plantation as a place where different species interact. Simultaneously, workers and nature can live from what the plantation provides. For instance, workers earn an income and they use and perceive SLV in the oil palm areas (non-natural) and natural areas (e.g., forests). Nature uses the plantation as a habitat, biological corridors and food source.

7.4.2. A naturalized oil palm plantation

The code observation of fauna shows local fauna is using the conservation areas and oil palm as refuge, habitat and food source and workers can witness and experience the naturalization process. The oil palm plantation enhances the natural sphere, it "gets to be more natural", is transformed throughout the years. The socio-ecological process is constant and workers see it and recognize it. The following quotes prove that workers are experiencing this transformation:

*"[…] there are animals, that can live from what the palm produces, as a natural forests, as something like a park where animals live, people live there and work there" (*supervisor, working on the Macondo plantation for 10 years, code: 15)

"[…] it is a natural habitat there" (supervisor, working on the Macondo plantation for 8 years, code: 4*)*

> *"[…] in some sectors the palm is already tall, it has already some years… there is herbaceous vegetation and animals can freely walk, and now you can say […] that the palm could serve or already serves as an ecological corridor […]"* (supervisor, working on the Macondo plantation for 6 months, code: 7).

Participants perceive the oil palm plantation as a nature-enhanced plantation. Inside the plantation, there are other landscape elements such as other vegetation types, water bodies and oil palms as the production systems. First, participants expressed immediate benefits from working in the plantation, such as income. Second, participants could recognize other benefits, such as use and perception of SLVs. Management practices as soil cover or life fences create various vegetation layers for fauna. Participants perceive the plantation might resemble a forest with various vegetation layers and fauna moves freely. They expressed that oil palm is a living being, is "natural", which provides habitat for species and oxygen. However, participants also mentioned that oil palm is "not natural" because humans brought it, planned it and maintain it. In other words, the oil palm is "not natural" it is not part of the local ecosystems and needs human intervention. The "natural" according to participants, simply occurs it is not planted. Participants related local ecosystems and biodiversity to nature, to the wilderness, considering that the company has many management practices to maintain and conserve the nature inside the plantation. Local ecosystems also require some human intervention, in this case, the management practices, to flourish. For instance, conservation measures require workers to "take care" of biodiversity conservation. Otherwise, without these measures, workers will not care about conservation. Participants mentioned the plantation sets an example for inhabitants to maintain flora and fauna. Furthermore, it is possible that implementing the management practices in the plantation brings together humans and nature, interacting through benefits, risks, experiencing positive and negative feelings.

Oil palm plantation becomes a shelter for other species and it provides benefits for workers. For some participants, the plantation recreates an agroecosystem that considers simultaneously local biodiversity and palm oil production. The oil palm plantation resembles the local ecosystems, though not natural, but provides an opportunity to other species to take part in the oil palm plantation:

> *"Nowadays we already have something pretty, because it is something like people are looking at a park, like a forest […] so it is something, as a natural forest… as if it were a natural forest but… is not natural, that we did it ourselves. It was sown"* (supervisor, working on the Macondo plantation for 10 years, code: 15).

Plantation design incorporates complex and heterogeneous vegetation diversity and has helped biodiversity conservation. Also, it facilitates harvesting, fertilization, maintenance of sectors and lots and the specific shape of lots succeeding the local geography and ecosystems. On this matter, the participants said:

> *"[…] has promoted to have other species. Here an exchange of resources has been happening, and the oil palm implementation helps to conserve and maintain the [gallery and riparian forests], they can keep more water and create some insects that help us, it benefits the crop. I think it is that relationship, that exchange"*

(supervisor, working on the Macondo plantation for 5 years, code: Participant FGD 1-5).

7.5. Perception of social landscape values in the Macondo plantation

Workers interact with the non-natural and natural areas in the plantation through the use and perception of SLV. The management practices enhance the quality and quantity of SLV in the plantation and workers and nature use them. The SLV category embraces the benefits that workers perceive as gaining from nature and the management practices bringing nature inside the plantation. Participants perceive direct SLV from nature inside the plantation. For instance, participants use water, extract food, benefit from shade and observe flora and fauna. These SLV enhance working conditions and human well-being. The fact that water and shade exist nearby the working places offers already better conditions for workers considering the high temperatures in Mapiripán (see section 2.1). Besides, workers could also find food under oil palms and the gallery and riparian forests, and workers could eat them. Pineapples and sugar cane were identified as a food source but not used or harvested by workers. Rather, they are used by the plant health office as raw materials to place inside the pest traps for *Rhynchophorus palmarum*.

Management practices such as reforestation, conservation areas and soil management create many habitats for fauna and maintain local flora, as perceived by workers. These management practices, as argued by workers, help for biodiversity conservation, and where they can observe native flora and fauna in the plantation. In this regard, local biodiversity persists inside the plantation for present and future generations. One participant said:

> "[…] *of course for the future, because let's say if people kill the flora, the fauna, all that, from now one in the future, our children or our children's children will not see that, only in flyers or on the internet […] The ban for burning, cutting trees, and animal hunting or something like that, so animals keep breeding there, in the future, you could see all that*" (Participant, FGD 5).

7.6. Emotions towards nature in the Macondo plantation

Participants experience positive and negative emotions towards nature. Nature is the local ecosystems as gallery and riparian forests that are spread around the Macondo plantation. Participants expressed positive emotions, including happiness, joy, and feeling humbled when they looked at an animal or the plantation. Participants also experienced negative emotions as feeling fear of wild animal encounters and feeling vulnerable. However, negative feelings could also translate into meaningful experiences. For participants, even when they felt fear and vulnerable, they had meaningful experiences were visiting a new pond, learning about local flora and fauna, or taking a new picture to show to relatives and co-workers. Some participants experienced both positive and negative feelings simultaneously. This reveals the ambiguous human-nature relationship. For the participants, the conservation areas represent positive and negative emotions. First, when participants encountered a deer or a bird, they felt joy and happiness. When participants looked at a snake or puma, they felt fear and vulnerability.

Participants expressed feeling humble when looking at the agricultural landscape and experiencing beauty simultaneously:

> *"[from there] you can contemplate everything. You look at the palm, forests… I mean you feel good, you stop and say: how small I am before all this magnitude"* (supervisor, working on the Macondo plantation for 24 months, code: 10).

The acceptability of an area to take a rest, looking for water or shade, is related to how workers perceive an area in terms of "clean and safe", "messy" and where they did not experience negative emotions. For instance, participants preferred the oil palms because they are "clean and safe" areas. The plantation management office oversees the maintenance of the plantation. Maintenance of the plantation includes pruning the understory vegetation to provide visibility and pruning oil palms to facilitate harvesting. Even though participants had also experienced fear of wild animal encounters in the oil palms, still under the oil palms was perceived as "safer" than in the forests. As one participant expressed:

> *"If I am in the field, I will probably look for shade under the palm. Because it is a clean cover that you will not find or there will not be many risks of wild animals encounter or excessive vegetation"* (coordinator, working on the Macondo plantation for 9 years, code: 6).

7.7. Perception of nature-related risks in the Macondo plantation

The risks category is the perceived dis-benefits that nature brings to workers while working on the plantation. First, workers walk or drive long distances to arrive at the working places. Participants explained that the plantation design and management practices allow wild fauna to move around the plantation. They found it good for biodiversity conservation, but problematic because wild animals might attack them. As one participant expressed:

> "*A risk can be some fauna that we find in the different sectors of the plantation, such as snakes - [in sectors 3, 4 and 6] - the puma is a risk, suddenly an attack, I imagine, the wild pigs - the herds of pigs - they can also be very aggressive*" (coordinator, working on the Macondo plantation for 8 months, code: 27).

Participants report wildlife sightings (e.g., pumas, snakes), thus so far, there are no reports of wild fauna attacking workers. Therefore, participants avoid certain areas, wild areas (e.g., gallery and riparian forests, wetlands) to lower the risk and stay "safe" inside the working areas (i.e., oil palms) because is a "cleaner area" meaning fewer understory vegetation. One interviewee mentioned:

> "*Inside the morichera, one does not feel very comfortable, and [human resources] recommends that one should not spend much time or walk inside the morichera […] they say we should not walk inside the morichera because there are dangerous animals, and they recommend that, so inside the morichera one does not feel very comfortable*" (fieldworker, working on the Macondo plantation for 5 months, code: 33).

7.8. Perception of management practices associated with SLV and emotions

Participants relate management practices that bring one or several SLVs that benefit them. Participants recognized the current conservation areas as important ecosystems as providers of SLVs. These areas allow local fauna and flora to be present inside the plantation, arguing that oil palm has become a habitat for many species, allowing biodiversity conservation. The conservation areas code was related to beauty, shade, take a rest and water provision was related to both negative and positive feelings (Table 6, Figure 21).

Participants related beauty, water and shade to conservation areas, specifically gallery and riparian forests. In the conservation areas, they could also admire the landscape and hear and see animals and feel joy and happiness. However, beauty was also related to feeling vulnerable and fear of something unknown, unexpected and encounter with wild animals. Participants found SLVs as shade, take a rest water provision in gallery and riparian forests but experienced fear or vulnerability. Thus, participants preferred old grown palms to enjoy SLVs, because they perceived fewer risks and they did not feel vulnerable or fear (Table 6, Figure 21).

Participants related conservation projects with most of the SLVs (Table 6). Other management practices, as the establishment of buffer areas together with conservation areas, were related to maintaining water bodies, thus providing fresh water for workers, contribute to soil formation and oxygen. Soil management includes the establishment of soil cover vegetation (e.g., *Pueraria phaseoloide*) to avoid erosion, maintain moisture, and add organic matter and nutrients to the soil, hence supporting the SLV soil formation.

Table 6 Perception of management practices related to SLV (source: author)

Management practices	Social landscape values
Conservation areas	Beauty, biological control, food provision, observation of fauna, observation of flora, shade, take a rest, water provision.
Reforestation	Observation of flora, shade, take a rest.
Wood production	Observation of flora, shade, take a rest.
Soil management	Observation of flora, soil formation
Buffer areas	Biological control, shade.
Hunting and fishing ban	Observation of fauna

The current management practices implemented in the Macondo plantation have promoted the ecological processes translated into SLV, perceived by workers. Many SLV co-occur. For instance, when workers fetch for water, they observed fauna and flora, beauty, and enjoy shade. Other workers perceived beauty in places where they could find shade. Workers experienced positive feelings while fetching for water and enjoy shade, while they appreciated the landscape (beauty), observing flora and fauna (e.g., deer). However, they also experienced negative feelings, such as fear that an animal (e.g., anaconda, puma) might attack them while drinking water (Figure 21).

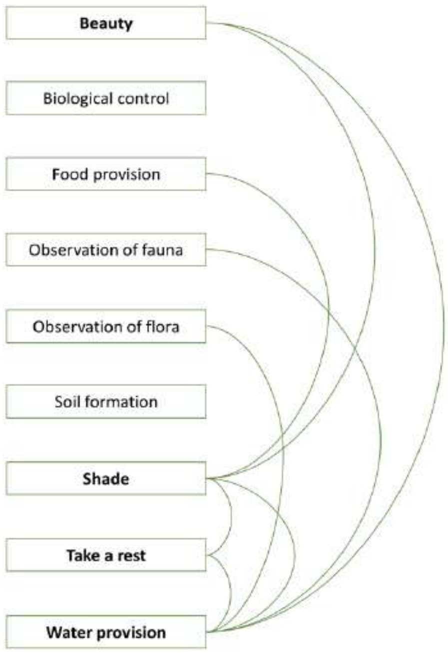


Figure 21 Associations among SLV as perceived by participants. The bold letters show the SLV that evokes positive and negative feelings simultaneously.

7.9. Discussion

The human-nature relationship is dynamic and influences each other through management practices (Comberti et al., 2015). The chapter shows the interdependency of both domains through the lenses of plantation workers. Macondo plantation is a place to conserve biodiversity and provide SLV to workers. The management practices shape the Macondo plantation landscape and workers experience it, creating social networks, interacting and experiencing nature through SLV. It is possible to argue that management practices enhance local ecosystems and agricultural practices. Workers perceive SLV, and fauna uses the ecosystems. Fischer-Kowalski and Haberl argued that this eco-evolutionary process between humans and nature is "maintained by the specific exchange relationship with the environment, by the particular way a society interacts with certain natural systems" (Fischer-Kowalski & Haberl, 2007: 14). Here the exchange is the gains for nature and workers from the management practices.

In the Macondo plantation workers are looking at the agricultural landscape, from different perspectives: 1) a new ecosystem in which species and humans co-exists using the resources and the SLV that the plantation design provides, 2) a transformed industrial landscape, where the local savanna ecosystem and its species have been changed. However, the transformation of the landscape highlights the potential of a nature-enhanced plantation design to provide SLVs and refuge for many species. It is possible to argue that, given the plantation design, a naturalization process is happening in the Macondo plantation. Oil palm becoming part of the local ecosystems and providing a habitat to local fauna (Peluso, 2012).

Participants mentioned oil palms as a human-made area that throughout the years, and due to implementing management practices, is becoming to look similar to the local ecosystems. The management practices done in the plantation not only modify the quality and quantity of SLV for workers but might also for inhabitants in the municipality of Mapiripán. For instance, Herrera et al. (2017) found that increasing the upstream forest land cover influences the water quality, thus improving health and sanitation for households downstream. Further studies are required to know how the Macondo plantation design and the management practices might provide SLV to inhabitants in the municipality of Mapiripán.

Implementing land sparing and land sharing approaches in the oil palm plantation allows nature inclusion in the production areas, for instance, the *epiphytarium*, wetland, or forests. Inside the plantation, the management practices as conservation areas or implementation of IPM allow native flora and fauna to regenerate and to be present, as perceived by workers. Comberti et al. (2015) concluded that forest management practices implemented by indigenous people in the Amazon and Pacific Northwest of North America (Cascadia) have enhanced biodiversity, functional plant species, soil quality and productivity, for instance. Evidence shows that humans changing landscapes enhance services that nature provides (Comberti et al., 2015). This reciprocal interaction the Services to Ecosystems (S2E), according to Comberti et al. (2015). S2E is "to acknowledge that ecosystems not only provide services to humans but humans also service ecosystems to ensure sustainability, increasing or stabilizing supply, and reducing demand, or competition" (Comberti et al., 2015: 257).

Participants highlighted that nature inside the plantation provides more benefits than risks. The benefits from natural areas include mental health and a sense of belonging that might outweigh the negative effects of these natural areas (Konijnendijk van den Bosch, 2012). For instance, workers that visited the *epiphytarium*, a conservation area inside the plantation, had a positive emotion: they felt peaceful and relaxed. Several studies demonstrate that walks in natural areas can reduce anxiety, rumination (negative thoughts), decrease blood pressure, lower cortisol levels (stress hormone), enhance memory, concentration and learning (Berman et al., 2008; Bratman et al., 2015; Nisbet et al., 2020; Park et al., 2009). Therefore, is possible to argue that natural areas inside than plantation provide a place for well-being and better working conditions.

Participants are also aware of the risks inside the natural and non-natural areas. Nature can affect workers' activities, for instance, long distances to the workplace and accidents with wild fauna. To prevent accidents, the human resources office has created a safety and health program, for instance, wearing personal protection equipment or avoiding forests. Through training programs, the human resources office communicates the risks present inside the plantation, thus it influences how workers perceive and interact with the natural and non-natural areas. As stated by Kals et al. (1999), communication and sharing experiences within the community influence the emotional affinity by making positive or negative associations between experience, perception and nature. Therefore, it is no surprise that workers are predisposed to feel fear inside the forest, along with instincts to protect themselves. However, feeling fear is an evolutionary factor, especially in life-threatening situations, for instance, snakes, spider bites, wild fauna attacks (e.g., pumas, wild pigs) and getting lost (Bixler & Floyd, 1997; van den Berg & ter Heijne, 2005). Many of the negative emotions were accompanied by meaningful experiences (van den Berg & Konijnendijk van den Bosch, 2012).

According to literature, trees and green spaces in cities improve the aesthetics of the surroundings, help to regulate temperature and offer mental and health benefits to people (e.g., Nisbet et al., 2020; Pritchard et al., 2020). According to the results, nature as local ecosystems and biodiversity inside the Macondo plantation is an important asset for the workers. Nature offers an enhanced working environment and well-being for workers. Participants also perceived other benefits from oil palm and forests translated into SLVs that they could use, such as water provision, shade, and food.

According to Brevik et al. (2020: 151), "[m]ost well-being literature deals with non-humans primarily insofar as it directly relates to humans (e.g., nature's gifts, natures benefits, ecosystem services), yet more-than-human well-being exists independently from, though inextricably entangled, human well-being". Workers' well-being is important, for themselves and the production process, also the well-being of nature, or the more-than-human, as expressed by Brevik et al. (2020), assures the provision of SLV. Both systems, the social and the ecological, beyond utilitarian perspective, are intrinsically connected, represented in relation values as denominated by Chan et al. (2012). Chan et al. (2012) define relational values as "any relationships between people and nature, including relationships that are between people but involve nature" (Chan et al., 2012: 1462). In this sense, the management practices implemented in the Macondo plantation provide well-being for workers and nature. First, they pretend to safeguard the workers' health by implementing the health and safety program. Second, implementing conservation areas, for instance, to maintain the quality or health of ecosystems (see Costanza, 2012; Costanza & Mageau, 1999). Third, workers perceive and use SLV in natural areas. The local ecosystems and the oil palm are intertwined, creating many habitats for fauna and local flora to regenerate through succession processes. Then, is possible that implementing agroecological practices disseminate the separation between the natural and the social processes and rather they interact concomitantly generating a new nature, a new landscape. Nature, biodiversity and workers into oil palm plantations can co-exist; with the benefits, risks, and ambivalent emotions that nature brings.

The results show co-occurrence among management practices, SLVs, emotions, and risks (see Figure 21, Table 6). Participants appreciate the local ecosystems as part of the oil palm plantation design. They identified several SVLs from the natural areas and the non-natural areas such as beauty, shade, water provision, and food. Workers prefer the oil palm cover to enjoy the SLVs because it has fewer risks and is a "cleaner" cover. According to Nassauer (1995) the "natural landscapes mostly have a rougher, wilder appearance and look "messy", and therefore they need "cues for care" to enhance their acceptability" (Konijnendijk van den Bosch, 2012: 292). Accepting nature and wilderness areas that might appear with "too much nature" or do not fit into our cultural expectations or within our imaginary picture of the natural areas is unpleasant (Nassauer, 2007). The *moricheras* inside the plantation might look messy and unpleasant and many workers might not enjoy or perceive SLV in natural areas. The distribution of SLVs perceived by workers depends on how workers react and feel about the non-natural areas and the natural areas. In the natural areas, workers experience fascination and fear, thus perceive less SLV. In the human-nature relationship, studies have shown that humans prefer managed areas, and natural areas with some human intervention, in a lesser degree, humans appreciate natural and wilderness areas but they can evoke insecurity and vulnerability (Jorgensen et al., 2007; Konijnendijk van den Bosch, 2012).

The SLV "beauty" is a clear example of ambivalence towards nature: "beauty" represented simultaneously fascination and fear, positive and negative emotions in the face of encounters with wild animals, forests, wilderness, and the unknown (van den Berg & ter Heijne, 2005). For instance, gallery and riparian forests provide several SLVs such as shade, food, water, and even habitat to insects (i.e., biological control) but participants experience fear and vulnerability. Encounters with the wilderness and the threatening features of nature can evoke fears as humans are "biologically prepared" to learn fears that threatened the survival of the human species, as found by Seligman (2016) and van den Berg & ter Heijne (2005). Negative emotions towards nature or wilderness might be driven by biophobia, the inherent fear towards nature, or non-man-made scenarios (van den Berg & ter Heijne, 2005). Evidence shows that fear and fascination for natural areas are interlinked and influence how humans relate to nature (Jorgensen et al., 2007; Konijnendijk van den Bosch, 2012).

7.10. Conclusions

Land sparing and land sharing implementation in the plantation allow the local ecosystems (nature) to be present together with oil palm production. Participants identified more benefits than risks from the plantation design. However, inevitably, participants feel fascination and fear towards nature. They highlighted they can see and hear animals which provides human well-being and SLV throughout the plantation. The plantation design can promote biodiversity conservation and improvement of working conditions and well-being.

The study reflects the complex and ambiguous human-nature relation. It is important to understand and acknowledge how this relation is perceived and experienced inside the plantation. It gives the opportunity to comprehend how the management practices influence the landscape design and thus affecting positively or negatively to workers.

7.11. Overview of the Chapter

The results of this chapter, which aims to qualify the relationship of workers and the nature-enhances plantation, prove that workers gain better working conditions because of the landscape structure of the plantation. Additionally, this structure also provides a place for other species, thus the socio-ecological systems are intertwined. The social and ecological spheres interact and workers see it and recognize it.

Research question: how is the relationship of workers with nature-enhancements on the plantation, in tangible terms (perception of management practices, social landscape values, and risks)?

Evidence

Workers understand the management practices can support the local ecosystem and give better working conditions for them. The management practices enhance the quality and quantity of SLV in the plantation and workers and nature use them. As seen in the previous chapter (Chapter 6) workers located many SLVs in complex and connected LSTs. Workers use SLV such as water and shade that enhance working conditions and human well-being. Workers experienced positive and negative feelings towards nature (i.g. gallery and riparian forests, wetlands). However, negative feelings could also translate into meaningful experiences.

Research question: how does the workers' perception of nature in the oil palm plantation reflect the naturalization process in the plantation?

Evidence

The fact that workers perceived and localized SLVs such as observation of fauna highlights that workers witness and experience the naturalization process. In the sense that the oil palm plantation is providing habitat and resources for other species. Implementing management practices such as conservation areas, buffer areas, soil cover vegetation brings together humans and nature, interacting through benefits, risks, experiencing positive and negative feelings.

7.12. Appendix

Appendix 1. Codebook

Categories	Codes	Sub-Code	Code Definition	Quotation example
Management practices	Hunting and fishing ban		The project has hunting and fishing ban for the conservation of fauna inside the plantation.	*[…] there is a great diversity of animals, of lakes, and that we mainly have as one of the most fundamental policies, is the ban on hunting and fishing for the conservation of species within the plantation* (supervisor, working on the Macondo plantation for 3 years, code: 3).
	Training programs		Training programs for biodiversity conservation, no burning, no hunting, no fishing, no deforestation, explain research projects.	*" […] in fact at all levels of the organization the environmental policy is presented and present the conservation projects […] we have and the desire to produce a quality oil, sustainable in time"* (leader, working on the Macondo plantation for 10 years, code: 16).
	Soil management	Organic matter	The organic matter input from the oil palm biomass can improve the soils.	*"The soils of Macondo are very rich, and with the management they will be better (MP6) There is already a completely different type of soil, there is already an organic matter layer and the soil changes"* (supervisor, working on the Macondo plantation for 10 years, code: 20).
		Soil cover vegetation	Soil management includes the establishment of soil cover vegetation (e.g. Pueraria phaseoloide) to avoid erosion, maintain moisture, and add organic	*"The project has established a soil cover vegetation"* (leader, working on the Macondo plantation for 10 years, code: 16). *"Of course, with the soil cover vegetation generates a lot of organic matter, throughout the plantation"* (fieldworker, working on the Macondo plantation for

			matter and nutrients to the soil.	18 months, code: 23).
	Implementation of IPM	Flowering plants that host insects.	Flowering plants along the roads and inside the oil palm plantation that can host beneficial insects to regulate pest populations.	*"In the "epiphytarium". There we have identified insects that are associated with the epiphyte and that are beneficial and that serves to attack crop pests"* (coordinator, working on the Macondo plantation for 9 years, code: 7).
	Wood production	Avoid deforestation	The forest plantation provides wood and is unnecessary to cut down trees in the natural forest.	*"Forest areas, timber, because it is a resource that traditionally, here in the region it is extracted from native forests and we consider it is one of the greatest impacts that, in general, at regional and national level is deforestation of forests"* (supervisor, working on the Macondo plantation for 8 years, code: 4). *"The wood production to avoid deforestation"* (supervisor, working on the Macondo plantation for 24 months, code: 10).
		Wood use	Extract wood from the wood plantation to improve infrastructure within the oil palm plantation.	*"The wood production has a benefit for the same plantation. With the wood, the lots are being marked. Forests are not being cut down because we need wood to mark"* (coordinator, working on the Macondo plantation for 9 years, code: 7).
	Reforestation		The reforestation program protects the water bodies-conservation of water bodies.	*"[…] all that wood good reforestation, and they're taking care of watersheds in words things"* (coordinator, working on the Macondo plantation for 9 years, code: 7).

	Implementation of buffer areas		Buffering the impacts from the agricultural activities and the natural ecosystems.	*"[…] that dampens all the intervention that has been done"* (supervisor, working on the Macondo plantation for 5 years, code: 5).
	Implementation of conservation projects		The plantation has conservation area that comprises local ecosystems. Those areas were left aside without oil palm.	*"The conservation issue has been very favorable in the company's area. Because here there were "chagras"* (in the forest of the epiphytarium)… good almost everything. And one can see a lot of deforestation"* (fieldworker, working on the Macondo plantation for 5 years, code: 9). *[…] the project is in an area of Mapiripán, and that is immersed within the different vegetation covers and diversity of the region, natural diversity* (coordinator, working on the Macondo plantation for 9 years, code: 6). **area for coca planting*
			High Value Conservation Areas (HCV) are part of the conservation areas of the plantation.	*"The benefit of HCV which is for support in general"* (coordinator, working on the Macondo plantation for 9 years, code: 6). *"Conservation areas, epiphytarium, forests. It is a benefit, because the peasants are not used to conserving a large part of the forest, because it is only savannah, you can see little threads of moricheras and people do not give them great importance"* (fieldworker, working on the Macondo plantation for 5 years, code: 6).

Social Landscape Values (SLV)	Beauty		Appreciate the beauty of the place or the landscape.	*"There is a sector […], the main road, and there is a very nice viewpoint (supervisor, working on the Macondo plantation for 6 months, code: 7).* *A part that I like very much is integrating the plantation, by the main road […]. It is a high hill, and it is possible to visualize e all, the water body, the forest, to differentiate the buffer strips, the natural barrier, the forest, the crop, the body of water and the landscape, a sunset, a morning"* (supervisor, working on the Macondo plantation for 8 years, code: 4).
	Shade		The flora provides shade.	*"[…]because the forest is re-growing, and it is quite large and one feels the difference because there are trees and provides shade, the freshness that the trees offer"* (supervisor, working on the Macondo plantation for 8 years, code: 4).
	Observation of flora		See flora inside the plantation differently from oil palm.	*"Almost all lots border with riparian and gallery forests. Then we can see trees in the forests"* (coordinator, working on the Macondo plantation for 9 years, code: 2).
	Observation of fauna		See local fauna	*“the deer, foxes and eagles, all these animals will be found almost throughout the plantation”* (supervisor, working on the Macondo plantation for 9 years, code: 2).
	Food provision		Available food on the plantation.	*“There are many fruit trees inside the plantation”* (supervisor, working on the Macondo plantation for 24 months, code: 11).

	Pest control		Local fauna act as pest predators or parasitoids.	*"In [sector 3] we found a fly that does biological control. In [sector 2], a wasp" (coordinator, working on the Macondo plantation for 3 years, code: 3).* *"One that I remember is the armadillo. That's a good pest control, they eat insects. And it's found everywhere. Also the anteater, and they eat the ants that sometimes damage the palms, when they are small"* (supervisor, working on the Macondo plantation for 6 months, code: 7). *"There are birds. There's a lot of fly-eating birds, they are everywhere"* (fieldworker, working on the Macondo plantation for 5 years, code: 9).
	Soil formation		Biomass from oil palms and vegetation covers contributes organic matter to the soil.	*"In the oldest crops, for example, in Yamu. Because of the friendly agronomic practices then in the crop are always making pruning of crop formation, is applied compost, has nitrifying coverage and all that coverage, that organic matter decomposes and is clear the formation of the soil, because before the layer of organic matter was very little or non-existent, now you can already see some soil layer consolidated"* (supervisor, working on the Macondo plantation for 9 years, code: 6).
	Water provision		Available water in the plantation.	*[…] but all those puddles that's a lot of benefit for all the workers too, for the animals, for everything"* (supervisor, working on the Macondo plantation for 6 months, code: 1). *"The water, which we can see almost everywhere"* (coordinator, working on the Macondo plantation for 3 years, code: 3).

	Take a rest		To use any vegetation type in the plantation for a time to take a rest.	*"Anywhere on the plantation. Take a moment, a break. Anywhere, because even under a palm is very nice"* (supervisor, working on the Macondo plantation for 5 years, code: 5).
Oil palm as nature	The plantations as an agroecosystem		The plantation includes other vegetation types and local ecosystems. Include animals that can benefit the plantation. Include local fauna.	*"There is something very important, and it is the complexity of the agroecosystem, there are many actors, there are soils, diversity of mammals, birds, plants, water networks"* (leader, working on the Macondo plantation for 10 years, code: 16).
	The plantation as part of local ecosystems		The oil palms are now part of the local ecosystems.	*"[…] there are animals, that can live from what the palm produces, as a natural forest, as something like a park where animals live, people live there and work there"* (supervisor, working on the Macondo plantation for 10 years, code: 15) *"[…] it is a natural habitat there"* (supervisor, working on the Macondo plantation for 8 years, code: 4).
Emotions	Positive		People have a positive experience with nature People can interact and feel joy when looking at the flora and fauna inside the oil palm plantation.	*"Nature is very beautiful, is pleasant, nice to see it, to look at it alive, to feel it"* (coordinator, working on the Macondo plantation for 3 years, code: 18).
	Negative	Fear toward wild animals	People fear wild animals that might attack them.	*"There are anacondas inside the plantation"* (fieldworker, working on the Macondo plantation for 8 months, code: 32).
		Vulnerability	People feel vulnerable.	*"If I am inside the plantation, I will probably look for refuge under an oil palm. Because is a clean cover,*

				and one does not find or there will not be many risks of animal encounters or grass so tall" (coordinator, working on the Macondo plantation for 9 years, code: 6).
Risks	Risk of animal attack		Animals in the plantation might attack the workers.	*"A risk can be some fauna that we find in the different sectors of the plantation, such as snakes - [in sectors 3, 4 and 6] - the puma is a risk, suddenly an attack, I imagine, the wild pigs - the herds of pigs - they can also be very aggressive"* (coordinator, working on the Macondo plantation for 8 months, code: 27).
	Nature affects labor		The presence of nature within the plantations can affect labor.	*"It depends on the labor. Because there are labors for us… as it takes so long that the forest has not been touched, there are huge shrubs […] then one gets lost"* (fieldworker, working on the Macondo plantation for 5 years, code: 9).
			Long distances to arrive at the workplace.	*"One cannot go through the forests, there are no bridges or roads to go through… then one needs more time to get to the working place, because one has to go around the forest to get to the other side"* (supervisor, working on the Macondo plantation for 5 years, code: 5).
5	**24**	**7**		

8. Chapter 8: General discussion and conclusions

8.1. General discussion

Humans have job opportunities, create social networks and get direct and indirect SLVs from the plantation design. Conservation areas and the understory vegetation in the plantation promote local flora and diverse habitats that the fauna uses. Fauna uses the plantation as a refuge, food source and as a corridor being able to move between forest patches. I see the Macondo plantation as a pioneering example, not only for oil palm plantations but also for other land use systems for two reasons. First, in the Macondo plantation, there are management practices to conserve and maintain landscape elements. In contrast, even certified RSPO oil palm plantations in Indonesia do not maintain landscape elements, for which the lots are rectangular (Renner et al., 2019).

Looking at Figure 10, it is possible to appreciate that the shape of the lots follows the landscape elements, thus they are not completely rectangular. Second, in the Macondo plantation, the land sparing and land sharing approaches are applied simultaneously, promoting SLVs for workers and supports biodiversity conservation. The landscape heterogeneity can be enhanced by diversifying patch types (e.g., forest and oil palms) and sizes and including local vegetation, as shown by Azhar et al. (2015). According to the results, landscape heterogeneity helps to control pests as *O. cassina* and *R. palmarum* and, also, provides other SLVs to workers.

Macondo plantation is a place to conserve biodiversity and provide SLV to habitants and workers. In this context, the plantation could engage in the understanding of the socio-ecological system and be a referent to analyze other oil palm plantations. Oil palm plantations should engage in biodiversity conservation by understanding how humans interact with nature and landscape to shape them into cultural landscapes, as argued by Berkes & Davidson-Hunt (2006). Cultural landscapes reflect human interaction with nature: between species, places, and environmental conditions, as stated by Roe & Taylor (2014). The management practices shape the Macondo plantation landscape and workers can interact and experience nature through SLVs. In the plantation is possible to see there are already associations among management practices, SLVs and risks. In Mapiripán, the land use and land cover change are continuous because of the "burning of savannas". In the past, the municipality experienced an expansion of coca plantation (see section 2.2.2) and, currently the oil palm project. The oil palm project implementing land sparing and land sharing might build a resilient landscape structure to maintain and improve the management practices, provide SLV and human well-being. However, further studies are needed to understand other human-nature relationships considering other stakeholders, the oil palm plantation and local institutions.

8.1.1. Land sharing and land sparing occurring in the same landscape

Implementing land sparing and land sharing approaches in the Macondo plantation aims at balancing agricultural production and maintenance and conservation of biodiversity. For years, the land sharing and land sparing debate has fallen into the applicability of one or the other but not simultaneously (e.g., Green et al., 2005;

Perfecto & Vandermeer, 2012). In the present study, is possible to show that both approaches are implemented in the Macondo plantation: homogeneous LST refers to areas dominated by oil palms and, simultaneously, high diverse LST refers to extensive areas with native vegetation. Under this debate, is essential to highlight that, although the protected areas are of high importance, they do not maintain diversity (Meijaard et al., 2018). Fauna moves throughout the landscape and requires food and habitat resources. Oil palm plantations then can play a role in the multifunctionality of landscapes, allowing fauna movement by generating biological corridors and connect forest patches (Meijaard et al., 2018). The conservation and maintenance of land covers is a step forward to achieve the RSPO requirements (Meijaard et al., 2018). Under this scenario, the local ecosystems can regenerate and be more resilient under a scenario of climate change and rapid agricultural expansion (Gagné et al., 2015; Meijaard et al., 2018; Santika et al., 2015).

The composition and configuration of the Macondo plantation (see Figure 18 and Figure 19) create landscape connectivity. The intermingling of the gallery and riparian forests, mixed forests, reforestation, soil vegetation cover, and flowering plants within oil palm sectors convey a compositional and configuration heterogeneity (Fahrig et al., 2011). The presence of natural areas along with the production areas will optimize and facilitate the movement of species among natural areas, as concluded by Grass et al. (2019). Landscape connectivity provides benefits to the landscape and the movements of species and well-being to people that interact with it (Mitchell et al., 2013).

Apart from the ecological aspect, the landscape configuration and composition influence the workers' perception of SLVs. The results show workers perceived SLV in landscape types (LTS) with connectivity and heterogeneity. While the SLVs perceived by workers in natural areas point to a certain success of the land sparing approach, the connecting elements in the planted landscape units may be sufficient to raise the value of the more homogeneous planted units thanks to the very presence of the adjacent spared natural spots. This would support the idea of a synergetic effect of using both sharing (integrating) and sparing approaches (Meijaard et al., 2018) in giving landscape and here more precisely on large-scale plantations.

From the results, and consistent with the literature (Lucey et al., 2014), is possible to infer that the heterogeneous and connected LST in the Macondo plantation allows the movement of fauna between forests and savanna patches. The movement of fauna and native vegetation patches are important for the provision of many ecosystem services, such as pollination and pest control (Foster et al., 2011; Nurdiansyah et al., 2016). Native flora and fauna stimulate well-being to humans, as stated by Fuller et al. (2007). For workers in the plantations looking at an animal, hearing birds, and have the possibility to get water and shade represents well-being through positive emotions and enhanced working settings.

8.1.2. Agroecological management practices: towards a naturalized plantation

Oil palm plantations have the potential to develop a heterogeneous agricultural matrix combining land sparing and land sharing approaches, with large agricultural systems, smallholders and biodiversity conservation (Koh et al., 2009). In this regard, the Macondo plantation and its nature-enhanced design is a pioneering example in Colombia. The agroecological practices such as soil cover, IMP, biomass application and maintenance of local ecosystems within the plantation can become a “new” ecosystem where humans and biodiversity can survive. Inside the plantation, the management practices as conservations areas or implementation of IPM allow native flora and fauna to regenerate and to be present, as perceived by workers.

It is also possible that external consumer demands and sustainability certifications (e.g., RSPO rainforest alliance) influence the agricultural landscape, the “dos” and “don’ts” that are possible in the plantation which changes how the plantation looks or should look like (externally), to have more acceptance and a positive connotation for the end consumers, plantation workers, governments and other stakeholders. Internally, there are benefits of implementing management practices in the plantation: conservation of resources (e.g., water), workers perceive and use several SVLs, human well-being, and better working conditions (e.g., Azhar et al., 2017; Furumo et al., 2020).

Córdoba et al. (2019) compared the perception of ecosystem services in traditional crops and oil palm plantations. In the study, participants have a positive perception of traditional crops as compared to oil palms. Positive perceptions included cultivated food, a beautiful landscape, and economic opportunities (Córdoba et al., 2019). However, in the study, the participants were external to the oil palm plantations. The participants thus experienced direct benefits from their traditional crops, where they are directly involved. In this case study, the participants were involved in the implementation and maintenance of the management practices in the Macondo plantation. Workers then could perceive the effect of the management practices. For instance, they could see soil formation because of soil management. They also perceive direct benefits, such as SLVs, that they observe and use, apart from the economic benefit. Pischke et al. (2018) found that oil palm plantations in Indonesia provided benefits such as income, clean air, bird habitat, beautiful landscape, desire to stay in the community. These results from Pischke et al. (2018), confirm that in an oil palm plantation, people can get SLVs comparable to traditional crops. This case study shows that including natural elements inside the Macondo plantation augments positive perception of people and therefore the use of SLVs (e.g., Tribot et al., 2018).

The participants perceive environment-economic benefits by implementing management practices following certification systems (e.g., RSPO) to support social and ecological facets. These results are comparable to the results of Adiprasetyo et al. (2019). The authors argued that the adoption of certification systems supported good cultivation practices. Good practices thus conveyed environmental and economic benefits to workers (Adiprasetyo et al., 2019).

The fact that the oil palm plantation has integrated land sparing and land sharing approaches allow local ecosystems to be integrated into the production areas, for instance, the *epiphytarium*, wetland, or forests. The local ecosystems and the oil palm are intertwined, creating many habitats for fauna and local flora to regenerate through succession processes and restore previous vegetation (Cramer et al., 2008). A naturalization process might happen in the Macondo plantation as oil palm becoming part of the local ecosystems and giving habitat to local fauna (Peluso, 2012). According to Ruiz-Ballesteros et al. (2009) workers might acknowledge naturalization through unique experiences in the working place, contrasting past and present and compared the plantation to other areas that are defined as natural.

Following this line of ideas, nature, in a heterogeneous agricultural landscape, survives. As argued by Achterberg (2002: 97), "in the world that we have received and used, must have the opportunities to survive (integrity) in the diversity which is characteristic of the biosphere. This is a non-anthropocentric argument. Nature *deserves* these opportunities when its "selfstandingness" and its own or intrinsic value have been recognized". The environmental management practices in the Macondo plantation aims at maintaining and restoring biodiversity. However, a "secondary effect", no planned or expected, is the provision of SLV to workers. In this way, it is possible to find a balance between nature and biodiversity conservation, agriculture expansion and human well-being. The results show that people (i.e., workers) and nature are present in a plantation (an industrial landscape). The plantation incorporates natural elements to give space to other species (to the non-human world). Then is possible to argue that the plantation is "giving or leaving [nature] the opportunities to an independent existence and a development of its own, just like we appropriately do justice to other entities, having recognized their intrinsic (or inherent) worth […]" (Achterberg, 2002: 97). We have to pursue the balance between the social and the ecological spheres by implementing sustainable land-use practices, incorporating land sparing and land sharing approaches, for instance. We can move forward "respecting integrity in ourselves and other people, we do not have a good reason to withhold that respect from the rest of nature. We are part of nature, and it is part of our human interest to integrate ecological concerns" (Schlosberg, 2009:138).

So far we have avoided and forgotten the existent or inherent balance of the social and ecological spheres, we dominate nature to extract resources and turn them into commodities to satisfy our needs, with no limitation (Leiss, 1994), which breaks the human – nature relationship, it divides the social and the ecological spheres. According to Fischer-Kowalski & Haberl (2007), humans transform the natural systems through technology and labor to fulfill our consumption demands. This transformation might trigger unintended changes and impacts to both the social and ecological spheres. In the case of the Macondo plantation, the management practices dominate and maintain nature simultaneously. For instance, the plantation management office maintains the oil palms, the soil cover so the "nature" will not take over the oil palms (dominate nature). Also, the management practices maintain the forests and boost the provision of SLV.

8.2. General conclusions

From the results, it is possible to design a heterogeneous plantation by integrating landscape connectivity and vegetation heterogeneity. Along this line, the LST from this study is a useful data analysis tool for understanding the relationship between the landscape, biodiversity, and agronomical implications. Landscape heterogeneity creates habitats for local species that act as a control agent to decrease pest populations of *O. cassina* and *R. palmarum*.

Land sparing and land sharing implementation in the plantation integrates the local ecosystems (nature) with oil palm production. These approaches are strong determinants of SLVs and may guide plantation design. The results show that practicing land-sharing and land sparing simultaneously in the same landscape provides social and ecological benefits.

Workers perceive, identify, and use the SLVs present in the land covers of the Macondo plantation. The workers identified SLVs for each land cover. Using participatory mapping proved to be an efficient tool to identify and localize the values that the workers developed through their interaction with the plantation. The human-nature relationship is ambiguous, but it allows the interaction of the social and the ecological spheres. The management practices influence the landscape design and thus affecting positively or negatively to workers.

Disclosure

For the purpose of this research project, land cover shapefiles and pest data records were requested from representatives of Poligrow Colombia SAS. I previously worked in the company prior to this research study. The supervisors confirm no conflict of interest relevant to the subject of this dissertation.

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10. Plates

Plate 1 High landscape connectivity between the gallery and riparian forests patches and water bodies (February 2019).

Plate 2 Heterogeneous landscape and high connectivity with different vegetation types of forests, natural grasslands and oil palm (February 2019).

Plate 3 High landscape connectivity between forest patches and homogeneous landscape (February 2019).

Plate 4 High connectivity and homogeneous landscape with natural grasslands, open areas with little vegetation, and oil palm (February 2019).

Plate 5 High landscape connectivity dominated with secondary or transition vegetation and oil palm (February 2019).

Plate 6 Low configurational heterogeneity with wood production and gallery and riparian forests vegetation types (February 2019).

Plate 7 Homogeneous landscape dominated by natural grassland vegetation (February 2019).

Plate 8 Homogeneous landscape dominated by oil palm vegetation (February 2019).

Plate 9 Homogeneous and fragmented landscape dominated by open areas and oil palm vegetation (February 2019).