Land use change and the impact of oil palm expansion on rural livelihoods:

A case study in Kampung Semada, Balai Ringin, Sarawak

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Section	Primary Author(s)	Primary Editor(s)
Abstract	Maria	All
Introduction	Larissa & Helene	Madeleine & Steffen
Context	Maria & Madeleine	Helene
Methodology	All	All
Results and Analysis	RQ1: Madeleine & Larissa RQ2: Maria & Steffen RQ3: Helene, Steffen, & Larissa	RQ1: Helene & Steffen RQ2: Madeleine, Maria, & Steffen RQ3: Maria, Helene & Larissa
Discussion	Shifts in livelihood: Madeleine & Helene Environmental Impacts: Maria & Steffen Positionality: Larissa Limitations: Larissa	All
Conclusion	Steffen	All

Abstract

Land use change caused by oil palm expansion is a major issue in Sarawak, Borneo. The ongoing changes impact not only the environment but also livelihoods of rural communities. The aim of this research is to assess how land use change impacts livelihoods of the community of Kampung Semada. To answer our research question, interviews and surveys were conducted, while for natural sciences water-, soil quality and biodiversity were assessed. The findings indicate that shifting to oil palm cultivation limited the diversification of livelihood activities. The majority of Semada's dwellers participate in the Joint Venture as well as smallholding of oil palm. The interviews revealed that most of the people are satisfied being part of the Joint Venture, however some complain about the dividend. The biggest issue the community faces is water quality and access. There is no treated water access, which means that people are fully reliant on rain and river water. Water analysis revealed that the river water is polluted with nutrient runoff from the plantations. Apart from the water quality, another issue is the reeds limiting river access. Fishing, which used to be a major cash generating activity in the past, has decreased and is not reliable anymore because of that. Apart from water pollution and eutrophication, environmental impacts include soil erosion and biodiversity loss. Overall, even though oil palm is the main source income for most households in Semada, it may bring challenges long-term due to environmental impacts.

Acknowledgements

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Thank you

Contents

Table of Figures

Introduction

Since its introduction to Malaysia in 1917, the oil palm (*Elaeis guineensis)* has become the country's primary cash crop (Cramb & McCarthy, 2016). Malaysia's significant role in global palm oil production, amounting to 27% of the total in 2019, has solidified its position as the world's second-largest producer, trailing only behind Indonesia (Ahmad et al., 2023). The expansion of oil palm plantations has been rapid in recent decades, with an increase of 5,06 million hectares between 2000 and 2018 (Li et al., 2020). The studied state, Sarawak, situated in the west of the Malaysian part of Borneo, currently hosts 1,623,660 hectares of oil palm plantations, accounting for 28.7% of the country's total planted oil palm, thus consolidating its status as a pivotal region in Malaysia's palm oil industry (MPOB, 2023).

The rise of large-scale oil palm cultivation in Sarawak was initiated in the 1960s and 70s as natural rubber prices fell, rendering oil palm cultivation more lucrative. Extensive conversion of primary forests, logged-over areas, shifting cultivation lands, and peatlands into plantations has occurred to facilitate the rapid growth of palm oil production (Varkkey, 2020). Accompanying these changes was a shift in agricultural practices especially for smallholders, characterised as small-scale farmers managing areas that vary from one to 10 hectares, who are often family focused, mostly using family labour for production and parts of their produce for consumption (FAO, 2013). They originally practiced swidden cultivation and adapted to cash crops like rubber and pepper over time, eventually transitioning to the cultivation of oil palm (Cramb & McCarthy, 2016).

While a lot of this transformation has taken place on state-owned land, many new plantations are established on Native Customary Rights (NCR) land. NCR lands are situated within the native customary law, the so called “adat”, that originated before the British colonial rule and entails traditional land use and farming systems of indigenous groups in Sarawak (Varkkey, 2020). During the colonial rule (1946-1963), different land laws were introduced to both protect and restrict the rights of the Dayak population, which include the Iban, Bidayuh, Kayan, Kenyah and other communities (McCarthy & Cramb 2009; Cramb & McCarthy, 2016). This involved limiting areas where the Chinese population could acquire land as well as excluding the Dayak population from the remaining primary forest (McCarthy & Cramb 2009).

In 1948 the land was divided into different zones (Ngidang, 2005): Mixed Zoned Land, Native Area Land, Native Customary Land, Reserved Land, and Interior Area Land (McCarthy & Cramb 2009; Ngidang, 2005). Building on this categorization, native customary law, acknowledging NCR lands, was first translated into formal land law through the establishment of the Land Code 1958 (Nelson et al., 2016), stating that *"customary rights to land could only be recognized if such rights were created prior to 1 January 1958"* (Ngidang, 2005). Additionally, the Land Code makes it illegal for non-natives to deal in native customary land (Porter, 1967 in Cramb, 2013). Therefore, the NCR limits governmental access to natural resources within NCR lands. This entails, as McCarthy & Cramb (2009) estimate, that approximately 25% of the total land area in Sarawak is proclaimed NCR land. Due to these limitations, various amendments and changes in land policy have been passed in the 1990s to facilitate the use of ancestral land for large-scale commercial use (Varkkey, 2020).

The autonomous status of the Sarawak state government, which has the authority to adopt policy regarding natural resources including land, water, forests, and wildlife, facilitates such policy changes (Varkkey, 2020). Abdul Taib, in his time as the Chief Minister of Sarawak, introduced several changes in land policies, which marked a policy shift and increased emphasis towards the role of oil palm and other cash crops as the driver of economic growth and development (McCarthy & Cramb 2009). Favouring large-scale estates over smallholder production, Taib's government introduced different schemes involving smallholders consolidating their land into larger production entities. This includes the 'Joint Venture' approach, managed by the Land Custody and Development Authority (LCDA) and the 'managed smallholder' approach, which is typified by the Sarawak Land Consolidation and Rehabilitation Authority's (SALCRA) schemes (Cramb & Sujang, 2013). The LCDA is regarded as a 'native', allowing it to deal within customary land (Cramb, 2013). The role of the LCDA is partly to declare land as development area as well as to function as an intermediary between landholders and the private companies in the Joint Venture approach (Cramb, 2013). The classification of land as a development area is based on the Minister's perception of this being of interest for the inhabitants (Cramb, 2013). SALCRA´s declaration of suitable land as 'development area', gives it powers to develop the area on an estate basis and involving smallholders to manage portions of this land. The smallholders will eventually be issued full titles of the lands to individual lots (Cramb & Sujang, 2013). These initiatives create ways for the government to bypass the Land

Code 1958, to acquire more land for the expansion of oil-palm production. Apart from the two schemes, a model that is based on rental, which is implemented by the private sector in mutual agreement with landowners, also known as the rental model, has often been used.

Accompanying these changes in land use is a wide range of environmental impacts of oil palm expansion. Those impacts include biodiversity loss, greenhouse gas emissions, soil erosion and a decline in water quality (Meijaard et al., 2020). There was a 23,1% deforestation rate increase in Sarawak from 1973 to 2010. It was predominantly caused by wildfires, shifting cultivation and plantation conversions (Gaveau et al., 2014, 2016). This deforestation severely impacts biodiversity and ecosystem function (Berry et al., 2010; Qu et al., 2024). A systematic review on the biodiversity impact of oil palm plantation, revealed that the conversion of forest to oil palm plantations reduce species richness and significantly alter the composition of species assemblage (Savilaakso et al., 2014). According to Itoh et al. (2023), oil palm plantations along rivers are correlated with significantly increased electrical conductivity and dissolved ion concentrations when compared with up-river forest sites, indicating a large impact of fertilizer runoff on aquatic nutrient loads downstream.

Extensive studies have been conducted in tropical regions, and Borneo in particular, to understand the ecological impact of oil palm on water and soil (Tripathi et al., 2016; Thompson-Morisson et al., 2023; Chellaiah & Yule, 2018). Beyond impacting the environment, the expansion has also driven significant rural livelihood adaptation (Krishna et al., 2017). However, this research tends to be approached through single-disciplinary lenses. Therefore, this study aims to adress these topics through a more interdisciplinary approach to understand the interplay of oil palm's environmental and rural livelihood impacts. This will be done by conducting a case study in a rural Iban community in the Sarawak region: Kampung Semada. Studying this development will be the focus of this case study, which is structured as follows. After providing an overview of the context and research objective of the study, the underlying methodology will be outlined. The findings will then be presented and embedded into the greater context of the case study in the discussion. Finally, some concluding remarks will be offered.

Research questions and objectives

The objective of this study is to assess the impacts of the expansion of oil palm cultivation on the longhouse community of Semada, Sarawak. The study assesses both the environmental

impacts and the role of oil palm cultivation in the composition of livelihoods in Kampung Semada. The impacts on livelihoods have been assessed using the Sustainable Livelihood Approach. For the environmental impacts the focus lies on soil and water quality. As soil and water are assets of importance to rural livelihoods, assessing the quality of the two can give insights into the implications that the cultivation of oil palm has on livelihoods, specifically related to the potential for further crop cultivation and access to water. Including both livelihood and environmental impacts in the study makes it possible to gain a comprehensive understanding of the impacts on the community.

To assess this, the following research questions and sub questions have been developed:

Research Question 1**:** What are the observable trends in land use change for oil palm production from 2000 until present in Kampung Semada?

Research Question 2**:** How does the oil palm cultivation impact the water and soil quality in Kampung Semada?

Research Question 3**:** How does the cultivation of oil palm impact rural livelihoods in Kampung Semada?

- What are the trends in livelihood strategies in Kampung, Semada?
- What are the potentials and challenges related to livelihoods within the institutional context of the longhouse communities?

Context

The research was conducted in the longhouse community of Semada, Balai Ringin district, Sarawak. Located approximately 50km from Serian town and 110km from Kuching city, it is a rural area primarily inhabited by people from the Iban ethnic group. Kampung Semada consists of 3 settlements: Tengah, Mawang and Belatok, totaling 63 households. The area is characterized by relatively flat terrain, immediate access to the Barai River, one of the primary tributaries of the Kerang River, and extensive swamp lands. In the past, the river was a crucial part of the community's daily life, as it was used as a means of transport, as well as a water and food source. However, that has recently changed as the river became inundated with reeds and invaded with an increasing crocodile population, which lead to further limitation of the

economic opportunities in the area. Aquatic resources were historically supplemental to more traditional agricultural practices such as rice cultivation, rubber tapping, and pepper. However, these practices have faced challenges such as pest infestations, low market prices, and unsuitable soil conditions. This has facilitated the transition in the community towards Joint Venture agreements with oil palm companies as well as the increase in small-holder planting of oil palm.

Methodology

Interdisciplinarity

Moving on to the methodology, this research project aims to have an interdisciplinary approach, merging social and natural sciences. This approach allows us to triangulate and explain complex phenomena, such as livelihoods of rural communities. To reach an interdisciplinary perspective the concept of crossdisciplinarity according to Krishnan (2009) is applied.

GIS Analysis

The methodology employed for identifying and assessing the development of oil palm plantations in Semada using ArcGIS deep learning involved several steps. Initially, the study area was delineated as 10km^2, centered on Kampung Semada Tengah (1.092433, 110.789014). Data was sourced through the Sentinel Hub EO browser, focusing on Level 2 True Color imagery, with less than 15% cloud coverage. The time series of satellite imagery spanned from 2000 to 2015, relying on Landsat imagery for the years 2000, 2005, 2009, 2015, and Sentinel-2 imagery for 2020 and 2023. Originally, data from every 5 years was to be used, but due to cloud coverage and the style of data produced by Landsat 7 in 2010, an adjustment was made to source clearer data from Landsat 4-5 in 2009 instead. After pulling data tiles into ArcGIS Pro, the data was clipped to the extent of the study area and enhanced for analysis. A training dataset was then compiled, comprising labeled samples of oil palm plantations and non-oil palm land cover types, to teach the program (Appendix B1; "Detecting Palms", n.d.). Training was initially conducted using 2023 imagery, with the intention of then being applied to each of the other years. However, with the change in image resolution, a second model needed to be created to apply to the Landsat imagery between 2000 and 2015. Each of the trained models were subsequently applied to classify the corresponding satellite imagery into oil palm plantations and other land cover types. The classified results are converted into polygons, representing the

boundaries of oil palm plantations, with area being automatically calculated. Finally, the mapped oil palm plantations were analyzed to understand temporal trends and implications for land use change in Kampung Semada and its immediate vicinity.

Based on noticed trends while analyzing oil palm expansion and based on concerns voiced by the community, the analysis was expanded to include closer visual inspection of aquatic vegetation growth on the Barai River. Images were pulled from the same source, with Sentinel-2 imagery focusing on the river taken from each year between 2018 and 2024. Primarily used as a source for triangulation with community mapping and interviews, visual analysis was performed to observe the changes more broadly.

Sustainable Livelihood Approach

The assessment of the impacts on livelihoods has been guided by the sustainable livelihood approach, which emphasizes that poverty and living standards are not restricted to material standards, such as income level, but include more subjective matters (Steel & Zoomers, 2009). A livelihood is defined as the capabilities, assets and activities that composites people's lives and means of living, while sustainable refers to the livelihood's capability to cope with and recover from stress and shocks, maintain, or enhance its capabilities and assets and provide sustainable livelihood opportunities for next generation, which is the focus of the approach (Morse & McNamara, 2013). Assets refer to both tangible assets such as resources, and intangible assets such as claims and access to these resources (McLean, 2015), meaning that households do not necessarily own their assets to have access to them. The capital assets are divided into five groups or types of assets: Human Capital (skills, knowledge, labor), Natural capital (soil, water, air, genetic resources etc.), Physical capital (infrastructure), Social capital (social relations, network, associations etc.), financial capital (economic assets, such as monetary assets, land etc.) (Morse & McNamara, 2013). The Sustainable Livelihood Approach in this study was used to analyze the livelihood strategies and diversification in Kampung Semada.

Stakeholder mapping

A stakeholder mapping was conducted with each Tuai Rumah separately. It provided an overview of the dynamics and characteristics of the community, and knowledge about which people were the most knowledgeable on different matters for further data collection.

Community and Timeline mapping

Through Participant Rural Appraisal (PRA) a map of the community and a timeline of changes to land use and the environment was developed, based on the participants' perceptions. Using PRA, specifically participatory mapping, the perceptions, and experiences can be assessed, through the frame and concerns of the local people, rather than being based on the researchers established professional frame (Chambers, 1996). Further as Chambers (1996) explains, the shift in the role of the researcher as being the observer makes it possible to watch and analyze the interaction and dynamics among the participants, as well if information is being distorted or withheld. Two timelines and community maps were made. One based on the perceptions of people from Mawang, and another on the perceptions of a group of people from Tengah, as well as one participant from Belatok.

Household survey/questionnaire

Surveys were conducted among households of the three villages within Kampung Semada. The aim was to survey 70% of the total population of 63 households, using stratified sampling. Stratified sampling is used when different subgroups within the population should be represented in the sample (Bryman, 2012). In this study the different stratas are the three different settlements within Kampung Semada, and the sampling strategy was selected to have an equal representation of each village. Further, it made it possible to assess if there was any pattern in responses based on the villages. In total 29 households were surveyed. The aim of the survey was to establish an insight into the composition of livelihoods in Kampung Semada. The survey was mainly built on closed questions with a fixed number of answers to select from, which as Bryman (2012) explains makes it easy for the respondents to complete the survey and makes it more straight forward to compare the data. The questions within the survey included selection of activities performed and crops cultivated by the households today and 20 years ago, as well as ranking of these for income and own consumption. Further the respondents were asked about participation in small scale oil palm cultivation as well as in the joint venture scheme.

Semi-structured interviews

Following the household survey, semi-structured interviews were conducted with some of the respondents. Semi-structured interviews are qualitative interviews, where the researcher used

one interview-guide for all the interviews to lead the conversation towards certain topics or questions, so that in practice all interviewees are asked about the same topics (Hurst, 2013). As Brinkmann (2020) argues, qualitative interviews are an appropriate method when analyzing human experience and interactions which comprises of qualitative features. One male and one female interviewee were asked to participate within each of the three villages in the community. The interviewees were selected partly based on the information obtained through the household survey and based on who was available. In total six interviews were conducted. The interview guide was built based on the different capitals from the sustainable livelihood approach and further involved questions about perceptions of and experiences with oil palm cultivation on small scale and the joint venture participation. All the interviews were recorded after having gained permission from the interviewees and later transcribed. One of the interviews was conducted fully in Iban, and the transcription was translated, while for the rest of the interviews the responds were being translated during the interviews, and the translation was transcribed. The transcripts have been coded in Nvivo, using predetermined codes based on the sustainable livelihood framework, and the research questions. Based on the transcripts the interviews have been analyzed using meaning condensation, defined by Kvale (1996) as the process of compressing the interviewees statements into shorter versions containing the main meaning of the statement.

Soil sampling and analysis

Soil quality was examined to find out how oil palm expansion impacts the environment. It was assessed by analyzing soil samples, which were collected in two different sampling sites from joint venture and smallholder land. The sampling plots were 10x10m squares, one uphill from the other and draining towards the Barai River to account for the topography and provide results that are comparable with the water samples. Within those plots, 2 smaller 2x2m subplots were chosen. All samples were taken from the subplots. At each subplot a composite of 3 different samples was

Picture 1: Soil sampling

taken with an auger at two depths: 0-20cm and 20-40cm. Moreover, 2 cylinder samples for bulk density were taken from each site.

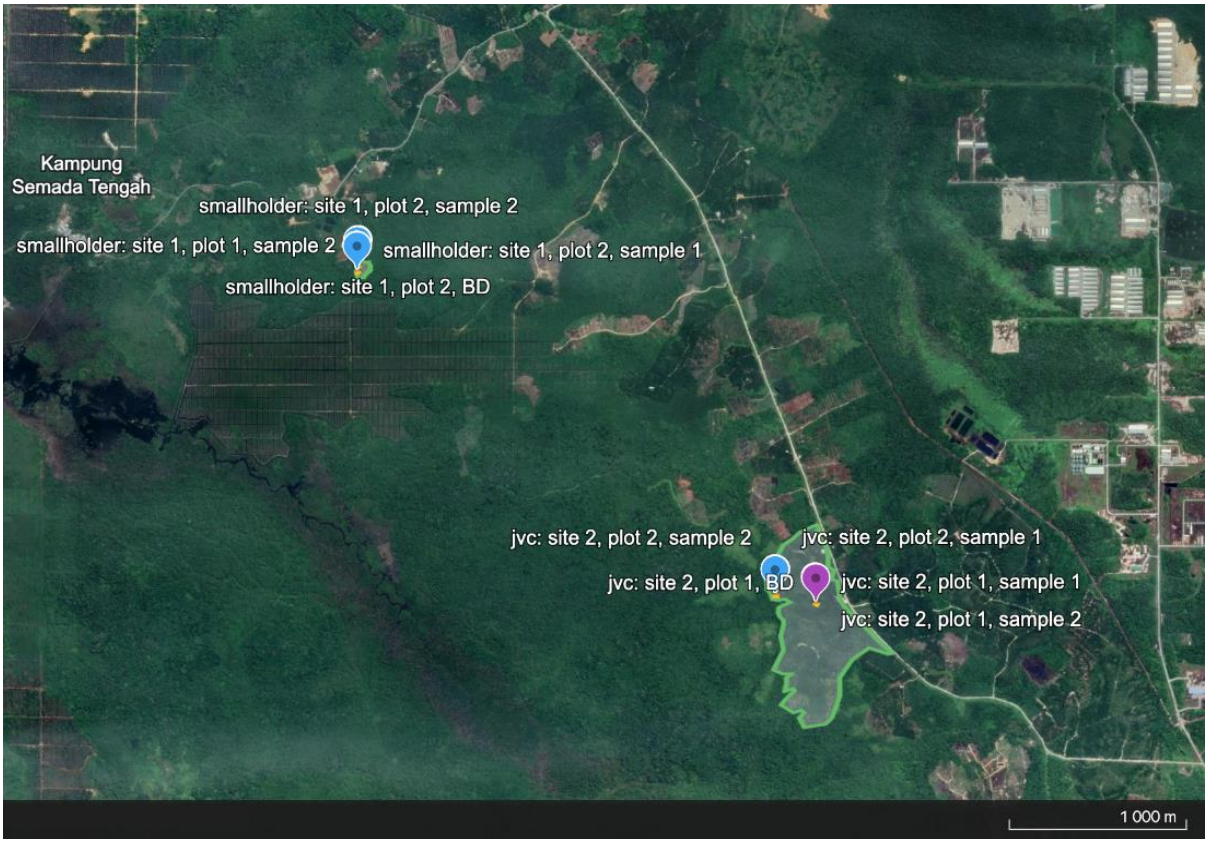

Figure 1: Soil sampling sites

In the laboratory, the following variables were assessed: pH, salinity, moisture content, nitrate, total carbon and nitrogen, ammonium and phosphorus. Soil pH evaluated due to its ability to regulate the availability of nutrients that influence crop productivity (Oshunsanya, 2019). It was measured using the pH-meter. Soil salinity is assessed through measuring electrical conductivity, where high salinity levels in soil can lead to a decrease in soil health, which influences crop productivity (Daliakopoulos et al., 2016). The EC was measured by dipping the conductivity meter into the soil extract. Soil moisture content plays a crucial role in plants' growth and has a big impact on soil's biological and ecological functions (Lekshmi at al., 2014). It was assessed by weighing wet and dry soil and then calculating the moisture content. Soil organic matter content is one of the most important soil properties (Krull et al. 2004). Soil organic matter, especially organic carbon, is responsible for the soil structure stability, enabling the nutrient flow and water retention (Krull et al., 2004). Total carbon was measured by a dry combustion method. By checking the nitrate, ammonium and phosphorus levels, potential

groundwater pollution and a link between the nitrate and phosphorus content and soil acidification were explored. Ammonium and nitrate were assessed by the Flow Injection Analysis, while phosphorus was measured using the Olsen method. Total nitrogen in soil can be used to assess nitrogen availability (FAO, 2024). It was measured by putting foil capsules with dried soil inside into the CHN (carbon hydrogen and nitrogen) analyzer.

Water quality

Due to water accessibility being an issue in the region the water quality was assessed. Therefore, water samples were taken for the analysis of water quality at three different sites: Upstream at Sungai Barai, Riverside with Kampung Semada Belatok and at a Large-scale oil palm plantation. The marine indicator invertebrates were investigated in the same areas.

The above-mentioned sites were chosen based on the following criteria: The locations had to be on the Sungai Barai river or at connecting tributaries, and there had to be a minimal interference from other factors (e.g. other pollutants, contaminants than they use in the oil palm plantation).

Picture 2: Water sampling

To examine the oil palm cultivation impact on the water, water samples were taken using an in-situ meter probe to investigate physical parameters like; pH and total dissolved solids (TDS), and chemical parameters, such as biochemical oxygen demand (BOD), dissolved oxygen (DO), phosphate and nitrite and biological parameters, such as total coliform count (TCC) and fecal coliform count (FCC) at each site.

Simultaneously, bioindicators for the three different water sites were examined. This was done by sampling the macroinvertebrates at the riverside with fishing nets of various meshes. The

Biological Monitoring Working Party (BMWP) and the Malaysian Family Biotec Index (MFBI) were used. Within these parameters each species correlates to a certain index number, from 1-10, where a higher score indicates a higher water quality, because the species are sensitive to lower water quality. BMWP identify the value of the score and MFBI correlates to species richness.

Biodiversity assessment

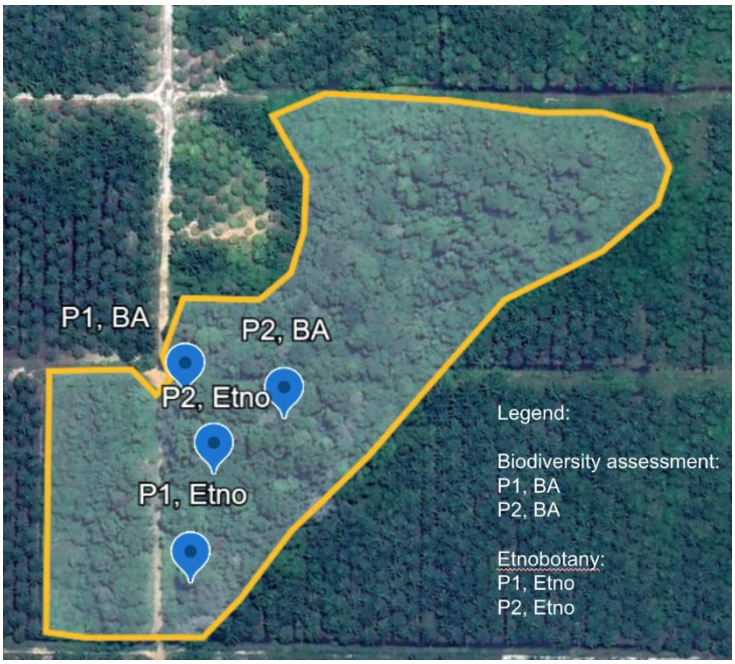

Figure 2: Biodiversity and ethnobotanical site

Aiming to get further insight in how oil palm expansion affected rural livelihoods, a biodiversity and ethnobotany assessment was conducted. Choosing a representative secondary agro-forest area, the ethnobotany within the area was analyzed by identifying and counting traditionally utilized flora species in a transect area consisting of 8 areas of 5x5m. Ethnobotany was assessed on a plot where the previous longhouse as well as rubber and fruit trees were located. The area, which is approximately 48 hectares, has been left fallow for more than 50 years. Furthermore, the total carbon storage was assessed by measuring diameters of mature trees (above 5cm) and identifying species of trees in four different plots of 20x20m (Figure 2). The DBH (Diameter at Breast Hight) measurements were taken at 1,3m above ground (Nelson et al., 2022). After gathering data, the Shannon index was used to estimate the biodiversity of the assessed plot. The biomass, carbon storage and importance value were calculated as well.

Results and Analysis

RQ 1: What are the observable trends in land use change for oil palm production from 2000 until present in Kampung Semada?

Main events that marked development and changes around the community affecting their daily lives were determined in the community and timeline mapping. Among the changes the community mentioned was the expansion of oil palm in the area. This includes the establishment of the Joint Venture, led by the company Masranti, on smallholder and NCR land close to Semada Mawang in 2003 and the development of the T.H. Plantation close to Semada Belatok. Further development was mentioned with the expansion of the Masranti plantation in 2010 and 2020. Connected to these events, the establishment of road infrastructure was mentioned. Related to the improvement in infrastructure, the community referenced the improved supply of electricity in 2011. A specific event that the community referred to in relation to the establishment of the T.H. Plantation was that some community members were openly resisting the planting of the plantation, leading to seven of them being incarcerated for a week (Appendix C2).

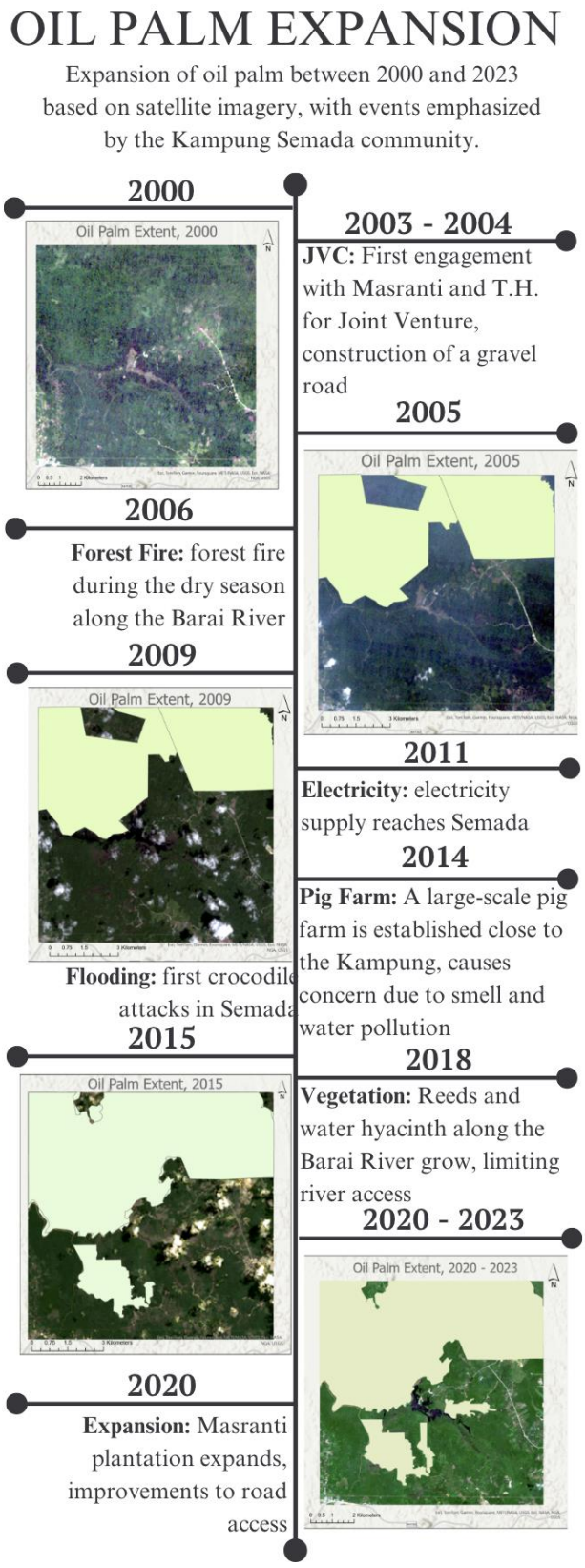

Figure 3: Community and GIS timeline

Other aspects referenced within the mapping were several environmental changes and events, including a forest fire 2006, a flood in 2009 that marked the first appearance of crocodiles in in area, and more recently the emergence of reeds and water hyacinth in 2018 covering Barai River. The establishment of a pig farm close to the village was mentioned for affecting the community negatively through smell and water pollution (Appendix C1, and C2).

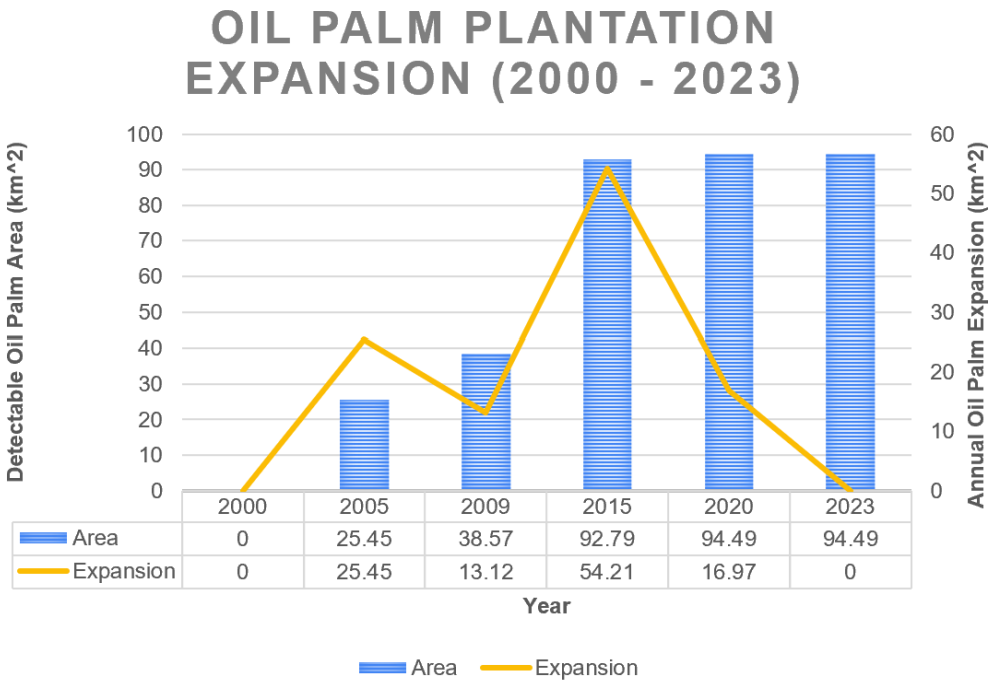

Figure 4: Oil palm expansion

Satellite imagery of the study area around Kampung Semada unveils pronounced trends in land use change for oil palm production from 2000 to the present (Appendix B2). Initially, in 2000, the absence of oil palm plantations indicates a landscape that was primarily characterized by alternative land uses, including: agroforestry, rubber cultivation, rice paddies. However, between then and 2005, a significant transition began, as oil palm cultivation emerges. Over just five years, oil palm plantations grew to occupy an area of 25,45km^2. This initial establishment period marks the commencement of oil palm expansion, indicative of a shift in land use dynamics. Validating this calculated increase in the area, documentation and the community mapping shows that Masranti and the T.H. plantation initially arrived in Kampung Semada in 2003, driving the bulk of oil palm planting in these years (Appendix C1). During this period, all oil palm development occurred directly north of Kampung Semada (Figure 3). Subsequently, by 2009, the area devoted to oil palm further expanded to 38,57km^2, suggesting

sustained growth and consolidation of oil palm cultivation within the study area (Figure 3; Figure 4). Notably, the most substantial transformation occurred between 2009 and 2015, with oil palm plantations rapidly expanding to cover a vast expanse of 92,79km^2, over doubling the previous area oil palm occupied (Figure 3; Figure 4). This period saw a previously unseen surge in oil palm production, likely driven by economic incentives and land use policies favoring agro-industrial development (Varkkey et al., 2018). Interestingly, the period spanning from 2015 to 2023 presented a contrasting pattern, characterized by a stabilization in oil palm plantation expansion, with no observed change at 94,49km^2 between 2020 and 2023 (Figure 4). The expansion of land area used for oil palm production between the year 2000 and 2023 had an average expansion rate of 15,03km^2 per year. This indicates an average annual growth rate of nearly 50% since 2005 (Figure 4). With the assumption of previous active use of all the surrounding land, this enormous shift in land use indicates a likely drastic change in livelihood strategies for members of Kampung Semada.

RQ 2: How does the oil palm cultivation impact the water and soil quality in Kampung, Semada?

Indicated in results from multiple of the conducted methods, a challenge facing the community is reduced access to treated water and river water. In processing and analyzing satellite imagery for oil palm plantation expansion, imagery data from 2018 to 2024 was collected, to track the growth of vegetation on the water. Indicated in the community mapping activity, 2018 was the year that community members recall the vegetation in the water beginning to increase. During the fieldwork process, the blanket of weeds and water hyacinth covering much of the river was identified. The information from community members is backed up by imagery data from 2018 (Figure 5). Showing Sentinel-2 data from each year between 2018 and 2024, there is a clear increase in vegetation coverage of the river, indicated by the shift towards bright green reflectance over the years. 2018 and 2019 show initial vegetation growth towards the banks of the river, while there appears to have been a temporary decrease in growth between 2020 and 2022. However, this is in stark contrast to the following two years, where the blue reflectance picked up by the satellite sensors completely disappears from the primary channel, replaced by vivid green vegetative reflectance.

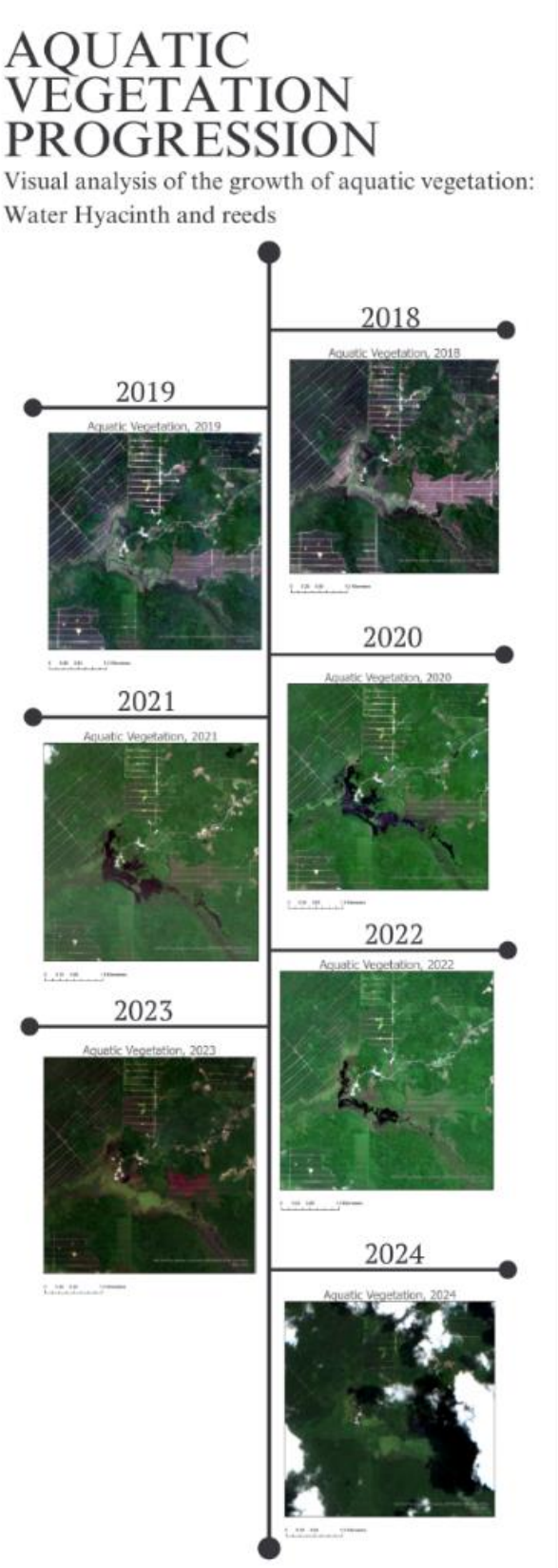

Figure 5: Aquatic vegetation growth (2018-2024)

Focusing on the water quality, specifically for the physical parameters (Figure 6), we found that the pH was slightly more acidic at the large-scale oil palm plantation and at Kampung Semada Belatok, respectively 6,7 and 6,6, than at the upstream with 6,9. This can be due to atmospheric deposition, wastewater discharges or surrounding rock formations (University of Massachusetts Amherst, 2016). The other physical parameter, total dissolved solids (TDS), is higher in the upstream area and at Kampung Semada Belatok with respectively 63,4 mg/L and 62,94 mg/L, and we found 60,45 mg/L for the large-scale oil plantation. Besides that, the difference isn't that significant, it may indicate pollution or contamination (Weber-Scannell & Duffy, 2007). This is seen in the below mentioned figure:

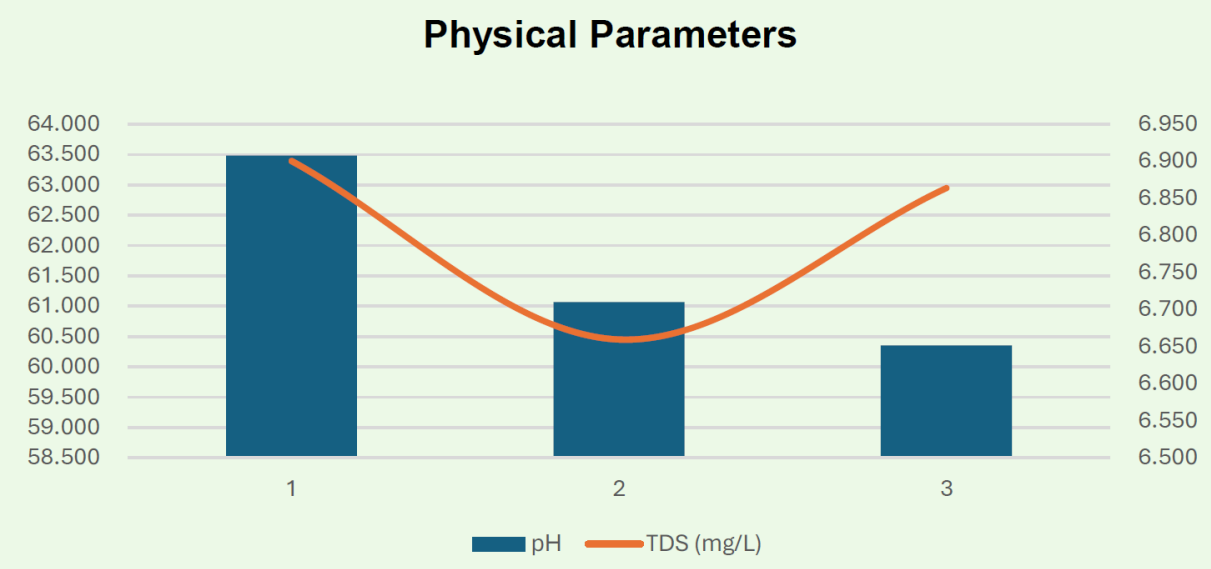

Figure 6: Physical water parameters. (1) Upstream Sungai Barai, (2) Large-scale oil palm plantation, (3) Riverside Kampung Semada Belatok

For the chemical parameters (Figure 7), we found the largest amounts of phosphate at the large-scale plantation with 0,060 mg/L, 0,030 mg/L for Kampung Semada Belatok and non-measurable amounts of phosphate for the upstream site. The Nitrite-concentration is highest with 0,017 mg/L for Kampung Semada Belatok, and 0,010 mg/L and 0,009 mg/L for respectively the large-scale oil palm plantation and the upstream. The largest concentration of DO was found at the upstream with 3,48 mg/L, followed by the large-scale plantation with 3,17 mg/L and then the riverside at Kampung Semada Belatok with 2,56 mg/L. The BOD concentration was found at the Kampung Semada Belatok with 1,17 mg/L, followed by the large-scale plantation with 0,46 mg/L and 0,38 mg/L for the upstream. Higher DO may indicate

poor water quality, while BOD can indicate higher presence of aerobic bacteria, which consumes the DO in the water (USGS, 2018). The chemical parameters are seen in the following graph:

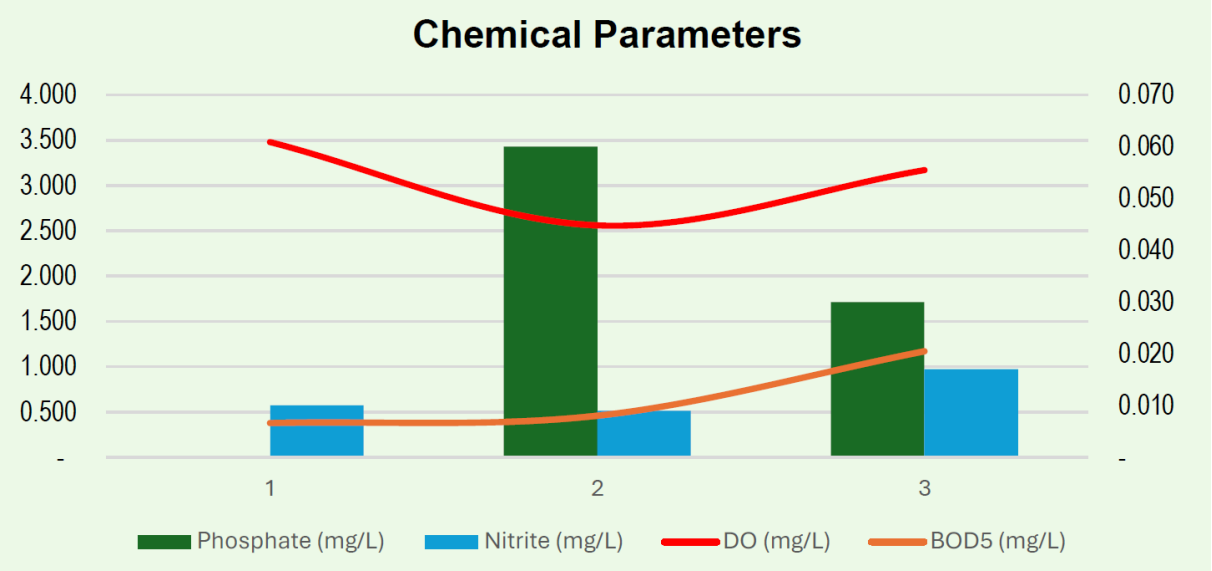

Figure 7: Chemical water parameters. (1) Upstream Sungai Barai, (2) Large-scale oil palm plantation, (3) Riverside Kampung Semada Belatok

For the biological parameters (Figure 8), we found the largest number of colony forming units for the total coliform count (TCC) at the large-scale plantation with 6375 CFU/100 ML, followed by 5400 CFU/100 ML for the upstream and 1575 CFU/100 ML at Kampung Semada Belatok. Simultaneously, we found 3050 colony forming units (CFU/100 ML) fecal coliform count (FCC) for the upstream, and 50 for both the large-scale plantation and at Kampung Semada Belatok. This is seen in the below mentioned graph:

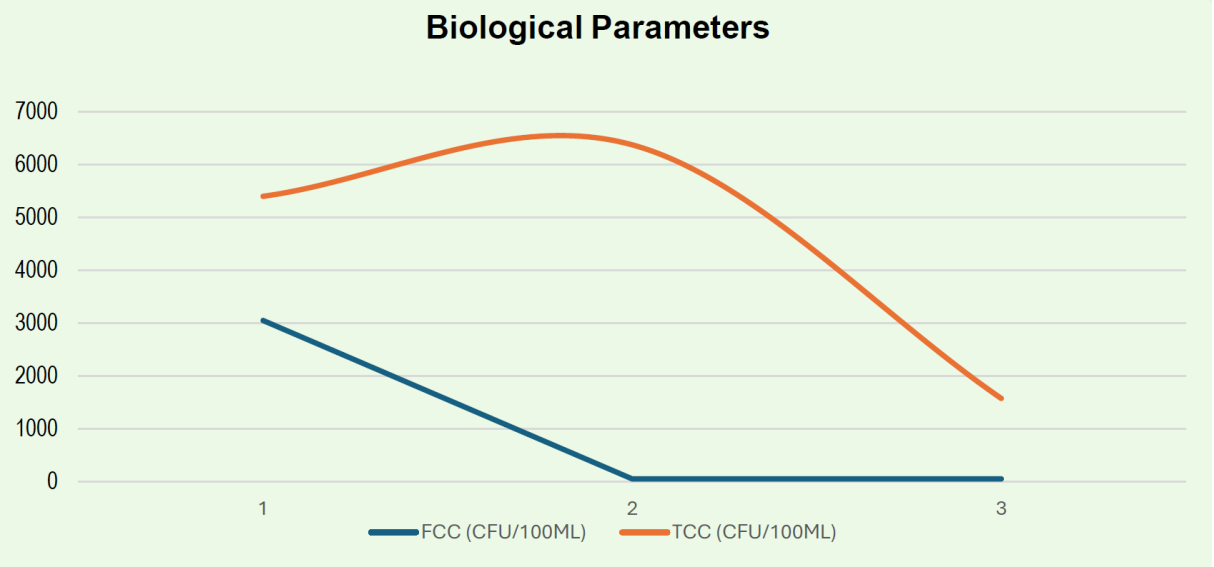

Figure 8: Biological water parameters. (1) Upstream Sungai Barai, (2) Large-scale oil palm plantation, (3) Riverside Kampung Semada Belatok; FCC: Fecal Coliform Count, TCC: Total Coliform Count

Regarding the bioindicators, we found 17 taxonomic different macroinvertebrates, with a BMWP and MFBI of respectively 33 and 5 for the upstream. For the large-scale oil palm plantation, we found 11 taxonomic different macroinvertebrates, with a BMWP and MFBI score of respectively 15 and 5, and for Kampung Semada Belatok, we found 8 taxonomic different macroinvertebrates, also with a BMWP and MFBI of 15 and 5. BMWP stands for Biological Monitoring Working Part and MFBI for the Malaysian Family Biotec Index. BMWP identifies the value of the score and MFBI correlates to species richness. In our examination it correlates to a fair BMWP for the upstream area, and a poor for the large-scale plantation and Kampung Semada Belatok. The MFBI value of 5 corresponds to a good value. These values can be a proxy for the water quality, so potentially indicates that the water quality is better at the upstream area than at the large-scale plantation and at Kampung Semada Belatok (Table 1).

Table 1: Bioindicators. (A) Upstream Sungai Barai, (B) Large-scale oil palm plantation, (C) Riverside Kampung Semada Belatok

2	Odonata	Coenagrionidae	5	6	5	30
3	Mollusca	Ampullariidae	3	4	3	12
4	Ephemeroptera	Baetidae	6	1	6	6
5	Lepidoptera	Pyralidae	5	1	5	5
6	Coleoptera	Hydrophilidae	6	4	6	24
	Total			**17**	**33**	**5.00**
	Water Quality Rating				Fair	Good

Site B - Oil Palm

No	Taxonomic Class	Taxonomic Families	Score	Numbers	BMWP	MFBI
1	Odonata	Libellulidae	5	7	5	35
2	Odonata	Coenagrionidae	5	1	5	5
3	Hemiptera	Notonectidae	5	3	5	15
	Total			**11**	**15**	**5.00**
	Water Quality Rating				Poor	Good

Site C - Belatok

No	Taxonomic Class	Taxonomic Families	Score	Numbers	BMWP	MFBI
1	Odonata	Libellulidae	5	3	5	15
2	Hemiptera	Gerridae	5	4	5	20
3	Lepidoptera	Pyralidae	5	1	5	5
	Total			**8**	**15**	**5.00**
	Water Quality Rating				Poor	Good

Another factor being analyzed was soil quality. The collected soil samples were analyzed in the laboratory in Denmark. It is crucial to mention that to ensure an accurate comparison of soil between sites, a soil map was used to choose sampling spots. Soil on the JVC land was a white grey podzolic, while on the smallholder land it was a red yellow podzolic.

Based on a pH analysis, JVC land is slightly less acidic than the smallholder land. In both cases samples from plots closer to the river have a lower pH, which may potentially be caused by leaching or river flooding. Total nitrogen levels were so low, that it was only detected in 2 samples. Both samples were from the smallholder land and the total nitrogen reached 0,13% and 0,14%. This data can lead to a conclusion that soil in the JVC land is more eroded and has a lower level of organic matter.

Contrary to what was predicted, nitrate levels were higher in samples from the smallholder land. Higher nitrate levels were expected in the JVC land due to the use of fertilizers. This data can indicate that soil from smallholder land is more fertile. Moreover, in case of smallholder land, a significantly higher nitrate content was found on the plot closer to the river (Figure 9), which can indicate nutrient runoff.

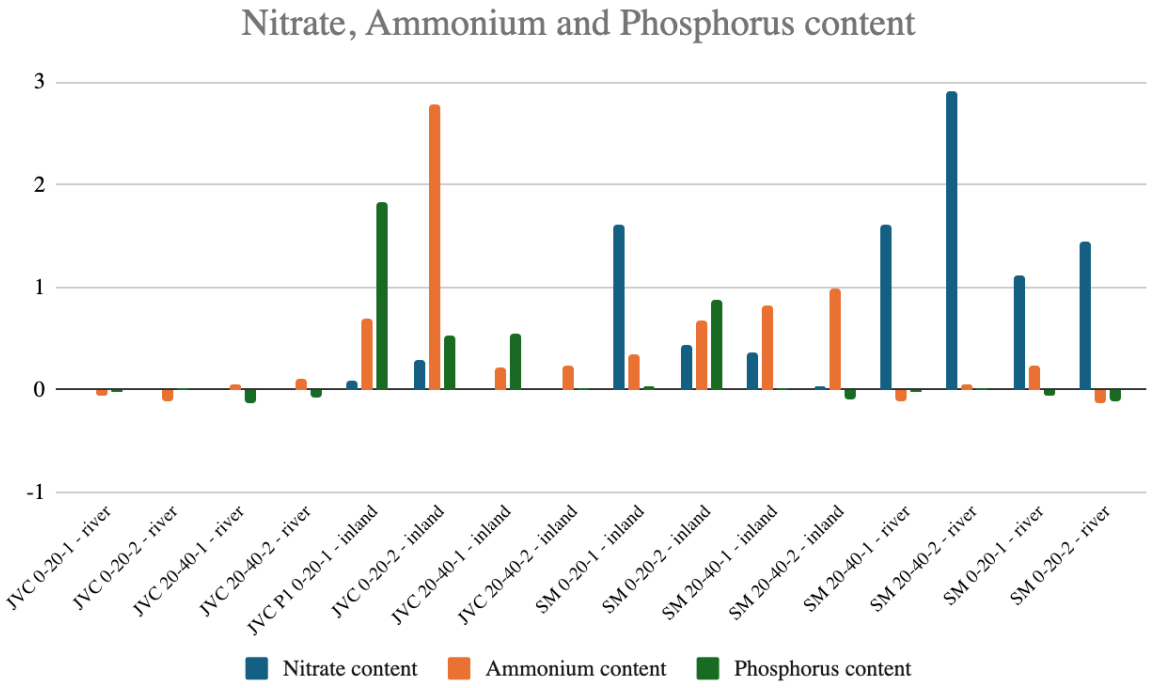

Figure 9: Bioindicators. (A) Upstream Sungai Barai, (B) Large-scale oil palm plantation, (C) Riverside Kampung Semada Belatok

The highest ammonium content was found in soil from the plot further from the river on the JVC land, which can potentially be linked to nutrient leakage. The same situation happened on the smallholder land, where the ammonium levels were slightly higher on the first plot. On both plots close to the river, ammonium content was barely detectable.

The analysis of Olsen-P revealed that the highest phosphorus concentrations were found in the plot further from the river on the JVC land. The plot far from the river on smallholder land is also richer in phosphorus than the other, just like in the case of ammonium. Again, this might be a sign of nutrient leakage, but also since the phosphorus levels are visibly higher on the JVC land, it might be a sign of more frequent fertilization.

Analysis of electrical conductivity revealed that soil from both sites is non-saline. Another assessed soil parameter was moisture content. Soil from the smallholder land turned out to have a higher moisture content, with the mean value reaching 24,77%, while soil from the JVC land reached 17,28% on average. Higher moisture content can indicate that soil from smallholder land is richer in clay and organic matter, as these qualities positively impact soil's water holding capacity.

Bulk density turned out to be higher on the JVC land (mean value of 1,47g cm^{-1}, while the mean for smallholder land is 1,01g cm^{-1}). It might have been caused by the use of machinery on the plantation land. All details of the soil analysis are presented in appendix E.

RQ3: How does the cultivation of oil palm impact rural livelihoods in Kampung Semada?

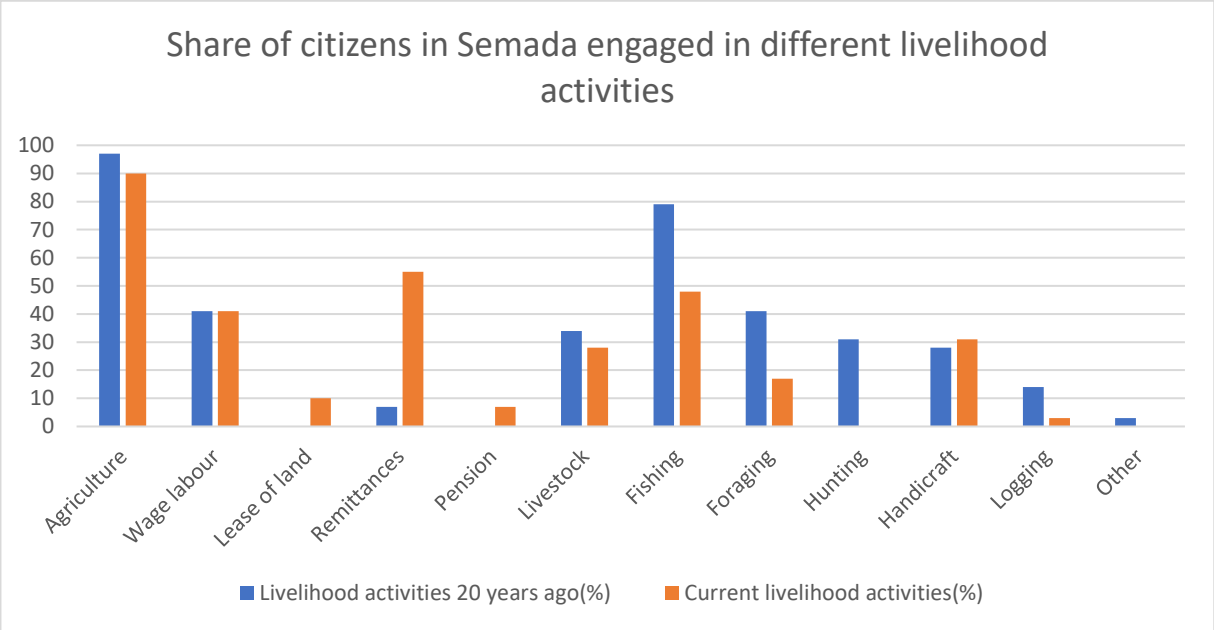

Figure 10:Share of livelihood activities households engaged in over time

Aiming to assess the livelihood strategies of the households in Semada, surveys were conducted with 29 (46%) of a total of 63 households in the three villages Semada Mawang, Semada Tengah and Semada Belatok. Through the survey it was found that 9 households (14%) do not live in Semada anymore but are still considered as part of the community. The respondents tended to be the heads of the respective household. The majority of the respondents are male (78%). In terms of ethnicity 90% of the respondents are Iban, other ethnicities being Malay, Bidayuh and Iban/Chinese. Furthermore, the survey showed that 86% of the households in Semada have members living outside of the household. Of these an average of 52% of the members live outside of the household.

Regarding the livelihood activities the activities (Figure 10) most households would engage in in the past were: agriculture (97%), fishing (79%), as well as foraging and wage labor (41%). The activities that the respondents marked most important for their income in the past were agriculture (66%) and wage labor (24%).

Compared to past activities, despite agriculture still being actively pursued by most households, there has been a slight decrease of 7% of households engaging in agricultural activities. Furthermore, there has been a significant increase of 48% in households that rely on remittances now (55%) than in the past (7%). Moreover, the number of households that engage in fishing (48%) and/or foraging (17%) has decreased compared to 20 years ago. The activities that are regarded as the most important for their income have also slightly shifted with agriculture being mentioned as the most important by 66% and remittances by 14% of the households.

Focusing on the agricultural activities, 93% of households engaging in agriculture have their own smallholding and 48% of the respondents stated that they are part of the JVC. In the past most households cultivated rubber (86%), rice (83%) and pepper (76%) with rice and rubber being of most importance for the household income. Currently, most households cultivate oil palm (79%), leading to a significant increase in oil palm cultivation of 72% compared to the past. Besides that, rubber (66%) and vegetables (41%) are cultivated by most of the households. Oil palm has been marked as the most important for the household income by 86% of the respondents. The households that have their own smallholding of oil palm have an average of 541 oil palms on their land.

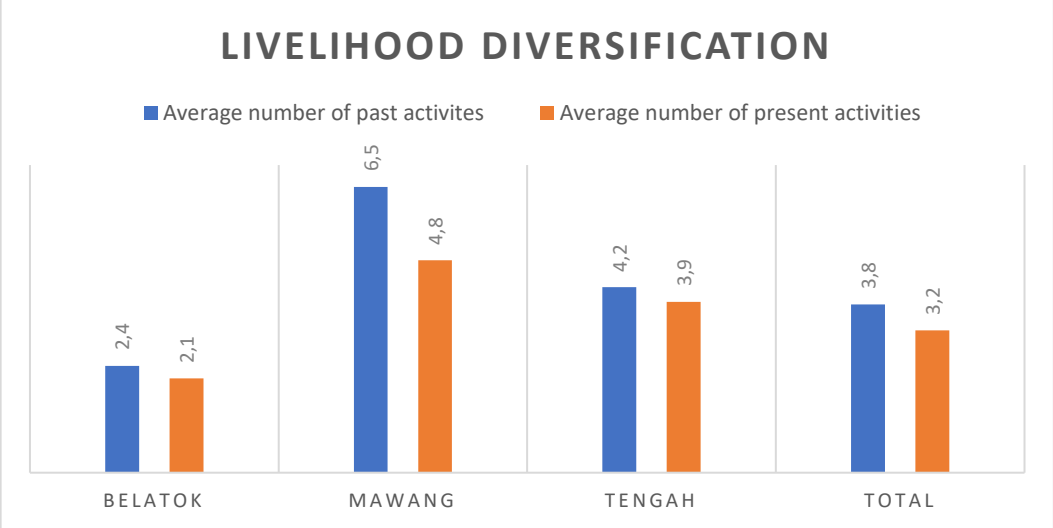

Figure 11: Average number of livelihood activities past and present

Regarding livelihood diversification (Figure 11), the number of livelihood activities that households engaged in was slightly higher in the past with an average of 3,8 activities per household. In the present this number has decreased, nowadays households averagely engage in 3,2 activities. Observing the number of livelihood activities in each village separately it can

be seen that the strongest decrease in livelihood diversification can be seen in Semada Tengah with an average decrease of 1,7 activities per household in the last 20 years.

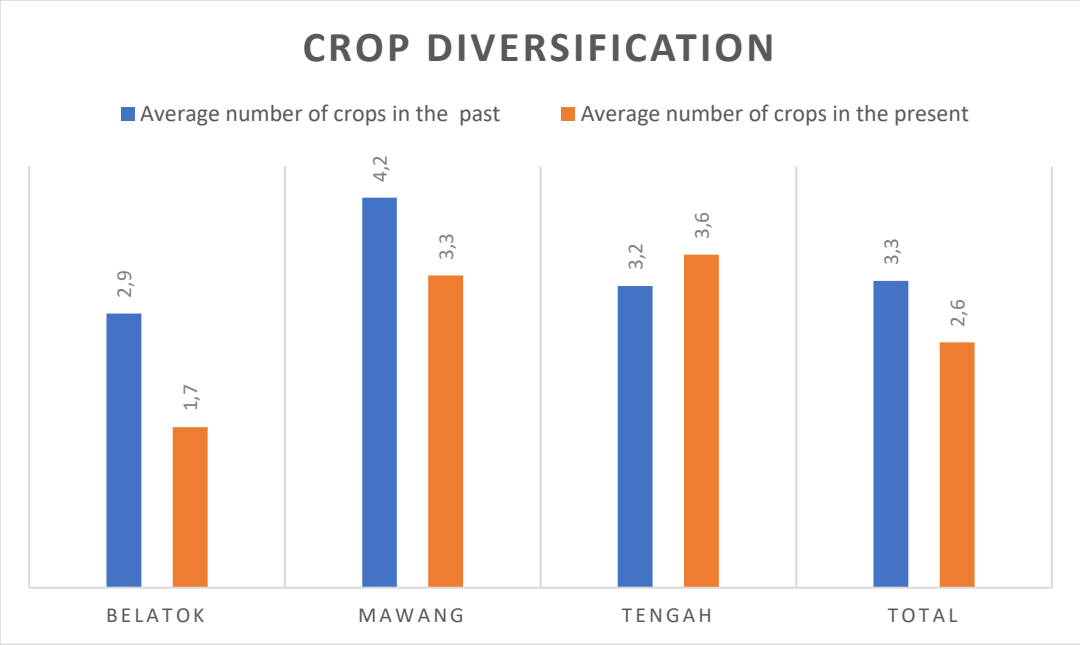

Figure 12:Average number crops cultivated past and present

Assessing the diversification in crop cultivation, showed that the average number of 3,3 crops households cultivated in the past decreased by 0,7 in the last 20 years. Among the villages, Semada Belatok with 1,2 shows the highest decrease in crop diversification, whereas in Semada Mawang the decrease is 0,8. Semada Tengah on the other hand shows an increase in crop diversification going from an average of 3,2 crops 20 years ago to 3,6 in the present.

The relationship between the number of current livelihood activities and the number of oil palms households have on their land was explored through linear regression (Appendix F1). The hypothesis was that a higher amount of oil palm could result in a lower number of livelihood activities and therefore less diversification. The analysis with $P > 0,05$ and a coefficient of 0,00 concluded that there is no significant correlation between the two, indicating, that the two variables are unrelated.

Community Structure

Figure 13 contains the key findings from the interview analysis, which are elaborated in the following sections.

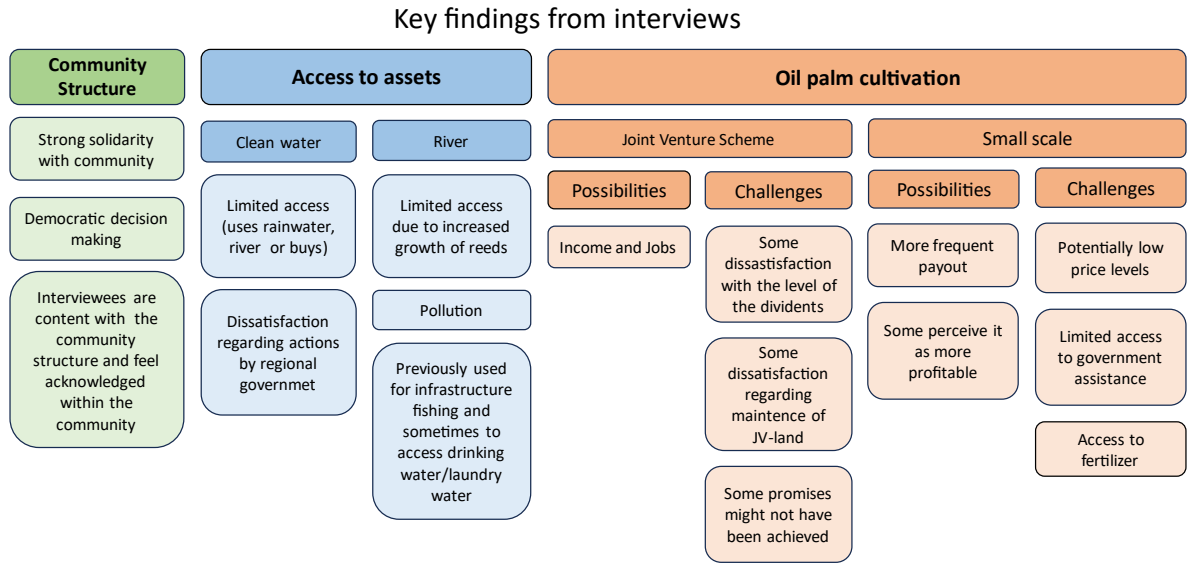

Figure 13: Key findings from the semi-structured interviews

Kampung Semada is located within Balai Ringin within the Serian district in Sarawak, and comprises of three villages, Mawang, Belatok and Tengah. Each village has their own local government with an elected headman or woman (Tuai Rumah) and committees. Within the three villages decisions are made democratically by majority vote at meetings with all citizens. Challenges for example related to water access is also managed jointly in the village, and there appears to be a high degree of solidarity within the community:

„[we]work as a community and her problem is everybody's problem. [we] take care of each other. All of the people from this community are participating." – female interviewee A

For matters unsolvable at the community level, the issues are brought to the regional government by the Tuai Rumah after having assessed and decided upon this at a community meeting. On the regional level the District Office, the State Administrative Officer, and the Community Leader oversees the villages. While the interviewees expresses that they are content with the structure and problem-solving within the villages, there appears to be a dissatisfaction when it comes to the management on the regional level regarding challenges and concerns in Semada. Another relevant institution is the Agricultural Development Committee (ADC), which facilitates the communication about concerns regarding the Joint Venture Company

Masranti. Similar to the perceptions of the regional government, the results from the interviews indicate a dissatisfaction and challenges related to the communication with and actions taken by the ADC.

Access to assets

Lack of access to water and to the river seems to be the main concern and challenge faced by the community. The main source of drinking water is rainwater, which is collected in tanks. During longer periods of insufficient amount of rainwater, the village can request water from the Water Board (Regional Government), however the interviewees express that the amount of water they receive is insufficient. In that case households will have to buy bottled water for drinking and cooking. The river was described as having previously been important for infrastructure and fishing. As can also be seen on the satellite image, the river has been overgrown with reeds, making it inaccessible by boat. In some of the interviews the river water was described as polluted, reducing the number of sources for drinking water. The lack of fishing opportunities was partly assigned to the lack of boat access due to the reeds, and a concern of crocodiles. Another reason that was given by an interviewee for the lack of fishing options was that some of the previously used fishing spots are inaccessible due to being located on Masranti land. There are some uncertainties regarding the severity of these issues relating to fishing as it was being carried out, particularly by the women.

Cultivation of oil palm

While the decision to engage in the joint venture scheme was made on a community level, and it is mainly community land that is being leased to joint ventures. Some of the interviewees also leased out an amount of their private land to joint venture. Regarding this there are some inconsistencies in the information gained through the fieldwork, as none of the respondents selected lease of land as one of their activities in the survey. Most of the households also cultivate their own oil palm. In general, the interviewees are positive towards the joint venture scheme, presenting job and income opportunities as well as road access as some of the positive outcomes. Some negative outcomes and challenges related to the joint venture scheme were also presented by the interviewees, the access to river, and fishing spots already being mentioned. Three of the interviewees explained that within the community there was a

dissatisfaction with the level of the dividend, and that the community had brought this to the Masranti asking for an increase, but with no success.

The communication with the joint venture company follows the general community structure, where a decision is made on community level, and the Tuai Rumah will then present the concerns at a meeting with the Area Development Committee (ADC). The general notion among the interviewees is that their concerns are not being acknowledged by the ADC, and that they do not see actions being taken.

While the dividend from the joint venture schemes is received twice a year, the smallholders can harvest their oil palm once or twice a month, making it more profitable according to some of the interviewees:

"(...) from the JV we receive money only twice a year and while for smallholders [we] get money every month, [we] get more profit from smallholding" – female interviewee A

Some challenges to small scale cultivation of oil palm can also be identified including the price level and access to inputs, such as fertilizer and seeds. Several of the households wished to expand their own oil palm cultivation but are lacking financial capital to do so. There is a government initiative providing subsidies in the form of seeds and fertilizer to start up oil palm cultivation for smallholders. However, it was explained by the interviewees that due to the number of people cultivating oil palm the subsidies had been exhausted, and therefore they used their savings to start cultivating oil palm. Further one of the interviewees expressed that the current price level was quite low compared to the price of inputs:

"(...) the cost of maintaining is almost the same as the price [we] get when [we] harvest their fruits. (...) the price is quite low at the moment (...) "- male interviewee A

Further the same interviewee explained that to obtain enough fertilizer for the oil palm cultivation, they will receive fertilizer from the Department of Agriculture for rice cultivation which they will use for the oil palm cultivation:

"[we] have the assistance of the Department of Agriculture, mainly for paddy. So sometimes *[we]* will use *[our]* fertilizer for paddy and use it on *[our]* oil palm."- male interviewee A

This indicates that the lack of assistance for oil palm cultivation may partly be rooted in a poor allocation of the assistance.

Biodiversity

To assess how the cultivation of oil palm affects rural livelihoods in Kampung Semada, a biodiversity assessment was conducted, with a focus on investigating ethnobotany and tree species in an agroforest close to the plantation, to illustrate which kind of ecosystem services the community is losing when an area is turned into oil palm plantations. Combining these two assessments, led to the following results:

Table 2: Biodiversity assessment

No.	Description	No. of Species	Diversity Index	Biomass (MT/Ha)	Carbon storage (MT/Ha)	IV
1.	Ethnobotany sp.	35	1.4	N/A	N/A	N/A
2.	Tree sp.	79	2.0	173.87053	85.19656	90.35 (Getah)

For the ethnobotany assessment, we found a significant large diversity of tree species of 79 different species with a Shannon diversity index of 2.0, with a mean biomass of 173,87 MT/Ha, a carbon storage of 85,2 MT/Ha and an importance value (IV) of 90,35. Furthermore we identified 35 different flora species with a Shannon diversity index of 1,4. Usually, the Shannon diversity index range from 1,5-3,5, so the ethnobotany and tree species diversity is in the lower end, but not close to being a monoculture (Bobbitt, T., 2021). Regarding the biomass, the average Malaysian forest´s biomass ranges from 89-276, with most of them having a biomass of 164-196 MT/Ha. In that light, the biomass we found is in the lower end of the average biomass (Raihan, A. et al. 2021). The importance value, 90.35, is a bit higher than the average Malaysian mean value of 86, indicating that the area consists of many, large tree individuals (Koshy, N. et al. 2019). We couldn´t tie the carbon storage to a mean value.

Discussion

Shifts in livelihoods and land use

The observable trends in land use change for oil palm production from 2000 to the present in Kampung Semada, have not only reshaped the landscape but also influenced the livelihood activities of the households in the region. Initially, the community's engagement in agriculture was nearly unanimous, with 97% of households involved, alongside high participation in

fishing, foraging, and wage labor. Agriculture was perceived as being the most important source of income for the community in the past, which reflects the historical importance of agriculture for livelihoods among the Dayak population (R. Cramb & McCarthy, 2016).

The findings indicate a shift in livelihood strategies among households as well as a decrease in diversification of livelihood activities. While agriculture remains the predominant activity, other activities like fishing, foraging, hunting, and logging have decreased (Figure 12). In contrast, reliance on remittances has increased dramatically, possibly due to the aging population and outmigration in Kampung Semada.

Impacts of oil palm on rural livelihoods

Within agriculture there has been a shift in cash crops away from pepper and rubber towards oil palm reflecting the general trend in Sarawak (R. Cramb & McCarthy, 2016). The increase in households with oil palm smallholdings, averaging 541 oil palms, illustrates the crop's current centrality to the community's economy. This can also be seen in the GIS results, indicating a significant increase of oil palm in the area. The scope of oil palm cultivation in the area underwent substantial changes between 2000 and the present, reflecting broader trends in agricultural development and land use patterns (Li et al., 2020). The rapid expansion of oil palm plantations, from undetectable in 2000 to covering significant land areas by the present, highlights the impact of oil palm cultivation on the landscape of Kampung Semada. This growth in oil palm cultivation reflects not only political drivers but also economic incentives and global demand for palm oil products (Murphey et al., 2021). While some of the increase in oil palm cultivation in Kampung Semada came from smallholders, the bulk was driven by commercial enterprises or joint venture companies (JVCs). This follows the influence of corporate interests and in the expansion of oil palm plantations as well as the shift in policy to promote rural development and participation in oil palm (MPOB, 2023; Varkkey, 2020).

Effects of these incentives can be seen in the combined establishment of plantation areas and road infrastructure in Kampung Semada. The road access may have had further impacts on the composition of livelihoods, by providing the community with increased access to assets such as jobs outside the community, and education as well as access resources outside the community. In that way the road access could potentially have impacts on the community’s

dependency on local resources. However, the specific contributions of the road have not been assessed in depth through the data collection, although it was mentioned as a positive outcome.

Income and input regarding oil palm cultivation

The involvement in Joint Venture Companies (JVCs) by 48% of respondents indicates a high level of engagement with commercial oil palm cultivation, blending smallholder practices with the larger-scale plantation. A positive impact of the joint venture oil palm cultivation mentioned in the interviews was the access to jobs as well as income opportunities. However, the survey and interviews did not indicate further that the households were particularly engaged in labor on the joint venture land, and the survey did not show a change in the number of households with members engaged in wage labor from 20 years ago to now.

The oil palm being a cash crop may however provide the community with income opportunity through both the joint venture and the small-scale cultivation. The joint-venture provides a positive impact through cultivation of soils that might be difficult and expensive for the community to cultivate and providing the households with an income from this land through the dividend. At the same time, small-scale production further provides the households with monthly income through their own cultivation and harvesting. However, the interviewees also mentioned some limitations to the benefits of cultivating oil palm, one of these being the price level being equal to the financial input needed for fertilizer. Another was the lack of capital to expand and to begin cultivating oil palm, as subsidies were no longer available.

Long term challenges and vulnerabilities following oil palm cultivation

The decreasing diversification of livelihood activities and number of crops observed within the community could potentially become a challenge to their livelihoods. The reliance on oil palm as the primary cash crop in Kampung Semada, while economically beneficial in the short term, introduces potential long-term vulnerabilities related to market fluctuations, pests, diseases, and the impacts of climate change (Li et al., 2020; Murphey et al., 2021). This is further complicated by the flattening rate of oil palm expansion around Kampung Semada, which could be indicative of reaching a physical or ecological limit to further expansion within the immediate region or a combined result of the Malaysian Sustainable Palm Oil Scheme (MSPO), launched in 2015 (MPOB, 2023).

The regression analysis made to assess a potential correlation between the number of oil palms and the number of activities the households were engaged in did not show a correlation. The reason behind this may be the size of the sample providing skewness to the data, or the limited variability in the amount of oil palms that the different households have. In general, the different households have close to the same amount of oil palms, around 300, with few households deviating much. It might also be that the number of oil palms cultivated by a household has no impact on the diversification of livelihood activities. Other factors possibly impacting livelihood diversification include age and out-migration. Particularly in Semada Belatok the population was at the retirement age, which might lead to a decrease in the number of activities. The number of members in the households may also have implications for the number of activities as more or fewer members can perform the activities. The data shows a decrease in the number of activities that each household engages in over time. The regression, however, assesses the current number of oil palms and not the changes over time. Comparing the livelihood diversification over time with the number of oil palms over time might show a significant correlation. However, other factors, such as age, outmigration and changes to access to the river could also influence the result, rendering it insignificant.

Through the survey it was found that several households had left the community. The purpose of moving and whether it was with the intention to move back was unclear. Furthermore, the out-migration might indicate lack of opportunities or insufficient assets or income opportunities within the community. New opportunities outside the communities or other pull-factors may also be a driver. The push- and/or pull-factors driving the migration could be assessed through interviews with the emigrated households, which could potentially also provide the study with a broader insight into the community and the impacts of the oil palm cultivation.

Environmental Impacts of Oil Palm Cultivation

The expansion of oil palm has resulted in a substantial decrease in agroforestry areas and the near disappearance of secondary forest patches, altering the landscape and biodiversity of the region (Figure 3). In addition to the implications for livelihoods, the expansion of oil palm cultivation often has wide-ranging environmental consequences, affecting biodiversity, soil health, and water resources.

Oil palm cultivation can have different impacts on soil parameters depending on the soil type and topography (Comte et al., 2013). Land-use change from forest to oil palm plantation influences water quality as well, which is mainly linked to leaching of fertilizers (Itoh et al., 2022). The case of Semada is no different in terms of the oil palm's impact on soil and water quality.

Water quality and accessibility are issues that were brought up the most frequently during interviews. People mentioned to us that the river resources were one of the major ways to sustain their livelihoods in the past, but it's not feasible anymore due to overgrowing reeds and the presence of crocodiles. The aquatic vegetation growth was confirmed by satellite imagery, on which it is visible how in 2018 vegetation started to increase. Based on these above-mentioned perceptions, we investigated what impact oil palm cultivation has on the water and soil quality for the community.

Looking at water, the analysis revealed that pH is lower in the oil palm plantation and at Semada Belatok. pH levels lower and higher than 7.0 can be harmful to sensitive aquatic species, especially their physiological processes (Kleinhappel et al. 2019). TDS (Total Dissolved Solids) is higher in the upstream area and at Semada Belatok. High TDS levels may indicate pollution, excessive salinity or presence of contaminants, in this case probably from the upstream area and oil palm plantation, which could be harmful to human health or aquatic ecosystems (Weber-Scannell, K. P. and Duffy, K. L., 2007). For the chemical parameters, BOD is highest at Semada Belatok (point 3), which may indicate higher presence of aerobic bacteria (USGS, 2018), and is probably due to an excessive number of reeds, woody debris and dead plants observed at Semada Belatok (point 3), both physically and on the GIS-maps. Furthermore, the community also mentioned the increased concentration of reeds in the river making it inaccessible for boats and decreasing the fishing opportunities, as well as the pollution of the river. This suggests that while the introduction of the oil palm plantation had the positive impact of supplying the community with infrastructure in the form of a road, as mentioned in the previous section, it also had a negative impact by limiting another element of infrastructure and asset to the community.

Regarding phosphate, the large-scale oil palm plantation (point 2) has the highest phosphate-concentration recorded. This may indicate fertilizer run-off, due to flooding and then stagnant

water in the area, which may accumulate phosphate (Uttran, A. 2023). The Nitrite-concentration is highest in Semada Belatok (point 3). This can be due to contamination from run-off fertilizers and residential discharges, from the adjacent traditional farming and residential area (Uttran, A., 2023). Dissolved Oxygen (DO) levels are the lowest for the large-scale oil palm plantation (point 2), and may indicate poor water quality, which may be due to agricultural run-off and poorly managed drainage. For the biological parameters, TCC (Total Coliform Count-Microorganisms) is probably high due to pollution from settlements and livestock in the upstream area and due to fertilizer use for the oil palm plantation. FCC (Fecal Coliform Count), e.g. E. Coli, is probably low due to good practices by the locals such as livestock policy and wastewater management, as some of the Malaysian resource persons told us.

The nutrient runoff is a major problem related to the expansion of oil palm plantations, not only in the context of water quality but also soil health. However, it is a natural issue in the tropics, caused by frequent and high precipitation and high temperatures (Ah Tung et al., 2009). The topography also contributes to it (Zhang et al., 2018). The nutrient leakage is revealed by the difference in nutrient levels between the plots close to the river and the ones far from it. Soil erosion can also contribute to the transport of fertilizers which stick to suspended solids and due to heavy rainfall, it results in moving the nutrient pollution further from its source (Wantzen, 2006).

The bulk density analysis revealed that soil on the JVC land is more compacted than on the smallholder land. Since the soil is more compacted, it can take longer for water to infiltrate. It means that JVC plantations are potentially more exposed to floodings. Furthermore, bulk density can be linked to moisture content. Soil on smallholder land, which is characterized by a lower bulk density, is more porous what positively impacts the water holding capacity.

Supporting our assumptions of a denser soil at the oil palm plantations, a case study from Indonesia by Jaya et al. (2018) revealed that the surface runoff was bigger on oil palm plantation than on the forest area during every rainfall. The erosion was also greater on the plantation land, due to the canopy cover. This data shows how land use transition to oil palm plantations makes the ecosystem more vulnerable.

Looking from a broader perspective of the issue of fertilizer usage, plantations consume enormous amounts of fertilizers, which significantly impacts the greenhouse gas emissions in Malaysia (Tang, 2018). It shows how the oil palm expansion has not only local but also global consequences.

Both soil and water are general issues in the Sarawak region (Mahyan, R. N. and Selaman, S. O. 2016, Neergaard D. A. et al. 2008). Several researchers have investigated practices like rainwater harvesting, desalinated- and reclaimed water (Mahyan, R. N. and Selaman, S. O. 2016) and alternative methods for terrain management and logging activities to prevent soil erosion (Vijith, H. et al. 2018). However, it will possibly take some time to see a significant effect of these implementations. Possible strategies, that could be worth investigating, could be practices like more effective buffer zones, shifting to bioorganic fertilizers and implementation of stormwater ponds.

Addressing sustainability concerns about oil palm expansion may involve pivoting towards diversification of agriculture and livelihood activities, enhancing the resilience of the community to economic and environmental changes. Diversification strategies might include the introduction of intercropping with oil palm to increase biodiversity and soil health. Such strategies necessitate support from government policies, research institutions for sustainable agricultural practices, and development programs that emphasize economic diversification, sustainability, and community empowerment.

Regarding the biodiversity assessment, we didn´t have the necessary time and resources to fully assess it aligning with our projects scope, and that´s the reason why we wound not discuss it in this section. With more time and resources, we intended to make similar assessment at a small- and large oil palm plantation and another natural forest to compare them

Positionality and Collaboration

Regarding our positionality within the Iban community there were some limitations we faced due to us being outsiders. Due to time and resource constraints when working on the project, there was a limited amount of time to fully comprehend the cultural, political, and social context of the study area. Furthermore, the short time spent within the community only gave us a basic understanding of the culture. Therefore, we are still limited by our background resulting in biased perspectives and are not knowledgeable enough to interpret the data with a deep cultural

understanding of the community, limiting the results that we can generate from it. Additionally, due to the language barrier and the limited knowledge of culture and customs, it was sometimes hard to establish professional boundaries within the community.

These constraints also influenced the general circumstances when collaborating and communicating with our counterparts from UNIMAS. Due to our different academic specialization, requirements, and time schedule we varied in our approach to the field work. Moreover, the size and diversity in cultural and language background as well as the dynamic of the group would confound communication at times. Nevertheless, we perceived our work together as a very successful collaboration. Due to our counterparts starting their project later, and aligning their methodology to ours, we initially felt that there was a possibility that we were dominating the collaboration. Therefore, and because we appreciated the focus they set within their research; we amended our research direction to theirs. From there we reviewed and conceptualized all our methods and guidelines together. During this process and later within the data collection we were able to learn a lot from our counterparts and our research was enhanced through the different perspectives and expertise that was integrated into it.

Limitations

In the context of data collection for this study, we encountered various limitations that need to be taken into account considering the results.

Due to our status as outsiders to the community and not knowing the language we faced a translation bias that influenced all aspects of our study. Firstly, we were highly dependent on our translators and counterparts to help with establishing relationships, plan activities, logistics and select participants for our methods. This limited our influence in decision making and judgement in these situations. Furthermore, not being able to communicate restricted our ability to participate in community activities. Implementing social science methods, we couldn't guarantee that the framing of questions came across as intended, possibly leading to misunderstandings and skewed answers. Additionally, we possibly lost a lot of valuable explicit and implicit insights the respondents gave us in the translation process. This is especially the case in some of the interviews, that have been conducted entirely in Malay and Iban. In these cases, we only got a translation of the answers and not to how the questions were phrased. The presence of one of the Tuai Rumah at one of the interviews could have affected the answers the

respondent gave. Furthermore, especially within the social science methods, the number of respondents of the surveys and interviews might not be representative of the whole community.

Regarding our reliance on the Tuai Rumah of the communities when searching for samplings sites and respondents for focus groups. We were influenced by their judgement in these situations, possibly disregarding other options that would have been interesting. This selection bias could have possibly been mitigated through having more time to establish relationships within the community and exploring the surrounding area.

When implementing the natural science methods, we encountered a lot of physical limitations that we had to adapt to in the field. Firstly, we were there in monsoon season, therefore most of the areas we wanted to use for soil, water and biodiversity sampling were inaccessible due to flooding. Furthermore, access to the river for sampling was additionally limited due to the presence of reeds, because of which we couldn't use a boat to sample and the presence of crocodiles that posed a danger to our general safety. Originally, we planned to conduct the water, soil and biodiversity sampling at the same sites. However, because of the mentioned flooding problem we had to diverge and a set of different sites for sampling, which limited the comparability of our data. Another limitation regarding soil sampling was that the soil map we used to identify our sampling sites was inaccurate, leaving us with two different soil types within our samples. This restricts the comparability of the soil samples between sites. Additionally, due to high precipitation levels and flooding during our time in the community, it is likely that the soil and water samples we took are slightly diluted and not representative during seasons with less precipitation. After returning, GIS analysis faced limitations with the resolution of publicly available satellite imagery, resulting in higher uncertainty for each calculation.

Conclusion

To assess the research questions in a comprehensive way, an interdisciplinary approach was used with a variety of methods both from social- and environmental science. The conclusions are based on the observable trends of land area used for oil palm cultivation between the year 2000 and 2023, which had an average expansion rate of 15,03km2 per year. This indicates an average annual growth rate of nearly 50% since 2005. Furthermore, the oil palm expansion may have environmental impacts both for the soil and water quality in the area. For water, the

impacts are especially observed in the oil palm cultivation, where the observed parameters indicated a larger amount of fertilizer runoff to the river, which also impacts the water quality at the riverside in Kampung Semada Belatok. The same trends are seen for the soil quality, where soil samples from smallholders and large-scale oil palm plantations indicated a larger nutrient runoff and challenges with soil erosion. The livelihoods at Kampung Semada were also impacted by the oil palm plantations, where the findings indicate a shift in livelihood strategies among households as well as a decrease in diversification of livelihood activities. While agriculture remains the predominant activity, other activities like fishing, foraging, hunting, and logging have decreased. In contrast, reliance on remittances has increased dramatically, possibly due to the aging population and outmigration in Kampung Semada. Within agriculture there has been a shift in cash crops away from pepper and rubber towards oil palm reflecting the general trend in Sarawak, which shows to be economically beneficial in the short term. In Kampung Semada, the increasing oil palm plantation gave the JV initiative to establishing a road and thereby providing the community with increased access to assets such as jobs and education outside the community and access to resources outside the community, possibly resulting in less dependency on self-sufficiency. But oil palm plantations may also introduce potential long-term vulnerabilities and challenges related to livelihoods, market fluctuations, pests, diseases, and impacts of other environmental challenges (Li et al., 2020; Murphey et al., 2021). The oil palm expansion thereby may provide some benefits and assets in the short run, but also may bring long-term challenges and impacts for the community.

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Pictures: All the included pictures have been taken by the KU and UNIMAS students partaking in this project.

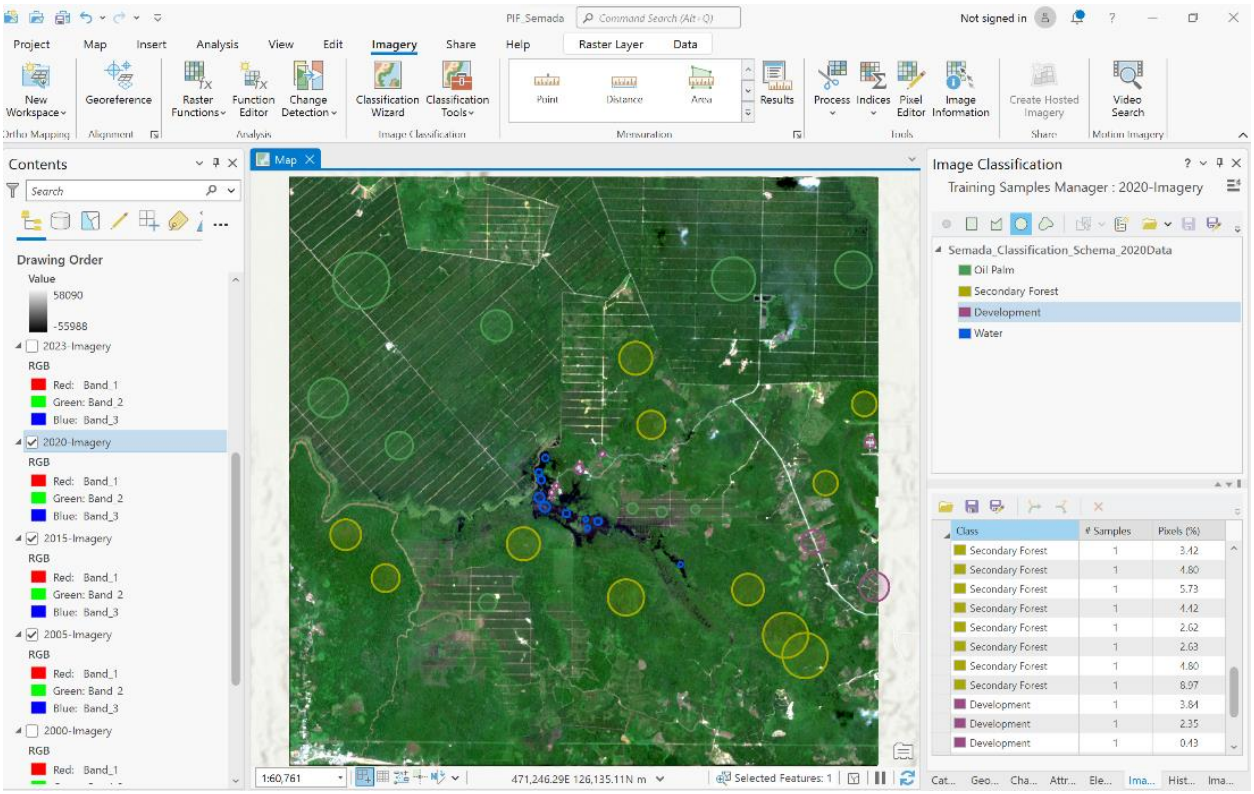
Appendix

Appendix A: Data Collection

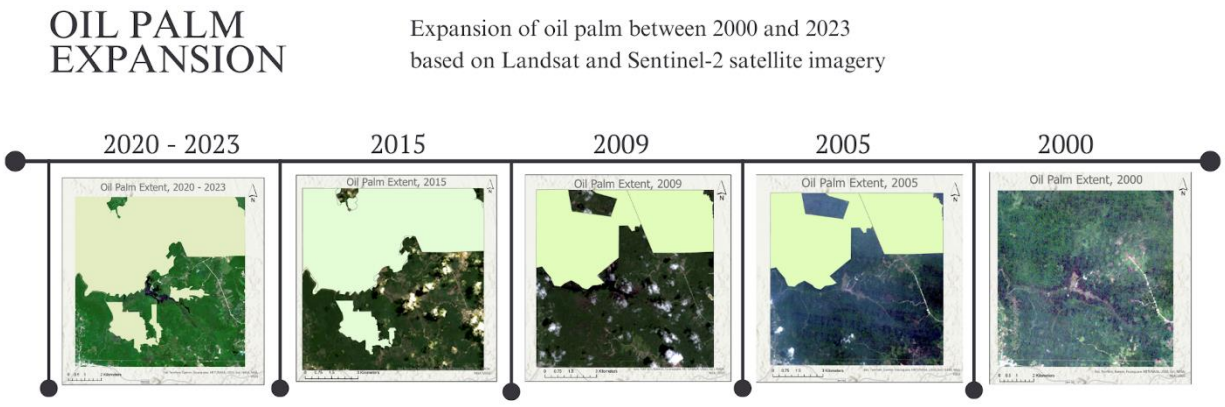
Method	Count
Stakeholder Mapping	2
Community & Timeline Mapping	2
Households Survey	29
Semi-structured interview	6
Soil Sampling	2 sites, 16 composite samples, 8 cylinder samples
Water Sampling	3 sites, 6 lab samples, 6 in-situ samples
Biodiversity Assessment	1 site, 2 plots
Ethnobotany Assessment	1 site, 6 plots
GIS	1 site, 10 model training samples per land cover class

Appendix B: GIS Analysis

Appendix B1: Labeling of model training samples for oil palm identification. 10 samples were used per land cover classification, assuming space allowed.

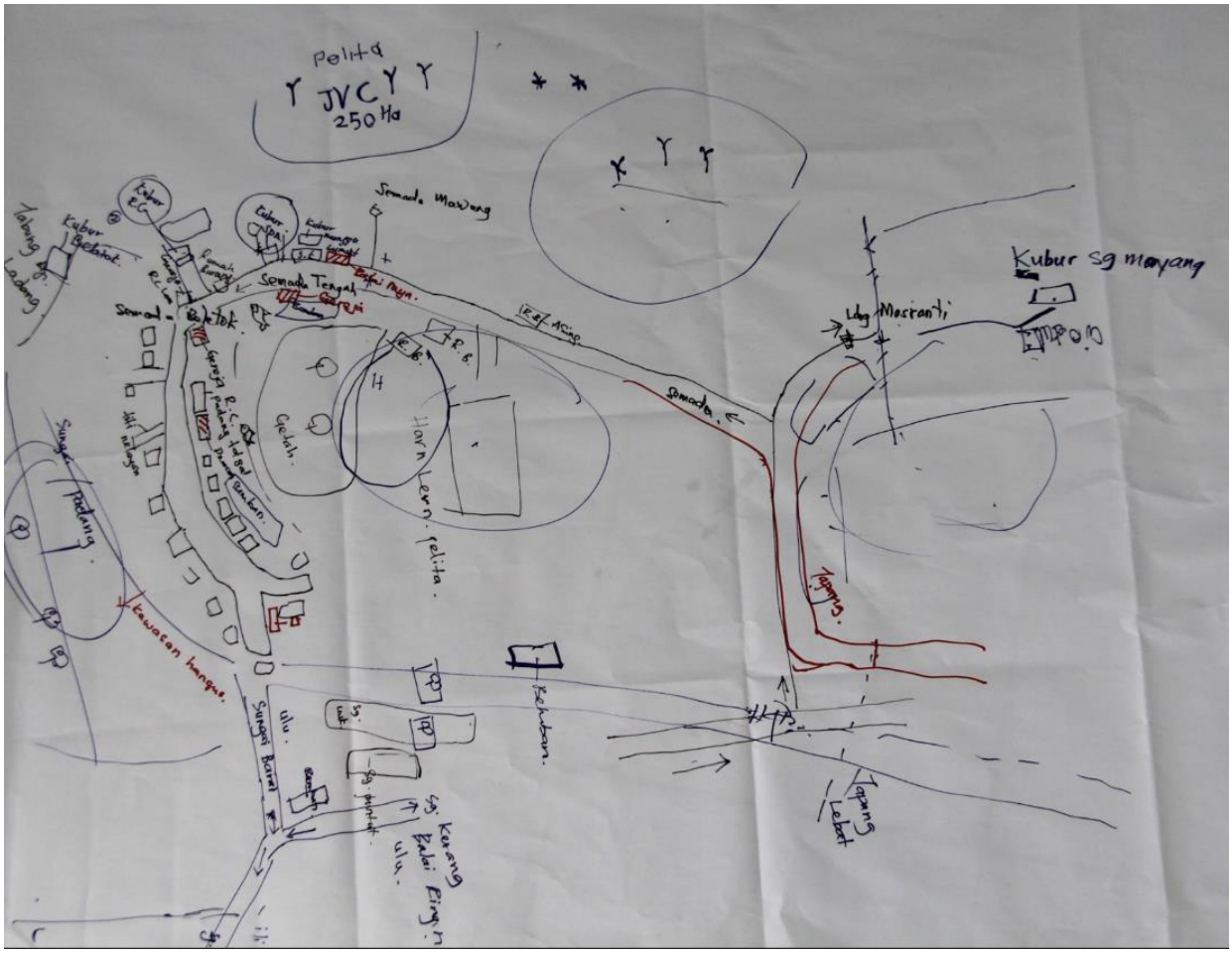


Appendix B2: Oil palm expansion between 2000 and 2023 based on Landsat and Sentinel-2 satellite imagery.

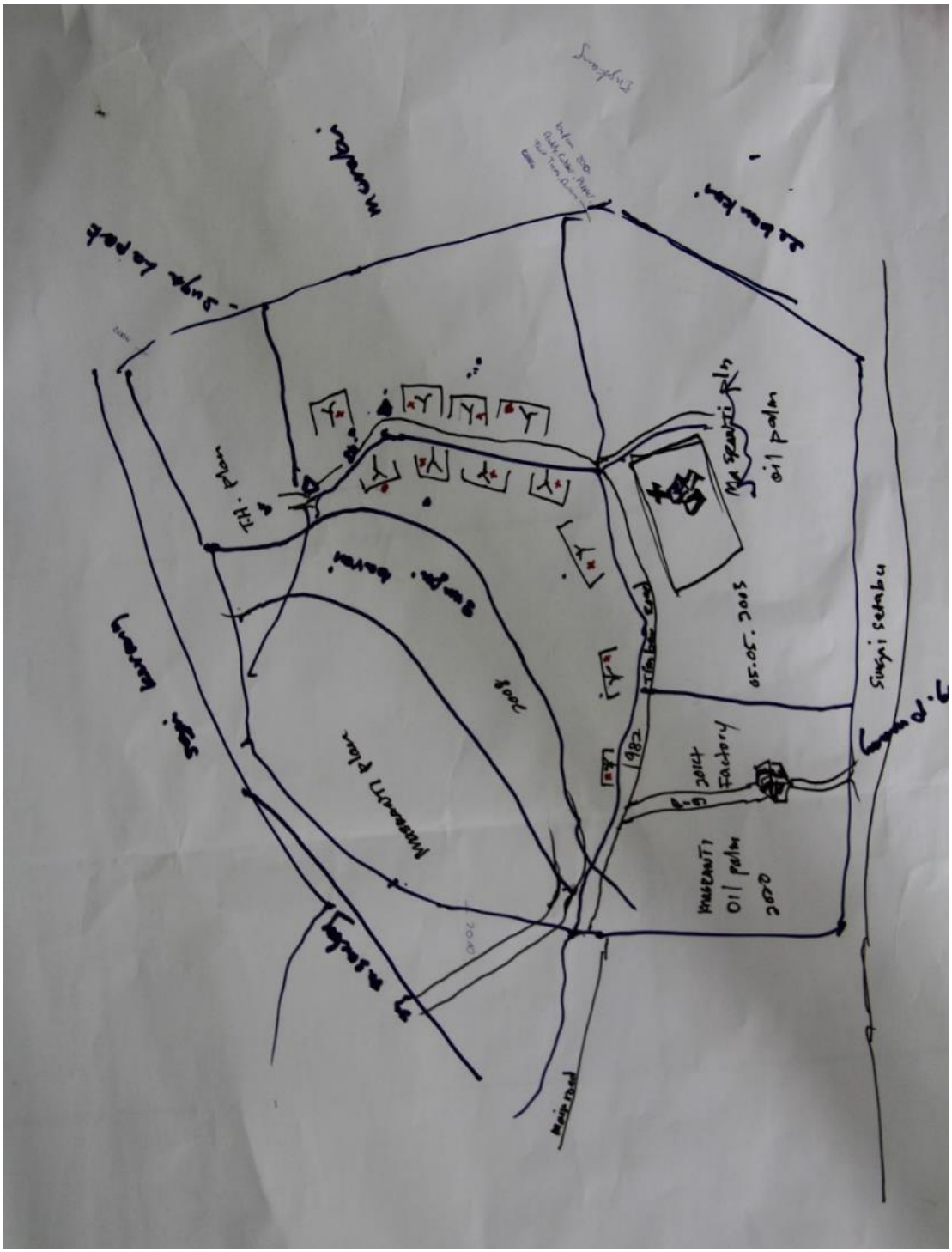


Appendix C: Community Mapping and Timeline

Appendix C1: Belatok and Tengah community mapping and timeline result.



Appendix C2: Mawang community mapping and timeline result.



Appendix D: Water Sampling

Appendix D1: Illustration of Kampung Semada and surrounding area. The three different numbers identify the sites where we took our water samples.

Focusing on water analysis, we choose the following three sites, as illustrated in figure:

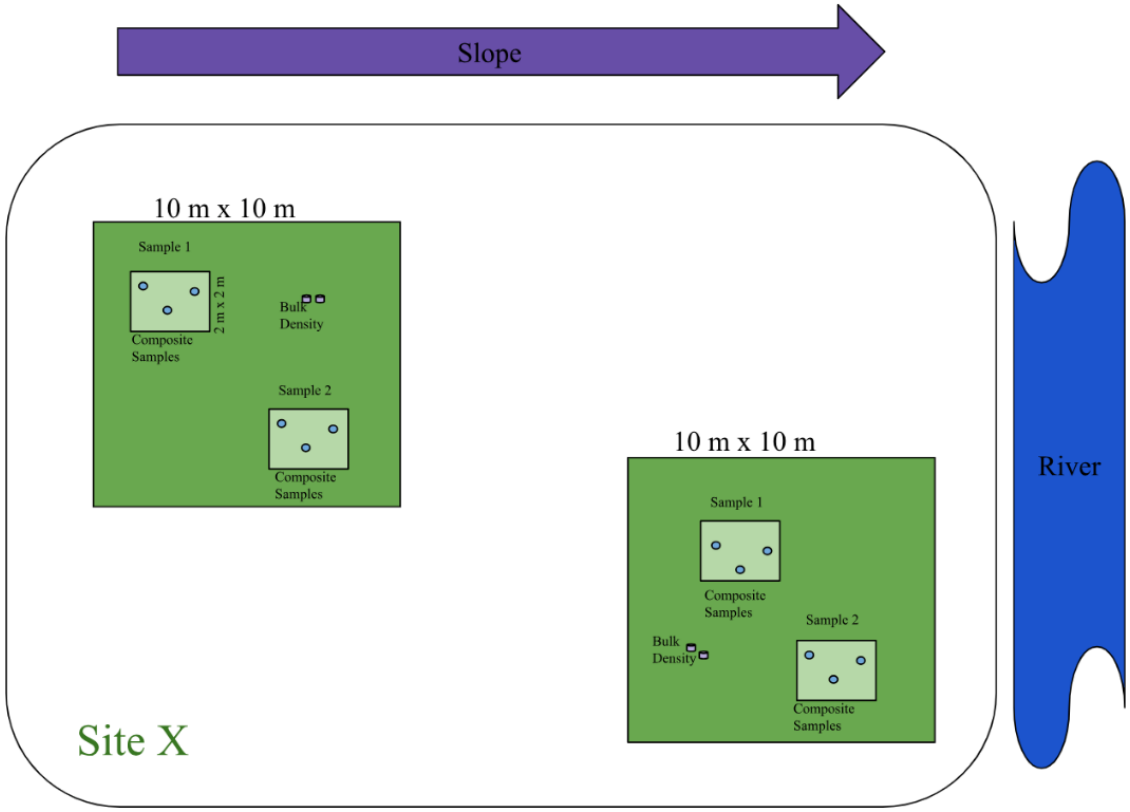
Site 1: Upstream – Sungai Barai

Site 2: Large-scale oil palm plantation

Site 3: Sungai Barai riverside at Kampung Semada Belatok

Appendix E: Soil

Appendix E1: Soil sampling methodology, two plots of 2 sampling sites each. Sites are located on slopes draining towards the Barai river.

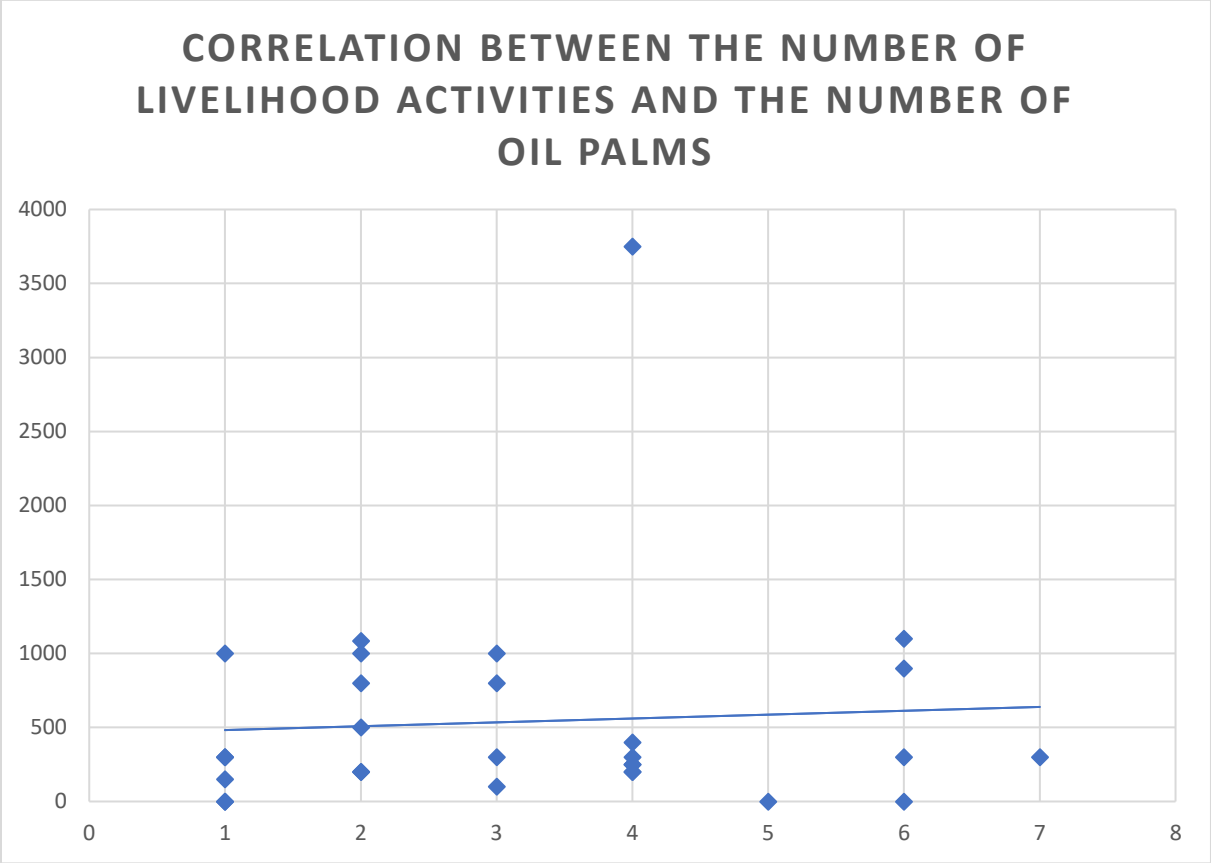


Appendix E2: Bulk density calculations.

Plot	Sample	Weight box	Weight Soil + box (Before 105°C)	Weight Soil + box (After 105°C)	Fresh weight of soil (g)	Dry Weight soil (g)	Bulk Density
Smallholder	P1 S1	5.987	157.087	110.76	151.100	104.773	1.048
Smallholder	P1 S2	6.083	153.389	103.686	147.306	97.603	0.976
Smallholder	P2 S1	5.939	148.584	109.541	142.645	103.602	1.036
Smallholder	P2 S2	5.954	140.612	104.792	134.658	98.838	0.988
JVC	P1 S1	6.066	196.702	159.904	190.636	153.838	1.538
JVC	P1 S2	5.943	178.132	141.863	172.189	135.920	1.359
JVC	P2 S1	6.042	193.367	158.266	187.325	152.224	1.522
JVC	P2 S2	5.942	183.315	150.164	177.373	144.222	1.442

Appendix F: Regression Analysis

Appendix F1: Correlation of livelihood activities and number of oil palms known.

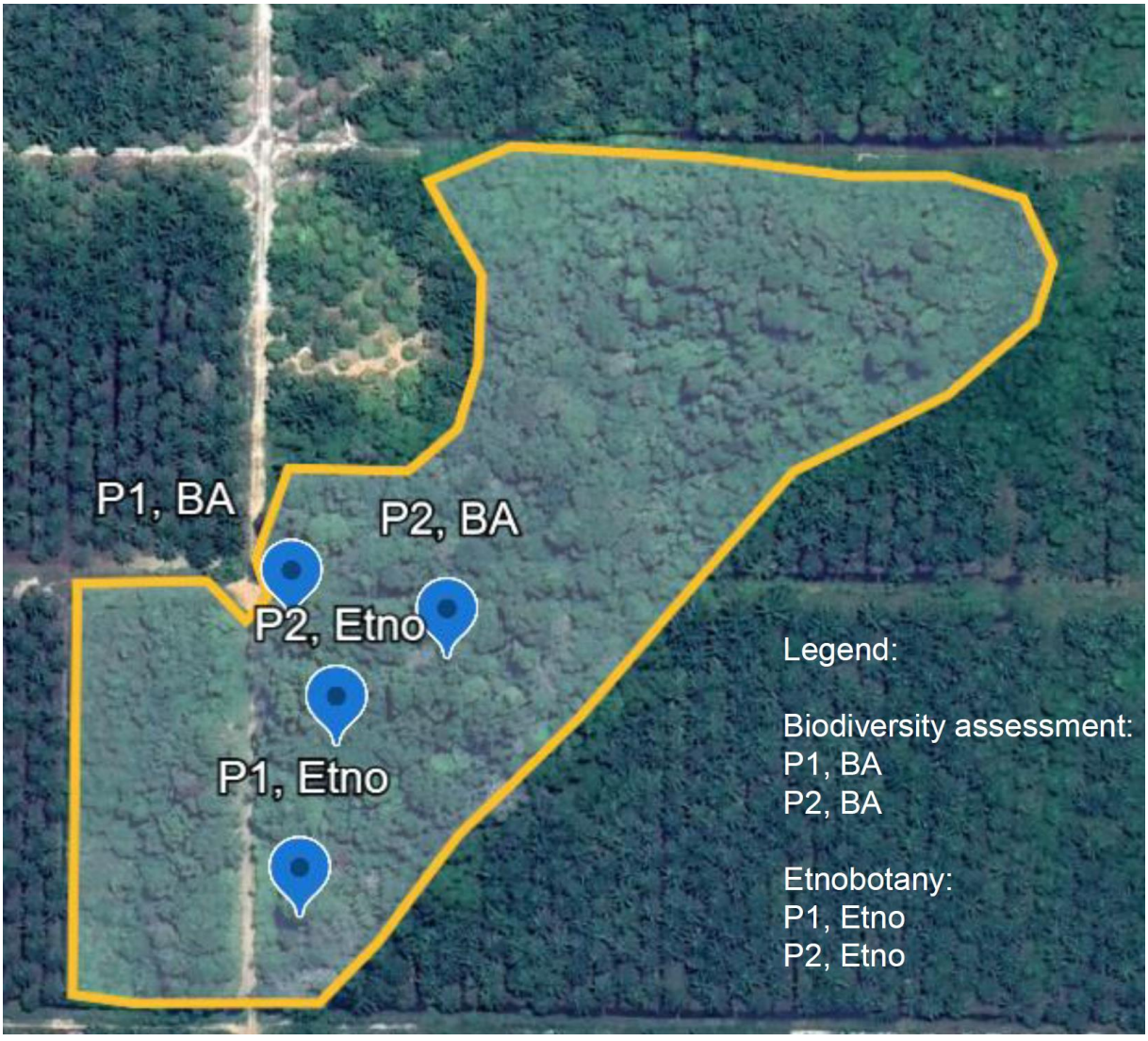


Appendix F2: Correlation analysis calculation results. No significant correlation found (P < 0.05 for oil_palm).

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	3,151550361	0,429976281	7,329591198	6,9561E-08
oil_palm	0,000166085	0,00048485	0,342548855	0,73459034

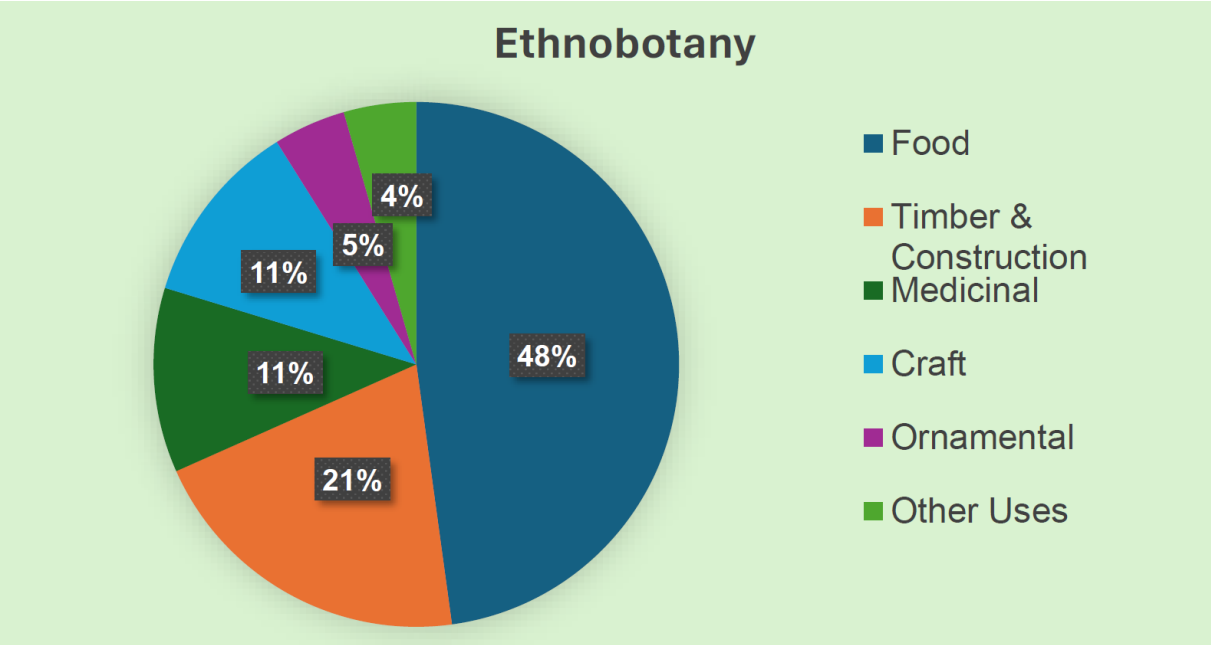
Appendix G: Biodiversity Assessment

Appendix G1: Location of the ethnobotany and tree-species assessment. P1, Etno to P2, Etno is the transect, where we assessed the ethnobotany, and P1, BA and P2, BA is the two locations, where we assessed the tree species. The location is at the Large-scale oil palm plantation, seen as number two in the figure.



Appendix H: Ethnobotany and tree species assessment

Appendix H1: Figure and table from the results of our ethnobotany assessment. From the assessment, we found nearly half of the flora-species was used as a food-source, around 20% was used for timber and construction, 11% for medical use, 11% to craft, 4,4% for ornamental and 4,4% as other usage.



Total number of species	%	Usage
21	47.73	Food
10	20.45	Timber & Construction
5	11.36	Medicinal
5	11.36	Craft
2	4.44	Ornamental
2	4.44	Other uses

Appendix H2: There were 36 trees found that are used as a food source, distributed between 13 different species and 38 trees used as respectively for timber and construction and 38 trees used as commodity crops. Two species found with particularly high importance values (IV): Durio zibethinus and Hevea brasilienses.

Type of usage	No. of trees	No. of species
Food crop	36	13
Timber & Construction	38	1
Commodity crop	38	1

Type of usage	Scientific name	IV
Food crop	Artocapus integer	8.24
	Artocarpus heterophyllus	15.14
	Baccaurea macrocarpa	13.47
	Durio zibethinus	**69.55**
	Ficus geocharis	4.03
	Lansium domesticum	12.89
	Mangifera pajang	12.67
	Nephelium lappaceum	27.75
	Nephelium maingayi	4.03
	Scorodocarpus borneensis	4.07
	Syzygium sp.1	4.63
	Syzygium sp.2	4.07
	Syzygium sp3.	4.11
Timber & Construction	**Hevea brasiliensis**	**90.35**
Commodity crop	**Hevea brasiliensis**	**90.35**

Appendix I: Semi-structured Interview Guide

General information:

GPS-Point:	Interviewer/Interpreter:
Semada; Belatok/Tengah/Mawang	Observer:
Household code:	Date & Time:

Introduction

We are 11 students from UNIMAS and the University of Copenhagen (Denmark). We are here to conduct fieldwork on the topic of land use change and rural livelihoods. Our objective is to understand the livelihood strategies of households in Kampung Semada and how susceptible they are to the environmental impacts of land use change. Therefore, we would like to ask you a series of questions. If you feel uncomfortable answering any of the questions feel free not to answer or withdraw from the interview. Furthermore, we ask for your permission to record the interview. The data we collect will be used solely for our school project, it will be treated confidentially, and the participants will remain anonymous.

Please note that it will take around 45-60 min to complete this interview. Thank you for your time and participation!

Meri tabi basa nuju kita sebilik ditu. Nyadi kami 11 iku tu nembiak master ari UNIMAS serta University of Copenhagen (Denmark). Pejalai kami sebuat kitu ianya kena ngerja pengawa pansik senentang pengidup urang diau di menua serta cara sida iya ngatur tanah kena tuju ngiga belanja tauka penatai pemisi. Pia mega kami lalu deka mansik rampa menua di Semada ditu sekali ke pemansang tu ngenatai ke penguntung tauka pengerugi ba pengidup setiap iku kita ditu. Nyadi enggau nya, kami arapka kitai sama bela ulih berandau serta bekaul manah lebuh maya ngaduka pansik tu laban sekeda utai ti dikena kami baka voice recorder endang disimpan kami kena tuju pansik tu aja.

Nyadi, nadai jaku bukai ari kami, muti deka madahka pengawa pansik tu deka belabuh udah tu. Terima kasih laban udah setuju deka enggau pengawa kami tu!

Introductory questions:

- What is your name? / Minta nuan madah ke nama nuan.
- How many people belong to your household? /*Berapa iku penyampau tubuh kita sebilik?*
- What is your relationship to them?/ *Kati ke tusun kaul nuan enggau sida iya? (cunto: apai, menyadi tuai, indai…)*
- What is your activity in the village?/ *Nama bansa pengawa dikerja nuan di menua Semada tu?*

Livelihood Strategies and Challenges: *(First we want to ask you about the activities you and your household normally engage in)*

- Can you tell me about the activities you do on a daily basis?/ *Kelimpah ari pengawa nya tadi, nama pengawa bukai diadu nuan ninting hari di menua tu?*
- What are the daily activities of the other members of your household?/ *Nama pengawa bala bukai serumah ditu ninting hari? (cunto: anak sekula, berikan…)*
- Does your household use the river?/ *Dalam ngerja pengawa kita sehari-hari, bisi tauka enda kita bekena ke ai Sungai ditu?*

  If so how you use it?/ *Enti bisi, kati ke cara kita bekena ke ai sungai?*

  How often?/ *Suah tauka enda?*

- Does your household use the forest?/ *Bisi tauka enda kita nurun ke babas?*
  - What do you do there?/ *Nyema bisi, nama pengawa kita ba babas?*
  - How often?/*Suah?*
  - What do you take from it?/ *Nama asil ulih kita ari babas?*
- Are there any challenges you face living here?/ *Bisi penanggul sekumbang kita diau tauka mindah ke menua Semada tu?*
  - If yes what are the challenges? Please elaborate./ *Nyema bisi, tau nguji nerang ke penanggul nya tadi?*
  - What do you do when you need help?/ *Enti bisi penusah, bakani kita bepinta tulung?*
  - Are you able to get enough help?/*Cukup tauka enda bantu diterima kita?*
  - If not, what could be improved?/ *Nyema enda cukup bantu, bisi cara bukai kini?*

JVC *(Now we will continue to ask you about the Joint Venture the community engaged in 2003)*

- To our knowledge everyone in the community takes part in the JV. Is that correct?/ *Nyadi ba penemu kami sebuat, semua kita ti diau di Semada ditu bisi enggau model kunsi (JV). Amat nya kini?*
- When the community decided to join the JV what was your opinion about it back then?/ *Lebuh kita setuju deka enggau model kunsi (JV), nama runding kita senentang nya dulu suba?*
- What are your drivers in this decision making?/ *Nama runding ti ngasuh kita setuju deka enggau pengawa kunsi tu tadi?*
- How do you feel about it now?/ *Kati baka asai sepi nuan sekumbang udah enggau model kunsi (JV) tu?*
- Do you gain any dividend for the JV?/ *Bisi udah nerima dividend tauka hasil kunsi ari pengawa nya?*
    - If yes, how much dividend did you received?/ *Berapa penyampau dividend/ulih udah diterima?*
- How frequent do you received your dividend?/ *Ni nyuah nuan nerima dividend/ulih?*
- Are you satisfied with the amount of dividend that you get?/ *Puas ati nuan enggau penyampau ulih ke udah diberi?*
- If you don't earn dividend, how do you sustain for living?/ *Nyema nadai nerima dividend/ulih, kati cara nuan ngidup ke diri?*
- Is there any other source of income?/ *Bisi penatai pemisi ke bukai?*
- Do you have a platform or focal person to turn to when there are problems about the JVC?/ *Bisi urang bukai endur kita betanya nyema bisi penusah senentang JVC tu?*
    - If so, are you satisfied with the help that you get there?/ *Puas ati enggau bantu nya tadi?*

SKIP TO COMMUNITY STRUCTIURE IF THEY DON'T HAVE SMALLHOLDINGS

Smallholders *(Now we will ask you some questions about your agricultural activity regarding oil palm)*

- When did you start to cultivate your oil palm?/ *Ni maya taun nuan ngepun ke pengawa besawit tu?*

- How many oil palm trees do you have in your land?/ *Ni pemayuh pun sawit iya ke ditanam nuan?*
- How do you manage your land?/ *Bakani cara nuan ngintu kebun sawit nuan?*
- How frequent is your harvesting activity?/ *Berapa suah nuan numbuk sawit?*
- How many tons does your land produce?/ *Berapa tan asil sawit ari tanah nuan?*
- How frequently do you fertilize your oil palm trees? /*Berapa suah nuan maja sawit?*
- Are your family members involved in oil palm cultivation?/ *Bisi tauka enda bala nuan sebilik enggau ngerja pengawa besawit tu?*
- Do you have workers to help you?/ *Bisi ngambi kuli enggau nuan begawa?*
- How much is the labor wage you pay the workers per ton or day?/ *Nyema bisi, kati cara nuan ngaji sida iya gawa?*
- Do you gain any profit from this cultivation?/ *Bisi natai ke penguntung pengawa besawit tu?*
- How much do you invest your capital to build this smallholding?/ *Berapa penyampau modal dikena nuan ngaga kebun sawit tu suba?*
- How much does it cost to buy the fertilizer & pesticides?/ *Berapa ungkus belanja dikena meli baja enggau racun?*
- Do you receive any subsidies/ incentives/ training from the government?/ *Bisi nerima subsidi tauka bantu/latih ari perintah?*
    - If yes, do you think it is sufficient?/*Cukup kini bantu diberi nya?*
    - Or would you need more help?/ *Tauka nguna lebih agi?*
    - If not, what would you wish for to happen/ improve?/ *Nama bantu bukai iya ke ulih diberi ngagai kita?*
- Why do you choose to cultivate oil palm in the first place?/ *Nama mai nuan keran amat deka besawit?*
- What were the drivers influencing your decision?/ *Nama pemai bukai ti ngasuh nuan keran deka besawit?*
- Are you satisfied with the decision to start oil palm cultivation?/*Puas ati nuan ngerja pengawa sawit tu?*
- Do you intend to expand your oil palm?/ *Bisi runding deka ngemesai ke agi tanah sawit kita?*

- Apart from oil palm cultivation activities, are there any other activities that you do in your household?/ *Kelimpah ari pengawa besawit, nama pengawa bukai dikerja ke nuan ninting hari?*

Community Structure *(Now we will proceed to ask questions about the community)*

- Can you tell me how the community generally makes decisions?/ *Ba runding nuan, kati cara kita di Semada ditu ngaga pemutus?*
- Do you think everyone is involved in community decision making?/ *Bisi tauka enda bala mayuh dikangau enggau pengawa baum kampung?*
- Do you have a proper channel to voice your concerns within the community?/ *Nyema bisi utai di kenangi, bisi tauka nadai endur kita mansut ke penemu?*
- When you voice your concerns, do you feel like they acknowledged you?/ *Lebuh maya nuan mansut ke penemu, bisi ka enda nuan ngasai ke urang mending ke nuan?*
- How do you feel about your community leadership?/ *Kati asai pegai tuai kita?*

Appendix J: Household survey guide

General information:

GPS-Point:	Interviewer/Interpreter:
Semada: Belatok/ Tengah/ Mawang	Observer:
Household code:	Date & Time:
Name of respondent:	Age of respondent:
Gender of respondent:	Ethnicity of respondent:

We are 11 students from UNIMAS and the University of Copenhagen (Denmark). We are here to conduct field work on the topic of land use change and livelihood. Our objective is to understand the livelihood strategies of households in Semada and how susceptible they are to the environmental impacts of land use and climate change. Therefore, we would like to ask you a series of questions. If you feel uncomfortable answering any of the questions feel free not to answer or withdraw from the survey. The data we collect will be used solely for our school project, it will be treated confidentially, and the participants will remain anonymous.

Please note that it will take around 20 min to complete this survey. Thank you for your time and participation!

Household composition

- How many members belong to your household?
- Are there any household members that are permanently living outside the household?
    - Yes
    - No
- If yes: How many?

Household activities and income

2. Please select the activities that your household engages in to maintain its livelihood. *(multiple answers possible, please put a tick if relevant to your household)*

Activity	**Notes**

Agriculture		
Fishing		
Lease of Land		
Livestock		
Hunting		
Logging		
Foraging		
Handicraft		
Wage labor		
Remittances		
Pension		
Other		

3. Please rank the three income sources contributing the most towards the total income of your household *(see the categories given above)*

1	
2	
3	

4. Please rank the three most important activities that do not generate cash income but contribute to consumption of your household *(see the categories given above)*

1	
2	
3	

→ If Agriculture has been selected:

5. Please select the crops that your household cultivates: (multiple options possible)

Crop		**notes**
Oil palm		
Pepper		
Rice		
Rubber		
Fruits		
Vegetables		
Other Crops		

6. Which crop is the most important for your household income? (use the categories given in the former question):

1	
2	
3	

Focusing on oil palm production

→ If the household is cultivating oil palm:

9. Which type of oil palm cultivation are you involved in?

- JVC
- Smallholding
- Both

Answer question 10 if involved in smallholding oil palm cultivation:

10. For how many years have you been cultivating oil palm?

7. How many oil palm are there on your land? _____

8. How many hectares of land do you sublease? ___

9. How much of your land is that?

- 0-25%
- 26-50%
- 51-75%
- 76-100%

Changes in livelihood strategies:

10. Please select the activities that your household engaged in approx. 20 years ago *(multiple answers possible)*

Activity		**Notes**
Agriculture		
Wage labor		
Lease of Land		
Selling of handicrafts		
Remittances		
Pension		

Livestock		
Fishing		
Foraging		
Hunting		
Handicraft		
Logging		
Other		

11. Please rank the three income sources that contributed the most towards your household's total income approx. 20 years ago *(see the categories given above)*

1	
2	
3	

12. Please rank the three most important activities that did not generate cash income but contributed to consumption of your household approx. 20 years ago *(see the categories given above)*

1	
2	
3	

→ If Agriculture has been selected:

13. Which crops did your household cultivate approx. 20 years ago and for what? (multiple options possible)

Crop	Activity	Notes
Oil palm		
Pepper		
Rice		
Rubber		
Fruits		
Vegetables		
Other Crops		

14. Which crop was the most important for your household income approx. 20 years ago? (use the categories given in the former question):

1	
2	
3	

Thank you very much for your time. We might be interested in conducting a longer interview with you for our project. Would it be okay if we contacted you about this at a later time?

- Yes
- No

Appendix K: Community and Timeline Mapping

- PRA: Participatory Mapping Exercise
- 3 groups with 4-5 members per group
- Quota sampling: Based on community, age, gender, land use activities.
- Estimated Time: 1-2h
- Equipment: 1 Poster, Paper, Markers

Introduction

Thanking the participants for their disposition to join. Explaining the concept, objectives, and process of the activity. Asking the participants for their consent to participate as well asking them if they consent that the interactions in the focus group will be documented by taking notes.

Concept: The participatory mapping exercise is used to engage community members to create a visual representation of their environment as well as their perspectives and knowledge about it.

Objectives:

- Understand and get an overview over the environment and land use in and around the community.
- Investigate how the environment was in the past and how the land was used in and around the community.
- Gain an understanding of how the community members have perceived and are continuing to perceive the change in land use and environmental conditions.

Mapping Exercise

Introduction:

We will first ask you to draw a map of your community and the area surrounding it. Then we will ask you some questions, while answering these we will ask you to add new aspects to your map and fill it with your knowledge. In the end we will look at the finished product and reflect on the activity.

We ask you for the permission to record the audio of this discussion solely for the academic purposes of our study. All the data and records resulting from the discussion will remain anonymous and confidential.

Step 1: Please draw a map of your community and the surrounding area:

- Please draw the settlements (village area), bodies of water (rivers, lakes, ponds etc.), vegetation (forest, swamp land etc.), smallholder land, plantation land.
- Please indicate on how the land areas that you mapped out are used (e.g. fishing, water supply, agriculture (if so which crops?), gathering (if so what?), livestock, living and leisure spaces etc.)
- Please map out areas that are not used. Why are they not used?
- Please put one of the sticky dots on the area, that according to you is the most valuable to your livelihood. Women (green), Men (red)

Result: Map of the current land and resource use of the community.

Step 2: Now we will ask you some questions about how the environment looked in the past. While you discuss and answer the questions, indicate the affected areas on the map.

- How did the area in and around the community look like before the appearance of the plantation around 2000 (20-25 years ago)?
- For what have the different land areas that you mapped out been used back then?
- When did the change in land use happen (please indicate a year)?
- Did the land use bring any changes to the community socially, economically and/or ecologically (soil quality, animal species, plants, vulnerability to natural phenomenon's etc.)? If so in what way?

Result: Map with sticky notes indication important dates and what happened around them, information about changes in the protocol of the session.

Step 3: Finalizing the map

- How do you like the map that you have created?
- Is there anything that you think is still missing? If so please elaborate and add to the map.

Step 4: Now we have a map in which we can see the environment and land use around the community in the past and present. Now that we have everything visualized, we ask you to reflect and discuss:

- What do you think are the reasons and drivers behind these changes?
- How do you perceive the change? What are the Pros and Cons about it?

Wrap-up: Summary of the discussion, map etc.

- Is there any additional information that you would like us to know about?
- Thanking the participants for their time and participation

Appendix L: Stakeholder mapping guideline

Guideline Stakeholder Mapping

- Meeting with the heads of the three longhouses
- Estimated time: 45-60min
- Equipment: Poster, Markers

Guiding Questions

Social Structure

- Request for the Organisation Chart of the village.
    - if not available, get the information on who are the assistant headman(s), committee under the headman
- Is there is any other association in the village? – e.g. churches, JV committee, Parent Teacher Association (PIBG) and who are the head/chairman/president of this association (s)
- Who are the headman advisors and / or elders that they would refer to in regards to any decisions, events?
- Who are the government officials that are in-charge of the village?
- Can you rank the individuals according to its importance to the village development?

Land Use & Resources (Identify Potential Candidate for In-Depth Interview)

- What activities and land uses are the village community involved in?
    - who owns the largest share in the JVC (have the most land in the JV)?
    - who owns the largest smallholding of oil palm?
    - if there is anyone that are not involved in oil palm cultivation and who are they?
    - Is there anyone that are planting oil palm and at the same time still farming other crops like paddy cultivation, pepper, fruit trees to support their economy?
    - Is there any other agriculture economics activities going on in the village? Bird nest, aquaculture, or others
- Any fishing activities or other natural resource dependent activities being practiced in the village such as handcraft, wood furniture? -can be useful for priority matrix preparation.

- Anyone produce locally made products in this village such as rice wine, langkau for sales?

Identify Potential Resource Person

- Who can we talk to, to get the permission to take soil samples from the plantation (JVC)?
- Who can we talk to, to get the permission to take soil samples from the smallholder?
- Who can guide us to collect water samples? At upstream, mid-stream and downstream of Barai River
- Who can support us in general data collection and become the resource person

Who should we call / invite to conduct community mapping and timeline mapping? (need to include those that have extensive knowledge of the area, history, and mixture of youth and women)

Appendix M: Final Synopsis

Synopsis

Oil palm expansion and vulnerability in longhouse communities in Semada, Sarawak.

https://www.thejakartapost.com/news/2019/10/10/oil-palm-plantations-continue-to-expand-despite-moratorium.html

Group members

Helene Bartholdy

Larissa Haaf

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Steffen Rassmussen

Table of Contents:

Introduction

Since its introduction to Malaysia in 1917, the oil palm (Elaeis guineensis) has become the country's primary cash crop (Cramb & McCarthy, 2016). Malaysia's significant role in global palm oil production, amounting to 27% in 2019, has solidified its position as the world's second-largest producer, trailing only behind Indonesia (Ahmad et al., 2023). The expansion of oil palm plantations has been rapid in recent decades, with an increase of 5.06 million hectares between 2000 and 2018 (Li et al., 2020). The studied state Sarawak, situated in the west of the Malaysian part of Borneo, currently hosts 1,623,660 hectares of oil palm plantations, accounting for 28.7% of the country's total planted oil palm, thus consolidating its status as a pivotal region in Malaysia's palm oil industry (MPOB, 2023).

To enable the rapid expansion of palm oil production in Sarawak, primary, logged-over forest, shifting cultivation land and peatlands have been turned into plantations. While a lot of this transformation has taken place on state owned land, new plantations are established on so-called Native Customary land, which according to Sarawak law is protected from alienation (Andersen et al., 2016; Land Code 1958). Accompanying these changes in land use there has also been a shift in agricultural practices. Smallholders, who originally practiced swidden cultivation, and adapted to cash crops like rubber and pepper over time, transitioned to the cultivation of oil palm (Cramb & McCarthy, 2016).

The existing literature on the oil palm expansion in Sarawak displays that the government of Sarawak plays a key role in this development. During the colonial rule (1946-1963), different land laws were introduced to both protect and restrict the rights of the Dayak population, (Cramb, 2009). This involved the limiting areas where the Chinese population could acquire land as well as excluding the Dayak population from the remaining primary forest (Cramb, 2009). In 1948 the land was divided into different zones (Ndgidang, 2005): Mixed Zoned Land, Native Area Land Native Customary land, Reserved Land, and Interior Area Land (Ndigang, 2005; Cramb, 2009). Cramb (2009) estimates that the Native Customary land accounts for approximately 25% of the total land area. In 1958 a new Land Code was introduced which added to the previous laws by stating that "*customary rights to land could only be recognized if such rights were created prior to 1 January 1958"* (Ndgidang, 2005, p.60). The Sarawak land code makes it illegal for non-natives to deal in native customary land (Porter, 1967 in

Cramb, 2013). During Abdul Taib's time as the Chief Minister of Sarawak there has been a shift in policy towards an increased emphasize on the role of large-scale production of oil palm and other cash crops as the driver of economic growth and development (Cramb, 2009), leading to changes in land policies in favor of this narrative (Ndigang, 2005). This includes Taib's introduction of the Joint-venture approach and the Land Custody and Development Authority (LCDA), which is regarded as a native allowing it to deal in customary land (Cramb, 2013). The role of the LCDA is partly to declare land as development area as well as to function as an intermediary between landholders and the private companies in the Joint-venture approach (Cramb, 2013). The classification of land as a development area is based on the Minister's perception of this being a interests of the inhabitants (Cramb, 2013). These initiatives create ways for the government to bypass the Land Code from 1958, to acquire more land for the expansion of oil-palm production.

Furthermore, it's especially important to assess the environmental aspects of oil palm expansion. The expansion has a wide range of effects, expanding from deforestation, biodiversity, water quality, air pollution and climate change. Focusing on deforestation, there has been a 23,1% forest decline from 1973-2010 in the Sarawak region. This is due to mainly (wild)fires, shifting cultivation and conversion of plantations (Gaveau et al. 2014; Gaveau et al. 2016). Deforestation has severe impacts on biodiversity. A study that examined the conversion of forest area to plantations found a 94-100% decrease of respectively primate groups, 61-81% of bird diversity and 54-65% of bat species in these areas in Sumatra (Danielsen, 1995). Other essential environmental aspects are respectively water quality and air pollution. The expansion of oil palm generates increased urbanisation and transport on the Sarawak River, and increased usage of fertilizers and other chemicals at the plantations (Nurlailah et al. 2013; Abdullah & Sulaiman, 2013). The Sarawak River water quality varies at the time of the study measurement´s (2013) from 65 to 89 out of 100. That indicates a Water quality Class II and III, and is thereby suitable for drinking, but the quality could be better (Nurlailah et al. 2013). Furthermore, the clearing and burning of forest area to conversion of oil palm plantations have a significant impact on the air pollution. In a recent study, the air pollution has been identified as having the largest effects on human health, agricultural crops and ecosystems in Malaysia from 2000 to 2020 (Afroz et al. 2003).

Field site: Semada

The study area for this project is centred on Semada, Sarawak. Semada is a longhouse community in western Malaysian Borneo that has seen a significant increase in development and oil palm expansion since the early 2000s. Located approximately 50km from Serian town and 110km from Kuching city, it is a rural area primarily made up of people from the Iban ethnic group. Consisting of three settlements and 64 total households, this study aims to understand the relationship between the communities and the large oil palm companies in the immediate area. The area is characterised by relatively flat terrain, immediate access to the Barai River, one of the primary tributaries of the Kerang River, and extensive swamp lands. A previous source of transportation, water, and food, the river has recently become inundated with reeds and a high crocodile population, further limiting the economic opportunities in the area. Aquatic resources were historically supplemental to more traditional agricultural practices such as rice cultivation, rubber tapping, and pepper. However, these practices have faced challenges such as pest infestations, low market prices, and unsuitable soil conditions. This has facilitated the transition in the community towards Joint Venture agreements with oil palm companies as

well as the increase in small-holder planting of oil palm, what this study aims to further investigate. The image below illustrates the temporal changes in the surrounding area, with the Landsat MODIS image from 2000 illustrating the land before large-scale plantations moved in. The Landsat MODIS image from 2010 depicts the dramatic increase in plantation extent during those years. The lighter tone indicates that the plantations were relatively new, as opposed to the Sentinel 2 images from 2020 where the canopy cover is significantly higher due to the maturity of the trees.

Research question and objectives

The objective of this research project is to assess the impact of the expansion of oil palm plantations on the vulnerability of longhouse communities in Semada, Sarawak. To investigate this matter we developed the following research questions:

> RQ 1: What developments regarding land use for palm oil production can be seen from 2000 until now in Sarawak?
>
> Progressive expansion of oil palm production.
>
> What are the observerable trends in oil palm production.
>
> RQ 2: What impact has the oil palm expansion had on the environmental conditions in Kampung, Semada?
>
> RQ 3: How does the oil palm cultivation contribute to the livelihood strategies of households in the community?

The aim is to build a vulnerability assessment for climate and land use change impacts on livelihoods within the longhouse communities through analysis of both the primary environmental and socio-economic factors (Füssel & Klein, 2006). As climate impacts continue to worsen, understanding the vulnerabilities and strengths of communities like the longhouse communities in Semada is important, to assess how they could act now and, in the future, to mitigate and adapt to these challenges. To address this, this research will initially analyse developments regarding land use for palm oil production from 2000 until now, using satellite imagery and global oil palm extent reports. The impact of oil palm expansion on environmental conditions within the communities will be assessed to determine the current state of biodiversity

and soil health. A comparative analysis will also be conducted to discern differences in environmental impact between commercial plantations and small-holder planting. Additionally, to develop a more comprehensive understanding of the community, the contributions of oil palm cultivation to community household livelihood strategies will be analysed. By examining these dimensions, the research aims to provide a nuanced understanding of the multifaceted impacts of oil palm expansion on the vulnerability of longhouse communities in Semada, Sarawak.

Methodology

Interdisciplinarity

The research aims to be interdisciplinary, merging social and natural sciences. This approach allows us to triangulate and explain complex phenomena's such as livelihoods of rural communities or climate change. The concept of crossdisciplinarity is used for this research. According to Krishnan (2009) crossdisciplinarity is an approach that looks at a certain concept through different disciplines to reach an interdisciplinary perspective. For our analysis of the rural livelihood strategies, we use the sustainable livelihoods approach focusing on livelihood strategies and vulnerability.

Stakeholder mapping

One of the first methods that we are going to use is stakeholder mapping in a form of a focus group with the heads of longhouses. It will allow us to get a visual representation of the community. The heads of longhouses will be asked to give us an overview of the dynamics and characteristics of the community. In consequence of that, we will know which people are the most knowledgeable on the matters we need information on.

Semi-structured interviews

In order to answer RQ3 about livelihood strategies, semi-structured interviews will be conducted. This type of interviews has been chosen so that interviewees have space to express their opinions and experiences. Our aim is to interview 10% of each longhouse in Semada, which would be 6-7 interviews. If that is not feasible, we will aim to interview as many households as possible. Each interview will take around 30-45 minutes. The method of quota sampling based on the pursued livelihoods strategy will be used. The interviews will aim to

give us information on how oil palm contributes to livelihood strategies within the community, what influenced the transition to oil palm cultivation and what are the potential challenges of different livelihood strategies. If given consent, interviews will be recorded and transcribed. Obtained data from the interviews will be analysed in nVivo.

Focus group

A focus group will be conducted in order to obtain information on how the local dwellers perceive environmental and land use change, with a focus on soil health and biodiversity. This data will allow us to answer RQ2 The group will consist of 4 to 5 people. The aim is to create a map of the area, using participatory mapping, in which environmental and land use change today and in the past is displayed. Quota sampling method based on age, knowledge on the environment and other factors will be used. Alternatively, snowballing sampling method can be used.

Household survey

A household survey will be conducted among households of the three longhouses of Semada to answer the RQ3. It will allow us to triangulate this quantitative data with the qualitative data from the semi-structured interviews and get a broader perspective on pursued livelihood strategies and social dynamics in the area. Ideally, all 64 households will be surveyed, if this is not possible, we will use random sampling to decide on which households to interview. Each survey will take 20 to 30 minutes. Apart from getting information on livelihoods, the survey will allow us to gather more personal information about the interviewees that they might have not been likely to share, e.g. during a semi-structured interview or focus group.

Land use transitions assessment through satellite imagery

Expansion of oil palm plantations in Borneo has an enormous impact not only on the pursued livelihood strategies but also on the environment. Those impacts include biodiversity loss, greenhouse gas emissions, soil erosion and a decline in water quality (Meijaard et al., 2020), therefore we want to assess the environmental changes. Due to the limited time in our research, we focus on assessing soil quality and biodiversity in the context of oil palm expansion. To assess the scale of land use transitions in the region and answer RQ1, satellite imagery from Sentinel 2 will be used. Maps presenting land use change from 2000 to 2023 within a 20km

radius of Semada will be created. Based on the maps, area´s turned into oil palm plantations will be calculated between years to gain an understanding of plantation expansion in the immediate area. To get a good overview of livelihood strategies, other types of land use will be assessed as well.

Soil sampling

Soil quality will be evaluated to answer the RQ2 on how oil palm expansion impacts the environment and people's vulnerability. Soil quality will be assessed by analysing soil samples, which will be collected from corporate plantations and small-holders land. If we don´t get permission to the corporate plantations, we will collect from a smallholder and a natural area. There will be two sampling sites in each of the different land uses. All cylinder samples will be taken at the depth of 10 cm. A composite sample and three cylinder samples will be collected from each of the sites. Variables such as pH, soil composition, salinity, organic matter and nitrate will be assessed in the laboratory. Soil pH regulates the availability of nutrients that influence crop productivity (Oshunsanya, 2019), which is why this variable will be assessed. Salinity of the soil will be assessed through measuring electrical conductivity. High salinity levels in soil can lead to a decrease in soil health, which influences crop productivity (Daliakopoulos et al., 2016). Soil organic matter content is one of the most important soil properties. Soil organic matter, especially the organic carbon is responsible for the soil structure stability, enabling the nutrient flow and water retention (Krull et al. 2004). By checking the nitrate levels, we will learn if there is a potential groundwater pollution and if there is a link between the nitrate content and soil acidification.

Biodiversity assessment

Biodiversity will be assessed to determine if there is a significant difference in biodiversity on large scale plantations compared to smallholder land. during this assessment aiming to answer RQ2, we expect a decrease in biodiversity from smallholder land to large scale plantations. Three different circles with an eight-meter radius on plantation and smallholder land will be outlined. In the circles, different kinds of tree species will be assessed. Furthermore, within the circles three random quadrats (1x1m or 0,5x0,5m) will be chosen. Inside the quadrats, on-ground species will be identified and counted. Lastly, the Shannon index (and maybe other

biodiversity index´s depending on the relevance regarding the data analysis) will be calculated and used to measure the diversity of species.

Limitations to the methodologies

There are different potential limitations and challenges to the presented field methodoliges. Firstly, there is a risk that we will not get access to plantations and therefore will be unable to carry out the comparative assessment of the soil quality and biodiversity on plantation and in small scale production. Regarding the semi-structured interviews, focus group and household surveys language barriers might lead to misunderstandings, which can affect the output of the surveys and interviews, and misguide the analysis and results. Another potential limitation is that we might not get a representative number of respondents to the survey and interviews, as some might not wish to engage in the surveys. The time limit of the field-study might also lead to a deficit of respondents.

Time schedule and collaboration with UNIMAS students

All tasks will be split evenly between UCPH and UNIMAS students. For most of the time, we will work in groups of 2-3 UCPH students and 3 UNIMAS students, unless we timewise need to split into smaller groups. We will try to make sure every student touch both the social and natural methods. A timeline with required equipment for each method is presented below.

	Activity	**Responsible Person**	**Material needed**
2-March	Evening: Welcome dinner and meeting UNIMAS students	All UCPH and UNIMAS students	
3-March	Semada group meeting and shopping for field work. Discuss the last details with the UNIMAS students	All UCPH and UNIMAS students	
4-March	Midday: Arrive in community/welcoming ceremony Getting to know the communities, whom can we talk to? (Participant observation)	All UCPH and UNIMAS students	
5-March	Morning: Stakeholder mapping potential forming of a focus group?	All UCPH and UNIMAS students	Notebook
	Afternoon: Stakeholder mapping		
	Evening: Getting to know the community		
6-March	Morning: Getting to know the community	2-3 UCPH and 3 UNIMAS students for each method	Cylinders, plastic bags, auger, shovel, marker, tablet, presents for taking part in the survey, notebook
	Afternoon: Getting to know the community		
	Evening: Preparing presentation		
7-March	Morning: Proposal presentation	UCPH and UNIMAS students We split up in groups consisting of 1-2 UPCH and 1-2 UNIMAS students	tablet, notebook, pens
	Afternoon: Household surveys/semi structured interview		
	Evening: Data analysis	UCPH students	
8-March	Morning: Semi-structured interviews/biodiversity assessment	UCPH students and UNIMAS students	

	Afternoon: Semi-structured interviews/biodiversity assessment	Groups of 1-2 UCPH and 1-2 UNIMAS students	measuring tape, waterproof notebook
	Evening: Data analysis	UCPH students	
9-March	Morning: Semi-structured interviews/biodiversity assessment	Groups of 1-2 UCPH and 1-2 UNIMAS students	measuring tape, waterproof notebook
	Afternoon: Semi-structured interviews/biodiversity assessment		
	Evening: Semi-structured interviews/biodiversity assessment		
10-March	Morning: Soil sampling/biodiversity assessment	2-3 UCPH and 3 UNIMAS students	Cylinders, plastic bags, auger, shovel, marker, measuring tape, notebook, pen
	Afternoon: Soil sampling/biodiversity assessment	2-3 UCPH and 3 UNIMAS students	
	Evening: Soil sampling/biodiversity assessment	2-3 UCPH and 3 UNIMAS students	
11-March	Morning: Semi-structured interviews	Groups of 1-2 UCPH and 1-2 UNIMAS students	notebooks, pens
	Afternoon: Semi-structured interviews		notebooks, pens
	Evening: Semi-structured interviews		notebooks, pens, measuring tape
12-March	Morning: Household surveys	Groups of 1-2 UCPH and 1-2 UNIMAS students	tablet, notebook
	Afternoon: Household surveys		
	Evening: Focus group		big piece of paper, markers, notebooks, pens
13-March	Morning: Buffer-day (assess, if there´s something we miss doing)	UCPH and UNIMAS students	
	Afternoon: Buffer-day (assess, if there´s something we miss doing)	UCPH and UNIMAS students	
	Evening: Buffer-day (assess, if there´s something we miss doing)	UCPH and UNIMAS students	
14-March	Processing data and preparing presentation	UCPH and UNIMAS students	
15-March	Processing data and preparing presentation	UCPH and UNIMAS students	
	Morning: Presentation of field work in Pantu District		

	Afternoon: Lunch & return to longhouses Evening: Farewell Party		
16-March	After breakfast: Leave for Kuching		

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Appendix

Research Matrix

Overall Objective	Asess the impacts of the expansion of oil palm plantations on longhouse communities in Semada, Sarawak.						
Overall Research Question	How does the expansion of oil palm impact the vulnerability of longhouse communities in Semada, Sarawak?						
Research Questions	**Sub-research questions**	**Data required**	**Methods**	**Variables**	**Data Analysis**	**Risks/Limitations**	**Initial Assumptions**
What developments regarding land use for palm oil production can be seen from 2000 until now in Sarawak?	What are the political drivers behind oil palm expansion in Sarawak?	Scientific literature and policy on land use in Sarawak/Serian	Literature review	Keywords: oil palm, Sarawak, Serian	Timeline, triangulation with land cover change	Lack of site specific literature	Relationship between government regulation and oil palm expansion
	How widespread are the land use changes?	Aerial/satellite imagery	GIS analysis, Earth Map	Time and land cover of oil palm	% land coverage change, timeline with policy	Image quality and accuracy of oil palm identification	
		Local perceptions of land use change over time	Focus Group: Interactive Mapping	Changes in land ownership, areas that transformed from forest/secondary forests into plantations etc.	Maps of the area	Availability of people, deciding on the area that will be assessed	Good communication and cooperation of people

What impact has the oil palm expansion had on the environmental conditions in Semada? Is there a difference in impact between the impacts of commercial plantations and individual gardens?	Which impacts does climate change have on the area?	Historical Climate data until present	Literature review	The extent and impacts of Climate Change in the area	precipitation changes, temperature changes, extreme weather events, biodiversity changes and adaptability to climate changes etc	Lack of site specific literature	Climate Change does have a negative impact on the area
	Assessment of ecological vulnerability to climate change in oil palm-based communities (comparative between small-holder and plantations). Reflecting on a national and local level	Soil samples	Willingness to share personal info, response quantity	mineral content, density, nutrient content	Lab work	Access to plantations and smallholder land	Consistent sample size,
		Biodiversity	Circles/quadrats, inside and outside the plantations, smallholder/oil palm plantations	Number of species, kinds of species	Counting the number of species, Shannon Index (diversity of species)	Potentially challenging to gain access to plantations and individual, seasonality, availability of community members	Access to plantations and gardens

	What is the local perception of the change in environmental conditions?	Percieved changes in soil productivity, biodiversity	Focus Group: Interactive Mapping, Trends Change Analysis	soil productivity, biodiversity, weather	Participant observation, Recordings, Visual outcome	Availability, language, conflict	Availability of participants, people feel comfortable sharing
How does the oil palm cultivation contribute to the livelihood strategies of households in the community?	What are the current livelihood strategies within the community?	Capital, political influence, land use, migration, education, on/off-farm work, subsistence	Household survey (personal information, security, etc),	Human, Social, Financial, Physical, Natural Capital	Sustainable Livelihood Framework, descriptive statistics analysis, across-method triangulation	Willingness to share personal info, response quantity,	People will be willing to share, individuals are willing to do interviews, we are able to get a significant enough and variable enough group of interviews
			Semi-structured interviews		NVivo, across method triangulation		
	What were the livelihood strategies of the community in the past and what were the driving factors behind the decision to change?	Capital, political influence, land use, migration, education, on/off-farm work, subsistence	Household survey (personal information, security, etc),	Human, Social, Financial, Physical, Natural Capital over time	Sustainable Livelihood Framework, descriptive statistics analysis, across-method		

					triangulation		
			Semi-structured interviews		NVivo, across method triangulation		
	What are the potentials/challenges of different livelihood strategies within the institutional context of the longhouse communities?	Most present assets, the institutions and structure of agreements between actors in JV (Joint Ventures)	Household survey (personal information, security, etc), Semi-structured interviews	Human, Social, Financial, Physical, Natural Capital, social dynamics, contractual terms in JV, power dynamics	NVivo, across method triangulation		

Household Survey

General information:

GPS-Point:	Interviewer/Interpreter:
Longhouse Name:	Observer:
Bilek:	Date & Time:

We are 11 students from UNIMAS and the University of Copenhagen (Denmark), we are here to conduct field work on the topic of land use change and livelihood vulnerability. Our objective is to understand the livelihood strategies of households in Semada and how susceptible they are to the environmental impacts of land use and climate change. Therefore, we would like to ask you a series of questions. If you feel uncomfortable answering any of the questions feel free not to answer or withdraw from the survey. The data we collect will be used solely for our school project, it will be treated confidentially, and the participants will remain anonymous.

Please note that it will take around ____ min to complete this survey. Thank you for your time and participation!

Household composition:

1. **Who are the members of your household?**

	Gender[1)]	Age	Education[2)]	Ethnicity[3)]	Occupation	Living Situation[4)]
1 *(respondent)*						
2						
3						
4						
5						
6						
7						
8						
9						
10						

1. *Male, Female, Don't want to share*
2. *No formal education, Primary school, Secondary school, Highschool graduate, University degree, Other*
3. *Iban, Malay, Chinese, Dayak, Other*
4. *living permanently in the longhouse, commuting, living permanently outside the longhouse, Other*

Household activities and income:

What activities does the household engage in to sustain their livelihood? *(multiple answers possible)*

Activity	Own Consumption	For income	Other
Agriculture			
Wage labor			
Lease of Land			
Selling of handicrafts			
Remittances			
Pension			
Livestock production			
Fishing			
Foraging			
Hunting			
Handicraft			
Logging			
Other			

1. **Rank the three income sources contributing the most towards the total household income?** *(see the categories given above)*

1	
2	
3	

2. **Rank the three most important for consumption of the household?** *(see the categories given above)*

1	
2	
3	

3. **What is your household's monthly income?**

0-1000 RM	
1000-2000 RM	
2000-3000 RM	
3000-4000 RM	
4000-5000 RM	
>5000 RM	

If Agriculture has been selected:

4. **Which crops does your household cultivate and for what?** (multiple options possible)

Crop	Own consumption	For income	Both	Other
Oil palm				
Pepper				
Rice				
Rubber				
Fruits				
Vegetables				
Other Crops				

5. **Which crop is the most important for the household income?** (use the categories given in the former question):

1	
2	
3	

If the household leases land:

6. **Who do you lease your land to?**

- Joint Venture
- Private individual
- Plantation Company
- Other: _____

9. **How much of your land do you sublease? (Maybe in % of total land)**
10. **What is the duration of the lease contract?**

Focusing on oil palm production:

If the household is cultivating oil palm:

11. **For how long have you been cultivating oil palm?**

- Less than 5 years
- 5-10 years
- 10-15 years
- More than 15 years

12. What influenced your decision to start cultivating oil-palm?

- Road access
- Access to mills
- Lower labour input
- Governmental incentives
- Other: _____

If the household is not cultivating oil palm:

13. State reasons that influenced your decision not to cultivate oil-palm

- Lack of access to technological input
- Lack of capital to buy seeds
- Soil quality
- Environmental Concerns
- Other: _____

Change and Shocks:

14. **What activities did the household engage in 10 years ago?** *(multiple answers possible)*

Activity	Own Consumption	For income	Other
Agriculture			
Wage labor			
Lease of Land			
Selling of handicrafts			
Remittances			

Pension			
Livestock production			
Fishing			
Foraging			
Hunting			
Handicraft			
Logging			
Other			

15. **Rank the three income sources that contributed the most towards the total household income 10 years ago?** *(see the categories given above)*

1	
2	
3	

16. **Rank the three most important for consumption of the household 10 years ago?** *(see the categories given above)*

1	
2	
3	

If Agriculture has been selected:

17. **Which crops did the household cultivate 10 years ago and for what?** (multiple options possible)

Crop	**Own consumption**	**For income**	**Both**	**Other**
Oil palm				
Pepper				
Rice				
Rubber				
Fruits				
Vegetables				
Other Crops				

18. **Which crop was the most important for the household income?** (use the categories given in the former question):

1	
2	
3	

If the household leases land:

19. **Who did you lease your land to?**

- Joint Venture
- Private individual
- Plantation Company
- Other: _____

20. **How much of your land did you sublease? (Maybe in %)**

21. **What were the reasons for change?** *(Please elaborate on your answers)*

Access to water		
Access to Forest		
Changes in soil quality		
Changes in Precipitation levels		
Access to infrastructure		
Price fluctuation		
Government incentives		
Other		

Thank you very much for your time. We might be interested in conducting a longer interview with you for our project. Would it be okay if we contacted you about this at a later time?

- Yes:
- No:

Interview Guideline

General information:

GPS-Point:	Interviewer/Interpreter:
Longhouse Name:	Observer:
Bilek:	Date & Time:

Introduction

We are 11 students, six from UNIMAS and five from the University of Copenhagen (Denmark), we are here to conduct field work on the topic of land use change and livelihood vulnerability. Our objective is to understand the livelihood strategies of households in Semada and how susceptible they are to the environmental impacts of land use and climate change. Therefore, we would like to ask you a series of questions. If you feel uncomfortable answering any of the questions feel free not to answer or withdraw from the interview. Furthermore, we ask for your permission to record the interview. The data we collect will be used solely for our school project, it will be treated confidentially, and the participants will remain anonymous.

Please note that it will take around ____ min to complete this interview. Thank you for your time and participation!

Theme	Main question	Sub-questions
Changes in livelihood strategies	Do you still use the same strategies to sustain your household as in the past?	- What were the reasons of change/ not changing? - Do you perceive any challenges regarding your previous and current livelihood strategies?
Social Capital	What is your role within the community?	- What tasks does your role entail?
	Are challenges for households addressed on a household or community level?	- How is problem solving organized within the household/community? - How effective is the current problem-solving procedure?
	How do you perceive the decision-making process in the community?	- Are you happy with how decisions are made? If not why? - Do you feel like you have the power to influence decisions?
Changes in environmental conditions	Have you perceived changes in environmental and/or climate conditions in the area?	- If so, how do these changes affect your daily life? - What do you think are the reasons for the observed changes?
	Have you perceived any changes in access to natural resources in the past decade?	- If so, what were the changes? - What do you think are the reasons behind these changes?
Questions for households that are engaged in the oil palm sector		
Oil-palm production	Why did you begin cultivating oil palm?	- Was there an alternative?
	Do you experience any challenges in the shift to oil	- How do the challenges differ between different crops?

	palm production/related to oil palm production?	- Do you perceive there to be more or fewer challenges related to oil-palm compared to other crops?
	Which inputs do you need in order to shift to oil palm compared to the other crops that you previously or also now cultivate.	- What is the costs related to inputs compared to other crops? - How do you access these assets, and do you see any challenges/obstacles to access them?
	Please describe the process through which you normally sell your produce.	- Where and to whom do you normally sell your produce? - Are there any obstacles or challenges you face when selling and marketing your produce?
	Do you have a formal contract with your buyers?	- If so, how long is the duration of the contract? - What are the benefits and/or challenges of this arrangement?
Selling of land to large scale oil palm plantation	Which factors did influence your decision to sell your land to the oil palm company?	- Do you still regard it as beneficial to have sold the land? - How has the selling of land changed your day-to-day life?
Benefits and challenges to JV	Have you leased out your land to a JV? How are you experiencing the participation in JV?	- Which benefits do you see/experience from your leasing of land to a JV? - Do you experience any challenges with the participation in/leasing of land through the JV? - How do you engage in the land/land management after leasing? Are you or anyone from your household employed on the plantation?

Guideline Stakeholder Mapping

- Meeting with the heads of the three longhouses
- Estimated time: 45-60min
- Equipment: Poster, Markers

Introduction

Thank the longhouse heads for their time and introduce the concept and objective and process of the stakeholder mapping. Asking for their consent.

Concept: A stakeholder mapping involves identifying individuals, groups, and other actors (e.g. organizations) that influence the community or have an impact on the community and putting them in relation to each other.

Objective: Find out more about how the community is structured (hierarchy, organization, activities etc.)

Process: We will ask you some questions about the three longhouse communities, the people living in it and other actors the community interacts with. While we talk, we will note down all the identified actors on the poster and document possible hierarchies, connections, dependencies or influences the actors have on each other.

Questions:

- Please talk about the people that live in your community, who are the individuals and/or that play a significant role? (e.g. in decision-making, community well-being)
- Can you rank these individuals and/or groups by importance? Who would you say contributes most to the community?
- What are the different roles of inhabitants in the community?
- What activities and land uses are the community members involved in?
- Who are the individuals/groups producing small-scale, large-scale, participating in joint ventures?
- Who are the individuals/groups outside the community, that have a significant impact on the community? (e.g. decision making, community well-being, land tenure, income)
- Who produce on a small scale, and who are the large-scale producers?

Wrap-Up

- Finalizing the Mapping
    - Are there any individuals/groups of importance that are missing on the mapping?
- Asking them how them how they liked the activity.
- Thanking the heads again for their time and insight.

Focus Groups

- PRA: Participatory Mapping Exercise
- 2 groups with 4-5 members per group
- Quota sampling: Based on age, gender, land use activities
- Estimated Time: 1-2h
- Equipment: 2 Posters, Paper, Markers

Introduction

Thanking the participants for their disposition to join. Explaining the concept, objectives, and process of the activity. Asking the participants for their consent to participate as well asking them if they consent that the interactions in the focus group will be documented by taking notes.

Concept: The participatory mapping exercise is used to engage community members to create a visual representation of their environment as well as their perspectives and knowledge about it.

Objectives:

- Understand and get an overview over the environment and land use in and around the community.
- Investigate how the environment was in the past and how the land was used in and around the community.
- Gain an understanding of how the community members have perceived and are continuing to perceive the change in land use and environmental conditions.

Process: We will first ask you to draw a map of your community and the area surrounding it. Then we will ask you some questions, while answering these we will ask you to add new aspects to your map and fill it with your knowledge. In the end we will look at the finished product and reflect on the activity.

Mapping Exercise

Step 1: Please draw a map of your community and the surrounding area using one color (black). Please outline how the different areas you map out are used or what vegetation you find there (e.g. smallholder lots, plantation land, village area, forest, swamp land etc.)

- You can decide the scale of your map yourself
- Please keep in mind that our main goal is to assess how the environment and land use has changed when you do so

Step 2: Now we will ask you some questions about how the environment looked in the past. While you discuss and answer the questions, please visualize the changes on the map in the color (green).

- How did the area in and around the community look like 10-15 years ago?
- Have there been any changes in the environment that you noticed (e.g. precipitation, wind, storm-floods, animals, trees)
- If you have noticed changes, have those changes affected the quality of the soil as well as the animals and plants that in the surrounding area?

Step 3: Finalizing the map

- How do you like the map that you have created?
- Is there anything that you think is still missing? If so please elaborate and add to the map.

Step 4: Now we have a map in which we can see the environment and land use around the community in the past and present. Now that we have everything visualized, we ask you to reflect and discuss:

- What do you think are the reasons and drivers behind these changes?
- How do you perceive the change? What are the Pros and Cons about it?

Wrap-up

- Reflect on the session
- Ask If there are any questions
- Thanking the participants for their time and participation

Sampling Guidelines

GIS Images

- Data from Google Earth Engine
- 20km radius around (Semada Tengah as center)
- Timeframe 1980-now (maybe 5-year intervals?)
- Land use types:
    - Forest land
    - Swamp land
    - Farm land
        - oil palm
        - other crops
    - Plantations
        - Oil palm
        - Other crops
    - village area (built up area)
- Estimated Time:

Biodiversity

- 3 different transect areas – large-scale plantation, smallholder and natural area
- Radius /depending on the density – 3 different circles in the transect area (8m approx. For each circle)
- 3 random quadrats (1x1m or 0,5x0,5m) inside the 8m circle
- Split the different species (sp1, sp2, sp3...) and number of the different species – both for the on-ground species and trees
- Shannon Index for both the plantation, smallholder and natural area
- Identify the % plant cover in each quadrat – take pictures
- Make a graph for the correlation between number of species and quantity of species
- Estimated time: 10h

Soil sampling

- Variables to assess:

    - Soil composition
    - pH: Nutrient availability (soil quality/productivity)
    - EC: Salinity (soil quality)
    - Organic matter (Soil productivity, soil erosion, climate vulnerability/resilience - burn it two times (100 degrees to get the water vapor out and 140 for burning the organic matter)
    - Nitrate
- Sampling Methods: Composite sampling (pH; EC; Nitrate); Cylinder (Organic Matter)
- Sample Factors:
    - Same previous vegetation type (GIS)
    - Plantation, Smallholder- and natural area
    - Random sampling inside the same transect, as the biodiversity assessment
- Sample size: 3 Sites (one plantation, one smallholder and one natural area)
    - Composite 3-5 samples per site
- Cylinder 3 samples per site (3 top layer (10 cm depth))
- Estimated time: 10h

Household Survey

- 64 Households (31 Semada Belatok, 21 Semada Tengah, 12 Semada Mawang)
- 20-30 min per survey
- Random/opportunistic sampling – select some random household samples → Hat method (put in all the names, and then randomly pick them up from the hat)

Semi-Structured Interviews

- 10% of each longhouse (3 Semada Belatok, 2 Semada Tengah, 1-2 Semada Mawang)
- Approximately 30 min per interview
- Quota sampling: based on livelihood strategy (hh with oil palm; people without oil palm; JV participants)

Focus Groups

- 4-5 participants

- Quota sampling (gender, age, experience/knowledge about environment); snowball sampling

Stakeholder mapping

- To get an overview of the community
- Talk to the longhouse leaders and map out the different actors/whom to talk to about what?
- Get the necessary allowances for access and sampling on the large-scale plantations and smallholder´s land.