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SUSTAINABILITY ASSESSMENT OF THE OIL PALM (*Elaeis guineensis* Jacq.) PRODUCTION SYSTEM IN ACAPETAHUA AND VILLA COMALTITLÁN MUNICIPALITIES

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SUSTAINABILITY ASSESSMENT OF THE OIL PALM (*Elaeis guineensis* Jacq.) PRODUCTION SYSTEM IN ACAPETAHUA AND VILLA COMALTITLÁN MUNICIPALITIES

PAMELA STEFANIA ESTEVEZ ESPINOSA, 2023

Keywords: Sustainable development, sustainable indicators, oil palm production system, MESMIS.

Elaeis guineensis Jacq. or oil palm is a native species of West Africa. Its oils, extracted from the fruit mesocarp and the kernel are widely used in the food industry, industrial applications, and bioenergy production. Due to its versatility, profitability and growing demand, the global oil palm agroindustry raises concerns regarding deforestation, effects in biodiversity, contamination and related to social issues such as labor conditions, poverty, and social conflicts. In Mexico, the establishment and subsequent growth of the oil palm industry was promoted by past government policies and financial support. In Chiapas the current main producer of the country, the expansion can be also attributed to oil palm resilience to floods, hurricanes, and the economic profitability.

The objective of this study is to evaluate the sustainability status of the oil palm production system within Acapetahua and Villa Comaltitlán Municipalities by analyzing the indicators of sustainability. To achieve this, the Evaluation Framework for Natural Resource Management Systems (MESMIS), was adapted to measure the attributes status of productivity, stability, reliability, resilience, self-management, equity, and adaptability, of the different dimensions of sustainability (environmental, social, political, and economic).

It was identified that MESMIS is an appropriate framework to study oil palm system in Acapetahua and Villa Comaltitlán municipalities. The methodology allowed the identification of critical points, and relevant indicators that include: land use and vegetation cover changes, oil palm cashflow, good agricultural practices, farmers´ training, level of participation and farmers´ well-being. As a result, it was identified that vegetation and land use changes were principally from pastures land and previous oil palm plantations, and a positive profitability in the last two years. Soil and water conservation practices are implemented, and farmers have received different trainings principally from social mills, but other good agricultural practices and awareness of social problems should be improved, while the social participation evaluation showed a weak status of the political dimension.

EVALUACIÓN DE LA SOSTENIBILIDAD DEL SISTEMA DE PRODUCCIÓN DE PALMA DE ACEITE (*Elaeis guineensis* Jacq.) EN LOS MUNICIPIOS DE ACAPETAHUA Y VILLA COMALTITLÁN

PAMELA STEFANIA ESTEVEZ ESPINOSA, 2023

PALABRAS CLAVES (5): Desarrollo sostenible, indicadores de sostenibilidad, sistema de producción de palma de aceite, MESMIS.

Elaeis guineensis Jacq. o palma de aceite es una especie nativa de África Occidental. Sus aceites, extraídos del mesocarpio del fruto y del kernel, se utilizan ampliamente en la industria alimentaria, aplicaciones industriales y producción de biocombustibles. Debido a su versatilidad, rentabilidad y creciente demanda, la agroindustria mundial de la palma de aceite genera preocupación con respecto a deforestación, efectos en la biodiversidad, contaminación y relacionado a temas sociales como condiciones laborales, pobreza y conflictos sociales. En México, el establecimiento y posterior crecimiento de la industria de la palma de aceite fue promovido por pasados políticas gubernamentales y apoyos financieros. En Chiapas, el principal productor actual del país, la expansión puede atribuirse también a su resistencia a inundaciones y huracanes, y a su rentabilidad económica.

El objetivo de este estudio fue evaluar el estado de sustentabilidad del sistema de producción de palma de aceite en los municipios de Acapetahua y Villa Comaltitlán mediante el análisis de los indicadores de sustentabilidad. Se generó una adaptación del Marco de Evaluación de Sistemas de Manejo de Recursos Naturales (MESMIS), para analizar los atributos de productividad, estabilidad, confiabilidad, resiliencia, autogestión, equidad y adaptabilidad de las diferentes dimensiones de la sustentabilidad (ambiental, social, política y económica).

Se identificó que MESMIS es un marco apropiado para estudiar el sistema de palma aceitera en los municipios de Acapetahua y Villa Comaltitlán. La metodología permitió la identificación de puntos críticos, e indicadores relevantes que incluye: cambios en el uso del suelo y la cobertura vegetal, flujo de caja, buenas prácticas agrícolas, capacitación de los agricultores, nivel de participación y bienestar de los agricultores. Como resultado, se identificó cambios de uso de suelo y cobertura vegetal principalmente de pasturas y previas plantaciones de palma, y la rentabilidad positiva de palma aceitera en los últimos dos años. Se aplican prácticas de conservación del suelo y agua, y los agricultores han recibido diferentes capacitaciones, principalmente por molinos sociales, pero otras buenas prácticas agrícolas y la concienciación sobre problemáticas sociales deben mejorar; mientras que la evaluación de la participación social muestra una débil situación de la dimensión política.

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Sustainability assessment of the oil palm (*Elaeis guineensis* Jacq.) production system in Acapetahua and Villa Comaltitlán Municipalities

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ANIAME	Asociación Nacional de Industriales de Aceites y Mantecas Comestibles (National Association of Edible Oils and Fats Manufacturers)
COMEXPALMA	Consejo Mexicano para el Desarrollo de la Palma de Aceite (Mexican Council for the Development of Oil Palm)
CONAGUA	Comisión Nacional del Agua (National Water Comission)
CONANP	Comisión Nacional de Áreas Naturales Protegidas (National Commission for Natural Protected Areas)
CONEVAL	Consejo Nacional de Evolución de la Política de Desarrollo Social (National Council for the Evolution of Social Development Policy)
CPO	Crude Palm Oil
DPSS	Desarrollo Productivo del Sur Sureste (Productive Development of the South-Southeast)
FAO	Food and Agriculture Organization of The United Nations
FEMEXPALMA	Federación Mexícana de Palma de Aceite (Mexican Federation of Oil Palm)
FFB	Fresh Fruit Bunches
FIRA	Fideicomisos Instituidos en Relación con la Agricultura (Trust Funds Established in Relation to Agriculture)
FIRCO	Fideicomiso de Riesgo Compartido (Shared Risk Trust Funds)
FN	Financiera Nacional (National Financial)
ha	hectare
INEGI	Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography)
INIFAP	Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (National Institute of Forestry, Agriculture and Livestock Research)
IRBIO	Instituto de Reconversión Productiva y Bioenergéticos (Program of the Institute for Productive Reconversion and Bioenergetics)
MXN	Mexican pesos
NGO	Non-Governmental Organization
OECD	Organization for Economic Co-operation and Development

PTH	Proyecto Trópico Húmedo (Humid Tropics Project)
RSPO	Roundtable on Sustainable Palm Oil
SADER	Secretaría de Agricultura y Desarrollo Rural (Ministry of Agriculture and Rural Development)
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food)
SAGYP	Ministerio de Agricultura, Ganadería y Pesca (Ministry of Agriculture, Livestock and Fisheries)
SEMARNAP	Secretaría de Medio Ambiente Recursos Naturales y Pesca (Ministry of Environment, Natural Resources, and Fisheries)
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Ministry of Environment and Natural Resources)
SIAP	Servicio de Información Agroalimentaria y Pesquera (Agro-food and Fisheries Information Service)
SIAVI	Sistema de Información Arancelaria Vía Internet (Internet-based Tariff Information System)
SWOT	Strengths, Weaknesses, Opportunities, and Threats
t	ton
UNESCO	United Nations Educational, Scientific and Cultural Organization
WGI	Worldwide Governance Indicators

CHAPTER 1: INTRODUCTION

1.1.Problem Statement

The oil palm (*Elaeis guineensis* Jacq.) is a species native to West Africa, whose oils, extracted from the mesocarp of the fruit and the seed, are widely used. Oil palm is a highly productive crop, it contributes 36% of the demand for vegetable oils, but represents less than 6% of the territory of oil crops, thus the area required for oil production is less compared to other oilseeds.(González Cárdenas, 2016; Rival and Levang, 2014).

Both the oil from the mesocarp of the fruit and the palm kernel oil obtained from the seed of the fruit, can be used in the agro-food industry, manufacture of oleochemical and biofuel products; In addition, the biomass of the plant such as palm oil manufacturing effluent (POME), leaves and trunks can be used for the generation of biogas, activated carbon, paper, among others (Pantzaris and Thin Sue, 2017)

Other authors, point out the potential of oil and palm fruit for feeding animals or highlights activated carbon from the oil palm fruit as a low-cost compound with a significant capacity to remove heavy metals in bodies of water (Abdulrazak et al., 2017; Durán, 1995). Even if there are other potential uses, 68% of palm production is destined for the food industry, 27% for industrial applications and 5% for bioenergy production (Ritchie & Roser, 2020).

One of the most important challenges in the coming years will be the production of food that meets the population demand. For 2050, the estimated demand for vegetable oils will be approximately 240 million tons and due to the low cost of palm oil production, this would experience a high increase (Corley, 2009).

Although it is difficult to quantify the exact incidence of deforestation from oil palm cultivation, according to sampling generated in 20 co tries; 45% of the plantations in Southeast Asia, 31% in South America, 2% in Meso America and 7% in South Africa were forest areas in 1989 (Vijay et al., 2016).

However, these studies do not record whether the cause of the change in forest cover was the planting of oil palm or if this was generated after deforestation, even so, the constant increase of this crop is evident and because the demand is greater than the production, the tendency to expand continues.

The presence of the crop also implies a change in the composition of the ecosystem. The cultivation of oil palm lodges less than half of the vertebrate species than a primary forest, in what corresponds to birds, primates, lizards and bats (Fitzherbert et al., 2008).

Compared to other crops and forest cover, the oil palm hosts equal or less fauna species than the cultivation of cocoa (*Theobroma cacao*), smaller than coffee crops (*Coffea canephora* Pierre ex A. Froehner), like other tree crops, equal or less to mixed crops and greater than grasslands, although less compared to abandoned grasslands (Fitzherbert et al., 2008).

From the experiences in Malaysia and Indonesia, oil palm production can be a key strategy in poverty reduction; when managed effectively, it holds significant potential benefits, but at the same time large-scale palm oil production evidence pour working conditions, low wages, inadequate housing, social conflicts, land expropriation, indigenous populations displacements and effects in the cultural heritage (Hoyle and Levang, 2012).

Thus, oil palm has become the subject of controversy. Its high profitability, better yield, and high demand are faced with environmental problems related to deforestation and decreased in biodiversity, in addition to others social problems.

1.1.1.Justification

Natural resources are our means of survival, but the management of these has been mainly destined to a productivism approach that seeks the optimization of systems and increase of profitability, when it has been determined that the most productive systems are not necessarily the most sustainable (Galvan-Miyoshi et al., 2008).

Analyzing sustainability implies addressing other conceptions, not entirely linked to productivity, but also to the resources conservation, guarantee of human well-being, the resilience of the system and its maintenance over time; the importance of this analysis can be linked to the proportion of facilities in decision-making and the development of activities around the evaluated production processes (Cruz et al., 2018).

In this context, the question arises of how to measure agricultural sustainability, since there are great difficulties related to the fact that the concept is dynamic and that a high capacity for observation and skills are required. Generated measurements do not always satisfy the search of the system components relations, many consume too much time making it impractical, and many allow to know the progress, but not the relations of cause and effect of the system (Hayati et al., 2010).

For this complexity, diverse approaches have arisen, one of those are multicriteria evaluation methods, which involve both qualitative and quantitative analysis and that allows the development of strategies for a transformation towards greater sustainability (Acevedo Osorio and Angarita Leiton, 2013).

Sustainable assessment can be applied to identify opportunities, select priority actions, and evaluate the effectiveness of policy interventions; they are used as a mechanism in participatory processes to establish consensus on goals, and are used to characterize the results of modeling efforts for future scenarios (Parris and Kates, 2003).

Therefore, this study aims to assess the sustainability of oil palm agroecosystems in Acapetahua and Villa Comaltitlán Municipalities, through the adaptation of a multi-criteria evaluation framework, that allows the integration of qualitative and quantitative indicators of the different dimensions of sustainability and permits identify different aspects of intervention.

1.1.2. Study Zone

The study zone corresponds to the Acapetahua and Villa Comaltitlán Municipalities located in Chiapas State. Acapetahua municipality covers a surface of 559.8 km^2, with a total population of 26,899; this equals to a population density of 48.1 hab./km^2, with a total economically active population of 61.2%, composed mostly by males (Instituto Nacional de Estadística y Geografía, INEGI, 2021a).

On the other side, Villa Comaltitlán municipality covers a surface of 445.2 km^2, with a total population of 30,297 individuals according to the 2020 national census. This equals to a population density of 68.0 hab./km^2 with an economically active population of 56.7%, composed mostly by males (INEGI, 2021a).

Besides, the study zone includes a part of "La Encrucijada" Biosphere Reserve, which was established by Presidential Decree in 1995. Land tenure in this area is 76.1% private, 8.9% federal, 8.4% ejido properties, and 6.6% national, which has meant a problem in the elimination of activities that are not in accordance with the protected area (López Hernández and Ixtacuy López, 2018).

The Centro de Estudios Sociales y de Opinión Pública (2019) and the Agrarian Law by Cámara de Diputados del Honorable Congreso de la Unión (1992) define "ejido" as one form of land tenure for agrarian social ownership, stablished with the objective of ensuring food security; the nuclei of ejidal populations are owners of the lands and operate according to their internal regulations, with no more restrictions, except for what the law says.

According to the Secretaría de Medio Ambiente Recursos Naturales y Pesca (SEMARNAP) (1999), the Biosphere Reserve "La Encrucijada" was established for conservation of ecosystem services, which included protection of different vegetation types such as mangroves, coastal scrub, jungles, among others; the reserve has an extension 144.868 ha and a buffer or impact zone of 150,000 ha, that is a total area of 300,000 ha These ecosystems are threatened by the expansion of productive activities, among the three main ones are fishing, livestock, and agriculture, which are mainly concentrated in the buffer zone of the reserve (Trejo Sánchez, 2018).

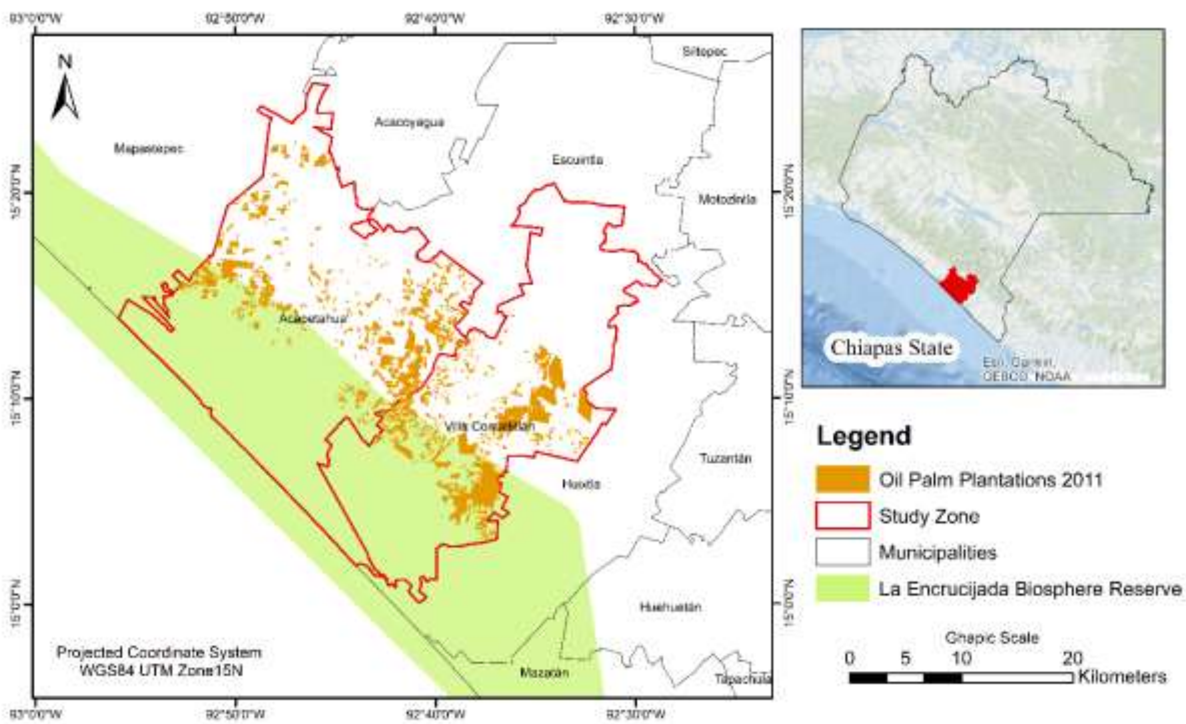
La Encrucijada Management Plan identified that the increase of the agriculture and livestock territories was supported by programs and that oil palm production was increasing frontiers due the establishment of small mills; the aim was to reach an area of 35,000 ha of oil palm plantation (SEMARNAP, 1999).

Effectively, specimens of oil palm have dispersed within the La Encrucijada Biosphere Reserve, colonizing forests, and mangrove areas, even finding specimens in the nucleus conservation zone (Castellanos-Navarrete, 2021).

Figure 1, show the area of study and the oil palm plantations identified by Trejo Sánchez (2018).

Figure 1.

Study zone.



Note: based on information from INEGI (2021b) and Trejo Sánchez (2018).

1.1.3. Objectives

Evaluate the sustainability status of the oil palm production system within Acapetahua and Villa Comaltitlán Municipalities, in Chiapas, Mexico; by analyzing the indicators of sustainability attributes.

Research questions

What variables should be measured to determine the degree of sustainability of oil palm production?

How sustainable is the production of oil palm?

What can we do to lead to a more sustainable system?

1.2. Conceptual-Theoretical Framework

1.2.1. Sustainable Development

There is a discrepancy in the definition of sustainable development. Initially, the term development was used to determine the abilities of organisms to achieve their genetic potentialities, directly linked to Darwinian approaches to evolution (Esteva, 1996). The integration of this concept to the social scheme is carried out at the end of the seventeenth century with Justus Moser using it to explain social change, from this point the concept will be used to describe different forms of growth, evolution and other dynamics related to man (Esteva, 1996).

The United Nations (UN) (1987) through the Bruntland report, recognized sustainable development as guarantee the satisfaction of current needs, without compromising access to future generations to satisfy their own, development limited by natural resources, social organization, and technological development. This definition will establish sustainable development as an integral vision of well-being and will provide it with political significance, but it will prevent this concept from being fully realized (Luisa et al., 2008).

The evolution of this term and its applicability is defined by the approach that addresses it. Authors such as Gallopín (2003) position development as the idea of change, not necessarily growth, the term is conceived as the deployment of potentialities, that improve the system. Similarly, (Provencio and Carabias, 1993) highlights the definition of sustainable development as a social strategy, which allows economic viability and ecological feasibility. Other authors like Luisa et al. (2008) highlights the need to redefine sustainable development, by modifying the current economic scheme, and eliminating the definitions of developed and developing countries.

From a global perspective Parris and Kates (2003) mentioned that shared objectives and goals are reducing sustainable development definition as the fulfillment of human necessities, diminish poverty and preserve natural systems.

Although, there have been discrepancies around the term and the political and rhetorical purpose that has been provided, sustainable development has been established as the means of balancing and reconciling socio-economic and environmental aspects, to ensure long-term well-being (Galvan-Miyoshi et al., 2008).

1.2.2. Sustainable Agriculture

As with the concept of sustainable development, there is no consensus defining the implications of sustainable agriculture. In the case of sustainable agricultural production, it will be defined as minimizing impacts on the land, while wanting to optimize production, which requires the generation of a series of activities linked to the management of water, soil, biodiversity, and crops (Martínez Castillo, 2009).

Although more than optimizing production, it is to obtain security for farmers. During the last decades a change of the current agricultural system has been proposed, where two principles can be highlighted: agroecological practices and the recovery of peasant agriculture (Martínez Castillo 2009).

Many authors consider agroecosystems as the object of study of agroecology; agroecosystems then are defined as a set of plants and animals configured in a specific space and time, which are managed by a producer for commercial purposes (Lugo Perea and Rodriguez Rodriguez, 2018).

Although, other authors will define it as the integrated site or place of agricultural production understood as ecosystems (Altieri, 2002; Gliessman, 1998) also identifies this complexity and establishes agroecosystems like communities of plants and animals interacting with their modified environment, system which purpose is food, fiber, fuel, and other products production for human consumption.

According to Martinez Castillo (2009), agroecosystems implies that biological and social systems depend on each other and the understanding the functioning of these subsystems can contribute to the improvement of the agroecosystem. Then these systems can be managed by understanding their multidimensional ecological and social levels of coevolution, structure, and function (Altieri, 2002).

1.2.3. Measuring Sustainable Development

There is no standardized methodology to evaluate sustainability, instead, a series of instruments and techniques have been developed. Between the few consensuses reached from the scientific disciplines and development sectors in sustainable analysis, is the importance of incorporating environmental and social indicators and criteria, alongside long-term economic and agronomic indicators (López-Ridaura et al., 2002).

Indicators measurement can be applied to local and global studies, as quantitative measures that track progress towards or away from a specific goal; this is a common approach with over 500 initiatives (Lampridi et al., 2019; Parris and Kates, 2003).

But the ambiguity of sustainable development concept, diversity of objectives, the challenges in terminology, data availability and variety of measurement methodologies implies that there is no universally accepted set of indicators, that are supported by a robust theory, includes rigorous data collection and analysis, and that has significant policy influence (Parris and Kates, 2003).

Nonetheless, the use of indicators as an effort to address the different dimensions, put sustainability into practice and permits the organization and representation of information in a more understandable way (Galván-Miyoshi, 2008).

Galvan-Miyoshi et al. (2008) generalize the use of indicators into three categories:

- The generation of lists of indicators treated separately without a form of integration.
- The generation of composite sustainability indicators.
- Evaluation framework as adaptable methodologies that guide the evaluation process with steps and determine general evaluation attributes.

However, experience has become evident that extensive lists of indicators are not practical and that in Natural Resource Management System (NRMS), every NRSM has a specific context and actors, thus fixed templates are unsuitable (López-Ridaura et al., 2002).

1.2.4. Systems Approach

Sustainable development is a dynamic process in which the understanding of its different dimensions lies, one of the most convenient approaches to address it is systems approach (Gallopín, 2003). According to Clayton and Radcliffe (1996) a system is a group of components that interrelate and interact with each other and generate the emergence of new properties (cited in Ortíz-Ávila, 2008). Likewise, Bertalanffy (1976) defines it as "*complex of interacting elements".*

Meadows (2009) establishes that a system goes beyond the addition of its elements and that it evidences: adaptability, dynamism, has a purpose (function in non-human systems and purpose in human systems), intention to persevere over time (resilient), even in certain occasions it is capable of evolving. Thus, the behavior of the system can be modeled by its purpose, the change in interactions or by changing its components. There are closed and open systems, seconds maintain exchange of flows, matter, and energy with the outside (Ortíz-Ávila, 2008). In open systems, there is production of positive and negative entropy (Bertalanffy, 1976).

These schemes arise in need of science to encompass beyond the mechanistic approach (sum of its parts), and separate causal lines. To proceed to include the interaction of the different systems, so that emerging aspects such as adaptability, intentionality, purpose, among others are considered (Bertalanffy, 1976).

From this perspective of interactions, the long-term sustainability can only be managed as a total socio-ecological complex system, where resources, the units, the users, the organizations, are differentiated, but interact with each other to generate outputs of each level (Ostrom, 2009). These outputs feed back to the system or to others of greater or lesser scale, which allows the amplification or damping of a change; in the case of socio-ecological systems the change will determine the capacity of the biosphere to maintain human development and progress (Fischer et al., 2015; Ostrom, 2009).

The agroecosystem is a type of socio-ecological system, and its sustainability will be the product of combining human knowledge and preference of ecological components (Gliessman, 1998). Lampridi et al. (2019), establishes that for this socio-ecological system, scale in an important element to considerate, and the study mentions that most of the sustainable agriculture studies are developed in a global context. The system is subjected to different pressures according to the scale it has; at a production level, agricultural practices or soil management will determine the sustainability of the system; while, on global scales, aspects such as climate stability, distribution of resources or international treaties generate the greatest pressure (Hayati et al., 2010).

CHAPTER 2: AFRICAN OIL PALM

2.1. Crop characteristics

2.1.1. Environmental Requirements

Elaeis guineensis Jacq. is a species native to the coastal regions of West Africa. It has a photosynthetic metabolism C3 and an average height of 12 to 15 m (Forestry Department, 2001; Romero et al., 2007). It´s root system is mainly superficial, since it has a higher density of roots in the first 10 and 50 cm deep, although it can extend horizontally up to 25 m from the trunk (Jourdan et al., 2000; Jourdan and Rey, 1997). The production ideally develops in deep, loamy or clay loam, with flat or wavy reliefs (Durán, 1995; Forestry Department, 2001; Janick and Paul, 2008).

This crop belongs to areas with maximum temperatures between 29 ºC to 33 ºC and minimum between 22º C and 24º C. Regarding the water requirement, the palm has an optimal development, with a rainfall between 2000 and 2500 mm per year, without dry periods or less than 100 mm per month. Although it also develops in areas with rainfall between 650 and 4500 mm per year and periods of 2 to 4 dry months (Durán, 1995; Janick and Paull, 2008).

2.1.2. Oil palm Production System

The species of the genus *Elaeis* that are exploited for its oil are: *E. guineensis* and E. *oleiferous,* the latter native to the Amazon basin. In Latin America, farmers have generated hybrid plantations of these species, since the fatty oil contents of E. *oleiferous* are lower, it provides greater resistance to diseases such as bud rot (Rival and Levang, 2014).

The Roundtable on Sustainable Palm Oil (RSPO) (2020).explains that palm oil palm supply chain consists of the processing of the raw material until the product is obtained and includes the stages of production, processing, storage, transportation, refining, manufacturing, and final product. As regards only to the production or cultivation stage, Espinosa et al. (2021). establishes that palm cultivation has its own inputs such as: the use of water for irrigation, the use of fossil fuels in machinery or in transportation, chemical or biological substances, other tools used in production. While the outputs include common waste from the infrastructure, hazardous waste such as agrochemical containers, domestic and non-domestic wastewater, greenhouse gas emissions from changing plant cover, transportation, or fertilization, among others.

The usual economic life span of the oil palm is 25-years (Jusoh et al., 2003; Svatonová et al., 2015). The oil palm production process can be divided in four main phases: the "yield building phase", the first 2 to 3 years where production has not started, "steep ascent yield phase" between 4 and 7 years, when production increase linearly; "plateu yield phase", from 8 to 14 years where production stabilize; and production decline between 15 and 25 years (Woittiez et al., 2017a).

In a more regional context, according to Gobierno del Estado de Chiapas (2006), during the three first years of the plantation there is no fresh fruit production; after this period, there will be gradual growth until reach 50% of the production capacity and reaching a stable production by the seventh year.

2.1.3. International Context

Over the past 50 years, global palm oil production has grown from 2 million tons in 1970 to more than 74 million tons in 2019; with Malaysia and Indonesia dominating the market, with 84% of world production (Food and Agriculture Organization of The United Nations (FAO), 2022; Forestry Department, 2001).

However, the expansion potential on these countries is reaching a saturation point, while new producing territories are starting to emerge. It is estimated that the greater potential for expansion nowadays is in Latin America and Africa. In Latin America, there is a rapid expansion of oil palm plantations, to the point where 8 of the 20 global top farmers of the crop are in this region (De la Vega-Leinert et al., 2021).

Given the flexibility of the crop, palm oil plantations are subject to powerful transnational actors that hoard and store huge volumes of the product, increasing speculating practices on the agricultural finance markets. This causes that even when global production of oil palm is constantly rising, fluctuations and abrupt drops in pricing are notoriously common. It is important to note that many non-producing countries, like Germany, Netherlands, and USA, among others are part of the top 20 exporters of palm oil, indicating the high influence of transnational actors originating from these countries in the sector (De la Vega-Leinert et al., 2021).

2.1.4. Roundtable on Sustainable Palm Oil (RSPO)

In this context of sustainable development, RSPO is a non-profit organization formed by members of plantations, processors, traders, financial institutions, and environmental and social NGOs, also arises; the organization objective is to promote the production and use of sustainable palm oil through the application of global standards (RSPO, 2020).

The parameters that establish sustainable palm production are defined in the RSPO Principles and Criteria, Indicators and Guidance, which in turn are committed to compliance with the United Nations Universal Declaration of Human Rights and the International Labor Organization Declaration on Fundamental Principles and Rights at Work and support the fulfillment of the Sustainable Development Goals (SDGs): goal 2-Zero Hunger, goal 6-Clean Water and Sanitation, and goal 15-Life of Terrestrial Ecosystems (RSPO, 2018).

2.2.Oil palm crop in Mexico

2.1. History

In Mexico, it is estimated that the first plantations were established in the forties and fifties of the 20th century, in the coastal area of Chiapas (Trejo Sánchez, 2018). The production grew along the years through government programs that sought satisfy the demand of the agro-food industry and was later promoted for the generation of biofuels, although currently its main purpose continues to be the food industry.

Fletes Ocón et al. (2013) emphasize the existence of two official programs in the state, one between 1990-1991 and in 1997. In this decade the National Institute of Forestry, Agriculture and Livestock Research Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP) defined 2.5 million potential hectares for oil palm production, distributed in the states of Veracruz, Chiapas, Tabasco, Campeche, Quintana Roo, Oaxaca, and Guerrero (Mata García, 2014). According to the testimonies of farmers and officials of government institutions, an essential part of these programs focused on deliver free plants.

Subsequently, between 2007 and 2012, international entities like World Bank and Inter-American Development Bank incentivized the incorporation of oil palm production in policies of sustainable production and biofuels (Castellanos Navarrete, 2018). Thus, the Instituto de Reconversión Productiva y Bioenergéticos (IRBIO) was created with the purpose of planting 300,000 hectares of oil palm; thus, this program delivered three million seedlings, and granted subsidies for production (Castellanos Navarrete, 2018; Trejo Sánchez, 2018).

Additionally in 2009, the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) established the “Proyecto Trópico Húmedo” (PTH); the project operates through three entities: Fideicomisos Instituidos en Relación con la Agricultura (FIRA), Financiera Nacional (FN), and Fideicomiso de Riesgo Compartido (FIRCO); the objective of the PTH was increase the surface and productivity of crops and relevant activities in the tropical humid and sub-humid zones of Mexico, allocating a 26% of the budget to oil palm (SAGARPA & FAO, 2015)

As result, between 2010 and 2014, the project reported a yield increase of 29 % of oil palm production in Mexico, and 70% increase of the cultivated land in Chiapas between 2009 and 2011; the beneficiaries included individual farmers and groups, in addition to support the establishment of extracting mills, such as the 12.6 million MXN subsidy given to a big company in Chiapas (SAGARPA and FAO, 2015)

By 2015, the same PTH was change to “Desarrollo Productivo del Sur Sureste” (DPSS) and for 2018, oil palm incentives would continue through this project and FomenPalma (Ávila Romero and Albuquerque, 2018; SAGARPA and FAO, 2015). Subsequently, SAGARPA became Secretaría de Agricultura y Desarrollo Rural (SADER).

According to the interview with José Hernández, representative from the Ministerio de Agricultura, Ganadería y Pesca (SAGYP) (pers. comm. April 14, 2022), incentives for this crop are no longer carried out.

Regarding current production, the Servicio de Información Agroalimentaria y Pesquera (SIAP) (2018) informed that in 2017, Mexico generated more than 873 thousand tons of palm oil; Chiapas was the main producer with 57.3%, followed by Veracruz and Tabasco with 29.8% and Campeche with 13.8%.

However, planting, and extracting oil palm is not enough to supply demand. According to Sistema de Información Arancelaria Vía Internet (SIAVI) (2021). In 2021, the import of Crude Palm Oil (CPO) was more than 41 million dollars**;** Costa Rica contributed with 28% of imported oil, Guatemala with 20%, and Colombia with 16.7%

The fact that Guatemala is the second-largest producer in the Americas is significant because the main production area of this country is Sayaxche, located on the borders with Mexico (Trejo Sánchez et al., 2020).

The state of Chiapas possesses three significant areas where oil palm is produced: the Isthmus Coast and Soconusco, the Lacandona Jungle, and the Maya region (Trejo Sánchez et al., 2020). The report of Federación Mexicana de Palma de Aceite (FEMEXPALMA) (2020) Acapetahua occupies 36.5% of the planted area in the state, while Villa Comaltitlán 10.6%.

The increase of oil production in last decades in Chiapas: can be explain in the environmental and ecological suitability, includes the palm ability to withstand floods and hurricanes; the past policies and financial support; the influence of the international market and the economic profitability; and the farmers appropriation of the oil palm due the historical presence in the state (Pro Natura Sur A.C., 2022).

2.2. Legal Framework

Additional to the public policies and program generated in the past, current legislation related to oil palm production in the study zone, includes:

- The Agrarian Law established by the Cámara de Diputados del Honorable Congreso de la Unión (1992); the law includes a set of regulations that govern land ownership, farmers rights, agricultural and livestock promotion, communal property, and other aspects related to agriculture and food production.
- The National Water Law, regulates allocation, concessions, practices, restrictions related to the use of water including agricultural activities.
- Mexican national interpretation of the RSPO principles and criteria to produce sustainable palm oil, that adapt RSPO principles and criteria to the challenges and regulations of the country (RSPO, 2018).
- Mexican Norm NMX-F-817-SCFI-2020: Oil-establishing the requirements and specifications of the sustainable palm oil value chain, was created due the complexity to apply other standards; thus SADER, Secretaría de Economía, Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), and other stakeholders' development this standard for sustainable certification.
- The Management Plan of La Encrucijada Biosphere Reserve to regulate activities inside the reserve, promote sustainable resource use, facilitating education and capacitation, among others (SEMARNAP, 1999).

Other resources include:

- The RSPO Principles and Criteria, Indicators and Guidance to support the fulfillment of the Sustainable Development Goals. Other relevant RSPO standards include: 2019 RSPO Independent Smallholder Standard and 2020 RSPO Supply Chain Certification Standard (RSPO, 2019, 2020).
- It should be mentioned international efforts to create laws to regulate supply chains of different products. De la Vega-Leinert et al. (2021), highlight the initiative creation of the Supply Chain Law to internalized environmental and

social cost by German corporations, by monitoring and sanctioning these companies. These types of regulations can influence the demand for products that may include palm oil.

2.3. Stakeholders

In the investigation of Trejo Sánchez and Valdiviezo Ocampo (2022b) , seven nodes of actors from the coastal microregion of Chiapas were identified, the nodes correspond to:

- Small, medium, and large palm farmers.
- Government agents from the institutions: SADER, SAGYP, FIRCO and Comisión Nacional de Áreas Naturales Protegidas (CONANP).
- Private mills that are El Desengaño-Pakal, Oleofinos, Propalma and Aceites de Palma S.A. Additionally, the existence of four social mills that include Bepassa, Zithualt, La Primavera and Oleopalmex. The private and social mills that are established only Acapetahua and Villa Comaltitlán municipalities can be identified in Table 1.**Table 1.** Private and social mills in Acapetahua and Villa Comaltitlán**.**
- The international organizations of RSPO, Solidaridad and Earthworm
- National organizations that include academic and technical institutions such as FEMEXPALMA, the Asociación Nacional de Industriales de Aceites y Mantecas Comestibles (ANIAME) and the Consejo Mexicano para el Desarrollo de la Palma de Aceite (COMEXPALMA).
- Actors from La Encrucijada Biosphere Reserve.
- Social organizations.

Table 1.

Private and social mills in Acapetahua and Villa Comaltitlán**.**

Mill	Legal entity	Type	Year	Municipality	Number of associates
La Primavera	Cooperativa Unión de Palmicultores de la Costa de Chiapas, S.C. de R.L. de C.V.	Social	2015	Acapetahua	284
Bepassa	Aceitera Chiapaneca La Palma, S.P.R. de R.L.	Social	1995	Acapetahua	144
Propalma / Oleosur	Promotora de Palma del Soconusco, S.A. de C.V.	Private	2002	Acapetahua	-
Aceites de Palma	Aceites de Palma S.A. de C.V.	Private	2020	Acapetahua	-
Zitihuatl	Procesadora de Aceites de Palma, S.A. de C.V. S.P.R. de R.L.	Social	2012	Villa Comaltitlán	340
El Desengaño	Pakal Consultores en Agro negocios del Sureste, S.A. de C.V.	Private / Social	1994	Villa Comaltitlán	-

Note: based on Pro Natura Sur A.C. (2022); Trejo Sánchez (2018) and Zitihualt (pers. comm. April 25, 2023).

In the states of Chiapas, Veracruz, Tabasco and Campeche, there is an estimated of 12,000 oil palm farmers (Ávila Romero and Albuquerque, 2018). Approximately 4,780 are in the sixteen municipalities of the coastal microregion of Chiapas, of which 768 possess shares in the social mills Zitihualt, Bepassa and La Primavera ubicated in Acapetahua and Villa Comaltitlán, and 450 belong to the social enterprise Oleopalmex that is in the process of installing a mill in Huehuetán (García, 2018; Oleopalmex pers. comm. April 12, 2022; and Trejo Sánchez, 2018).

2.4. Problems Related to Oil Palm

Hernández-Rojas et al. (2018) determinates that in Mexico 52% of the vegetation that were replaced by oil palm since 1980 were pastures; thus, the increase of cultivation in this country was generated mainly in areas that have already been transformed. Other institutions link oil palm problems to social aspects and the location of oil palm close and within reserves. As mentioned before, SEMARNAP (1999) already identified the potential increase of small mills near La Encrucijada. Effectively, new establishment like Aceites de Palma mill in Acapetahua, and the willing of creating social mills are presented in the zone. While La Encrucijada Biosphere Reserve (pers. comm. April 13, 2022) identifies other the invasive potential of the oil palm.

Regarding this, the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) (2017) recognizes oil palm as a highly invasive species. The problem is generated by the transport of loose fruits due heavy rains in the zone, that mobilize the seeds on the plots and that are dispersed on the roads that connect plots and mills, downstream to the nucleus of the reserve (Castellanos-Navarrete, 2021, La Encrucijada Biosphere Reserve, pers. comm. April 13, 2022).

About social problems, even if Chiapas is the main producer of oil palm, more than 76% of the population is in a state of poverty (Ávila Romero and Albuquerque, 2018). A Mexican oil palm smallholder has an average production area of five to seven hectares; but to reach above the family poverty line of USD 5,124, an oil palm farmer needs around 5.2 ha and 9.4 ha to make a living income (Solidaridad, 2022).

According to the study by Trejo Sánchez, 2018) the farmer can clearly identify higher profitability compared to other crops such as corn, beans, and sugarcane. The same study points out the lack of alternatives to match the profitability of the palm which generates the establishment of this crop within and outside the boundaries of la Encrucijada Reserve.

A basic analysis of yield volatility VP/SS of oil palm by De la Vega-Leinert et al. (2021), identified large variations in volatility in previous years between 2000 and 2006, but it stabilized from 2006. Countries like Malaysia and Uganda control the Fresh Fruit Bunches (FFB) prices in their territories; while in Latin America countries, FFB prices are determined monthly or weekly from CIF (Cost, Insurance and Freight) Rotterdam or

Malaysia; the percentage differs depending on the country but in the case of Mexico, it was identified a percentage of 12,5% from the Rotterdam price (FEMEXPALMA, 2020; Solidaridad, 2022).

Trejo Sánchez and Valdiviezo Ocampo (2022a) examined the effort of farmers to impact in the market prices, the study analyzes the social enterprise Oleopalmex in Chiapas, as a collective effort that permits the creation of social capital and could partially control the penalties imposed by private extracting mills.

But even with social efforts and that more of 14,000 farmers in the micro region coastal zone of Chiapas belongs to a social mill or social enterprises (Zitihualt, Bepassa, La Primavera, Oleopalmex) given them strong cohesion; Trejo Sánchez and Valdiviezo Ocampo (2022b) identifies the governance system of the oil palm industry is mainly led by the RSPO certification and the Mexican Government, while in previous years the control of this production chain was managed by private mills.

CHAPTER 3: RESEARCH METHOD

3.1.Methodologycal Framework

As mentioned before, one of the main methodologies to evaluate sustainable development is the use of indicators, due to their wide application in studies and initiatives, as well as the fact that they facilitate the information understanding.

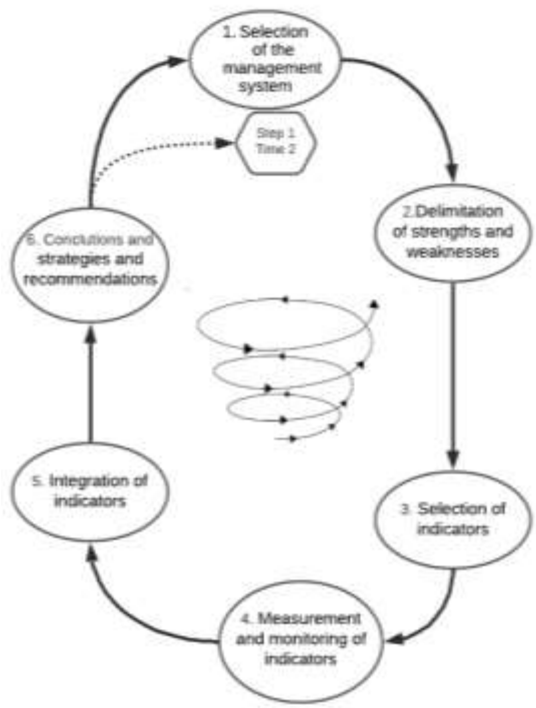
There are two different approaches to derive sustainability indicators: "Top-down" approach, consist in consultation with experts or social actors to determinate objectives or issues perceived; while in the "Bottom-up" approach, the indicators are obtained from the critical points of the system, it means that the system is previously characterized and analyzed, and then the indicators are derived from these characteristics (Galván-Miyoshi et al., 2008). Critical points refer to positive or negative aspects that are most relevant to the system and that reinforce it or place it in a position of vulnerability (Merlín-Uribe et al., 2013).

The Natural Resources Management Systems Evaluation Framework (MESMIS) method is based on the bottom-up approach; it is a broad and general framework that performs the evaluation of sustainability through the analysis and selection of indicators of the attributes: productivity, stability, reliability, resilience, self-management, equity, and adaptability (Galván-Miyoshi et al., 2008).

MESMIS proposes that the evaluation of sustainability can be generated through a successive cycle of six steps (Figure 2). The evaluation carried out an analysis and feedback of the resource management systems; the hierarchical scheme is followed, starting from the identification of strengths and weaknesses until obtain a robust set of sustainability indicators that consider environmental, social, and economic aspects and ends in recommendations and conclusions to start another cycle of evaluation (Masera et al., 2008).

Figure 2.

MESMIS evaluation framework



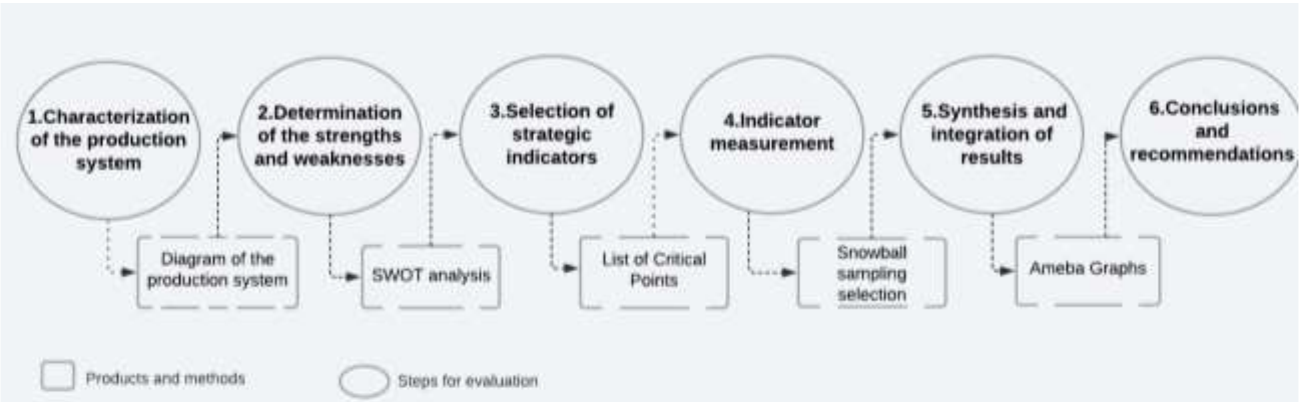
Note: Masera et al. (2008).

The MESMIS program was designed as a flexible and adaptive process, that incentives stakeholders to evaluate the social and ecological impacts of their natural resources management decisions and adapt their practices in response to the dynamic environment (Astier et al., 2012). MESMIS framework, adopts a mixed approach, hence open-ended and closed-ended questions, utilization of qualitative and quantitative data, statistical analysis, and text analysis can be implemented across the evaluation.

The repetitive cycle of MESMIS cannot be covered within the timeframe of the study. Nevertheless, the steps proposed by it are adopted in this study (Figure 3). After delimiting the productive system and identifying its strengths through a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, five indicators were selected. The information to measure these indicators came principally from surveys conducted to the oil palm farmers during April 2023.

Figure 3.

Evaluation framework for oil palm production system in Acapetahua and Villa Comaltitlán Municipalities.



Note: based on Masera et al. (2008).

As mentioned MESMIS framework belongs to a mixed (quantitative and qualitative) research approach. Depending on the timing of acquisition of the data, priority of data type, integration, use, among other characteristics Creswell (2009) identified six typed of mixed methods.

For this project, the concurrent embedded strategy type was selected. This implies simultaneous acquisition of qualitative and quantitative data, with the identification of a predominant method and a secondary database that supports a deeper understanding of specific aspects of the results (Creswell, 2009).

Indicators of the oil palm for this research includes discrete or continuous quantitative variables, as well as nominal or ordinal qualitative variables. However, for the integration of the indicators, all were transformed into a single range describing sustainability on a scale from one to ten. Therefore, the determination of sustainability is mainly a qualitative outcome, supported by qualitative and quantitative data.

3.2. MESMIS Aplication

As usual in the process of evaluation, the system or element must be characterized. In the case of oil palm production, the main aspects to be considered have been established in previous chapters and includes the oil palm production system and stakeholders. The literature review was complemented with two visits in April and July 2022. The interviews included dialogues with public institutions, representatives of NGOs, representatives of social organizations, and independent oil palm farmers from ejidos (Table 2).

Table 2.

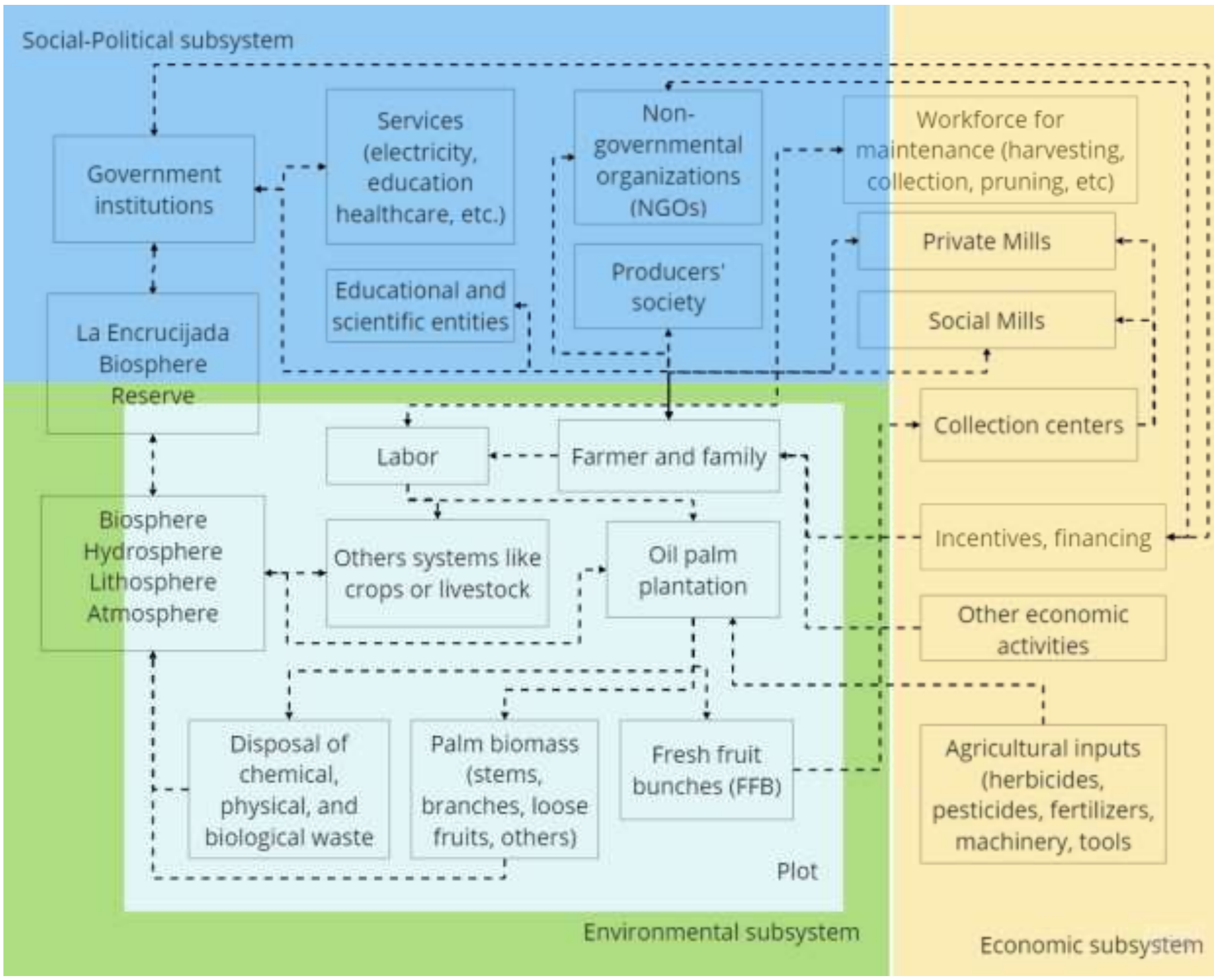
List of interviews and dates of the study zone.

Organization/interviewed	**Date**
Solidaridad Southamerica representative	April 14th, 2022
Oleopalmex representantive	April 12th, 2022
La Primavera representantive	April 12th, 2022
CONANP-La Encrucijada Biosphere Reserve representantive	April 13th, 2022
Palm producer	April 13th, 2022
Palm producer	April 13th, 2022
“Procuraduría Federal de Protección al Ambiente” (Profepa) SEMARNAT Tuxtla Gutiérrez representantive	April 19th, 2022
SAGYP-Tuxtla Gutiérrez representantive	April 19th, 2022
SADER-Tapachula representantive	April 20th, 2022
Earthworm representantive	April 22nd, 2022
“Agroindustrializadora de la Palma de Aceite” social organization members	July 17th, 2022
SPR Tutuam social organization representantive	July 18th, 2022
“Mapaneca de Productores de Palma de Aceite” social organization representative	July 18th, 2022
Ejido “15 de abril” oil palm farmer	July 19th, 2022

From the dialogues and literature, the oil palm system model in the study area is delineated (Figure 4). It should be noted that this system is not close but for the purpose of study only principal flow of matter, energy and information is established.

Figure 4.

Reference system and subsystems of the oil palm production system in Acapetahua and Villa Comaltitlán Municipalities.



In the reference model includes three important subsystems:

- The environmental subsystem where the plot is located, is the ecosystem modeled by the biosphere, atmosphere, lithosphere, and hydrosphere components, that provide and receive matter and energy of the productive activities. The farmer and the family dedicate their labors principally to the palm system but other productive systems such as crops, and livestock were identified too.

- The social and political dimensions were grouped in the same subsystem, due aspects such as governance, social participation, well-being, security, are the product of the interaction of the same components, however these dimensions are evaluated separated in the following steps.
- The economic subsystem is mainly related to activities that generate income and costs for farmers: maintenance, investment, sale of bunches, obtaining bonuses or incentives, mark the economic flow of the productive system.

3.2.1. Determination of Strengths and Weaknesses

To establish strengths and weaknesses, SWOT analysis was conducted; a simple tool widely used to evaluate internal and external issues in complex decision situations and strategic planning (Helms and Nixon, 2010).

The information for this analysis was obtained from the visits in April and July 2022. In the interviews, it was directly asked about the strengths and weaknesses of the palm production. To schematize the information, an interpretive content analysis was applied. Content analysis is a research approach used to infer patterns and insights from textual or similar materials (Drisko and Maschi, 2016). These textual or similar material also refer to interviews, audio or video recordings, or any other unstructured data.

The interpretive content analysis involves summarize and understand the collected data, then a code list was generated. In this case the information was classify into political (P), social (S), economic (E), or environmental (A), and second code was the SWOT: Strengths (S), Weaknesses (W), Opportunities (O), or Threats (T). The information was filtered based on the oil palm complex system diagram. Positive or negative aspects that were inside the principal system are consider strengths and weaknesses, outside aspects but that influence the oil palm production like other crops policies, regional or international changes is consider and opportunity or threat. Additionally, the information was filtered based on the information relevance, for instance internal problems in mills, or individual political opinions, were not consider in the final matrix of SWOT analysis (Table 3).

Table 3.

SWOT matrix of the oil palm production system in Acapetahua and Villa Comaltitlán.

Strengths	Weaknesses	Opportunities	Threats
Political			
PS1. Existence of Mexican legislation regarding the requirements and specifications for the sustainable palm oil value chain, includes NMX-F-817-SCFI-2020 norm, and Mexico interpretation of RSPO principles. PS2. Information availability for decision making from academic research, NGO´ and private projects products including the roadmap by Pronatura, National Interpretation of RSPO criteria for Mexico.	PW3. Lack of regulation and oversight of the oil palm production system PW4. Noncompliance of La Encrucijada management plan from oil palm farmers. PW5. Lack of coordination among public institutions. PW6. Lack of natural resources management by public institutions specially related to pollution and misallocation of resources. PW7. Lack of oil palm farmers' participation of in decision making.	PO8. Initiated process for update La Encrucijada reserve management plan.	PT9. Government policies and incentives to other crops like "*Sembrando Vida*" program does not match the oil palm economic benefits.
Social			
SS1. Producers received training by field schools from social mills, private mills, and NGO´s. SS2. Improve of welfare of small farmers due to more access to mobilization, education, housing improvements, among others economic benefits. SS3. Creation of jobs places related to oil palm production.	SW4. There are still gaps in technical knowledge of the production specially with fertilizers appliance. SW5. Non-associated growers' experience vulnerability and less economical agreement opportunities. SW6. Deficits in services and infrastructure, especially roads in ejidos. SW7. No consensus of the regional or national farmers´ representation.	SO8. The growing number of social organizations aiming to establish their own mills will enhance social cohesion, negotiation capabilities, and enhance competitiveness, among other benefits.	ST9. Other crops are displaced due to the prioritization of oil palm production.
Economical			
ES1. Permanent income for farmers, due production of fresh fruit brunches along the year. ES2. Oil palm production is currently profitable.	EW7. Low diversification of economic activities, most of the income depends on palm production, and not on other economic activities like, livestock or other crops.	EO10.Investment opportunities from the oil palm surplus generated by good FFB yield and sales	ET11. Change of the oil palm fruit price and demand in the global market. ET13. Change in the price of agricultural inputs specially fertilizers or seeds.

ES3. Immediate payment upon product delivery. ES4. Facility to sale fresh fruit bunches (FFB) due to the presence of several mills and collection centers. ES5. Fruit transportation availability through own vehicle or freight. ES6. Capacity of mills to buy and process all the harvest.	EW8. Labor supply for harvesting does not satisfy the demand. EW9. Informality of some economic agreements between oil palm farmers with mills.		ET14. Absence of government financial support and lack of access to bank loans.
Environmental			
AS1. Oil palm resistance to dry seasons and flood. AS2. Land use change mainly from pastureland. AS3. Low presence of pests and fungi in plantations. AS4. Permanent ground cover including disposal of crop residues, leaves, and stems on the plantations ground. AS5. Palm production required minimal tillage.	AW6. Invasion of palm plants and production near and in the core zone of the reserve. AW7. Deforestation in some zones for palm establishment. AW8. Oil palm high demand of nutrients and fertilizers. AW9. Mainly, the plantations are monoculture.	AO10. Initiation of RSPO certification process for farmers and organizations.	AT11. Climate variations change frequency of floods in Chiapas coastal zones. AT12. Installation of new mills and refineries with higher impacts than the plant production near the reserve.

3.2.2. Selection of strategic indicators.

Not all the strengths and weaknesses can be considered and measure, therefore the next considerations were applied to SWOT matrix to prioritize the most relevant:

- Strengths, Weaknesses, Opportunities or Threats that has larger scale implications, regional or national, are more relevant than those that produce local impacts.
- Strengths, Weaknesses, Opportunities or Threats that are composed or that affect a group of strengths and weaknesses have greater importance. For instance, well-being is composed of services, governance perception, education, medical services, among others.

Based on this criteria and bibliography research, Table 4 contain the critical points and the indicators selected. It should be notice that the nature of the indicators for the oil palm production system in Acapetahua and Villa Comaltitlán, include both qualitative and quantitative data, and cover the seven sustainability attributes of the MESMIS (productivity, stability, resilience, adaptability, reliability, equity, and self-reliance) and four dimensions (social, political, economic, and environmental). Two aspects including governance and the price change of fresh fruit bunches (FFB), were considered relevant but cannot be evaluated due lack of access to public institutions interviews and lack of FFB monthly prices information.

Table 4.

Critical points and indicators for the oil palm system assessment.

Attribute	Critical Point	Indicator	Other elements of the SWOT evaluated through the indicator	Method to collect information	Blibliograhic Source
Productivity	ER2. Oil palm production is currently profitable	Cash flow Net Present Value		Survey	(Svatonová et al., 2015)
Stability, Resilience and Reliability	AW8. Deforestation in some zones for palm establishment	Land use and vegetation cover change	AR2. Land use change mainly from pastureland	Satellite images	
	AW7. Invasion of palm plants and production in the core zone	Application of Good Practices	AR3. Low presence of pests and fungi AR4. Permanent ground cover AR6. Palm production required minimal tillage AW9. Oil palm high demand of nutrients and fertilizers AW10. Mainly, the plantations are monoculture	Survey	(RSPO, 2018)
Adaptability	SW4. Gaps in technical knowledge	Farmers´ training	SR1. Farmers received training	Survey to farmers and mills	(RSPO, 2019)
	PW7. Lack of participation in decision making	Level of participation		Survey	(Kaufmann et al., 2009)
Equity	SR2. Improve of welfare of small farmers	Well-being	SW6. Deficits in services and infrastructure	Survey	(De Jesús and Vega, 2011)

3.2.3. Measurement of indicators

The main sources of information were the oil palm farmers' surveys in the ejidos inside of Acapetahua and Villa Comaltitlán Municipalities. The information obtained was used for the indicators of cash flow, application of good practices, farmers´ training, level of participation and well-being. While for land use change, the analysis of satellite images of the plots was used.

The absence of official data from a public institution of the population size of oil palm farmers in the municipalities; and limitations of time and resources did not allow the determination of a representative sample for the oil palm farmers.

For this reason, the snowball sampling method was employed. Snowball consists in identify relevant actors of the study and require for other people contacts that possess the attributes desired (Berg, 2001). The limit of this method includes the representativeness of the sample is not guaranteed but permits to reach populations that are difficult to sample due to distance and limitation in time, an attribute that was already identified from the first visit to the area.

For this research, initial contacts include representatives of associations and community leaders, as well as researchers in the area. It was able to generate a contact and apply the survey to a sample of 22 farmers.

3.2.4. Annual cash flow

The Cost-Benefit Analysis (CBA) is an economic tool that compares the total costs (C) and benefits (B) of a policy/project, quantifies in monetary terms the consequences to the society and help to the social decision-making (Boardman et al., 2018). A key outcome from this analysis is the net benefit (NBS):

$$NSB = B - C$$

This is a broad assessment that can consider environmental impacts, social costs, economic benefits, and other effects for the time of the project. According to Boardman et al. (2018), it is important to try to cover all the potential impacts of a project or focus on a limited number of significant impacts.

But the time and resources needed for this analysis were not available, thus a cashflow analysis was implemented. Svatonová et al. (2015) formula describes cashflow as the difference between the amount of money flowing in and out a certain of the project:

$$CF = Rf - (C + T)$$

Where:

CF: cash flow

Rf: revenue

C: capital cost

T: recurrent cost

For the application of cashflow, it was recognized that the farmers´ plots has different plantations years and that many already exceeded the normal oil palm cycle of 25 years. This was supported once the surveys were made, where results shows that 11 from 22 farmers possess plots with plants over 25 years old. Additionally, farmers could not provide accurate data from past years due the majority did not generate a registration of cost and profits. This way the information that could be obtained correspond to the years 2020, 2021, 2022, then annual cashflow for these years were reported. For the analysis next assumptions and statements were considered:

- Svatonová et al. (2015) determinates two important cost types: capital and recurrent cost; but according to the technological package of COPLANTA, instance of the State Government, investment oil palm cost includes establishment and maintenance cost (Gobierno del Estado de Chiapas, 2006).The technological package adapted in the study of Gobierno del Estado de Chiapas (2006) didn't include aspects like land acquisition, road, and drainage infrastructure that Svatonová et al. (2015) does consider. Thus, from this national context it was decided not to incorporate these capitals to not overestimate costs.
- There is palm trees depreciation: replantation is a progressive process in the zone, due the high cost of plants. Then, is considered there is a depreciation of the current plantation due there are costs to establish new ones every year.
- The exact cost from replanting in the past was not available for the reasons just mentioned: variability in the plot and no access to accurate values in the past, so an estimation of establishment cost per hectare was obtained, based on current prices informed by farmers. Boardman et al. (2018) establish that fixed costs adjustments should be considered in long-term projects due various factors are subject to change and suggest the amortization of these fixed costs over the project's life. This way, the establishment cost was linearly amortized, by a replanting rate. obtained from the average extension of plots replanting in the last three years and after 2010, when no more free plants were given in the zone.

With this context, Table 5, includes the comparison of benefits and costs obtained in other studies and the ones selected.

Table 5.
Costs and benefits considered in cashflow analysis of the oil palm production system.

Svatonová et al. (2015)	Gobierno del Estado de Chiapas, (2006)	**Case Study**
Revenues: • FFB Sale	Revenues: • FFB Sale	Revenues: • FFB Sale • Social mill profits
Capital Cost: • Land acquisition • Reconnaissance, • Establishment of pre-nursery • Establishment of nursery • Land clearing, • Construction of buildings and other facilities • Construction of road and drainage infrastructure • Machinery • Planting plants	Establishment Costs • Planting • Weed Control • Fertilization • Pest Control • Pruning • Harvesting • Transportation • Equipment • Services	Establishment Costs • Planting • Weed Control • Fertilization • Pruning • Harvesting • Transportation
Recurrent costs • Fertilization and other maintenance • Survey • Maintenance of roads and drainage infrastructure • Pruning trees • Maintenance of buildings and other equipment • Harvesting and transport • Salaries of administrative staff • Operating costs.	Maintenance Costs • Weed Control • Fertilization • Pest Control • Pruning • Harvesting • Transportation • Equipment • Services	Maintenance Costs • Plot Cleaning • Cleaning around the trunk • Fertilization • Chemicals for weed and plagues management. • Pruning • Harvesting: FFB cutting • Align leafy stems. • Cleaning of loose fruit FFB Carry / Reel • Canoe usage • FFB Transport

Note: based on Gobierno del Estado de Chiapas (2006); Svatonová et al. (2015)

Then, Cashflow (CF) is adapted to the next formula:

$$CF = Rf - (E + T)$$

Where:

CF: cash flow

Rf: Revenue

E: amortized establishment cost

T: recurrent/maintenance cost

Scores for sustainable cashflow was obtained from the comparison with the income extreme poverty line (basic basket) and the poverty line (basic basket plus no food basket) per person from National Council for the Evolution of Social Development Policy (Consejo Nacional de Evolución de la Política de Desarrollo Social-CONEVAL), (2023) The data was summed up for the year and multiply per 4 members of a family and compared for each annual cashflow result (Table 6). The number of 4 members was determinate as an average number from the surveys. No inflation rate is used in this part of the analysis, since cashflow already reflects the real prices and values at that time, without the need of adjustment.

Table 6.

Scores for profit surplus related to income poverty line and average real labor income.

Year	Poverty Lines	Annual Incomes (MXN)	Surplus Score
2020	Rural extreme poverty line 2020, family of 4 members	Under 61,935.6	1
		Above 61,935.6 and under 120523.16	2
	Rural poverty line 2020, family of 4 members	Above 120523.16	3
2021	Rural extreme poverty line 2021 family of 4 members	Under 66237.12.28	1
		Above 66237.12 and under 127726.52	2
	Rural poverty line 2021, family of 4 members	Above 127726.52	3
2022	Rural extreme poverty line 2022, family of 4 members	Under 75,021.08	1
		Above 75,021.08 and under 140707.24	2
	Rural poverty line 2022, family of 4 members	Above 140707.24	3

Note: based on CONEVAL (2023).

As a result, farmers were assigned with three scores, one per each study years 2020, 2021, and 2022, and a final sum of all the farmers' scores is calculated to obtain the final indicator.

Net Present Value

Net present value can be defined as the overall financial performance of the project and is estimated as the discount income and cost (Svatonová et al., 2015). A general NPV for all the farmers is established to complement the information obtain in the annual cashflow. For this analysis next statements were considered:

- Future benefits and costs are adjusted in relation to the present through a process of discounting, this rate arises when the project has an opportunity cost to be invested elsewhere, discounting is different from inflation, but inflation must be considered (Boardman et al., 2018). Oil palm farmers' main capital is the own labor. Farmers reported expenses are covered with savings even if social mills members can access to credits. Additional Mexico's inflation rate is unstable, the inflation rate from INEGI (2023) at the beginning of each year, shows an Inflation rate of 3.24% for 2020, 3.54% for 2021, 7.07% for 2022.
- Under these uncertainties, an arbitrary rated was selected, Boardman et al. (2018) proposed a discount rate of 3.5%, while studies of oil palm in Malaysia like Jusoh et al. (2003) and Svatonová et al. (2015), use a discount of 10%. The oil palm study of Gobierno del Estado de Chiapas (2006) did not report the exact rate applied, but results show a discount near 5%. This way, extremes rates were avoided and a discount of 5% was selected from the Chiapas study.

Based on the Net Present Value (NPV) calculation by Svatonová et al. (2015), the next formula was applied:

$$NPV = \sum_{r=0}^{r=R} \frac{CF}{(1+i)^r}$$

Where:

- CF:cash flow
- i: discount rate
- r: time (for this study 25 years)

3.2.5. Land Use Change

According to the Mexico national interpretation of the RSPO, to fulfill the sustainable principles, the land change from 2005 should not have caused the clearance of primary forests or any areas necessary for the preservation and improvement of High Conservation Values (HCVs), areas with significant environmental, social, or cultural attributes (RSPO, 2018). Therefore, it was decided to analyze changes in land use and vegetation from 2005 to 2022.

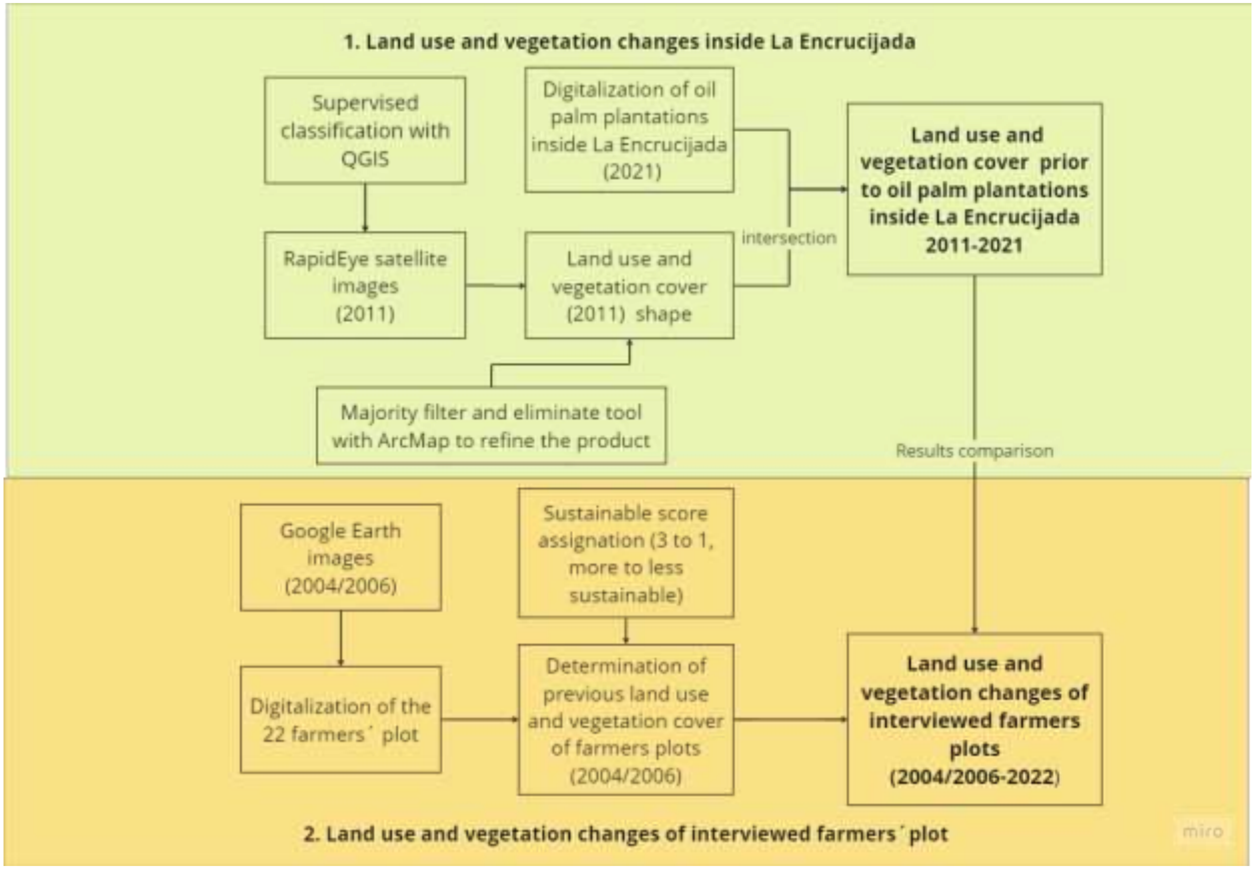
However, the boundaries of the farmers plots could not be totally determined in the field, but the location of the plot and the extension reported by the farmers was used to generate a digitalization through Google images.

Because of this estimation of the boundaries should be made, it was decided to support interviewed farmers land changes by the results comparison with general changes of oil palm plantations in the municipalities.

This way two analysis were made. The first was the general characterization of the land use and vegetation changes prior to oil palm plantations inside La Encrucijada Reserve; and the second was the change of each interviewed farmer´s plot. Figure 5 summarizes the steps applied in this section.

Figure 5

Flowchart for land use change analysis**.**



1. Land use and vegetation changes inside La Encrucijada

For this analysis, a supervised classification was generated thought ArcGIS for Desktop ArcMap software (licensed by TH Köln) and the open-source software Quantum GIS (QGIS). Supervised classification includes selecting training samples of a class to classify the remaining pixels of the satellite image (Campbell and Wynne, 2011).

RapidEye satellite images from 2011 were obtained to generate this process, the images were available in the Planet (2022a) platform https://www.planet.com/explorer/, and its specifications are detailed in the Table 7. This images where selected due cloudiness was low, permitting the visualization of the image, and because more of the 90% of the municipality's territory were covered.

Table 7.
RapydEye-3 image characteristics.

Note: based on Planet (2022b).

The initial classification of land use and vegetation cover were taken and adapted from La Encrucijada study of Velasco (2009). Next classes were obtained based on the zone conditions and to avoid incorrect classifications by the software:

- Mangrove
- Oil Palm
- Urban Zones
- Pastures
- Crops
- Water Body
- Forest
- Swamp ecosystems
- Mango trees

The supervised classification was performed in QGIS using the Random Forest algorithm. The result was a shape file of land use and vegetation cover of Acapetahua and Villa Comaltitlán for the year 2011. To identify previous land uses in current oil palm plantations, this map was intersected with all the oil palm plots inside la Encrucijada Biosphere Reserve, plots digitalized with Google images. Even if La Encrucijada is not the total study zone, the reserve is the main conflict area and the most important for the environment conservation.

2. Land use and vegetation changes of interviewed farmers´ plot

Google Earth images of the years 2004 and 2006 were used in this section to determinate previous land uses of the 22 farmers' plots.

The value of sustainability was given depending on the type of the previous land uses. Three transition scores were created, with score 1 representing a significant impact of change, and 3 indicating a more sustainable transition (Table 8). The categories are supported under the following considerations:

- Score 1 (transition from mangroves, swamp, or forest to oil palm): Oil palm supports much fewer species compared to forests and mangroves; specially in La Encrucijada mangroves constitute a crucial area for conservation in Mexico, these vegetation type possess a high potential for carbon storage and provides high value ecosystem services (Fitzherbert et al., 2008; Velázquez-Pérez et al., 2019). Additionally, wetlands ecosystems can be identified in the zone, including "Popales", vegetative communities of freshwater swamps, dominated principally by "Platanillo" (*Thalia genniculata*); and "tulares", aquatic plant communities primarily constituted by *Typha dominguensis* (SEMARNAP, 1999). Both swamp ecosystems are ecologically important, due they serve as shelters for animal species, and contribute to the maintenance of ecological processes like soil conservation or nutrient cycles (SEMARNAP, 1999). Any transformation of this vegetation or deforestation, implies changes in the ecosystem's services and functions, therefore independent of the percentage of change, if a current oil palm plot is occupying these previous land uses it implied an environmental effect, thus the land use change is not sustainable.
- Score 2 (transition from crops to oil palm): Compared to other crops, there is a substantial overlap in species composition between oil palm and other tree crops and supports similar or higher species diversity compared to mixed crops (Baptista et al., 2010; Fitzherbert et al., 2008). Thus, similarities are found, land changes from crops to oil palm are not totally unsustainable.
- Score 3: (transition from pastures or uncovered ground to oil palm): Oil palm showed higher diversity than pasture and urban mown grass (Fitzherbert et al., 2008). Also transition from urban zones or soil without coverage represents more support for ecosystems services, due this transition is considered sustainable.

Table 8.

Land use and vegetation cover transitions score (2004/2006-2022).

Code	Previous land use and vegetation cover	Transition Score
1	Mangrove	1
2	Oil Palm	3
3	Urban Zones	3
4	Pastures	3
5	Crops	2
6	Water Body	-
7	Forest	1
8	Swamps ecosystems	1
9	Mango trees	2
10	Uncovered ground	3

3.2.6. Good Practices

The good environmental practices (Table 9) were based on the Mexican National Interpretation of the RSPO principles and criteria of the RSPO (2018). Currently, RSPO is the most relevant certification company for the palm oil production system. The certification manages robust standards in environmental, social, and economic terms. The criteria selected and adapted for this case study were taken from the Principle 7: Protection, conservation and enhancement of ecosystems and the environment.

Table 9.

Good practices variables.

N	Code	Description	Categories
1	Fire_use	Does not use fire on the property to prepare land, control pests or remove waste	Yes/No
2	Pes_use	Does not use pesticides (herbicides; fungicides; insecticides and bactericides) like World Health Organization Class paraquat Type 1A or 1B, or Stockholm or Rotterdam Convention lists	Yes/No
3	Plag_man	Apply two or more integrated pest management practices	Yes/No
4	Was_dis	Waste disposal (packaging, bags) according to its toxicity and dangerous characteristics, fertilizer bags for loose fruits are not reused or there is no waste that requires special handling	Yes/No
5	Soil_Fer	The fertility of the property is monitored with soil or plant tissue studies	Yes/No
6	Fer _use	Optimum use of inorganic fertilizer, specific required amounts are known and applied based on fertility studies, or no inorganic fertilizers are used	Yes/No
7	Bio_rec	Biomass recycling (leaves, stems, others)	Yes/No
8	Plan_div	Production of other crops on the plot	Yes/No
9	Plan_div_001	Integration other productive systems (livestock or timber trees)	Yes/No
10	Sis_om	Organic matter incorporation (crop residues or weeds, manure, compost)	Yes/No
11	Sis_use	Use of loose fruits for other systems	Yes/No
12	Soil_ero	Soil erosion is minimized with permanent cover palm residues, bushes) or terraces	Yes/No
13	Qua_well	The quality of well water is appropriate for irrigation or there is no irrigation that causes negative effects on the soil.	Yes/No
14	Slo_plan	No plantations are generated on steep slopes	Yes/No
15	Boli_ver	Loose fruits collection is carried out during the summer season	Yes/No
16	Boli_inv	Loose fruits collection is carried out during the winter season	Yes/No

Note: based on RSPO (2018)

The non-use of inorganic fertilizers is considered a good practice, as inorganic fertilizers. do not improve soil structure, moisture retention or nutrient retention capacity or long-term fertility. In addition, climatic conditions in the study area include abundant rainfalls and a tendency to flood, which favors the risk of nutrient leaching to groundwater or runoff to water bodies.

To determine if the water quality is appropriate for irrigation in the case of farmers that use wells, it was used the Subterranean Quality Report at the national level. The monitoring site closest to the study area corresponds to the Municipality of Huixtla well, Code: OCFSU307, sampling of September 27, 2021, the water parameters indicate that the water quality is appropriate for irrigation (Table 10).

Table 10.

Water quality of the Huixtla well site, code: CFSU3077.

Parameter	Code	Value	Description
Alkalinity	ALC_TOT	241.3	Water suitable as a source of drinking water supply
Fecal coliforms	COLI_FEC	>2400	Waters with bacteriological contamination. Indicates substantial alteration from the normal condition
Nitrogen from Nitrates	N_NO3	0.0944	Drinking water. Uncontaminated water or normal condition
Total dissolved solids	SDT	200	Excellent for irrigation of all types of crops
Conductivity	CONDUC_CAMPO	220	Excellent for irrigation of all types of crops
Iron	FE_TOT	0.12491	Drinking water. Uncontaminated water or normal condition
Fluorides	FLUORUROS_TOT	0.6939	Water with a medium level of fluorides
Manganese	MN_TOT	<0.0015	Drinking water. Uncontaminated water or normal condition
Arsenic	AS_TOT	<0.01	Drinking water. Uncontaminated water or normal condition
Cadmium	CD_TOT	<0.003	Drinking water. Uncontaminated water or normal condition
Chrome	CR_TOT	<0.005	Drinking water. Uncontaminated water or normal condition
Mercury	HG_TOT	<0.0005	Drinking water. Uncontaminated water or normal condition
Lead	PB_TOT	<0.005	Drinking water. Uncontaminated water or normal condition

Note: based on Comisión Nacional del Agua (CONAGUA) (2023).

In addition, agroecological practices, such as integrated pest management, integration of other productive systems in the plots, use of fruits in other productive systems and incorporation of organic matter are evaluated. Likewise, this section does not consider land use change, as it is addressed as other indicator.

3.2.7. Farmers´ Training

As well as the application of good practices, the trainings considered in this composite indicator (Table 11). Variables are those stated by the RSPO (2019) in the Independent

Smallholder Standard. Training in Good Agricultural Practices (GAP) were separated into soil management and pesticide management.

Table 11.

Farmers´ training variables

N	Code	Description	Categories
1	Cap_work	Training on, rights at work, free and fair work	Yes/No
2	Cap_risk	Training or knowledge about production risks (use of herbicides, protective equipment)	Yes/No
3	Cap_disc	Raising awareness about discrimination, abuse, and harassment	Yes/No
4	Cap_fore	Training or knowledge about the importance of High Carbon Stock forests	Yes/No
5	Cap_soil	Training or knowledge on your property about practices to maintain soil fertility and avoid erosion	Yes/No
6	Cap_pest	Training or knowledge on pest management, weed management and invasive species	Yes/No
7	Cap_rip	Training or knowledge on riparian buffer zones (transitional areas between land and freshwater ecosystems)	Yes/No
8	Cap_nor	Training in RSPO certification criteria and principles	Yes/No

Note: based on RSPO (2019).

3.2.8. Level of participation

The Worldwide Governance Indicators (WGI) project covers 212 countries and territories and generate indicators value in six dimensions, based on hundred individual variables and 35 different data sources, including surveys from firms and individuals, non-governmental organizations, multilateral aid agencies, and public sector agencies (Kaufmann et al., 2009). The WGI project provides a comprehensive and diverse approach to measuring governance perceptions worldwide, including participation.

From this extensive array of indicators and sources and inside the Voice and Accountability dimension, three indicators were selected: "Freedom of Association" and "Respect for Minorities." from The Institutional Profile Database; and “Voting and Citizen Participation” from the Global Integrity Index. Last one disaggregated into active participation in dialogues or negotiations and awareness of decision-making processes (Table 12).

Table 12.

Participation variables.

N	Code	Description	Categories	
1	Dec_know	Knowledge of decision making, policies generated related to oil palm.	0=low knowledge	4=a lot of knowledge
2	Act_part	Active participation in consultations, negotiations, dialogues) in the last 12 months in relation to oil palm production	0=none, 1=one, 2=two, 3=three, 4=four or more	
3	Free_asso	Freedom to associate and withdraw from a mill or social organizations	0=little freedom	4=A lot of freedom
4	Min_resp	Respect for minorities (ethnic, religious, linguistic, etc.)	0=little respect	4=Much respect

Note: based on (Kaufmann et al., 2009).

3.2.9. Well-being

The indicators for well-being were based on the National Quality of Life Index (INCAVI) for Mexico, proposed by the University of Monterrey (García Vega, 2011). At same time, INCAVI is based on the key domains to measure the population well-being, mentioned by the Stiglitz Commission (Commission on the Measurement of Economic Performance and Social Progress): material living standards (income, consumption, and wealth); health, education; personal activities; political participation and good governance; social connections and relationships; environment (present and future conditions); and insecurity of an economic and physical nature (García Vega, 2011).

Indicators were adapted from INCAVI (Table 13) due it was considered they are adjusted to the Mexican context.

Table 13.

Well-being variables.

N	Code	Description	Categories	
Health Domain				
1	Hea_sta	Perception of health status	0 =poor health	4=Good health
2	Doc_vis	Times you have visited the doctor in the past six months	0=none, 1=one to two, 2=three to four, 3=five to six; 4=seven or more	
3	Med_ser	Quality of medical services	0=poor quality of services	4=good quality of services
Economic Domain				
4	Hou_acc	Easy to get suitable house/room	0=easy to acquire house/room	4=Difficult to acquire house/room
5	Sell_RFF	Easy to sell Fresh Fruit Bunches (FFB)	0=easy to market FFB	4=difficult to market FFB
6	Sell_RFF5	Ease of selling fresh fruit bunches 5 years ago	0=easy to market FFB	4=difficult to market FFB
7	Food_nee	If you reach the money for food needs	0=Not enough money for food	4=If you reach the money for food
Education Domain				
8	Edu_perc	Perception of academic level of schools	0=low academic level	4=High academic level
9	Edu_acc	Access to good education	0=low access	4=A lot of access
Security Domain				
10	Prop_conf	Disputes or conflicts over the use of the properties	0=no dispute	4=A lot of security
11	Ins_vic	Victim of insecurity in the last 12 months	4=none, 3=one, 2=two, 1=three; 0=four or more	
12	Aut_capa	Authorities' capacity to deal with insecurity	0=low capacity	4=A lot of capacity
Good Governance Domain				
13	Hon_gov	Honesty of government authorities managing oil palm	0=little honesty	4=A lot of honesty
14	Efic_gov	Efficiency of management of oil palm production authorities	0=low efficiency	4=Very efficient
15	Qua_ser	Quality of public services	0=low quality	4=Good quality of public services
Community Life Domain				
16	Cli_sta	Climate stability for production	0=low stability	4=A lot of stability
17	Env_Qua	Environmental quality for production	0=poor quality	4=good quality
18	Eas_mov	Easy to move around the area	0=uneasy	4=Very easy
Personal Wellness Domain				
19	Lif_qua	Perception of your quality of life	0=poor quality	4=good quality
20	Fam_time	Time and ease to live with family and friends	0=short time and ease	4=A lot of time and ease

Note: based on (García Vega, 2011).

3.2.10. Integration of indicators

The weighting of variables was not performed, since as mentioned by Schuschny and Soto, (2009), the use of identical weighting factors may be appropriate when working with sub-indicators that cover different dimensions, as in the case of sustainability; but the absence of this weights can be justified when a balanced approach is sought, this means not prioritizing any dimension or when there are significant correlations between variables. Schuschny and Soto (2009), also mentions that to aggregate the sub-indicators in a composite indicator, different approaches can be used:

- sum of rankings
- the count of variables exceeding a given benchmark
- weighted arithmetic mean.
- weighted geometric average.
- multi-criteria approaches.

The sum of rankings offers the advantage of being a simple method independent of outliers. Geometric and arithmetic averages consider the different variables interact and compensate each other, these methods reflect the balance and interrelationship between the variables in the calculation of the composite indicator (Schuschny and Soto, 2009). Value counting involves counting the number of indicators that are above or below certain reference values, this strategy is usually applied after performing an exploratory analysis.

Considering this, the selection of the aggregation method is based on the indicator's variances between farmers, that determinates the dispersion of the individual values from their average. A high variance in the data for the training and the well-being composite indicators were detected. Thus, the sum of values per famer is made to preserve complete information and individual differences.

Subsequent, to integrate indicators (good practices, training, well-being, participation) a total sum for all the farmers is made, and a min-max score value transformation is generated. The new scale corresponds to a range between 1 and 10, and it was based on indicators for governance of Donner et al. (2022) document and the well-being indicators of García Vega (2011) study.

$$new\ score = \frac{(\text{new upper} - \text{new lowest}) * (original\ value - original\ lowest)}{\text{original upper} - original\ lowest} + new\ lowest$$

CHAPTER 4: RESULTS

4.1. General characteristics

4.1.1. Farmers and plantation characteristics

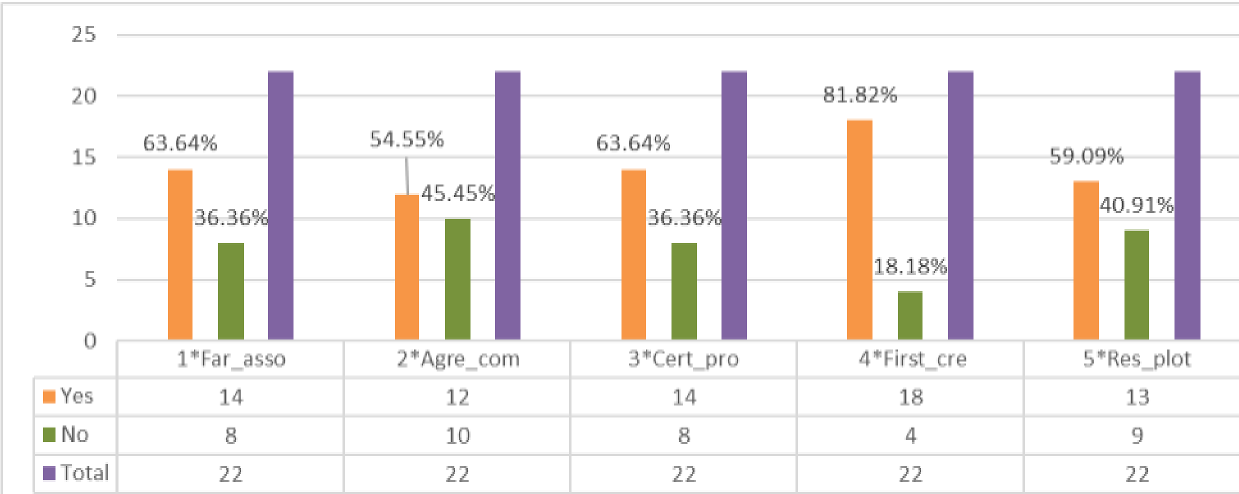
Twenty-two interviews were conducted and consider in this analysis, 16 in the Municipality of Acapetahua: 6 interviews in the ejido “15 de Abril” and 9 in the ejido “El Arenal”; while 7 surveys took place in the Municipality of Villa Comaltitlán, in the ejido Luis Espinosa.

In relation to the level of education, 18.2% of the interviewees did not complete any level of study, 40.9% crossed primary studies, 31.8% secondary education and 9.1% high school studies or higher. Regarding the production of oil palm (Figure 6), 63.64% belonged to a farmers’ association, it was identified members from Zitihualt (7), Bepassa (4) and La Primavera (1). Then these 12 farmers have agreements with these mills that guarantee FFB sale, but two farmers are associated to other social organizations but do not have affiliation to a private or social mill to guarantee the received of FFB.

All farmers belonging to social mills are willing to participate in the certification process. Although, according to interview with Bepassa (pers. comm. April 24, 2023), representatives, they have not yet been officially registered in the certification process due to the required budget, while Zitihualt (pers. comm. April 25, 2023) informed they are already adhered to RSPO certification.

Figure 6.

General farmers and plots characteristics (Yes/No questions)



	1*Far_asso	2*Agre_com	3*Cert_pro	4*First_cre	5*Res_plot
Yes	14	12	14	18	13
No	8	10	8	4	9
Total	22	22	22	22	22

1 Far_asso: Member of a farmers' association; 2*Agre_com: Agreement with a private or social mill for FFB sale, 3*Cert_pro: Purpose of certification, 4*First_cre: Credit or incentives for the first oil palm plantation, 5*Res_plot: Plots within the La Encrucijada Reserve.*

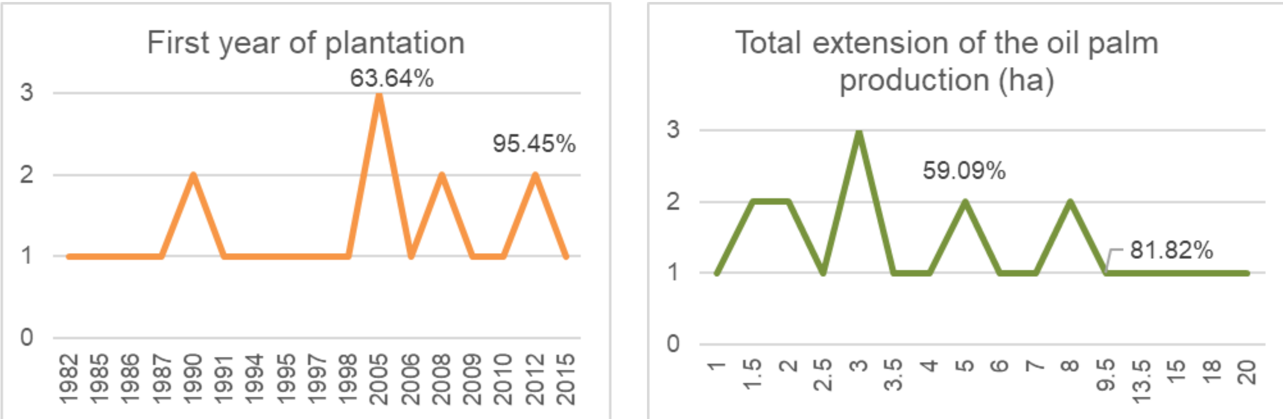
The 81.82% of the growers received incentives for their first oil palm plantation, in all cases the incentives came from the Government, only in one received additional incentives from the National Fruit Commission (CONAFRUT). While the four plots that did not receive incentives correspond to the years 1994, 2008, 2010 and 2015.

The government incentives would come from the mentioned official Chiapas State Programs established between 1990-1991 and 1997; and the Program of the Institute for Productive Reconversion and Bioenergy (IRBIO), maintained between 2007 and 2012; and the FIRCO and FomenPalma's Southeast Productive Development Program until 2018.

Figure 7 shows that 81.82% of farmers interviewed have less than 10 ha of palm plantation. It should be noted that 63.64% of the first plantations were stablished before 2005, the year from which the RSPO principles request justification of the environmental impact. The same way, 95% of the plantations are prior to 2012, the year that the National Interpretation of the RSPO Principles for Mexico was released.

Figure 7.

Year and extension of the farmer´s oil palm plots.



4.1.2. Additional incomes and expenses

Even if in the past, farmers received benefits like free oil palm plants, currently none of them informed government incentives for the production. Only one of the farmers reported economic benefits for the oil palm production from Agrovita project by PepsiCo. Regarding additional incomes from others production systems, 6 farmers (27%) do not report any economical additional activity, 10 (45%) reported at least one additional activity, principally related to other crops production, and annually earn less than 50.000 MXN and 6 farmers (27%) received more than 50.000 MXN.

All the new investment costs such as plants, transportation for new plantations in the last three years are fully paid, except for one farmer. The expense with the longest payment interval observed are fertilizers, as associated farmers can purchase inorganic fertilizers from the social mills and completed the payment at the end of the year.

Additional incomes from other systems are not considered in the surplus analysis, continue generated, since other activities were identified in the plots but those were not informed by the interviewees, thus there were inconsistencies. While the costs for new plantations were omitted as they are still in the growth stage and do not generate profits or the profits are minimum.

4.2.Sustainability Indicators

4.2.1. Annual Cash Flow

Revenues Record

The revenue calculation includes the profits from FFB sales and social mills profits, both obtained from the surveys. The tickets of the FFB sales or records were asked for all the cases but great part of the farmers didn´t maintain a registration. Thus, an estimation base on productivity along months was used.

The are three possible approaches to deal with missing data, the first is to eliminate the information, which can lead to systematic differences. The second option is to remove the variable if it has less than 5% missing data compared to the total set it is not desirable to remove it. The third option involves simple imputation of the data using averages, medians, modes, or regressions with the available information (Schuschny and Soto, 2009).

Eliminate the indicator or the farmer survey that did not have productivity records would imply a big loss of information. To avoid this, an implicit modeling was used. Implicit modeling involves fill information gaps using units that behave similarly or substituting missing information with existing records or source values (Schuschny and Soto, 2009).

Farmers who kept records or save their FFB sale tickets, the values of those records were transcribed, and any missing data were completed by taking the average between the immediately preceding and succeeding values, or by using an average of the maximum or minimum values provided by the farmer.

In the cases that tickets were not available, farmers provided an estimation of highest and lowest months of production and the tons usually produced. An average of these maximum and minimum was calculated for medium productivity months.

Regarding the differences in production between years, some farmers reported that there were variations, mainly related to climatic factors, while others stated that production remained similar along recent years.

According to the information provided by Gobierno del Estado de Chiapas (2006) and Woittiez et al. (2017b), it is considered that starting from the 6th or 7th year, production stabilizes. Therefore, same production tons were assigned for the three years of analysis, except for plots where differences in production between years were reported.

Costs Record

The recurrent or maintenance costs vary in the method of payment. For activities such as cutting, pruning, or transportation, costs are charged per ton of FFB. However, for activities like collect loose fruits, the charge is made depending on the number of sacks; while for the cleaning, weeding, or thinning, payment is made by hectare. For this reason, the payment method, values, and frequencies were registered differently for each producer.

About establishments costs, from farmers that reported replanting after 2010 (10 of 22 farmers), and average of 2,08% change per year was obtained. This average was calculated from reported changes in the last three years, with a result of replanting 2,3% of the plots per year. Thus, a constant replanting rate of at least 2% of the plots was apply to all farmers. The average expenses with prices from 2022 indicate the next establishment cost:

Table 14.

Establishment cost for one hectare of oil palm.

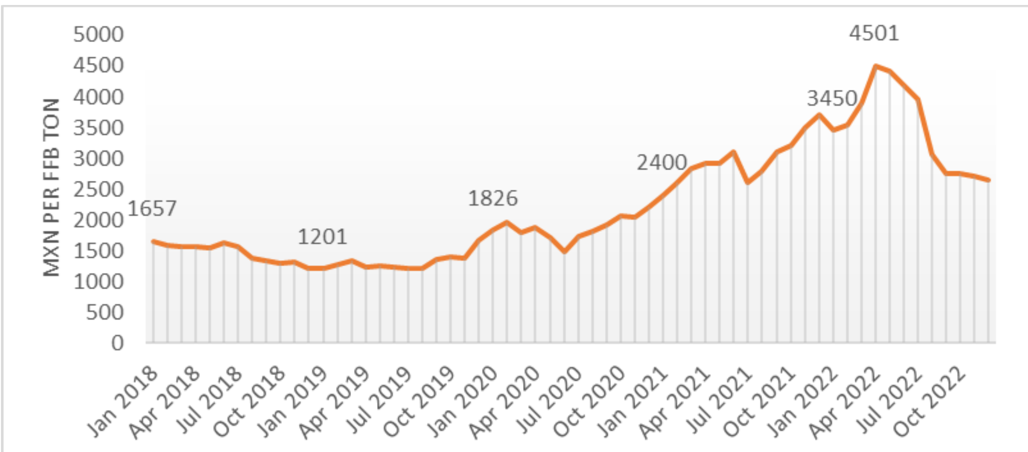
Establishment Costs for a plantation of 100 plant per hectare (MXN)	Unitary (MXN)	Per ha (MXN)
Planting	105 per plant	10500.00
Fertilization	1000 per bag, 5 bags per ha, twice one year	10000.00
Weed Control	4000 per ha	4000.00
Pruning	1500 per ha	1500.00
Transportation	1000 per trip	1000.00
Services	2000 for sowing	2000.00
	TOTAL	29000.00

Prices change.

A list of prices was facilitated by famers and includes monthly production from 2018. From the list can be noted an increase in the sale price of FFB, although there are months that prices drop, there has been an increase along years reaching the highest of more than 4,500 MXN per FFB ton. Although after this peak a declination started reaching a price of 2500 MXN for March 2023, same value that FFB had in February 2021.

Figure 8.

Monthly variation of FFB prices between 2018-2022.



Cashflow Results

With this background, data obtained for the 22 farmers, shows the profits generated by sales and earnings from associations, exceed the costs for maintenance (Figure 9, a). On average, the production per hectare is estimated at 1,1 t of FFB every 15 days of harvest, only two cases possessed yield upper than 2 t of FFB.

The data demonstrates an increase of profits over the three years of study. This increase is notable between years 2020 and 2022 (Figure 9).

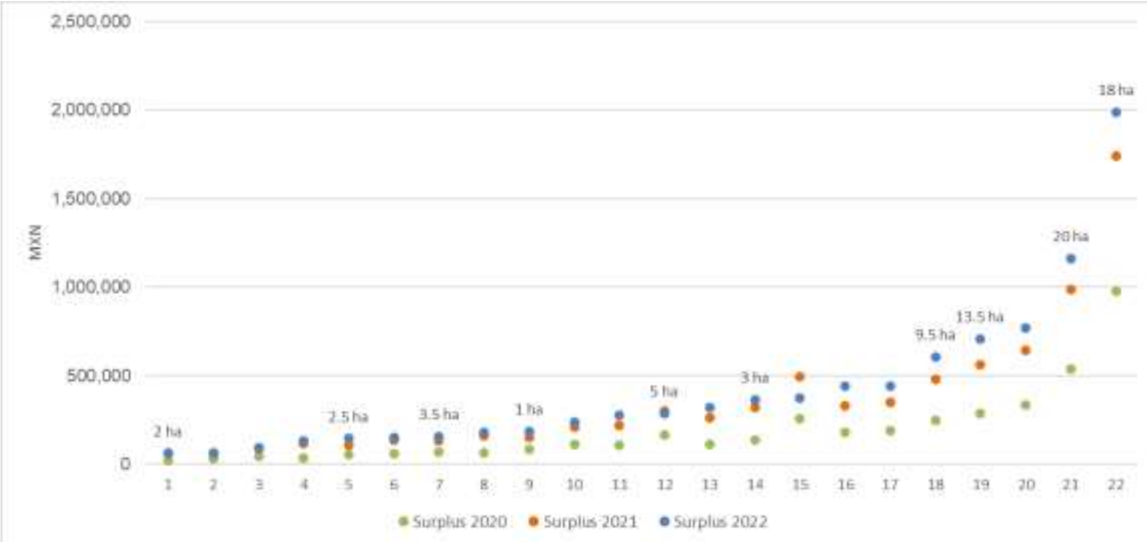
Figure 9.

Comparison of cost and benefits of oil palm production per farmer for the years 2020, 2021 and 2022.

For 2022, the year with better FFB prices, the highest surplus was of 1,989,352.00 MXN, Meanwhile, the minimum recorded was 63,454.43 MXN per year. The differences of incomes between farmers are directly related with the extension of the plots destinated to the oil palm production. For the same farmer the surplus value for 2020 was 19,977.00 MXN thus the income for 2022 is almost twice compare with 2020, and similar results is identified in the rest of the farmers (Figure 10)

Figure 10.

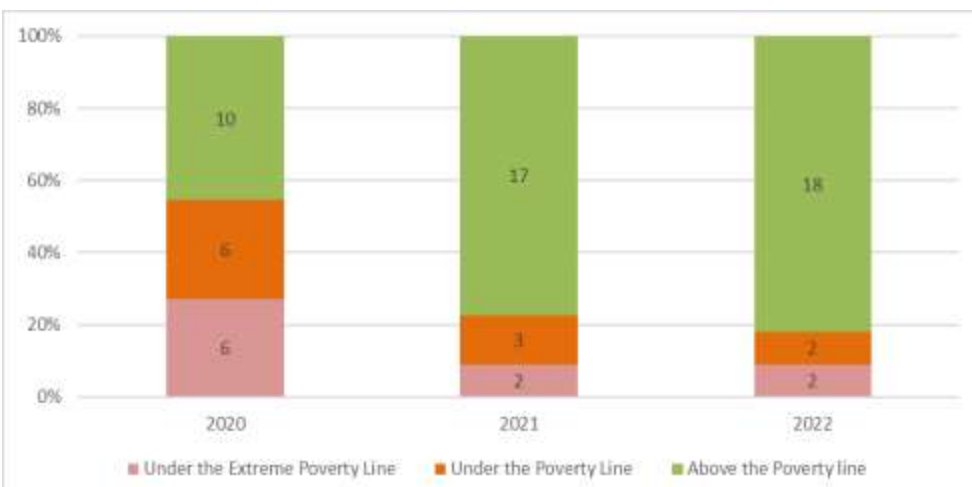
Comparison of cost and benefits of oil palm production per farmer for the years 2020, 2021 and 2022.



Even if incomes have improved between years, for 2022 and 2021 at least 2 farmers were below the extreme poverty line for a family of four members. Before 2021 year where FFB prices were lower, 6 farmers were under the extreme poverty line and other 6 under the poverty line, this means that more than 50% of the farmers were in a poverty situation in past years. An improvement of the earnings has been experienced in the last two years, that permit overcome poverty.

Figure 11.

Profit surplus score (1 to 3) for the years 2020, 2021 and 2022.



Net Present Value

According to Gobierno del Estado de Chiapas (2006), first three years of plantation doesn´t provide income, until the fourth year where yield arise to the 16.67% and the production reaches 100% of yield after the seventh year. But as mentioned in the methodology chapter, it's important to consider that changes in plots are progressive and that there is plantation producing while others are replaced. Considering this constant change, the Net Present Value (NPV), is an average of the surplus from the cash flow where a constant change of 2% was already applied; the values chosen to correspond to 2021, as 2022 FFB prices had already dropped.

Table 15.

Present Value of oil palm production per hectare

Financial Measure	
Average income (MXN/ha/yr)	77693.55
Average cost of production (MXN/ha/yr)	17185.18
Establishment cost (MXN/ha)	29000.00
Average surplus (MXN/ha/yr)	59928.36
NPV (5% discount) for 10 years	462750.93
NPV (5% discount) for 25 years	844627.03

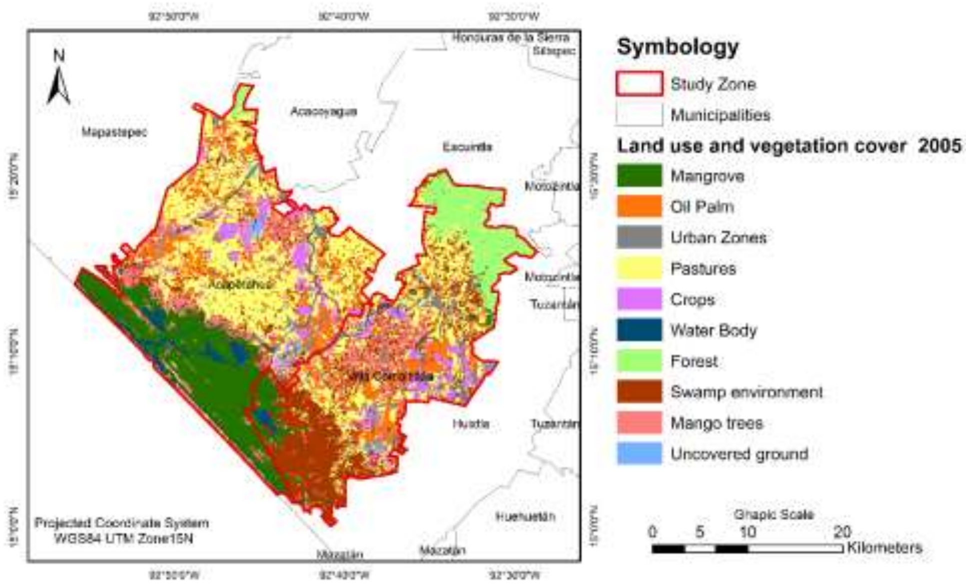
NPV for 10 years and 25 years of the plantation is positive, then the is more income generated that establishment and maintenance costs, due the oil palm plantation is profitable based on 2021 FFB prices.

4.2.2. Land use change

From the supervised classification using RapydEye satellite images, a shapefile of land use and vegetation cover for the year 2011 was obtained (Figure 12). In general, the identification of pasture, crops, and oil palm areas didn´t represent problems for the Random Forest algorithm. However, difficulties were encountered in classifying urban zones and uncovered ground, as well as distinguishing between swamp and forest, despite efforts to distribute the training sample, an optimal level of classification could not be obtained. This way, it was decided to group swamp with forest, and urban zones with uncovered ground, as they had similar transition scores and still supported the indicator.

Figure 12.

Land use and vegetation classification for the year 2011, through supervised classification of RapydEye-3 images.



From the intersection results of the land use and vegetation cover for 2011 with the oil palm plots within the Encrucijada for the year 2022 (Figure 13), approximately 39.66% of the plots were already producing oil palm in 2011, 30% were pastures, and 11.34% were identified as swamp or forest (Table 16).

Figure 13.

Oil palm plots inside La Encrucijada biosphere reserve, obtained thought the digitalization of Google images 2022.

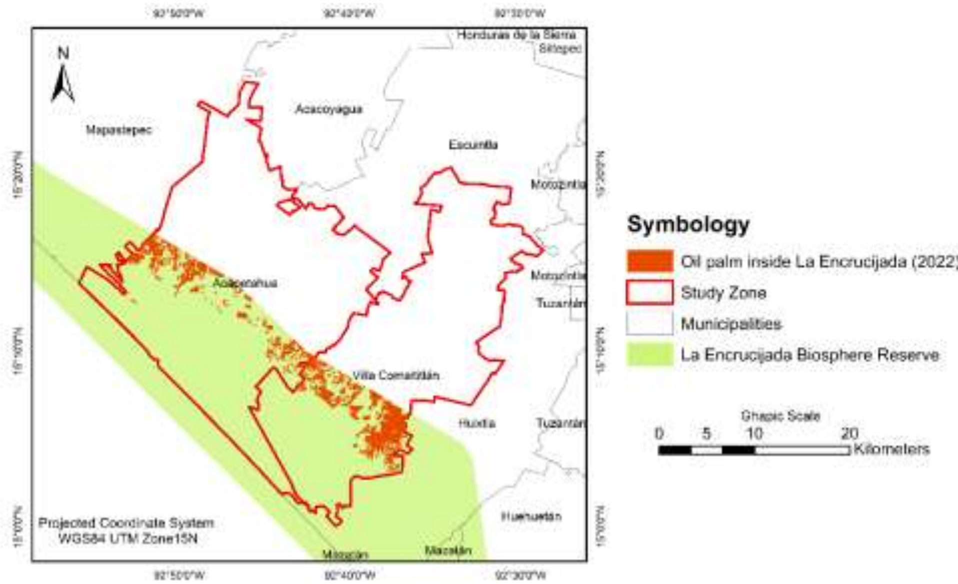


Table 16.

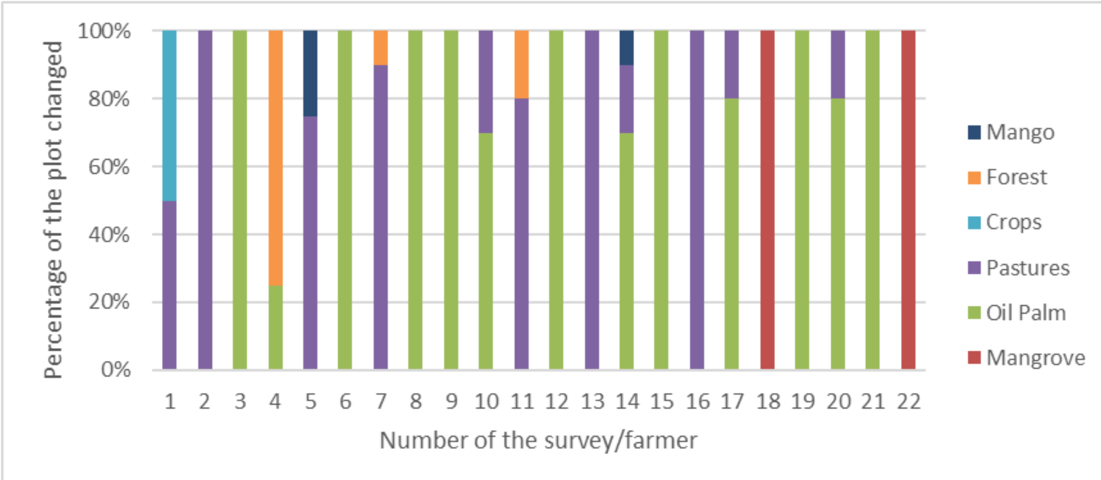
Land use and vegetation changes to oil palm production between 2011 and 2022.

Code	Type	Area (ha)	Percentage
1	Mangrove	0.79	0.01%
2	Oil Palm	2192.36	39.66%
3	Urban Zones/	388.94	9.19%
4	Pastures	1659.02	30.01%
5	Crops	416.95	7.54%
6	Water Body	14.06	0.25%
7	Swamp ecosystems/Forest	626.76	11.34%
8	Mango trees	110.68	2.00%
9	Undecovered ground	118.69	2.15%
	Sum	5409.571	100.00%

For land use and cover transition from 2005 to 2022, obtained from Google Earth visualization, it was identified that the greatest change of the interviewed farmers palm plots corresponded to pastures or that the palm production already existed. Figure 14 shows the proportion of change of each plot.

Figure 14.

Land use and vegetation changes to oil palm production of interviewed farmer (n=22) between 2005 and 2022.



Results of this analysis and the change between 2011 and 2022 are consistent. The main change identified in both approaches are pastures and previous oil palm plantations followed by natural cover change like forest and swamp. Even if the farmers plots were estimated, there is concordance in the results and the transition score can be use like indicator.

The score for each farmer is the change that generated the greatest environmental impact, regardless of the proportion of the plot changed. Thus, 15 of the farmers obtained a score of 3 because the previous land use in 2004/2006 were pastures or oil palm. Two farmers that made changes to crops and mango trees, were categorized with score 2. Two cases of oil palm production were previous mangroves, both located in Ejido 15 de Abril; and three cases implied the removal of forests in the past, obtaining values of 1.

4.2.3. Good Practices

One the surveys were generated, the variable of avoid planting on steep slopes, more than 25% by (RSPO, 2019) was omitted. Acapetahua coastal micro-watershed includes flat and undulating topographies (Medina Mendoza, 2011); but due all the surveys fall in flat territories there were no representative slopes variations.

For the rest of good practices, all farmers include incorporation of organic matter, recycling of biomass, permanent cover of the ground and of well water of appropriate quality for irrigation. Regarding the latter, two of all farmers use a well for irrigation.

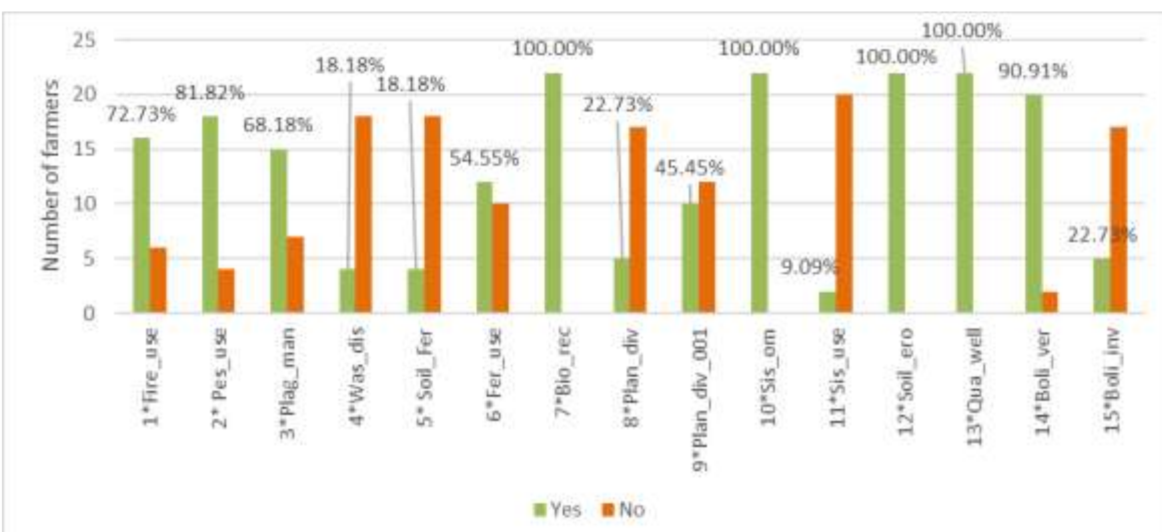
The aspects that partially fulfilled but include at least 80% of the farmers are: not using fire or hazardous pesticides. Farmers who did not comply with the parameter of pesticides apply Paraquat; while pesticides used that are not within the classifications of the World Health Organization (WHO) (2020), type 1A or 1B of the Stockholm Convention lists, included Cypermethrin, Aminopyralid and Glyphosate. Two of them does not belong to any social mill or social organization, the other two belongs to social organizations but that does not possess field schools.

Integral pest management practices included mechanical management such as traps, pruning leaves or elimination of affected individuals; and biological control with plants such as shrimp beard (*Justicia brandegeeana*)

Aspects with less compliance include loose fruit collection in winter due to partial flooding of the plots for at least two months, the correct disposal of residues and the use of fruits in other productive systems. Even if the use of other crops on the plot is low, at least 45% of farmers incorporate other productive systems, among livestock (4) and timber threes such as oak and cedar (7).

Figure 15.

Agricultural practices apply for farmers (n=22).



*1*Fire_use: use fire; 2*Pes_use: does not use pesticides WHO type 1A or 1B, or Stockholm or Rotterdam Convention lists; 3*Plag_man: apply two or more practices to the integrated pest management, 4*Was_dis: correct waste disposal; 5*Soil_Fer: soil fertility is monitored; 6*Fer _use: optimum use of inorganic fertilizer; 7*Bio_rec: biomass recycling (leaves, stems); 8*Plan_div: production of other crops; 9*Plan_div_001:integration other productive systems; 10*Sis_om: Organic matter; 11*Sis_use: use of loose fruits for other systems; 12*Soil_ero: permanent cover to avoid soil erosion; 13*Qua_well: well water is appropriate for irrigation; 14*Boli_ver: loose fruits collection during the summer; 15*Boli_inv: loose fruits collection during the winter.*

On average, farmers carry out 9 out of 15 good environmental practices, with a total sum of 199 score out of a possible maximum of 330 (Table 17).

Table 17.

Score of good agricultural practices

Best possible score per farmer	15
Average obtained	9.05
Variance between farmers	2.62
Sum of individual scores	199
New score: 0 to 10 (Min-max transformation)	$\frac{(10-1)*(199-0)}{330-0}+1=5.43$

4.2.4. Farmers´ Training

Of the twenty-two participants, two have not received formal training from any institution, while eleven farmers who are members of social mills, have been instructed in field schools of the societies, and includes Zitihualt (5), Bepassa (5) and La Primavera (1). Zitihualt and Bepassa reported that workshops were held through Solidaridad foundation.

During the personal dialogue with Bepassa (pers. comm. April 24, 2023), it was informed that in previous years, the trainings were carried out based on agreements with the ONG, Solidaridad. While, in the interview with Zitihualt (pers. comm. April 25, 2023), it was highlighted that the training is provided by the mill technicians, through field school programs.

Other trainings came from: government through programs such as Sembrando Vida (2) and the National Forestry Commission (1); other social organizations (1);

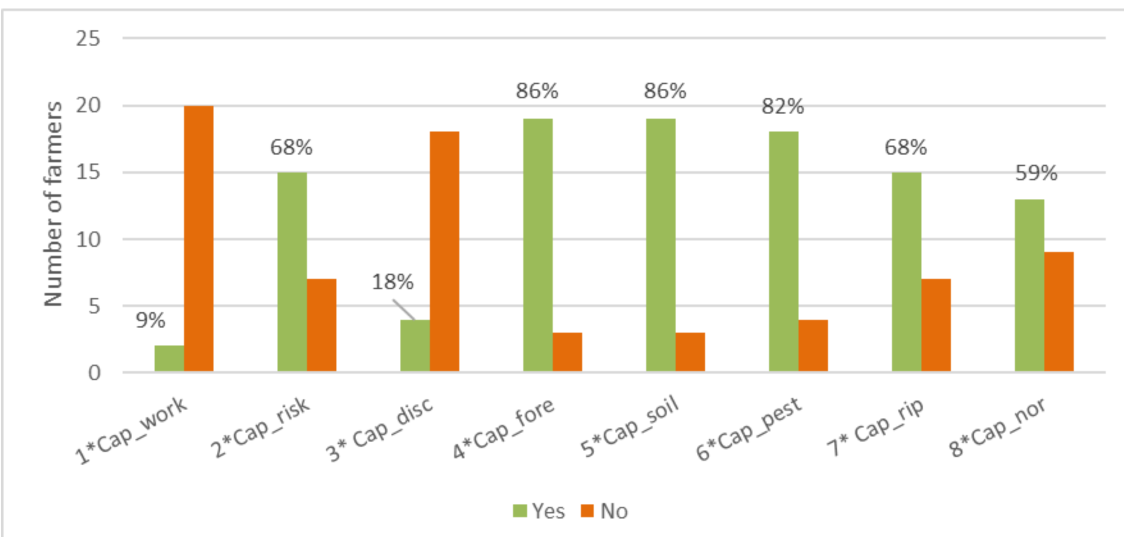
FEMEXPALMA(1), and private companies like Propalma (2), S.A.P.I (1) and PepsiCo (1). Even if farmers have received this training not necessarily because they possess oil palm, it was considered due they use this knowledge in the plantation.

Training from field schools or workshops was not the only way of knowledge identified. Teaching from parents to children in topics like conserving the cover to avoid soil moisture lose or throwing weeds to the same soil were also considered in the results.

This way, farmers possess more training or have more knowledge in topics like pest management, forest conservation and soil management. In addition, more than half of the interviewees have knowledge in the conservation of buffer zones in riparian areas, principles, and criteria for certification as well as risks in the production process. However, there was a notable lack of training related to fair work and discrimination (Figure 16).

Figure 16.

Knowledge or sustainable training received by farmers (n=22).



*Training or knowledge in: 1*Cap_work: rights at work, free and fair work; 2*Cap_risk: production risks; 3*Cap_disc: raising awareness about discrimination, abuse and harassment; 4*Cap_fore: importance of High Carbon Stock forests; 5*Cap_soil: practices to maintain soil fertility and avoid erosion; 6*Cap_pest: management, weed management and invasive species: 7*Cap_rip: riparian buffer zones; 8*Cap_nor: RSPO certification criteria and principles.*

Table 18.

Score of farmers knowledge or training received.

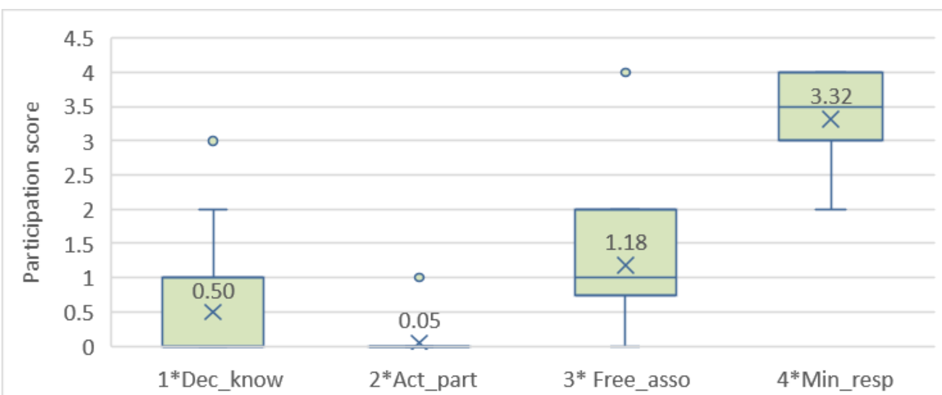
Best possible score per farmer	8
Average obtained	4.77
Variance between farmers	4.09
Sum of individual scores	105
New score: 0 to 10 (Min-max transformation)	$\frac{(10-1)*(105-0)}{176-0}+1=6.37$

4.2.5. Level of participation

Figure 17 shows the results for the four indicators considered. The two related to decision-making: knowledge and participation in some dialogue with authorities, have a value close to zero. What means that individual participation is null, but farmers who are associated to some type of society can find representation through these organizations.

Figure 17.

Farmer level participation indicators (n=22).



*1*Dec_know: Knowledge of decision making, policies generated related to oil palm.; 2*Act_part: Active participation in consultations, negotiations, dialogues) in the last 12 months in relation to oil palm production; 3*Free_asso: Freedom to associate and withdraw from a mill or social organizations; 4*Min_resp; Respect for minorities (ethnic, religious, linguistic, etc.)*

However, in the interviews held with representatives of Zitihualt and Bepassa, the mills reported the participation in the last year was related to the conservation. Zitihualt joined two dialogues related to La Encrucijada biosphere reserve, that representative informed they were not officially initiated and Bepassa was part of conference of environment conservation. The participation in other topics related to oil palm production were not identified.

In the case of freedom to associate, the indicator has an average value of 1.18. The reasons reported for this low score includes discrepancies of interest between members of the associations and in the case of the social mills, new members are not accepted in recent years. Shares can be sold but this implies high cost for the farmer interest in joining. The indicator with the best results and low choice of answers is respect for ethnic minorities, with a score of more than three.

Table 19.

Score for level of participation

Best possible score per farmer	16
Average obtained	5.05
Variance between farmers	2.21
Sum of individual scores	111
New score: 0 to 10 (Min-max transformation)	$\frac{(10-1)*(111-0)}{352-0}+1=3.84$

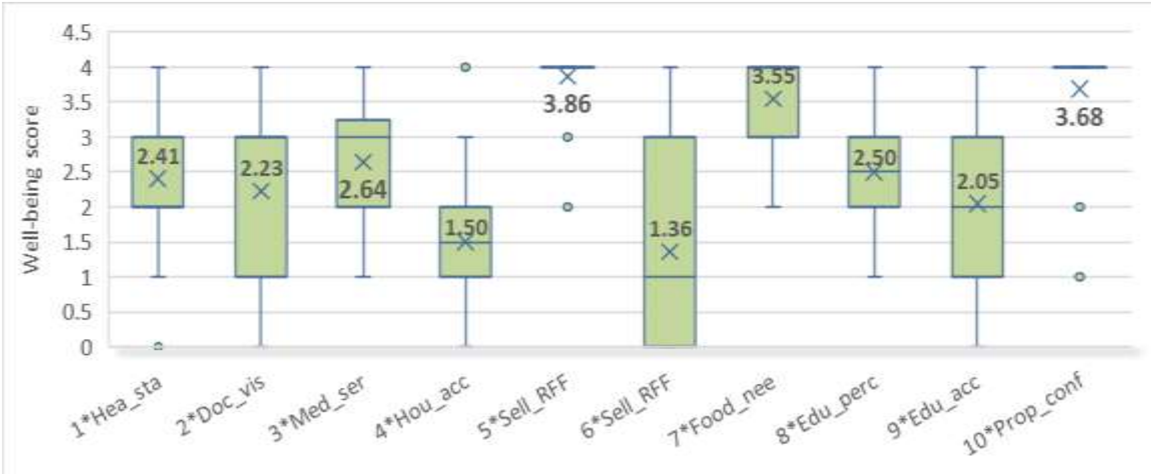
4.2.6. Well-being

The box plot graphic (Figure 18), permit the visualization of the variability of the well-being scores obtained from the 22 farmers. A larger the box represents a bigger variability and discrepancies between farmers answers.

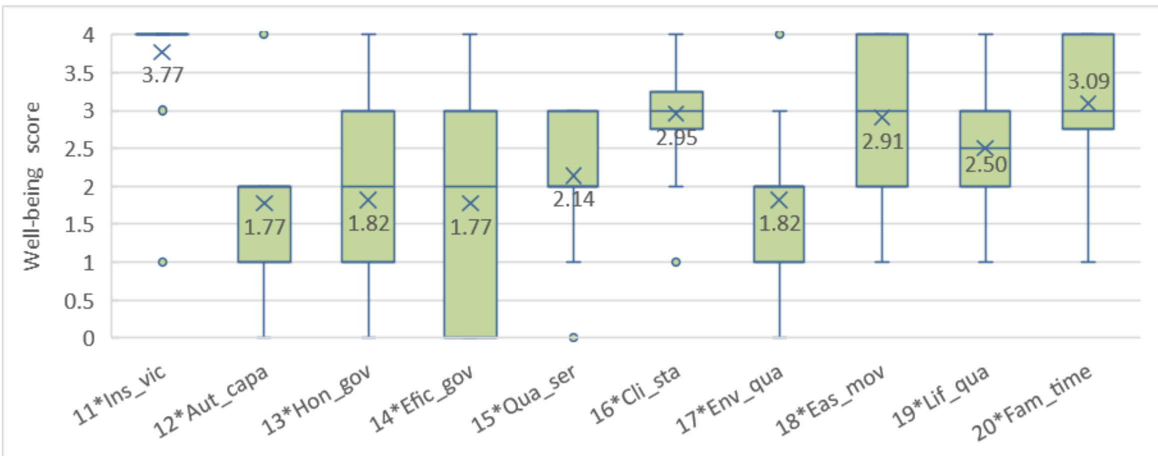
Figure 18.

Distribution of well-being farmers scores (n=22)

(a)



(b)



(a) 1 Hea_sta: Perception of health status; 2*Doc_vis: Times you have visited the doctor in the past six months; 3*Med_ser: Quality of medical services; 4*Hou_acc: Easy to get suitable house/room; 5*Sell_RFF: Easy to sell FFB; 6*Sell_RFF5: Ease of selling fresh fruit bunches 5 years ago; 7*Food_nee: If you reach the money for food needs; 8*Edu_perc: Perception of academic level of schools; 9*Edu_acc: Access to good education; 10*Prop_conf: Disputes or conflicts over the use of the properties;*

*(b) 11*Ins_vic: Victim of insecurity in the last 12 months; 12*Aut_capa: Authorities' capacity to deal with insecurity; 13*Hon_gov: Honesty of government authorities managing oil palm; 14*Efic_gov: Efficiency of management of oil palm production authorities; 15*Qua_ser: Quality of public services; 16*Cli_sta: Climate stability for production; 17*Env_Qua: Environmental quality for production; 18*Eas_mov: Easy to move around the area; 19*Lif_qua: Perception of your quality of life; 20*Fam_time: Time and ease to live with family and friends*

Box plot graphic: values in the upper and lower extremes of the box represent the upper quartile and lower quartile, upper and lower extremes of the whiskers represent the maximum and minimum score obtained.

The higher discrepancies between opinions are related to facilities to sell FFB 5 years ago and efficiency of authorities to manage oil palm production. Only the members of the Zitihualt were able to state that years ago their products could be easily sold while according to other farmers testimonies, there were occasions that the mills didn´t receive the product, one motive was the lack of capacity to process all the product.

While better results include high facilities to sell FFB, full satisfaction of food needs, high availability of time, and high security in the aspects of low victims of insecurity and few conflicts.

Low average scores, means below medium value two, includes: ease of obtaining housing, capacity of authorities to combat crime, government honesty, and efficiency of the government. Although the environment quality indicator has a low score, principally related with rivers contamination, there is a good perception of the climate stability to produce oil palm.

At last, although there is a perceived economic advantage in meeting their food needs and a good current sale of the product, the quality of life perceived by the farmers is just above an average value of two, that means the main needs have not been fulfill. Under these considerations, the total welfare score obtained was 1107 out of 1760.

Table 20.

Score of farmers well-being

Best possible score per farmer	80
Average obtained	50.32
Variance between farmers	50.5
Sum of individual scores	1107
New score: 0 to 10 (Min-max transformation)	$\frac{(10-1)*(1107-0)}{1760-0}+1=6.66$

4.3. Integration of Indicadors

From the transformation to the new scale of sustainability (Table 21), between 1 and 10 of all the indicators, a high score for to land use change and profit surplus were obtained. Knowledge or training levels, as well as farmers well-being, are closer to the median of the sustainability measured in the study, while the level of participation would denote low sustainability for the system.

Table 21.

Summary of indicators results, and new score obtained.

	Profit Surplus	Land use change	Good agricultural practices	Farmers´ training	Level of participatio n	Well-being
Best possible score per farmer	9	3	15	8	16	80
Average obtained	7.59	2.45	9.05	4.77	5.05	50.32
Variance between farmers	3.78	0.74	2.62	4.09	2.21	50.5
Sum of individual scores	167	54	199	105	111	1107
New score: 0 to 10 (Min-max transformation)	8.59	8.36	5.43	6.37	3.84	6.66

Figure 19.

Amoeba graph with sustainability indicator scores

4.4. SWOT analysis, indicator results and recommendations

Table 22.

Summary of strengths and weaknesses of the system, main results of the indicators and recommendations for each dimension.

Strengths, Weaknesses, Opportunities, Threats (Critical points underlined)	Indicators and main results	Recommendations
Political		
PS1. Existence of Mexican legislation regarding the requirements and specifications for the sustainable palm oil value chain, includes NMX-F-817-SCFI-2020 norm, and Mexico interpretation of RSPO principles. PS2. Information availability for decision making from academic research, NGO´ and private projects products including the roadmap by Pro Natura Sur A.C. (2022), and the National Interpretation of RSPO criteria for Mexico. PW3. Lack of regulation and oversight of the oil palm production system PW4. Noncompliance of La Encrucijada management plan from oil palm farmers. PW5. Lack of coordination among public institutions. PW6. Lack of natural resources management by public institutions specially related to pollution and misallocation of resources. <u>PW7. Lack of oil palm farmers' participation of in decision making.</u> PO8. Initiated process for update La Encrucijada reserve management plan. PT9. Government policies and incentives to other crops like "*Sembrando Vida*" program does not match the oil palm economic benefits.	Level of participation: 3.84/10 There is a very low knowledge of decision-making related to oil palm production. Only farmers associated to social mills or main palm social organizations can have representation in the decision-making process, but only few dialogues were reported. The dialogues are limited to topics related to La Encrucijada reserve, and no other economic or social problems are addressed. Farmers facilities to associate is limited, due conflicts of interest between members that discourages the participation; and related with high cost and no acceptance of new members in social mills.	Generate spaces for dialogue between public institutions with local, regional, and national representatives. Meetings destinated to coordinate interest and that cover wider range of economic, social, and environmental problems related to oil palm production and industry. Implementation of open and effective communication channels, that facilitate the flow of information between stakeholders, some media can be seminars, conferences, or worktables. Encourage farmers to join farmers´ associations in order that farmers interests can be represented and to catalyze collaboration. Furthermore, strength the cohesion between existing social organization and social mills, for example through the creation of advisory councils formed by various societies.
Social		
SS1. Producers received training by field schools from social mills, private mills, and NGO´s. <u>SS2. Improve of welfare of small farmers due to more access to mobilization, education, housing improvements, among others economic benefits.</u> SS3. Creation of jobs places related to oil palm production. <u>SW4. There are still gaps in technical knowledge of the production specially with fertilizers appliance.</u>	At least half of the farmers are members of social mills, the association proportioned benefits such as access to fertilizers, credits, and guaranteed sales of FFB, but there are few opportunities to join this societies. Non associated farmers can currently sell their products, due the presence of more mills in the area and the increase of capacities to process the products. Farmers´ training: 6.37/10	The certification was the main reason for the increase of farmers´ training, thus its recommended to allocate incentives from companies, NGO´s or governmental institutions to obtain RSPO or NMX-F-817-SCFI-2020 certification for farmers outside the reserve and jurisdictional certification (recommended by Pro Natura Sur A.C., 2022) inside the reserve, NMX-F-817-SCFI-2020 can also be applied.

SW5. Non-associated growers' experience vulnerability and less economical agreement opportunities. SW6. Deficits in services and infrastructure, especially roads in ejidos. SW7. No consensus of the regional or national farmers´ representation. SO8. The growing number of social organizations aiming to establish their own mills will enhance social cohesion, negotiation capabilities, and enhance competitiveness, among other benefits. ST9. Other crops are displaced due to the prioritization of oil palm production.	Knowledge about soil, forest importance, and pest management has been prioritized, but there are still knowledge gaps. The main lack is related to social aspects like labor rights, fair work, discrimination, and buffer riparian zones. Well-being: 6.66/10 Overall scores indicate medium scores in education and health. Well-being is related to important aspects such as easy sales of FFB, satisfaction of food necessities, and high security. However, fulfilling other needs like housing and perceptions of governance generates low welfare.	Collaborate with NGOs or community groups that specialize in human rights and social justice to generate training in these social aspects.
Economic		
ES1. Permanent income for farmers, due production of fresh fruit brunches along the year. ES2. Oil palm production is currently profitable. ES3. Immediate payment upon product delivery. ES4. Facility to sale FFB due to the presence of several mills and collection centers. ES5. Fruit transportation availability through own vehicle or freight. ES6. Capacity of mills to buy and process all the harvest. EW7. Low diversification of economic activities, most of the income depends on palm production, and not on other economic activities like, livestock or other crops. EW8. Labor supply for harvesting does not satisfy the demand. EW9. Informality of some economical agreements between oil palm farmers with mills. EO10.Investment opportunities from the oil palm surplus ET11. Change of the oil palm fruit price and demand in the global market. ET13. Change in the price of agricultural inputs specially fertilizers or seeds. ET14. Absence of government financial support and lack of access to bank loans.	Oil palm remains the main income source for farmers. The absence of an efficient program of transition from this system to other crops and the resistance of palm to weather conditions results in all farmers being willing to renew plantations. Economic Surplus Score: 8.59/10 Oil palm is profitable for farmers, the income surpasses the poverty line and the average real income in Mexico in the last two years. Although nowadays there is vulnerability among farmers with small plantations 3 ha or less. The oil palm profitability is directly linked to FFB price increases, without high prices and like happened before 2021 the oil palm is not profitable.	Collaborate with universities, NGOs, government institutions to explore projects for oil palm mixed or agroforestry systems, as a transitional approach that can offer other income channels and adaptability for farmers.
Environmental		
AS1. Oil palm resistance to dry seasons and flood. AS2. Land use change mainly from pastureland. AS3. Low presence of pests and fungi in plantations. AS4. Permanent ground cover including disposal of crop residues, leaves, and stems on the plantations ground. AS5. Palm production required minimal	All farmers associated to social mills are willing to participate in the certification process, but the process is not officially initiated for all. Land Use Change: 8.36/10 Previous land uses were mainly pasturelands and crops, however changes from forest and mangroves are also identified within and outside La	Incentive the creation of community-based alternative systems for loose fruits collection. Strengthen the alliance between La Encrucijada and the mills to keep the groups that eliminate oil palm in the core of the reserve. Implement an agricultural waste

tillage. AW6. Invasion of palm plants and production near and in the core zone of the reserve. AW7. Deforestation in some zones for palm establishment. AW8. Oil palm high demand of nutrients and fertilizers. AW9. Mainly, the plantations are monoculture. AO10. Initiation of RSPO certification process for farmers and organizations. AT11. Climate variations change frequency of floods in Chiapas coastal zones. AT12. Installation of new mills and refineries with higher impacts than the plant production near the reserve.	Encrucijada. All farmers are willing to renew palm plantations and at least half of the farmers have completed the 25th cycle of plantations. Good Practices: 5.43/10 Good practices include minimal pesticide use, incorporation of organic matter, permanent ground cover, and no irrigation that negatively impacts the soil. A significant gap lies in the collection of loose fruits, especially associated with weather conditions, improper waste disposal, other production systems in the plot. After the establishment of strengths and weaknesses, in dialogues with social mills and La Encrucijada biosphere reserve, it was informed the existence of an agreement, "Amigos de la Encrucijada", program that organize brigades to eliminate oil palm plants in the core of the reserve.	management system, especially for containers and fertilizer bags, the system can include taxes, or penalties if the waste management in the plots is not applied. Do not provide permits for new mill since the already installed have the capacity to process all the product. Generate a registry of existing oil palm farmers to limit and control the growth of plantations since it is not recommended to eliminate existing ones without a beneficial alternative system.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

5.1. Discussion

Sustainability is a meta-concept, it means that it encompasses other concepts, since it includes different dimensions, has a long-term approach, and does not maintain a single definition; therefore, it can be determined and changed according to socio-cultural and environmental conditions (Galván-Miyoshi et al., 2008). The approach adopted for this study is sustainability not like a perfect future of oil palm production, but to try to maintain its permanence, in such a way that it is socially just, economically, and ecologically viable.

As established by Galván-Miyoshi et al. (2008), is a reconciliation among the different dimensions to maintain the system over time; and the system can be modeled around the goals and the path that is set.

Although sustainability implies an ambiguous definition, it's an increasing need to measure sustainable development. According to Parris and Kates (2003) efforts to develop indicators for sustainability are motivated by resources management, advocacy, participation, decision making and research. Galván-Miyoshi et al. (2008) mention that the importance to develop methods to evaluate socio-environmental systems, is to guide actions and policies.

For the same purpose, the assessment of the oil palm production system in the Municipalities of Acapetahua and Villa Comaltitlán, it´s imperative to understanding the system and generate actions to mitigate problems in the area. The indicators result of this study shows that several aspects are not viable in the system, thus an intervention and responses are needed. By responses it is referred to changes in the behavior of farmers, consumer preferences, agro-food chain changes or government actions.

Even if the study was generated for two municipalities of Soconusco region in Chiapas; the social, economic, political, and environmental problems of oil palm production and industry occurs in other regions of the state. Although the history and dynamics of each region are different, as in the Lacandona Jungle, the productive intensification of the territory (Castellanos-Navarrete, 2021) and the subordination of local actors to the rules established by private mills (Trejo Sánchez et al., 2020), are recurrent difficulties.

Astier et al. (2012) recommends that sustainability should include adaptive strategies that start from the local situation and scale to larger contexts (button-up), for this reason the MESMIS program had put efforts to allow small-scale farmers and other actors to evaluate the dynamics of the territory and generate decisions. In other words, the framework has mainly worked at a local scale and, as the same author mentions, it has survived because it was applied in short-term projects. Therefore, the application of MESMIS in the municipalities of Acapatehua and Villa Comaltitlán, where the greatest are small farmers, is considered feasible. Indeed, the MESMIS steps could be used to acquired information and to understand the situation and problematics of the palm system in the study zone.

The problematics emerges due MESMIS establishes a series of steps in a general way, no specific methodologies are determined. This gives the researcher or actors freedom to evaluate the systems according to the existing conditions, nonetheless subjectivity can alter the results. Specially the bad selection of indicators can lead to misunderstood of the reality, lack of attention to important issues, problems to implement enhances, additional costs, among others. For instance, Parris and Kates, (2003) established the lack of review of the indicators used or do not update them avoid credibility, and therefore their results, making not possible to identify if the system if improving or not.

MESMIS tries to address this issue with a framework that proposes continuous assessment cycles. MESMIS previous studies demonstrates that at least two cropping cycles and a series of techniques are required to generate a robust evaluation (López-Ridaura et al., 2002).

A new evaluation cycle could not be applied in this case, since this investigation is thesis research with a limit periodicity, thus, the framework used was a linear process. However, it is important to emphasize the necessity of this loop in the sustainable assessment.

This way, the subjectivity in this study could not be totally avoided. The prioritization of strengths and weaknesses and the selection of indicators steps were also identified as a greater challenge related to subjectivity of indicators.

Strengths and weaknesses were schematized through SWOT analysis that come directly from the testimonies of different interviewees and it covered a variability of actors among independent farmers, social organizations, social mills, government institutions.

Nevertheless, Helms and Nixon (2010) established that SWOT methodology is widespread used, but its simplicity can lead to the misguided utilization of an issue list, that lacks context and prioritization; thus, it is recommended supplementing SWOT analysis with additional tools, some examples include 5-Forces analysis or Multi-Criteria Decision Making. One promising method is the Analytic Hierarchy Process (AHP). AHP enables the evaluation and prioritization through the establishment of a decision hierarchy and the generation of pairwise comparisons with assigned element weights (Saaty, 2008). The pairwise comparison matrix is the core of AHP and is known as the Saaty matrix.

At the beginning, this matrix was applied to hierarchize the strengths and weaknesses of the oil palm system, four matrices were developed for each dimension: political, economic, social, and environmental. However, it was evident that the researcher criteria were not sufficient to assign values of importance, although it was possible to recognize which SWOT elements were more relevant than others; the ranks assigned required the participation of not only experts, but farmers, mills, and government. That implies a working group that cannot been held by the time the indicators were selected. Under these circumstances, general criteria were applied, and the importance was determined based on the scale of impact, whether local, regional, or national, and by whether the problem included other elements related to the SWOT.

The second challenge were the indicators selection; in this case it was applied based on the review of similar studies such as Astier et al., (2012); Leveau Tuanama (2018) and Merlín-Uribe et al., (2013). Thus, the indicators of surplus, land use change, good practices, farmers´ training, level of participation and well-being were chosen.

These indicators fall within those recommended by the Organization for Economic Co-operation and Development (OECD) (1999) for agri-environmental issues, that includes: nutrient use, biodiversity, pesticide use, habitats, water, landscape, land use and conservation, farm management, soil quality, financial resources farms, water quality and socio-cultural aspects.

Despite the constrains, the selected indicators are considered relevant and important to the oil palm production system, however, it is recognized that important aspects that could not be evaluated and could even have a greater effect on the system are the governance of oil palm and the price volatility.

Based on Kaufmann et al. (2009) dimensions of governance that includes: voice and accountability, government effectiveness, regulatory quality, and others; in the study of governance in Acapetahua and Villa Comaltitlán were considered variables such as: the effectiveness or absence of regulations, coordination among institutions, non-compliance with the management plan of the Encrucijada, among others; that could not be assessed due to the lack of response from public institutions, which hindered the acquisition of sufficient data to generate the indicator. In the case of volatility, a longer monthly prices database was requiring, while the data obtained corresponded only for the last 3 years.

Additionally, the indicators of this study were at a higher risk of inaccuracies, due they are made up of several variables. As mentioned by Schuschny and Soto (2009), it is imperative to critically evaluate and account for the sensitivity to changes in variable selection, given that even minor alterations to the composite indicator's structure can lead to significant impacts on the acquired values; the indicator may be affected by measurement errors, deciding on the inclusion or exclusion of sub-indicators, transforming sub-indicators, normalizing or standardizing data or addressing data gap. However, this approached of composite indicator was conserved, because they are easy to comprehend and monitor, allowing people to gauge progress; advantage that is emphasized by García Vega (2011), that mention that aggregating values retains the holistic information.

Efforts to dismiss subjectivity of the framework were generated; and the results of this study are not discarded. However, and as mentioned by OECD (1999) the interpretation of any indicator may need to be complemented by other indicators and viewed in the overall context of the indicator set. Thus, the results obtained are not strict values of sustainability and are considered a comprehensive overview of different aspects of the oil palm production system.

In the surplus analysis a significant issue arises due the absence of permanent records from farmers. Most of them do not maintain these personally, instead they retain records within the associations. This lack of production tracking decreased the analysis accuracy.

Despite estimations were made, surplus is a valid approached to understand the oil palm production economic flow of the last three years. As in the study of Lacandona Jungle region by Castellanos-Navarrete (2021), results shows that oil palm farmers depend mainly on this crop. In the case of Lacandona it was considered that farmers diversified activities and their income is supplemented by other crops, generating more or less incomes than the oil palm. It can also be inferred for the ejidos of this study (Arenal, 15 de Abril and Luis Espinosa), that there is diversification of other activities, not only crops but other professions or services from the farmers. However, the contribution of these activities is less than the income provided by oil palm.

The profits obtained for the years 2022 and 2021 exceed the extreme poverty line except for two farmers. Nevertheless, in the surveys it was informed that in previous years there were lower FFB prices and not all the production could be sold.

In comparison with other studies the profits obtained show higher values. In Lacandona Jungle study by Gobierno del Estado de Chiapas (2006), it was estimated a gross profit of 10,805 MXN pesos per hectare in 10 years. Value that can be consider as low profit, and that differs widely with the current 462,750.93 NPV for a 10-year plantation.

While Solidaridad (2022) estimated that to pass the family poverty line of USD 5,124 (102,480 MXN), an average production area of 5.2 hectare is needed; but in our case for the year 2021 the annual surplus for 5 ha is 299,641.8 MXN.

Therefore, cashflow indicates that investment of oil palm production is positive, but there may be an overestimation of the NPV, thus it is recommended to complement or generate a deeper analysis of this section.

It is important to stand out, that there is a lack of economic activities diversification that provides an important income for farmers. This generates vulnerability, and low adaptability to faced changes in FFB prices. Castellanos-Navarrete (2015) recognized less vulnerability than this study, due the existence of ejidal land tenure in Chiapas and the credit programs at the beginning of the palm establishment, that in difficult times would permit farmers to switch to growing food to survive without losing the basic assets.

Regarding to FFB prices dependence, efforts in social alliances like Oleopalmex, have partially controlled sanctions from private mills and therefore influenced in the perceived profit from FFB sale (Trejo Sánchez and Valdiviezo Ocampo, 2022a); but prices variability still depends on world market changes. For instance, Barría (2022) attributes the increase of prices in Latin America between 2021 and 2022, due to the increase of oil consumption, the Ukraine war that decrease the supply of palm oil and more global demand for biofuel industry. Even with this dependency from external factors, authors like Hernández-Rojas et al. (2018) established that in Chiapas oil palm is financially more profitable compared with other systems like maintaining pastures.

For the analysis of land use change and vegetation cover, the change detected through satellite images denoted previous land uses principally of pasturelands and crops. From the methodologies, supervised classification in QGIS and ArcMap does not provide adequate resolution for analyzing small parcels but give a general overview of the changes of the zone.

Results are consistent with Lacandona Jungle study by Castellanos-Navarrete (2021), where the 68% of the existing oil palm is in previous pastureland, and the substitution of maize was 3%, considered as minimal, according to the author the costs of clearing the land discourage many farmers from deforest, the clearing cost oscillates between 1500 and 4500 MXN per hectare.

Other studies like Hernández-Rojas et al. (2018), even estimated less deforestation, in the case of Acapetahua, changes from 2005 to 2013, corresponded 99% to agriculture lands and 1% to hydrophilic vegetation. In contrast with like Hernández-Rojas et al. (2018), in this analysis it was recognize the existence of previous mangroves and forest. In the case of mangroves, the possibility of use this land to produce oil palm should have involve a series of changes and slow processes as explained by Tovilla Hernández et al. (2020).

In the monitoring study of mangrove forests, it was identified that over the past 25 years, rivers rectification works were carry out in the municipalities of Acapetahua and Mapastepec; changes in the natural channels produced accumulation of sediments in the lagoons and subsequently the demand of dredging projects from fishing activities (Tovilla Hernández et al., 2020). This relocation of sediments affected mangroves and wetlands, allowing the creation of large areas of agriculture and livestock; the territories more affected included ejido 15 de Abril (Tovilla Hernández et al., 2020).Same Ejido of this investigation, where was identified two plots of oil palm that were previous mangroves.

In the case of De la Vega-Leinert et al. (2021) it was also established that oil palm plantations in Mexico principally were previously scrub, rainfed agriculture, pastures, and secondary vegetation, but it was considered that even if oil palm did not caused deforestation, it is indirectly stimulated by it, and prevents forest recovery.

However, there is no guarantee that without oil palm these areas will not be used for other crops or livestock activities, but it is recognized that currently oil palm is generating pressure in the zone. In this study at least half of the palm plantations already have 25 years old, and all the farmers have intentions to renew the plantation, thus the pressure will continue in the future; the factor that is avoiding this renewal is the plants high cost.

Agricultural good practices show medium scores results. Significant good practices include maintain soil cover, incorporate organic matter, and minimize the use of hazardous pesticides. However, two important deficiencies that decrease the sustainability is the lack of waste management and loose oil palm seeds collection.

According to a second personal interview with the representative of La Encrucijada Biosphere Reserve (pers. comm. April 24, 2023), the RSPO certification is designed to avoid deforestation, but it is not designed to decrease the invasion of the oil palm in the reserve. The same testimony mentioned that loose fruit collection should be generated not only in the plot but also along the transportation process and in the mills.

Other studies as Baptista et al. (2010) in Colombia and the Mexican report of (CONABIO, 2017) also recognize the potential damages of oil palm as a highly invasive species. The case in Colombia by Baptista et al. (2010) determinate potential impacts on the economy, significant changes in the structure of the habitat, and that its massive cultivation has transformed in some cases the original coverage without consider the consequences in the medium and long term on the diversity in the region.

Thus, the RSPO certification can lead the farmers to continue improving practices that have a good status in the zone, but new systems to limit the invasion potential of the oil palm should be implemented. The effort that already have an impact was informed in the same interview with the representative of La Encrucijada Biosphere Reserve (pers. comm. April 24, 2023) and the personal dialogue with Procesadora de Aceites de Palma, S.A. de C.V. S.P.R. de R.L. (Zitihualt) (pers. comm. April 25, 2023) and corresponds to “Amigos de La Encrucijada” (Friends of La Encrucijada), agreement between Secretaría de Medio Ambiente y Recursos Naturales (Ministry of Environment and Natural Resources), La Encrucijada Biosphere Reserve and the extracting mills to carry out oil palm removal brigades.

As farmers´ training, good agricultural practices can be described in a medium level of accomplishment. In general, there's an absence of social-focused training. Fair labor, or good working conditions is then a topic that has been disregarded and considering that low wages is a problem of the zone and not only of oil palm production, not paying attention to this topic could avoid improving in the future.

In other areas of the world such as Cameroon, the expansion of oil palm, has been linked to a working environment characterized by poverty, extremely low wages, poor housing conditions and many cases of human rights violations (Hoyle and Levang, 2012). De la Vega-Leinert et al. (2021), identifies among the disadvantages of the oil palm production in Mexico, the provision of only temporary jobs, precarious, or unpaid that do not allow overcoming poverty conditions.

Despite this, the efforts made in other areas are recognized and explain the medium status of training. Topics as soil conservation, reducing the use of chemical products through pest management and organic fertilizer, are carried out mainly by social mills, although other institutions were mentioned, there was no access to interviews. During the personal dialogue with Bepassa (pers. comm. April 24, 2023) and Zitihualt (pers. comm. April 25, 2023), it was inferred that he main driver for starting these trainings has been RSPO certification process. Social mills informed that obtaining this certification has become a requirement from companies that purchase the crude oil.

In the case of participation in decision making, the composed indicator shows the lowest score. Individual farmer participation is null, and participation through associations was more related to issues concerning the Encrucijada Reserve, but other significant aspects such as social responsibility, regulatory review, economical strategies were not part of the direct and indirect participation of the farmers, thus local participation was identified as marginal.

Similar situation can be found in the municipalities of Zamora and Benemérito study of Trejo Sánchez et al. (2020), in the northeast of Chiapas. In this zone, the governance of oil palm is marked by rules imposed by private mills rather than by the coordination of the different groups. In contrast, other agro-industrial organizations held better social cohesion. In the case of sugarcane in Mexico, 95% of farmers are affiliated to one of the two major farmers organizations; then an estimated of 153,000 sugar cane farmers are affiliated, what gives the organizations political influence and strong negotiating capacity with private entities and the government (Mertens, 2008).

Other aspects related to governance such as the effectiveness of regulations, compliance of norms and conflicts of interest, were also consider important for the study. Nevertheless, they could not be evaluated due to the lack of participation of public entities. However, in the interview with La Encrucijada Biosphere Reserve (pers. comm. April 24, 2023), it was informed the existence of necessary regulations in the area, between the main are the Reserve Management Plan and the National Water Law. The problem arises due the lack of compliance and contradictions, not between regulations but within the Plan of La Encrucijada itself. Thereby, the possibility that the governance indicator is in better condition than citizen participation is possible due to existence of regulations. Even so, the political dimension would still be one of the weakest aspects of the system.

At last, well-being results, show a current economic support from the sale of oil palm to meet food needs, but other essentials like housing are still perceived as difficult to access. Therefore, despite the perceived economic advantage, the farmers' life quality indicates unmet needs.

A farmer's income can greatly vary based on factors such as crop type, plot size, location, market conditions, policies, and other economic variables. De la Vega-Leinert et al. (2021) explained that oil palm profitability is largely influenced by factors beyond their control and that the profitability is affected by factors like: the absence of technical guidance, strong or low government support, lack of information of markets and prices, difficulty of low-rate credit.

The value for this well-being index (6.66), is lower than the well-being national sample reported by García Vega (2011), in which an average of 7.23 was obtained. García Vega (2011), also informed subindices of: health (7.84), economic (6.46), education (7.12), security (7.50), good governance (6.73), community (7.58) and personal well-being (7.35). Although a lower state of well-being is registered, it is denoted that both studies identified the greatest discomfort related to the economic and governmental aspects.

Thus, there are stable variables in the oil palm production system with potential for improvement and other factors that lead to non-sustainability of it and that requires intervention. However, Trejo Sánchez (2018) pointed out that alternatives that equal the current economic advantage offered by the oil palm have not been offered.

La Encrucijada Biosphere Reserve (pers. comm. April 24, 2023) mentioned two efforts in the search of alternatives: the Reversion Plan Towards Agroforestry Systems, which is in elaboration, and the Ecological Land Management Program for the Sierra Madre and the Coast of Chiapas, that is in the consultation phase and establishes criteria for crops outside protected areas. In both cases, there is still no reconciliation of interests or a solution to the array of existing issues.

5.2. Conclusions and Recommendations

MESMIS is an appropriate framework to study oil palm system in the Municipalities of Acapetahua and Villa Comaltitlán. Experience have demonstrated been applicable to small-farmers scale studies and projects, and it can make contributions related to the strategies generation from locals' levels and the continuous cycles of evaluation.

This repetition of the assessment cycle is important to update information and indicators, change methods or adapt strategies to the new reality. Hence, it is considered that projects based on this framework, with broader resources and timeframes could be relevant in this zone.

In the case of this study, limitation of resources and time did not allow the generation of a robust set of indicators, thus the understanding of the oil palm sustainability could be partially applied. Even with constrains, the methodology permitted the identification of some relevant variables among which stand out:

- Land use and vegetation cover, to monitor important ecosystems like mangroves and forest.
- Farmers economic benefits that can be analyses through cost-benefit, but in our case was applied as cashflow.
- Natural resources preservation evaluated as good agricultural practices but can also be interpreted with indicators like soil fertility or water pollution.
- Educational, health, personal wellness perceived from farmers, furthermore well-being changes in the general population due oil palm production is also an important aspect to consider.
- Governance, that was partially evaluated through farmers participation in decision making, however indicators like governance effectiveness or regulatory quality would provide more information of the political status of the system.

Independent of the framework implemented, it is suggested that the variables to be measure should be selected from a bottom-up approach, it means that the indicators originate from the system critical points, besides is recommended the prioritization of strength and weaknesses through a participatory process of different stakeholders.

Related to the results of sustainability, expected problems in oil palm cultivation, such as deforestation, unsustainable practices related to monoculture, and extreme poverty levels, were not revealed in this research. At least not in a state that prevents the viability of cultivation in a sustainable way. However, during the research process, new concerns arose, including the potential of oil palm as an invasive species, low social participation, low adaptability to changing markets, and low awareness of social problems, which could lead to a gradual degradation of the system with environmental, social, and economic consequences.

Even in an unsustainable scenario, oil palm removal would not be recommended without viable alternatives. The government was the one that principally favored the establishment of social and private mills, and the expansion of oil palm plantations. Consequently, it is the responsibility of government to initiate the transition towards a more sustainable production. Authors supports oil palm high flood resistance and better economics yields that other crops do not currently have. Then, if a shift to another production system should be made, is necessary a strategy that does not severely impact the local economy.

In the current circumstances, the change towards more sustainable agroecological practices; and reconciliation of interests between farmers, social and private mills, social organizations can be fundamental tools to explore better options within this productive system. In addition, it is suggested to encourage certification and explore mixed crops or agrosilvopastoral systems that provide efficient use of resources and generate sufficient income for families.

At last, the focus of this research was limited to the oil palm production system, and the farmers as the principal source of information. However, better understanding of oil palm agroindustry would be obtained with a selection of indicators that reflects not only farmers realities and the production system but also by measuring the sustainability the oil extraction and other stages of the supply chain. Furthermore, it is proposed to include a broader range of stakeholders including representatives of other cropping systems and representatives of ejido inhabitants or related with the oil palm system.

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