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Exploring the Expansion of Oil Palm Cultivation on Rural Livelihoods

A Case Study of Gua Dunggat, Sarawak, Malaysia

Practicing Interdisciplinary Field Research on the Environment

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Abstract

This paper investigates the multifaceted livelihood impacts of expanding oil palm cultivation in rural Sarawak, Malaysia through the Sustainable Livelihoods Framework. We specifically focus on Gua Dunggat, an Iban community experiencing agricultural land use change, as a case study. Using capital assets as an analytical starting point, this paper finds that oil palm cultivation socially benefits the community as it brings higher incomes and better infrastructure, yet fails to bring natural capital benefits with decreased water, soil quality, and biodiversity. Private and public institutions also greatly influence these land use transitions and thus, livelihood results of the community. Additionally, the paper evaluates the resilience of the community's livelihoods, citing issues such as land tenure, labor force instability, and environmental degradation as factors affecting long-term stability but also the economic benefits from the oil palm rising opportunities for financial-, human- and social- capital. Thus, the report comes with methodology limitations as the timeframe was limited and other applied methods challenges. The findings shows that oil palm cultivation reduces poverty and boosts infrastructure in the Area. External factors like Indonesian labor and land tenure instability affects the community.

Keywords: Sustainable Livelihoods Framework, Oil Palm, Capital Assets, Resilience, Land Grabbing, Labor Migration, Biodiversity, Sarawak, Malaysia

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Words	**Abbreviations**
Gua Dunggat	GD
Native Customary Land	NCRL
Sustainable Livelihoods Framework	SLF
Participatory Rural Appraisal	PRA
Participant Observation	PO
Oil Palm	OP
Land Customary Development Authority	LCDA
Joint Venture Agreement	JVA
Malaysian Palm Oil Board	MPOB
Ecosystem Services	ES
Meters Above Sea Level	m.a.s.l

1. Introduction

The forests of Sarawak sustain as rich reservoirs of biodiversity and store large amounts of carbon (Andersen *et al.*, 2016). The diverse environment provides ecosystem services (ES) and livelihood support for people in the area, including indigenous communities. Due to its rich diversity and ES, the Sarawakian economy has expanded on a global scale. In the past couple decades, rural Sarawak has undergone a transformation of its landscape due to the growing demand for cheap and high-yielding oil palm (OP) cultivation (Mertz et al. 2008), but the transformation comes with environmental impacts such as deforestation and impacts on ES (Alamgir et al., 2020). Sarawak is a hotspot of deforestation and forest degradation (Andersen et al, 2016), primarily due to the fact that Sarawak is being the last frontier for OP expansion in Malaysia. The key factor contributing to deforestation is expansion of OP plantations and other land development plans, which has affected how smallholders use their land (Mertz et al. 2008). The demand for OP is highly increasing due to its used variations in cooking oil and in food production, cosmetics and biofuels. The abovementioned demand, coupled with high yields and low cost of production, have made profitable growth and made it attractive for governmental agencies, private-sector partners, forming Joint Venture Agreements (JVA) and smallholders (Cramb, 2013). The transition from small-scale agricultural cultivation to large-scale oil palm production has resulted in socioeconomic development reaching different social segments, therefore excluding some indigenous groups and social layers (Osman, 2010).

This paper investigates and analyzes the effects of OP expansion in an indigenous longhouse community, Gua Dunggat (GD), in relation to the Sustainable Livelihoods Framework and

resilience. First, this paper will provide background knowledge on land use transition of OP development and an introduction to the study site of GD, followed by the research significance and research questions. Then, there is a short section highlighting theory and frameworks including the Sustainable Livelihoods Framework, resilience, and land grabbing. Next, we briefly introduce our methodology. For the analysis, we will highlight the five livelihood capitals of GD with some additional institutional context, followed by a section with combined analysis on livelihood resilience. Subsequently, there will be a discussion of outside literature related to our findings and method limitations of our research. Lastly, a conclusion will provide a summation of our research.

1.1 Research Significance

There is an accelerating anthropogenic impact on the environment with growing focus on deforestation and sustainable development in tropical forests. This report contributes to this focus through an interdisciplinary analysis to improve understanding of the impacts of OP expansion on an indigenous agricultural community. Therefore, the goal is to address livelihoods, social well-being, and environmental impacts through an interdisciplinary case study.

1.2 Research Question

The main research question of this report is *how does the expansion of oil palm impact livelihoods in Gua Dunggat?* To help answer this research question, the following sub-questions have been formulated:

- *What are the effects of oil palm cultivation on the livelihood capitals of the community?*
- *How have institutions and external actors influenced the community's involvement in oil palm cultivation?*
- *How does the cultivation of oil palm impact Gua Dunggat's ability to maintain resilient livelihoods?*

1.3 Background on Oil Palm Growth and Land Development

Indigenous peoples' land in Sarawak is currently referred to Native Customary Rights Land (NCRL). These lands claim around only 20-25% of the total land area but, 60-70% of the total agricultural land (Andersen et al, 2016). The principal claimants of NCRL are

indigenous groups such as the Iban community which primarily reside in longhouse communities and occupy extensive territories of forest and agricultural land for their livelihood strategies. These lands are often not surveyed or directly titled, but instead subject to various combinations of private and common property rights under community governance (Cramb, 2013). In 2013, over a million hectares of land had been reserved as ‘land banks’ allocated for OP development and experienced an increase of 10% expansion annually. In this context, 80% of OP plantations have been established by private actors which hold leases over state-owned land (Ibid). As the opportunities for profitable development of OP plantation on state land has been used up, the attention and persecution has shifted towards NCLR (Ibid). Hereby, customary landowners assign their land rights to the Land Custody and Development Authority (LCDA) as a trustee. Hereafter, LCDA has the facilitating role of forming JVAs with approved partners from the private sector. JVAs are consolidated leases of land over a 60-year period, with an agreement on landholders receiving dividends corresponding to their contributed area (Ibid). Then, the JVA uses the land as an asset to access loans to invest in the establishment of an OP plantation and manage it. In exchange, the landowners receive 30% share of any profit that may be generated, while the private actor holds 60% of the equity and LCDA holds 10%. (Andersen et al, 2016).

1.4 Study Site

The field study for data collection took place in GD in Sarawak, Borneo, Malaysia, an Iban community located around 158 kilometers southeast of Kuching. The 33 houses of GD are situated in a rural area, surrounded by forest and agricultural land. For generations, the community of GD has maintained a close connection with their natural environment while utilizing the resources for sustaining their livelihood strategy. Traditional farming methods such as hill rice cultivation “padi bukit" in Iban, has been a cornerstone of their traditional agricultural practices in this community. Traditional farming methods include the cyclical clearing of small plots of land, planting rice and other crops for a few seasons, and then allowing the land to revert to fallow vegetation to regain soil fertility. Moving away from traditional agriculture, GD began to cultivate cash crops such as pepper and rubber which have served as important crops to sustain their livelihoods. However, more recently, the community is beginning to clear their rubber and pepper plantations and instead cultivate OP through JVA and smallholder, or small-scale farming. This expansion is recently transitioning into uncultivated forest and becoming the most widely cultivated crop in the community.

2. Theory and Conceptual Frameworks

2.1 Sustainable Livelihoods Framework

The Sustainable Livelihoods Framework (SLF) is a conceptual tool to analyze the well being of rural communities and guide poverty reduction, sustainability, and livelihood strategies (Ellis, 1999). Livelihood strategies are the diverse activities individuals employ in order to better their capital assets thus bettering their livelihood such as increasing income. The framework consists of five capital assets which include tangible and intangible assets that influence an individual's livelihoods. The following are the five capital assets as defined by Ellis (1999) and are also shown in figure 1.

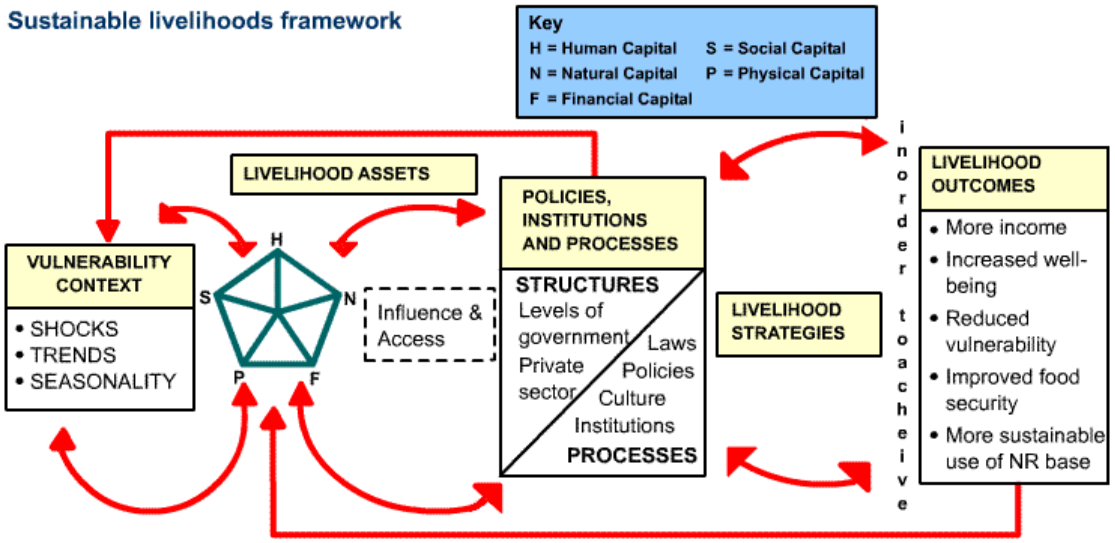


Figure 1: A Sustainable Livelihoods Framework graphic which explains the flow of key characteristics of rural livelihoods (Ellis, 1999).

Natural capital includes the natural resource stocks (soil, water, air, genetic resources etc.) and environmental services (hydrological cycle, pollution sinks etc) from which resources flow. Financial capital is primarily concerned with cash, credit/debt, savings, and other economic assets including property. Human capital is defined by the skills, knowledge, labor abilities, and health of individuals. Social capital is the social resources (networks, social claims, social relations, affiliations, associations) upon which people draw when pursuing different livelihood strategies. Physical capital includes the surroundings such as infrastructure, tools, equipment and access to services (Ellis, 1999). Institutions and policies include actions from the government, companies and other powerful actors that externally

impact livelihoods decisions (Ibid). Vulnerability includes shocks (unpredictable events), seasonality (predictable fluctuations based on seasons), and trends (slow-moving predictable changes) (Ibid).

2.2 Resilience and Adaptation

The scale of human actions coupled with the speed, spread, and connectivity of globalization create new complex dynamics and make the globe more socially-ecological interconnected than ever before (Folke, 2016). To understand the dynamics of these social-ecological systems, the resilience approach is developed to create an understanding of complex adaptive systems and resilience serves as a platform for interdisciplinary research. It deals with complex adaptive system dynamics and true uncertainty and how to learn to live with change and make use of it in terms of the ability of people, communities, societies, and cultures to adapt or even transform into new development pathways in the face of dynamic change. The approach emphasizes that social-ecological systems need to be managed and governed for flexibility and emergence by adapting, improving, and innovating rather than for maintaining stability (Ibid).

3. Methodology

This section explains applied methods for examination of the research questions and sub-questions. The report integrates social science and natural science methods, as well as qualitative and quantitative methods.

3.1 Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) is an approach to methodology that allows people to incorporate their local knowledge into research by “handing over the stick” (Chambers, 1994, p. 1254). PRAs are embracing local people’s natural analytical capabilities through visual means. To achieve these positive results, participants should not be rushed or interrupted in their work to eliminate any biases and reverse initial positionality (Chambers, 1994, p. 1256). This report utilized three PRAs: resource mapping, timeline, and a transect walk.

3.1.1 Resource Mapping

Resource mapping is a spatial form of PRAs that invites people to visualize their village’s land use and agriculture. This method was completed by inviting community members to the longhouse’s communal area and were asked to highlight land-use transitions and current

agricultural activities for their community. Different types of people participated in the mapping activity, such as the head woman, agrarian laborers, community elders, and mothers, to include multiple perspectives and avoid exclusion.

3.1.2 Timeline

A timeline was also completed alongside the resource mapping activity to increase efficiency in the beginning of the research. Participants were asked to write events in GD's history on 'sticky notes' and then paste them on a blank timeline, starting in 1987. The participatory timeline helped to build a historical background and inform subsequent methods, such as semi-structured interviews.

3.1.3 Transect Walk

The transect walk was conducted to gather information on the community's approaches to current land use, land use change, socioeconomic and environmental conditions. To collect detailed information regarding agricultural crops and land use changes, GPS waypoints, a recorder and fieldnotes were utilized to serve as an indicator where to do data collection for soil-, biodiversity- and water assessment. During the journey, we observed different forest products such as fruit trees, timber, younger and older OP plantations, the dam of the stream supplying water to GD, recently burnt areas for new OP plantations as well as unauthorized entry to Indonesia. Pictures from the transact walk are shown on picture 1 and the route on figure 2.

Picture 1: Transect walk. Upper left shows recently burnt areas. Upper right shows a young OP plantation and the water pipe. Bottom left is our guide. The bottom middle is a flooded area. The bottom right shows old OP.

Figure 2: Transect walk map.

3.3 Semi-structured Interviews

The semi-structured approach allows access to knowledge regarding the expansion of OP

plantations that only the respondents possess through their own experiences. The purpose of this form of interview is to gain an in-depth understanding of the livelihood contexts in GD associated with various perspectives and interests. This includes addressing issues relating to historical events, present circumstances and future outcomes. Semi-structured interviews enable the preparation of themes and questions in advance, therefore enabling the possibility of follow-up questions and digging deeper into other interesting topics that may arise during the conversation (Kvale & Brinkmann, 2015). To improve the quality of the data, we prepared interview questions and topics with a detailed interview guide in Appendix 3. The questions were formulated as research questions, which was then translated into more dynamic and understandable questions for the respondent (Hurst, 2023). A total of 6 interviews were conducted throughout the fieldwork. The key informants were identified by obtaining knowledge from previous methods especially from the questionnaire and other villagers referring to specific individuals. This resulted in interviews held with a young man that is raised in GD but lives in the city, a middle-aged man who was referred to as a key informant by people in the community, a woman who worked in the city but came back to take care of her mother and manage their plantations, the headwoman of the community, a woman with the highest income from OP plantations, and a woman who had a sick husband with varied plantations. The interviews have been transcribed and coded in relation to the different capital assets as shown in Appendix 4 to 9.

3.4 Participant Observation

Participant observation helps with understanding how the community acts and behaves as sometimes, an individual's actions contradict their stated values and beliefs (Hurst, 2023). The aim of participant observation (PO) was to gain information on livelihood assets. PO includes daily life activities and interactions among the longhouse, but also physical structures and materialities. The PO has been conducted through observing and engaging in daily routines, agricultural practices and other activities. In addition, unstructured conversations were utilized to gain background information for semi-structured interviews while establishing rapport. Therefore, PO is used as a supplement to obtain an understanding of livelihood strategies of the members of GD. The fieldwork has been conducted through field notes and photography which is shown in picture 2.

Picture 2: Participant Observation. The picture on the top left shows a modern power grid running through the community. The picture on the bottom left shows that every household owns a car. The two pictures in the center and in the top right, show daily activities such as drying rice in the sun, preparing food and harvesting paddy fields. The picture in the bottom right shows the use of fertilizer and pesticides in OP plantations.

3.5 Questionnaire

To gather information about the community's livelihoods, we employed an anonymous questionnaire. The data collection was carried out using a face-to-face approach with the interviewer physically present to ask the survey questions and to assist the respondent in answering the questions and is shown in Appendix 10 (Hansen and Andersen, 2009). Over the course of 3 days, we visited all households in GD to fill out the questionnaires. As the sample sizes needed to represent the entire population of GD, the information was collected over three days, and it was possible to collect information from 30 out of 33 households. The results are shown in Appendix 11. A household is defined as a person or group of related people who live together and make common provisions for food and other living essentials. The respondents were the head of the household which we defined as any member, whether male or female, who is considered the head of the household by other members of the household.

3.6 Biodiversity Assessment

Study Locations

1. Secondary forest - forest where woody vegetation has then taken over and trees have begun regenerating after clearing the land of much of its original forest vegetation. The secondary forest sits at an altitude of 40.74 meters above sea level (m.a.s.l), with a northward orientation exposing it to the northern aspect. Its vertical composition adopts a scalar structure, while its horizontal structure is characterized as random.
2. 2-year-old palm oil plantation - a OP cultivation area established 2 years ago included in biodiversity assessment to examine early impacts on biodiversity. The younger OP plantation is located at an altitude of 43.9 m.a.s.l. The slope on which the OP plantation is located boasts a northern-western exposure. The young OP plantation vertical structure is characterized by a monoplane configuration, meanwhile, the horizontal arrangement is structured in rows.
3. 24-year-old palm oil plantation - a mature OP cultivation area with several years of establishment to assess long-term effects on biodiversity. The older OP plantation sits at an altitude of 37,7 m.a.s.l. The location is exposed to the north. Its vertical structure is characterized by a monoplane, while its horizontal arrangement is described as in rows. Picture 3 shows some photos from the biodiversity assessment.

To comprehend the impact of environmental changes from the expansion of OP plantations, biodiversity from 3 sites were compared. The assessment was carried out in a secondary forest, a 2-year-old OP cultivation, and a 24-year-old OP cultivation. Measurements were conducted on 2 plots for each location. These plots were randomly selected with an area of 10x10 meters. The assessment considered the count of tree species with a diameter surpassing 5 cm, along with their diameters at a height of 1.3 m and estimated tree heights, determined using a mobile application Arboreal. Additionally, the assessment included recording the number of species present in all study sites. These measurements determine carbon stocks (estimated biomass using allometric equations) and assess biodiversity through two key indicators: species richness (the total number of tree/plant species in a specified area, both canopy and ground) and species evenness (the abundance of each species) (Kotowska et al., 2015). Biodiversity was measured using the Shannon index in both tree and undergrowth assessments (Asari et al., 2013). The undergrowth biodiversity assessment was carried out randomly within 2x2m plot areas. Its main objective was to evaluate the composition of forest undergrowth, including plant species, shrubs, and ground cover with two repetitions on each side..

Picture 3: Biodiversity assessment. Upper left and the bottom right exemplify the undergrowth biodiversity assessments. The rest show species identification.

3.7 Water Sampling

Water sampling collection involved data collection from 3 points along the stream: the water source, midstream, and downstream locations. The goal was to check the possible impact of agriculture on water quality. The first two mentioned points were exposed to the influence of oil palm plantations, while the third one was exposed to the paddy field. At each spot, comprehensive assessments were conducted, including measuring levels of phosphate and nitrate to evaluate nutrient concentrations and potential water quality impacts. Additionally, we undertook a macroinvertebrate assessment to check the overall health and biodiversity of the aquatic ecosystem in the midstream, and downstream locations (Carter et al., 2017). Levels of phosphate were calculated using the reactive orthophosphate ascorbic acid method, while levels of nitrate were calculated using cadmium reduction method. In the first mentioned method orthophosphate reacts with molybdate in an acid medium to produce a mixed phosphate/molybdate complex. Ascorbic acid then reduces the complex, which gives an intense molybdenum blue color (Hwang et al., 2013). To carry out the procedure, we employed powder pillows, bulk reagent tests, AccuVac Ampuls, and a spectrophotometer. In

the second mentioned method cadmium metal reduces nitrate in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt and the salt couples with chromotropic acid to form a pink-colored product (Wood et al., 1967). To conduct the method, we utilized powder pillows, bulk reagent tests as well as a spectrophotometer. Macroinvertebrate assessments were assessed within 30 mins period and with 3 persons carrying out this research, being equipped with 3 fishing nets and a plastic box. After catching fish and other river organisms, our task was to document, identify the species and then return the fauna back to the stream.

3.8 Soil Bulk Density

Bulk density refers to the mass of soil per unit volume and is an important indicator of soil compaction, porosity, and quality. The method was implemented with 2 samples coming from each location as mentioned in the biodiversity assessment section. The soil from the top 10 cm were taken in a sample. The samples were collected randomly within the 10x10 meters areas and bulk sampling rings were used. By studying soil bulk density, we aimed to assess soil quality, water retention capacity, and suitability for various agricultural, and environmental, purposes (Tanaka et al., 2009).

3.9 Ethnobotany

The goal of conducting ethnobotany was to study the interactions between people and plants, focusing on traditional knowledge and uses of plants by the locals. It involved documenting and understanding how and which plants are utilized for various purposes, including food, medicine, construction, and cultural traditions (Nasution et al., 2020). In the field there were 4, 20x5m plots. The location of the study was a secondary forest, and we had 2 guides: a man from the local community and a Professor Dr. Tonga Anak Noweg from UNIMAS helping carry out the assessment and applying their knowledge.

4. Results and Analysis

This section analyzes the collected data through the SFL and includes the resilience approach. It focuses on the effects of OP cultivation on the livelihood capitals of the community and the environmental impacts of the expanding OP cultivation. Furthermore, it also analyzes how institutions and external actors influence the community’s involvement in OP cultivation and the community’s ability to maintain a resilient livelihood.

4.1 Livelihood Capitals

4.1.1 Social Capital

The fieldsite proposes an uncomplicated hierarchy with a head woman (Tuai Rumah), as the leader of the longhouse and community. Villagers refer to the head woman for essential documents regarding demographic information and details regarding their respective JVA shares (Appendix 4). The head woman describes her ideal longhouse community as a place where everyone helps each other and works together (Appendix 7). This is seen in practice with the Iban tradition of *berduruk*, which acts as an informal agreement of reciprocal aid in harvesting throughout the community; in GD, *berduruk* occurs in their respective OP fields (Appendix 6). This sense of community is seen in the family structures, where multiple generations live together under the same roof. Even with the rise in rural-urban migration for younger generations, the youth will still come back on vacations or to help harvest OP during harvest seasons (Appendix 5). In fact, the combination of strong family bonds, a strong sense of community and job opportunities due to the expansion of OP, has even led to counter urbanization trends, where people come back to GD and surrounding settlements to work with or in the fields (Appendix 9).

Picture 4: Social capital. The pictures show social interactions and fellowship among the community. The picture on the bottom left illustrates the "nanny" of GD. The community's children were gathered in her custody during workdays. The other pictures show social gatherings and daily life, where people socialize in the longhouse and assemble when the head woman delivers information (bottom right).

The community of GD have a strong relationship with their Indonesian neighbors in both social and work-related activities. One villager states this about the community's relationship with Indonesians: *"They hire people from Indonesia, but they will come here and ask for if there are any jobs available, they are the ones who come here. She says that they have kept a good relationship with the Indonesians through generations. So even the elder generations, they already know each other and some of them they consider it as adopted family"* (Appendix 4). These existing social connections make it easier to employ labor for the expanding OP cultivation; however, the relationship also causes social problems with some cases of theft and violence (Appendix 6 and 9). One respondent answers the following when asked into the consequences of strengthening border control: *"The advantage is that we can control immigrants from Indonesia because there are cases of robbery and the ex headman got robbed here and the disadvantage is when they want to hire people to manage the paddy field or oil palm"* (Appendix 6).

4.1.2 Human Capital

Figure 3 shows the percentage of the various levels of education of the head of household. 44% of respondents have secondary school as their highest education level where about 53% have lower secondary school or lower as their highest educational level. 3% stated to have completed additional education. Figure 4 shows the percentage distribution of occupation within all the heads of households. The figure shows that 20% are farmers in subsistence agriculture. 17% work as agriculture workers such as OP workers and other agriculture which is not subsistence farming. 17% of all are retired and 13% are small business owners. Also, 10% are unemployed. Thus, GD is a predominantly agricultural economy, not requiring high levels of formal education but instead, the physical capabilities of manual labor. Despite this, informal knowledge is crucial for the success of agricultural labor.

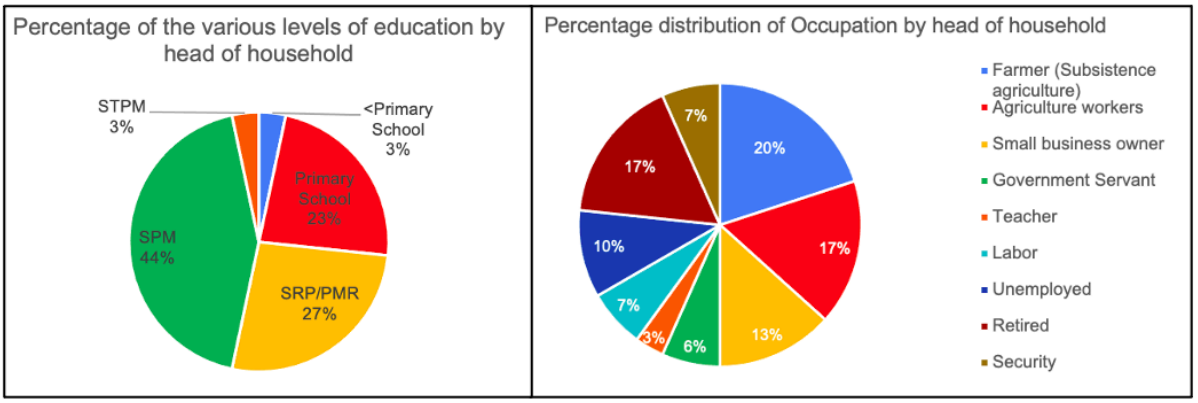


Figure 3: Pie chart to the left shows the percentage of the various levels of education.
Figure 4: Pie chart to the right shows the percentage distribution of occupation (Appendix 11).

Interviews suggest that new patterns are occuring with the younger generation moving to cities in search of higher education. Interviews claim that this is made possible due to the economic benefits of OP. An interview with a young man from the community shows that his future plans do not necessarily involve agricultural practices as his family has been for generations. *"My dream life or occupation?... Personally, I want to become a lecturer"* (Appendix 5). When asked about his reasons for continuing his studies outside of the community, he answered the following: *"The main reason I want to finish my studies because I want to get more knowledge, and I like to learn something"* (Appendix 5). Therefore, with the financial benefits of OP cultivation, there is an improvement in education, which increases the ability to achieve higher-wage occupations and increases personal empowerment through learning. However, labor availability is a difficulty in the small community of GD with many young, healthy individuals moving to the city for education, as mentioned above. Instead, this younger educated generation often moves back after retiring (Appendix 7).

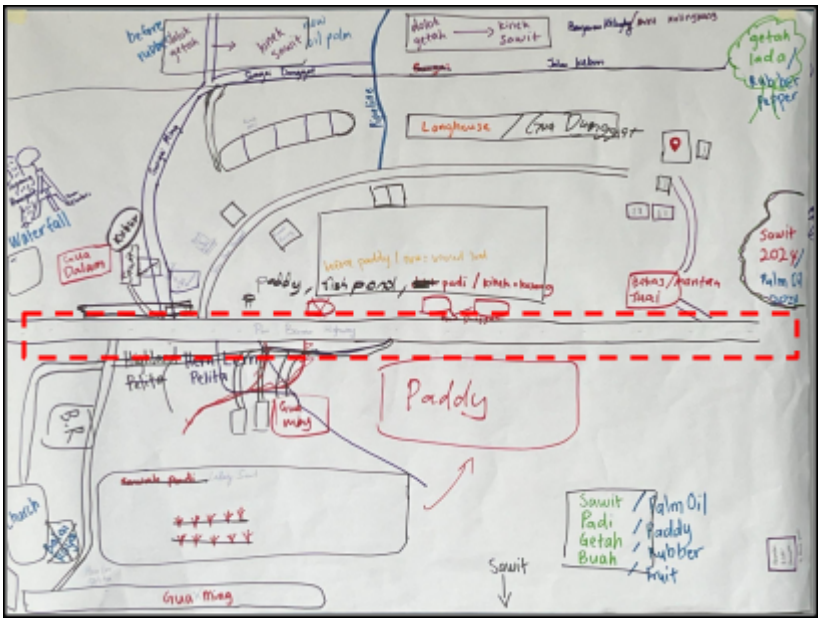
Thus, the aid of the Indonesian labor force is crucial for agricultural activities, specifically smallholder OP plantations. While living in the community, we observed Indonesian workers working on the fields and migrating home in the evening. Unstructured interviews suggested rumors that the government is planning to strengthen border control, to control illegal labor migration causing insecurities in acquiring labor (Appendix 13). When asked about the situation, a respondent answered the following: *"it will be hard because they really need the*

labor to harvest the oil palm, yes they are good at harvesting the oil palm. Then it will be hard because they will have to get pass, working pass" (Appendix 9). The head woman shares the same view: *"Without them, there is no working on the oil palm"* (Appendix 7). The need for Indonesian labor to work on private OP plantations is also backed by other key OP informants and stakeholders (Appendix 4). Thus, these social relations to Indonesian workers can be considered as an asset, but the governmental plans to prevent this daily migration could interfere with the amount of labor available for GD. Additionally, the amount of available labor is influenced by the strong belief that higher education is important for the younger generation. Contrariwise this issues some concerns among the community as they believe people with higher education are more likely to stay and work in the cities and first move back when they retire (Appendix 7). Ultimately, the combination of family members who have received higher education moving to the cities, intending to only return once they reach retirement, and the intensified border control, could possibly result in a lack of farm labor for OP.

However, the current labor force's knowledge and ability of cultivating OP and other crop types plays a major role in determining the success of yields and income; therefore, OP education is crucial for the betterment of livelihoods. Interviews indicate the government offers educational courses on how to plant, manage and harvest OP plantations encouraging smallholders to transition OP and increase yields (Appendix 8). As a result, the community uses these educational services to improve their skills and increase agricultural success, crucial to their livelihoods.

4.1.3 Physical Capital

GD is situated right beside the Pan-Borneo Highway, the main highway network that connects Sarawak and Sabah with Brunei and Indonesia. The resource mapping sessions showed that the highway is of great importance for the community with some villagers even claiming that the highway is the reason for the community split in 1987 (Appendix 12). The significance of the highway is supported by the results from the resource mapping. Here, the participants drew the highway in the center of the map with the sub-roads leading to their longhouse and plantations (Picture 5).



Picture 5: Resource mapping of GD. The Pan Borneo Highway is marked by the red-dashed box.

Moreover, the highway access contributes to the development and wellbeing of the villagers by supporting basic needs (Ellis, 1999). This access includes markets, schools, towns and hospitals which respondent from Appendix 6 highlights as crucial when asked about her daily activities: *"So in the morning, she will take her husband to the hospital and the dialysis will take 4 hours and after sending her husband to the hospital she comes back and sends her kids to school and then after sending her kids to school and after 4 hours, she will pick up her husband from the hospital. And then coming back here and pick up her kids from school and then come back here again" (*Appendix 6*).* This indicates that the villagers' access to the highway, a car, and relevant services is valuable for her family's livelihood. The head woman argues that physical capital has increased due to OP: *"Before, we can not see motorcycle and cars. But since oil palm in this area, everyone has cars" (Appendix 7).* Through responded observation, many 4-wheel drive vehicles in the communal parking lot were observed (Picture 4). Therefore, the transition to OP has increased the ability of the community to move freely to crucial services with improved road and car access.

Lack of infrastructure is also a limiting factor in the community with remote areas, not connected to Pan Borneo Highway, considered inaccessible land thus limiting their land use *"Since the land is actually pretty far from the main road, it doesn't make sense to go that far*

*away. It was also a swampy road and they couldn't develop it for agriculture" (*Appendix 7). Here, the community relies on the government to improve their physical capital to connect remote land to the main road and expand the capabilities of cultivation. The respondent from Appendix 7 mentions that they ask aid from the government for needed machinery to harvest in swampy areas. Another informant shared that she awaits better infrastructure, and therefore access, to cultivate her own OP plantation (Appendix 13). Furthermore, the community benefits from the power grid that was introduced in 2004 and the garbage dump that was built in 2019 (Figure 5).

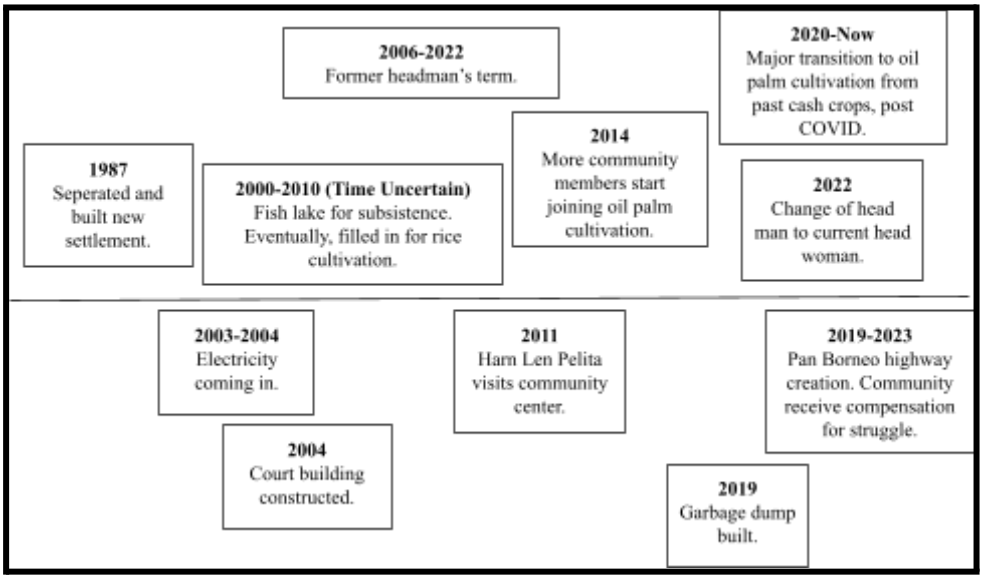


Figure 5: Timeline for GD.

Additionally, interviews and observations reveal the use of fertilizer and pesticides which is provided by Malaysian Palm Oil Board (Appendix 7 and Picture 2) This shows that villagers apply for specific improvement in the context of physical capital, such as infrastructure, electricity and machinery, which means they are heavily reliant on external processes to increase their assets. In addition, interviewees claim that implementation of such actions often ends up in stagnating processes (Appendix 4).

4.1.4 Financial Capital

From the questionnaire data, the distribution of the monthly income of GD varies from 50 MYR to 8000 MYR, and the monthly average is 1945 MYR (Appendix 11). Figure 6 shows that the median is 1500 MYR with 75% of the community earning less than 2871 MYR a month. The boxplot also indicates that two of the houses earn more than 6000 MYR a month

making them outliers within the community. As a reference, in 2020, the median income for Sarawak was 3831 MYR and the mean was 5087 MYR (Department of Statistics Malaysia, 2021).

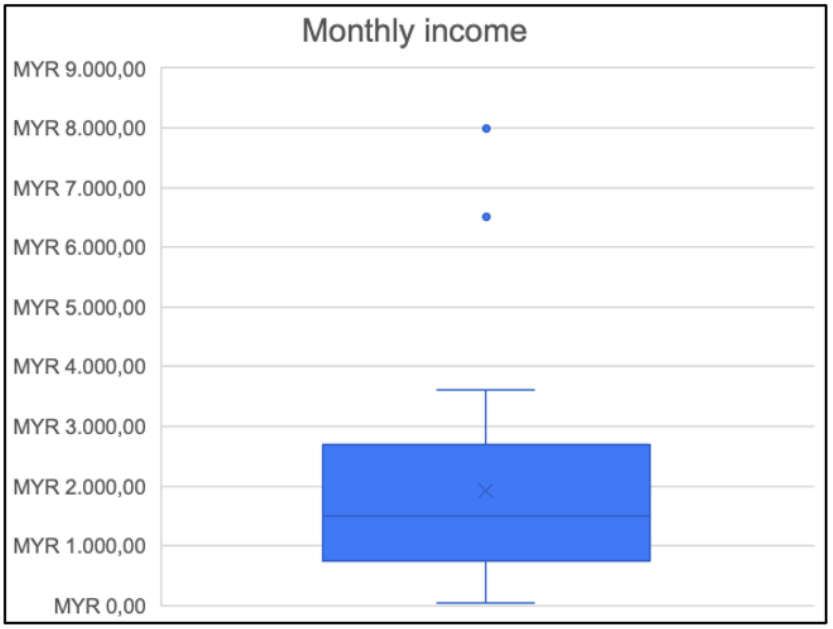


Figure 6: Boxplot on the monthly income (Appendix 11).

45% of the total households that cultivate crops mentions that they cultivate more than one crop. One community member mentioned that they cultivate a mix of rice paddy and fruit trees both for personal consumption and for sale. Additionally, they engage in OP plantation on both privately owned and leased land to ensure a steady income throughout the year. This approach demonstrates a strategy for diversifying their income sources and reducing financial risk. One of the key informants mentions another way to diversify her income: *"Last year I sold a lot of food from home. She sells it through social media to earn an income…. She wakes up at 2 to make all the food so all people can get it fresh"* (Appendix 6). Therefore, her aim is to diversify and increase her income while reducing her dependency on agricultural activities.

In GD, most households have transitioned their fields to OP plantations while others are awaiting infrastructure improvement. 90% of all households perceive positive economic impacts regarding the shift from the transition of traditional agriculture to OP cultivation and 74% of the households mention that the main factor leading to the transition from traditional agriculture to OP cultivation is related to economic opportunities. One of the key informants

mentions OP's increased frequency of income: *"Like for other plantations, they can harvest once or twice a year but for oil palm plantation is once or twice per month*" (Appendix 8). He also points out that OP plantations positively increase incomes due to the higher price per ton compared to prior cash crops like rubber and pepper (Appendix 8).

4.1.5 Natural Capital

GD is surrounded by secondary forests and agricultural land. For generations, this community has maintained a deep connection with their natural surroundings, relying on its resources to sustain their livelihood strategies. According to local guides familiar with the area and its traditions, the community relies heavily on forest ecosystems, showcasing a dependence on forest interactions to support their way of life. Appendix 13 shows an overview of forest 32 different tree species utilized by the community in GD.

Traditionally, the Iban people relied on subsistence farming practices for their livelihoods. However, in recent years, the community of GD has shifted towards cultivating cash crops such as pepper and rubber. These crops are now diminishing with the introduction of OP cultivation in their fields. According to questionnaire findings, 60% (18 out of 30) of respondents are employed full-time in farming activities (Appendix 11). While some community members are not engaged in agricultural pursuits, those involved, aside from OP cultivation, have been participating for varying durations, ranging from 1 to 44 years. The average duration of involvement among respondents is 14 years. Regarding OP cultivation, which is currently the most utilized crop, families typically involve between 1 to 4 members in these activities. On average, they have around 5 years of experience, with a maximum of 15 years.

To assess the impact of the transition to OP on the natural environment and community resources, various tests and research in the field of environmental sciences were conducted. Table 1 shows a comparison of biomass and biodiversity indicators between secondary forest and 24-years and 2-years old OP plantations sites.

Table 1: Comparison of biomass and biodiversity indicators between secondary forest and 24-year-old and 2-year-old OP cultivation sites.

	Total biomass	*Total C*	*C (t/ha)*	*Species richness*	*Shannon index*
Secondary forest plot 1	3358.181	1679.091	167.909	11	2.132
Secondary forest plot 2	3171.403	1585.701	158.570	5	0.927
24-year-old palm oil cultivation plot 1	1914.883	957.442	95.744	1	0.000
24-year-old palm oil cultivation plot 2	1871.805	935.902	93.590	1	0.000
2-year-old palm oil cultivation plot 1	300.061	150.030	15.003	1	0.000
2-year-old palm oil cultivation plot 2	357.498	178.749	17.875	1	0.000

Secondary forest plot 1 and plot 2 exhibit higher total biomass compared to all OP plantation plots, indicating a greater overall amount of living organic matter. Similarly, both secondary forest plots have higher carbon content and carbon content per hectare compared to the OP plantation plots, suggesting a greater accumulation of carbon. Species richness, which measures the number of different species present in each plot, is significantly higher in the secondary forest plots compared to the OP plantation plots. This indicates a greater diversity of plant species in the secondary forest habitats. The Shannon index, a measure of biodiversity that considers both species richness and evenness, also indicates higher diversity in the secondary forest plots compared to the OP plantation plots.

Table 2: Forest Undergrowth Assessment.

	Species richness	*Shannon index*
Secondary forest	25	2,819
24-year-old palm oil cultivation	10	1,554
2-year-old palm oil cultivation	7	1,210

The results of the Forest Undergrowth Assessment is shown in table 2 and revealed varying degrees of species evenness across the sampled habitats. The highest level of biodiversity was documented within the secondary forest habitat, exhibiting a species evenness of 2,819. Subsequently, the older OP plantation exhibited level of species evenness at 1,554. The youngest OP plantation demonstrated the lowest species evenness among the sampled habitats.

Figures 7 and 8 depict the comparison of species richness and Shannon index among the studied locations, respectively. In both instances, the highest values were recorded for undergrowth plants in the secondary forest.

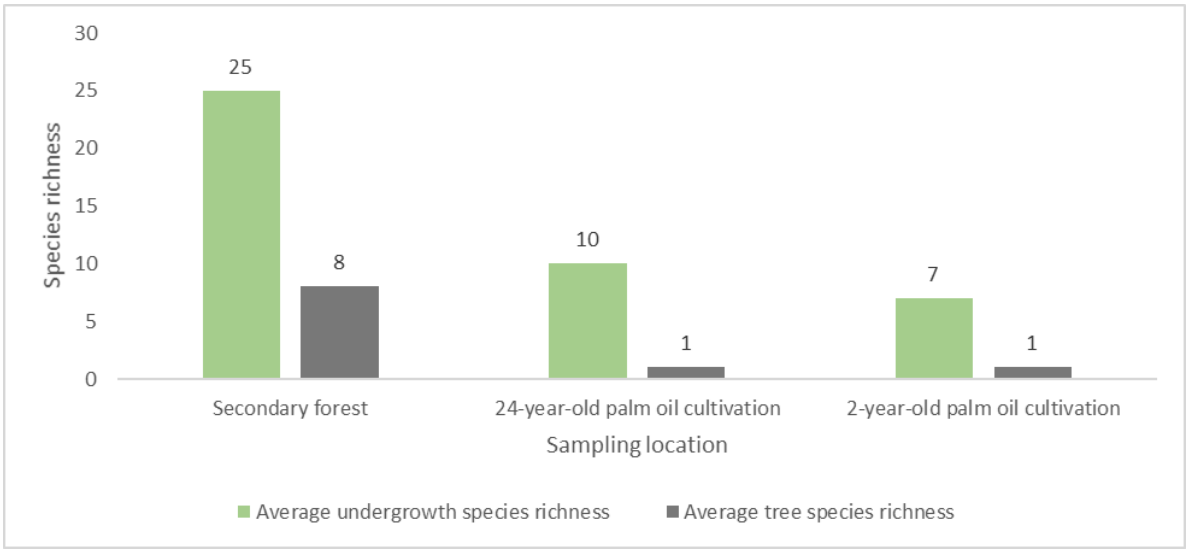


Figure 7: Comparison between the average tree species richness and the average undergrowth species richness.

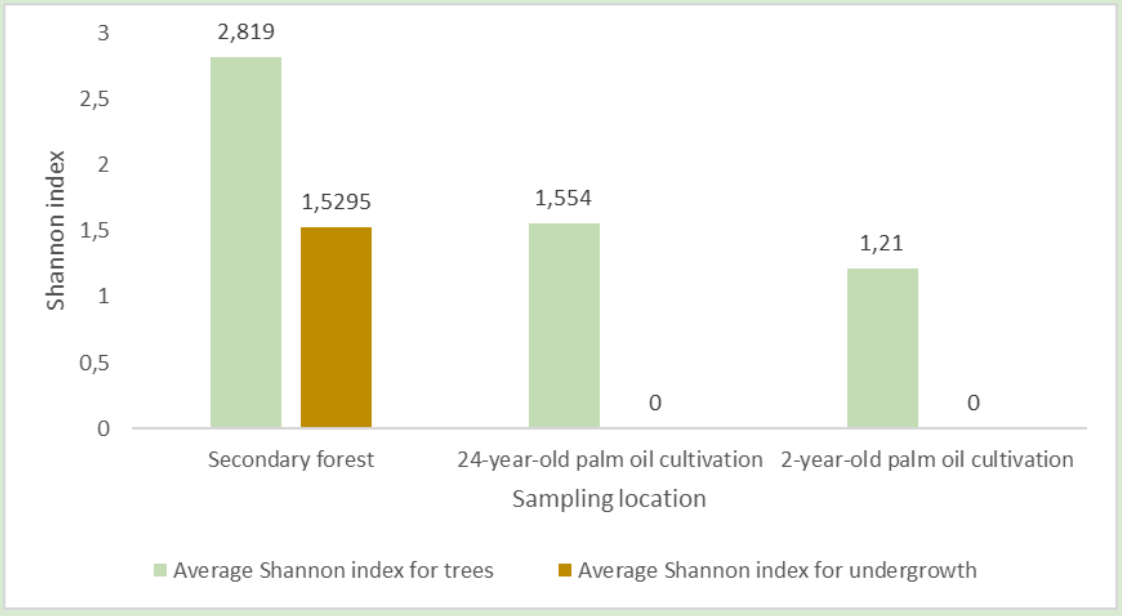


Figure 8: Comparison between the average shannon index for trees and the average shannon index for undergrowth.

Biodiversity assessment data was cross-referenced with residents' perspectives. 40% of respondents noted changes in land access. Among the factors mentioned, soil degradation was cited by 20% of the community. One respondent, representing 3% of the total, emphasized biodiversity loss in addition to deforestation and soil degradation, while another person emphasized biodiversity loss combined with deforestation. The issue of deforestation was also raised during interviews:*"For me personally, I am quite concerned about the deforestation. We can see many animals like monkey or something like that is extinct"* (Appendix 5).

As a crucial component of the ecosystem, local resources, and livelihoods, the village's water source underwent analysis. Originating from a water outlet situated atop a hill amidst a secondary forest and an adjacent OP plantation, this water is channeled to the residents of GD through a pipeline. It also serves as a tributary to a nearby rice field.

Table 3: Phosphate and Nitrate Levels in the Stream Supplying Water to GD.

Location	**Water source**	**Mid-stream**	**Downstream**
Phosphate mg/l	0,1625	0,075	0,12
Nitrate mg/l	0,000	0,00	0,0045

Table 3 shows the phosphate concentrations exhibit variation among the sampled points, with the highest concentration observed at the water source and a slightly lower concentration downstream. This suggests potential phosphate contamination entering the stream from upstream sources, likely associated with agricultural runoff, particularly from OP plantations. Conversely, the midstream point indicates a lower phosphate concentration compared to the water source and downstream points, implying some degree of dilution or reduction in phosphate levels as water flows downstream. Nitrate concentrations remained consistently low across all three points, with only a very low concentration observed downstream (0.0045), indicating minimal nitrate contamination in the sampled water. This may be attributed to factors such as limited nitrogen inputs or effective natural processes that mitigate nitrate presence in the water.

In the analysis of macroinvertebrates (Appendix 13), the highest number of organisms was observed in the downstream rice field. This could be attributed to the more complex habitat structure present in rice fields, including submerged vegetation, mud, and organic debris, which offer numerous niches and resources for macroinvertebrates compared to the water source or midstream areas. Additionally, the nutrient availability in the downstream rice field may have been higher compared to the midstream, providing ample food resources to support abundant macroinvertebrate populations. Another factor contributing to these results could be the modification of the water source by inhabitants, such as lining it with a special material to prevent soil erosion and facilitate water supply through a pipe. However, the flowing water in the midstream may have made it challenging to capture organisms during sampling.

Regarding changes in access to water, 30% of community members observed differences, while 6% did not answer the question, and the rest did not notice any changes. Among the factors indicated, 10% mentioned biodiversity loss, 16% cited changes in water quality, and 3% referred to other factors, with the majority not specifying any factors. The problem of water access was mentioned also during one of the interviews: *"There is changes in terms of water source due to oil palm, like before the oil palm they didn't have any issue with the water source, but after oil palm they suddenly have less water. When it's drought, they have no water, and even now when it's raining they still have a problem with the water supply, like we have experience this past few weeks. It can be due to the change in soil, more compact and it affect the water"* (Appendix 6). Indeed, as noted by one of the interviewees, the

characteristics of the land vary depending on its utilization, a fact corroborated by other measurements obtained.

Regarding soil type, the GD area, while diverse overall, exhibits a consistent soil type in the areas cultivated by local communities, where the research was conducted. The soil profile is shown in Appendix 13.

Table 4: Soil bulk density.

Location	*Bulk Density*
Secondary Forest plot 1	0,852
Secondary Forest plot 2	0,61
2-year-old palm oil cultivation plot 1	1,198
2-year-old palm oil cultivation plot 2	1,113
24-year-old palm oil cultivation plot 1	1,307
24-year-old palm oil cultivation plot 2	1,339

Measurements for soil bulk density are shown in table 4. Plot 1 and Plot 2 in the secondary forest exhibit lower bulk densities compared to all plots in the OP plantation. This indicates that the soil in the secondary forest plots is less compacted or denser than the soil in the OP plantation plots. Within the OP plantation plots, those with a 24-year-old plantation age generally show slightly higher bulk densities compared to the plots with a 2-year-old plantation age. The data reveals variations in soil density across different land-use types and ages, which can impact soil health, water infiltration, and plant growth. Lower bulk densities in secondary forests may signify healthier soil conditions conducive to diverse plant growth, while higher densities in OP plantations could suggest soil compaction due to agricultural practices.

To gain insight into the community's perceptions of changes and their impact on livelihoods, respondents were asked to assess changes in access to natural resources. The majority, constituting 63% of respondents, reported experiencing changes in access to natural resources. About 6% were uncertain, another 6% did not provide a response, and

approximately 23% did not notice any changes. Regarding factors influencing these changes, around 36% of respondents cited biodiversity loss, 6% mentioned deforestation, and 3% identified soil degradation. Additionally, 6% mentioned a combination of biodiversity loss and deforestation, while 3% collectively referenced deforestation, soil degradation, and air pollution. Notably, approximately 43% of respondents did not specify any particular factors.

4.2 Processes and Institutional Influence

Smallholder OP cultivation, one of the most popular income sources in the community, was significantly promoted through government intervention. Local government officials have visited GD for the past few decades to advertise OP cultivation's potential positive economic and infrastructural impacts (Appendix 7). In addition, these meetings would also serve as informational sessions on how to access free resources from the Malaysian Palm Oil Board, such as fertilizer, seeds, and informational classes (Appendix 9). In addition, Solaridad, a NGO seeking to promote sustainable supply chains, has also visited the community to advocate for smallholder OP production (Appendix 9).

However, perceived threats of land grabbing of NCR territory have also influenced GD to continue their expansion of smallholder OP on previously uncultivated land. The community repeatedly expressed concerns about the government seizing land classified as "underdeveloped" for public initiatives like urban expansion and farming (Appendix 4, Appendix 9). Consequently, the apprehension of land grabbing has promoted the expansion of OP cultivation onto previously unused land. Another insecurity of smallholder OP is supplying labor needed for more frequent and extensive harvests, as mentioned above. Being in close proximity to the border, many laborers cross the border illegally and work in the community's smallholder fields (Appendix 12, Appendix 4, Appendix 9). However, with governmental threats to increase border control, smallholder OP owners feel the pressure of sustaining a secure labor force for their harvests, which may impact their decision to maintain smallholder plantations (Appendix 4 and 9).

Joint venture OP leases managed by Harn Len Pelita Bengunan are also a widely employed source of OP cultivation in GD. Beginning in 2004, land agreements were steadily distributed through the Gua settlements to develop land previously deemed ‘difficult to maintain’ by the community (Appendix 7 and 9). Therefore, this economic proposal is widely seen as positively impacting the community’s livelihoods as it provides additional income without an

individual's laborious land cultivation (Appendix 11 and 12). Since its inception, Harn Len Pelita has also employed people from the community as laborers, contract workers, and executives, further increasing incomes (Appendix 7 and 11). However, there have been some concerns about the equity of these land leases, with many interviewees unclear of their shares of OP profit (Appendix 4 and 9). In addition, with the lack of clarity of native land ownership, conflicts previously arose to fairly distinguish land owners for joint venture leases (Appendix 9) .

Therefore, government agencies such as the Malaysian Palm Oil Board, NGOs, and Harn Len Pelita Bengunan have extensively promoted the transition of both JVA and smallholder OP cultivation through the promise of bettering financial capital in GD.

4.3 Livelihood Resilience and Environmental Impacts

The following section analyzes the capacity of all people across generations of GD to sustain, adapt and improve their livelihood opportunities and well-being despite environmental, economic, social and political disturbances. Rural communities are increasingly confronted with the simultaneous impacts of social and environmental dynamic processes at different scales, from the local to the global and these processes are testing the resilience of social and ecological systems and affect livelihood strategies (Folke, 2016). To broaden the concept of the SFL, present research is concerned with livelihood resilience, a concept that considers the vulnerabilities, or the resource for resilience that households and communities experience considering environmental and economic change (Abrams et al., 2019). Armitage (2007) defines resilient livelihood as *"those strategies, adopted by households or communities, that: (1) cope with and are able to recover from shocks and stresses, (2) maintain or enhance existing capabilities and assets despite uncertainty, and (3) ensure the provision of sustainable livelihood opportunities for future generations."*. The resilient livelihoods approach builds upon prior work on sustainable livelihoods (e.g. Scoones 1998; Milich 1999). Thereby, it is acknowledged that people's circumstances, cultures, values and perceptions have an impact on their ability to adapt and reorganize both in the short and long term (Quandt, 2018).

The findings from the analysis suggest that the community of GD thrives on a foundation of a strong social capital. The community's close-knit structure, embodied by the leadership of the head woman and characterized by strong familial and communal bonds, fosters a sense of

solidarity and mutual support. This is further reinforced by traditions like *berduruk* that strengthen this sense of reciprocity and cooperation, thereby bolstering the community's resilience in times of need. This social cohesion promotes livelihood resilience through sharing of resources, knowledge and labor, ensuring that individuals can rely on one another for assistance during livelihood activities. The strong relationship within the community, in combination with job opportunities due to OP expansion, has even led to some counter urbanization trends where people migrate back to the rural community. However, this trend seems to be overshadowed by the trend of youth migrating for higher education.

The human capital also plays a significant role in enhancing livelihood resilience. The combination of governmental agencies educating landholders on OP cultivation and the youth getting higher education, contributes to skill development and diversification. This prepares the community for a range of livelihood strategies which increases their adaptive capacity. However, the migration of the youth choosing to stay in the cities and the governmental threat of increasing border control, due to illegal Indonesian labor migration, intensifies the pressure on smallholder OP owners to secure a stable labor force.

The findings from the above analysis suggest that people in GD perceive the shift in agricultural practices to OP cultivation, as positive in terms of economic opportunities and impacts. The increase in financial capital is supported by the results of increased human and physical capital. This involves livelihood opportunities in terms of education and physical services such as the expansion of Pan Borneo Highway that enables access to services. However, results also show a big financial difference in how much individuals benefit from the expansion of OP indicating unequal development within the community. In addition, the increased reliance on one single cash crop exposes the community to market fluctuations, environmental degradation and vulnerabilities associated with monoculture farming. Ellis (1999) highlights the importance of a diverse portfolio of activities to sustain the long-run resilience and reducing vulnerability to external shocks (Ellis, 1999). Therefore, addressing income disparities and OP reliance is key for ensuring inclusive growth and strengthening resilience across all social segments of GD. However, it appears that the GD community seeks to preserve some of their subsistence farming practices. This decision contributes to livelihood diversification and represents a pathway toward enhancing livelihood security. While OP plantations provide a source of cash income and wage labor, supplementary endeavors such as shop-keeping, remittances, or other off-farm and non-farm diversification

activities can offer additional financial stability. Therefore, oil palm plantations form part of GD's multifaceted livelihood strategy, presenting both opportunities and risks that warrant further examination.

Institutional influence has led to increased assets in their physical capital represented by infrastructure and therefore access to essential services. This newfound mobility promotes economic growth and community-wellbeing, which plays a fundamental role in enhancing GD's resilience. Though, it is made clear that continued issues with limited access to remote areas underscore the importance of further investment in infrastructure development to support livelihood activities. This shows that the community relies on government infrastructure investment to not lose their remote land and making it hard for smallholders to cultivate their land to get benefits from remote land. Moreover, there is a chance that their land might be taken by the government if they do not cultivate it. These perceived threats of land grabbing and the increased influence from external actors, such as governmental agencies and private companies, raises concerns about the community's autonomy and cultural integrity. For instance, individuals may unexpectedly discover that they own land in a remote area and are presented with the opportunity to lease it out for income generation. While this might offer economic benefits, it also highlights the existence of land title insecurity within the community. Another issue occurs when they lease land out to OP companies; community members must talk together with neighboring land owners because the company does not want to lease small plots of land for OP cultivation.

Beyond the aspects analyzed, the expansion of oil palm cultivation can have detrimental effects on resilience, leading to a decline in crucial ES and exacerbating food insecurity. The resilience of the local community is closely intertwined with the resilience of the surrounding environment, which directly affects the availability and quality of environmental services (Truchy et al., 2015). For instance, forest plant foods or wild edible plants play a crucial role in ensuring food security in rural communities by providing essential nutrients during periods of crop scarcity (Susandarini et al., 2021). Our ethnobotanical assessment revealed that species from secondary forests are utilized by the community in various ways, serving not only as food but also as construction materials or crop cover, thus bolstering community resilience. Armed with this ethnobotanical knowledge, communities can adapt to changing conditions, such as climate variability or market demands. For instance, in the event of crop failure due to environmental factors. Communities with rich ethnobotanical knowledge can

turn to alternative plants for sustenance and income generation. Additionally, the GD community's ownership of additional farmland dedicated to crops beyond palm oil, such as rice, pepper, fruits, and vegetables (Appendix 11), enhances the community's resilience.

As outlined in the literature (Mabe et al., 2019), the stability of the community is influenced not only by the present environmental conditions, particularly those associated with oil palm cultivation in our case, but also by considerations of climate change projections and vulnerability assessments. The anticipated impacts of climate change are expected to diminish the suitability of cultivated areas and challenge growers' adaptive capacities. A study by Rival (2017) indicates that climatic factors such as temperature, rainfall, abiotic factors, diseases, pests, and pollinator stress are likely to adversely affect oil palm cultivation, potentially impacting both its quality and quantity. While oil palm production has increased incomes, created employment opportunities and reduced poverty among members of the GD community, the environmental impacts of oil palm cultivation and changing climate patterns increase vulnerabilities and threaten the sustainability of the sector.

5. Discussion

This section will compare our findings to relevant literature aiming to expose consistencies and inconsistencies in our data. Overall, our research highlights the tradeoffs and complexity of livelihood analysis in communities relying on OP. We found that OP cultivation brings primarily positive financial benefits to the community (Appendix 13), aligning with Malaysia's rural poverty reduction trends (Norwana et al., 2011). Specifically, OP smallholders experience the lowest incidence of poverty compared to other agricultural sub-sectors (Ibid). However, according to Santinka et al. (2019), these financial benefits can be uneven based on prior experience in cash-crop cultivation; therefore, GD’s experience with rubber and pepper may have positively influenced the financial benefits of OP transition compared to subsistence-only communities. Additionally, communities involved in OP agriculture are noted in the literature for enhancing their physical capital through the development of infrastructure and the acquisition of vehicles (Qaim et al., 2020). This, in turn, leads to national improved access to crucial services (Ibid). This phenomenon is visible in GD through the expansion of the Pan Borneo Highway and increased car ownership (Appendix 7). This allows villagers to move freely to access health and educational services, thereby contributing to the enhancement of human capital (Appendix 6).

However, the literature also highlights the instability and, inversely, dependence on Indonesian labor, accounting for 77% of the OP plantation labor force in Malaysia (Tang and Qahtani, 2020). Therefore, GD's case of reliance on Indonesian labor is not an outlier (Appendix 4 and 9). Land tenure instability through OP company agreements also has an essential impact on both our research and OP literature (Rist et al., 2010). Through an investigation of Sarawak court documents, we found a land title dispute between Harn Len Pelita Bengunan and a neighboring village to GD, indicating the proximity of these land-related issues (*Harn Len Pelita Bengunan Sdn Bhd Audit Summary,* 2019). Thus, GD mirrors the national instability of foreign labor reliance and land tenure.

Next, our discussion will explore the consistencies of our natural science findings with available literature. Kho and Jepsen (2015) compared carbon stock data from OP plantations and various forest types. Utilizing the same methodology employed in our report, which involved using allometric equations, the results ranged from 5.0 t/ha for 1.5-year-old OP to 26.2 t/ha for 27.5-year-old plantations. Additionally, carbon stock values ranged from 49 t/ha to 214 t/ha for secondary forests of unknown age. Although our data ranged from 15,003 t/ha for 2-year-old OP cultivation to 167,909 t/ha for secondary forest. However, it might differ from other studies due to methodological variations or environmental factors. Secondary forests accumulate significantly more carbon than OP plantations, aiding in climate change mitigation by reducing greenhouse gas concentrations and supporting diverse plant and animal communities, thus enhancing ecological resilience and stability. Notably, biodiversity, a focal point of research in OP contexts, also substantially differs between OP plantations and secondary forests. The findings of our report revealed varying results in the Shannon Wiener diversity index between the studied areas of secondary forest and OP cultivation. In the assessment of forest stands, the coefficient ranged from 2.132 to 0.927 for secondary forest, whereas for OP cultivation, it was 0.00. Similarly, for undergrowth plants, the index was 2.891 for secondary forest, 1.554 for 24-year-old crops, and 1.210 for 2-year-old crops. Interpreting these results in light of literature, particularly the insights provided by Balangen et al. (2023) can be inferred that biodiversity levels are low (value range 2.0000-2.5999) to very low (<1.9999) in forest stands and very low in OP cultivation areas. Regarding undergrowth plants, the indicator suggests slightly better biodiversity values, ranging from moderate in secondary forest to very low in OP cultivation areas.

Table 5: Shannon-Wiener (H') index interpretation (Balangen et al., 2023)

	values	Interpretation
Shannon-Wiener (H')	>3.5000	Very high
	3.000-3.4999	High
	2.5000-2.9999	Moderate
	2.0000-2.5999	Low
	<1.9999	Very Low

The Shannon Wiener index values obtained in our study align with those reported by other researchers examining similar ecosystems in Sarawak. For instance, Karyati et al. (2018) found values ranging from 2.09 to 2.70 for forests aged 5, 10, and 20 years, indicating low to moderate biodiversity. Similarly, Jana and Jusoh (2021) reported a value of 2.25, corresponding to low biodiversity, in a study on the structure and tree species composition of forest fringes within an OP plantation in Suai, Sarawak. These findings are consistent with the secondary forest environment, as most of the forests in GD originated from former rubber cultivation areas. Despite the interpretation of index values ranging from low to moderate, the substantial disparity in both the Shannon Wiener index value and species richness between secondary forest and OP cultivation areas remains evident.

The results of our nitrate and phosphate level tests in Table 3 were compared with the National Water Quality Standards for Malaysia. Phosphate levels were converted to phosphorus for comparison purposes by dividing the results by 3. According to the National Water Quality Standards for Malaysia, the water sampled from all surveyed areas was categorized as Class IIA/IIB. Class IIA indicates water suitable for Water Supply II, requiring conventional treatment, while Class IIB signifies water suitable for recreational use with body contact (Department of Environment, 2005). These classifications suggest that the water meets specific quality criteria and is generally considered safe for its designated purposes. Therefore, no significant water contamination was detected, especially considering it is not used by the community for drinking. However, given the nearby cultivation of palm oil and

other crops, ongoing monitoring is advisable to prevent the release of these components into the environment and potential contamination.

In relation to our bulk density results, Rahman et al. (2018) conducted a study on soil quality analysis in Malaysian Borneo, where changes in soil post-conversion from forest to oil palm (OP) plantations were examined. The study encompassed comparisons of soil bulk density across three age classes of OP plantations (29, 39, and 49 years old) and natural forest. Results showed bulk density ranging from 1.4 to 0.04 at a depth of 5-15 cm for natural forest soils, 1.3 to 0.07 for the youngest OP plantation (29 years old), and 1.3 to 0.09 for the 39-year-old OP plantation. In our study, bulk density ranged from 0.852 to 0.61 for secondary forest, 1.198 to 1.113 for younger (2-year-old) OP plantation, and 1.307 to 1.339 for older (24-year-old) OP plantation. Notably, the values obtained from the secondary forest were lower than those reported for the natural forest in the referenced study. Although the results for our younger OP plantation were slightly higher compared to the 29-year-old plantation in the referenced study, the findings for our older OP plantation surpassed those reported. While the bulk density of the 39-year-old OP plantation in the cited research was lower than our findings in the older OP plantation, the range of values was wider. Overall, while there are similarities in observed comparisons between the two studies, differences in plantation ages and the utilization of secondary forest versus natural forest must be taken into account.

In addition to documented impacts on water and soil, OP plantations also exert adverse effects on invertebrate populations and biodiversity. Mercer et al. (2014) conducted a comparative study on freshwater macroinvertebrates across nine streams traversing oil palm (OP) plantations, natural forests, and secondary forests. In our study, the midstream point that is resembling the stream in Mercer et al.'s research, which is situated in mountainous terrain and traverses an OP plantation, yielded 46 macroinvertebrates, compared to their documented 24. Notably, our sampling duration was 30 minutes, whereas Mercer et al. employed a 3-minute sampling period. For downstream points, akin to a paddyfield, we can draw comparisons with Shin et al. (2022) research on macroinvertebrates in conventional and organic paddy fields. In the conventional paddyfield, 74 species were recorded, while we found 8 species at GD. This difference could be attributed to the longer sampling duration and the use of a more time-consuming sampling method (rectangular prism-shaped samplers to catch organisms) in Shin et al. study.

5.2 Methodology Limitations

During the fieldwork, challenges regarding data collection were faced which affected our analysis outcome. Initially, the limited timeframe to collect data and the limited knowledge of the study site presented a dual challenge. On one hand, the study preparation was broad to anticipate various possibilities. On the other hand, it also made the research very limited as we had to quickly adjust our research plans within the first days of arrival. Second, concerning the sampling methods for interviews, we were primarily limited to women as the men were often not at home, not very easy to reach, or away for many days working on OP plantations. Also, sampling issues arose with our 6 semi-structured interviews as it may have not shown the variety of perspectives of the longhouse, yet with the time constraints we were unable to interview further. Moreover, the questionnaire was answered only by the head of household, there were also issues with analysis of all individuals from the community. For example, we were unable to properly access education levels and age distributions.

Regarding the PRA approach we faced challenges according to the resource and the timeline mapping. The resource map, shown in picture 5, indicates that the community did not quite agree on where to put their fields. This confusion hindered our ability to make a clear understanding on where they had their relevant fields located. However, this could also show that there is an insecure land tenure in the community as they were not able concisely place some of their fields. Also, part of the community's land was located far away from the longhouse and therefore, could not serve as a part of the research area. This is also affecting the timeline mapping which is shown in figure 5. The timeline shows that the current head woman is quite new, affecting her recall of important dates. Also, respondents in the timeline mapping were often hesitant to put stuff on because they said they could not remember any events, the specific year of events, or that they moved to GD recently and were unable to give any information. More generally, the social science methods might be biased because of our cultural background and biases about the OP industry. Additionally, language barriers and cultural differences may have impacted our results as we experienced in the interviews with some respondents answering something else to some of the questions.

Regarding the natural science methods, we planned to do more tests on soil samples. However, it was not possible for the Malaysian students to do all the planned tests. Therefore, there might be missing important data from soil that serves the natural capital assets. Another limitation arises in water sampling sources with tap water samples instead of water from the

source. Instead of utilizing water directly from the stream's highest extraction point, we opted to utilize water sourced from the pipe supplying households in GD. It's worth noting that the water from this pipe originates from the same location. In the biodiversity assessment, we may have sampling bias by rounding tenths of a number to the nearest whole number when measuring diameters of trees. We also encountered challenges in accurately identifying organisms during the macroinvertebrates assessment, particularly when taxonomic identification is difficult relying solely on a key for organism identification.

6. Conclusion

Our objective of this study was to investigate the livelihood impacts of oil palm (OP) cultivation in Sarawak, Malaysia looking at GD as a case study. We utilized natural and social science methods to create an interdisciplinary exploration with qualitative as well as quantitative methods. The Sustainable Livelihood Framework was used as the foundation of our analysis. The expansion of OP impacts livelihood in GD in different ways. The findings from the analysis shows that GD drives on a foundation of strong social capital that is embodied by the close knit-structure and the leadership of the headwoman which forms strong familial and communal bonds. This social cohesion promotes livelihood resilience through sharing resources, knowledge and labor. Human capital is affected by out-migration of the younger generation as they strive to get a higher education which can contribute to skill development and livelihood diversification and increase adaptive capacity. However, this trend can put pressure on local smallholders in terms of labor availability. For financial capital, the community benefits positively from OP, contributing to reducing poverty and enhancing physical capital through infrastructure development. However, the uneven distribution of financial benefits based on prior cash-crop cultivation raises concerns about inequalities within the community. Physical capital analysis shows that the community relies on governmental aid in terms of infrastructure investments to benefit from remote rural land. The natural capital analysis highlighted the negative impacts on the environment regarding biodiversity, soil quality, and water quality from OP plantations. External factors such as Indonesian labor and land tenure instability through company agreements, influence the community's involvement in OP cultivation. Land title disputes and reliance on foreign labor underscore the challenges faced by the community in navigating institutional choices. The analysis conceptualized the data by considering the resilience and genuine sustainability of OP dependent livelihoods further discussing the trade-offs and future vulnerabilities. Our

discussion confirmed our findings by consulting literature on OP livelihood transitions and environmental data. Overall, the impact of agricultural development on livelihoods was found to be highly complex and requires additional research to assess the effectiveness of livelihood strategies on rural communities

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Appendix

Appendix 1: Final Research Synopsis

Oil Palm Expansion in GD: Research Synopsis

Practicing Interdisciplinary Field Research
GD, Sarawak, Malaysia
University of Copenhagen
23 February 2024

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Word Count: 2485

Introduction:

This synopsis presents the preliminary outline of our field study of land-use change towards oil palm cultivation in GD, Sarawak, Malaysian Borneo. The data collection will be carried out from the 4th of March to the 15th of March 2024 in collaboration with counterparts from UNIMAS.

Context:

The forests of Sarawak sustain as rich reservoirs of biodiversity, store large amounts of carbon, and are home to several indigenous groups (Andersen *et al.*, 2016). In addition, the diverse environment provides vital ecosystem services and livelihood support for millions of people in the area, including many indigenous communities. Due to its rich diversity and ecosystem services, the Sarawakian economy has expanded on a global scale. For example, the government continues to implement several infrastructure expansion projects, mainly roads and hydroelectric dams, to enhance this newfound economic growth. One of these infrastructure investments, the Pan-Borneo Highway, promotes several societal benefits, including the development of an industrial corridor, regional transportation connectivity, easier access to social services, and increased access to natural resources such as timber and minerals. However, these roads cutting through the forested landscape might also generate numerous negative environmental, economic, and social impacts (Alamgir *et al.*, 2020).

With this expansion of infrastructure, Sarawak has also seen a significant agricultural transformation over the last decades with the growth of logging, cash crop production, and oil palm industry, thus influencing land-use choices for smallholders (Mertz *et al.* 2008). The planting of oil palms has played a key role in the transformation of the forest in this area. Palm oil is used primarily as a cooking oil but also in a variety of foods, cosmetics, and biofuels. It has a high yield and relatively low-cost production, which makes it profitable to make large-scale palm oil plantations. While some argue this development is a way for poor farmers to escape poverty, others warn of serious harm to local and global environments and human rights violations (Andersen *et al.*, 2016).

Currently, Native Customary Land (NCL) claims around 20-25% of the total land area and 60-70% of the total agricultural land (Andersen et al, 2016). The principal claimants of the NCL are indigenous groups such as Iban and Bidayuh, which primarily reside in longhouse communities and occupy extensive territories of forest and agricultural land. These lands are

often not surveyed or directly titled, but instead subject to various combinations of private and common property rights under community governance. Furthermore, the Sarawak Land Code prohibits non-natives from transacting in NCL. This consolidates a challenge because much of the capital for oil palm development is derived from profits from the timber industry, where many companies are owned by non-natives (Cramb, 2013). This situation also presents a dilemma for the government, which seeks to transform rural areas in Sarawak by encouraging private-sector plantation development.

Land change or land systems science is an interdisciplinary field that studies the terrestrial component of the Earth system while encompassing both human and natural components of global land systems. Land system science explains the social-ecological conditions explicitly concerned with understanding the cause and effect of land use change (Meyfroidt, 2016). With increasing urban populations and shifts in global diets, the primary agents of agricultural deforestation have changed from state-enabled smallholders in the 1980s to large enterprises producing for international markets in the 1990s (Shevade and Loboda, 2019). In order to meet international demand for these growing agricultural markets, sites of production are facing negative environmental consequences such as road building and clear-cutting. Regarding our research site's significance, Malaysia had the highest percentage of tree cover loss relative to its land area between 2000 and 2012 (Shevade and Loboda, 2019). Therefore, deforestation due to expanding oil palm plantations is a threat to biodiversity in Malaysia. Oil palm plantations specifically threaten biodiverse ecosystems as they support fewer species and are often planted on converted diverse peat swamps (Shevade and Loboda, 2019). Oil palm plantations have led to several consequences but also opportunities for people living in Malaysia. Sarawak is currently undergoing substantial rural-urban migration due to economic growth. This phenomenon has led to documented social and economic disruptions in longhouse settlements near GD (Ryoyi, 2001).

Therefore, we intend to investigate if the change in agricultural practices, from self-sufficient agriculture to commercialization, encourages sustainable socioeconomic development or, instead, harms human welfare and the environment on a local and global scale. GD, a small community in Sarawak engaged in diverse agricultural activities, serves as a compelling case study to examine stakeholders, power dynamics, and the impact of private-sector

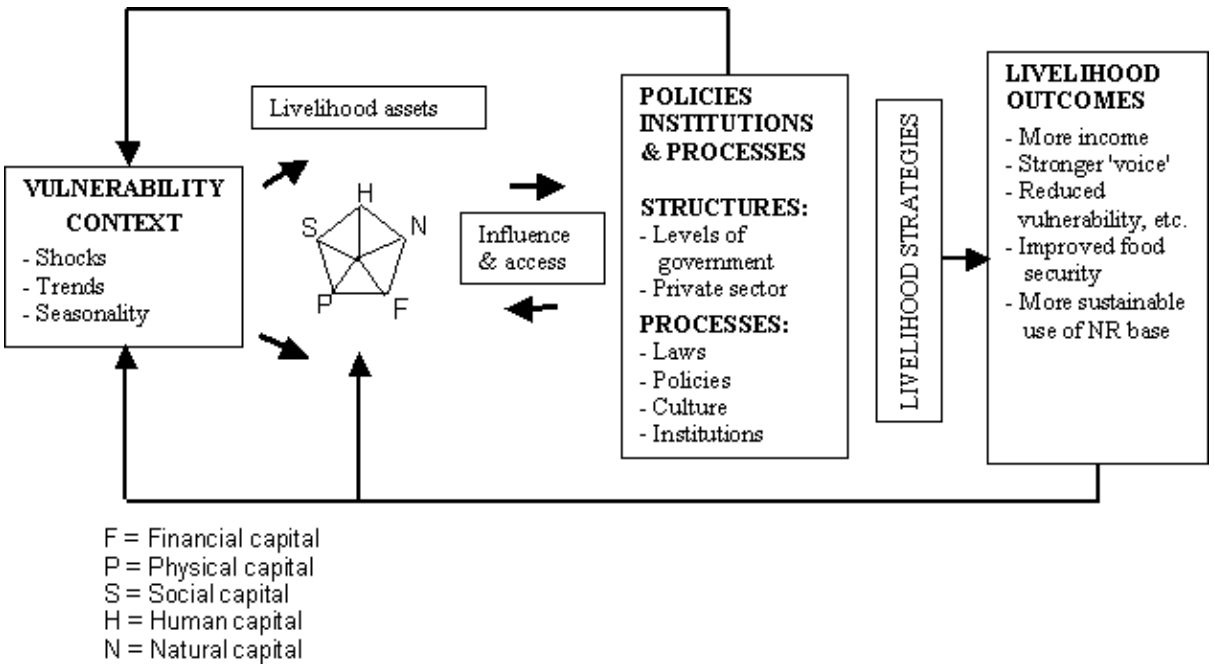
involvement, particularly through joint venture companies, on the community's land ownership and cultivation.

Research Justification and Significance:

There has been a growing focus on deforestation and sustainable development in tropical forests as they serve as rich reservoirs of carbon. Our research site in Borneo, one of the most biodiverse and carbon-rich landscapes globally, has been a central focus of conservation discourse for decades. However, the discussion around deforestation and environmental degradation in Sarawak is often centered on large-scale oil palm plantations. In contrast, GD is an interesting case of transition from subsistence agriculture into small-holder oil palm plantations. Moreover, social aspects warrant exploration in GD, as it is inhabited by the indigenous Iban people and has witnessed a worrying trend of rural-urban migration. Therefore, we intend to investigate if there are connections between the small-holder oil palm industry, the shifting power dynamics of longhouse culture, and possible environmental degradation in the special case of GD.

Objectives and Research Questions:

The overall objective of this study is to investigate what factors and proximate drivers contribute to the decline in traditional agricultural activities and how these changes influence socio-economic and environmental factors in GD. We have split the research into two main research questions with respective sub-research questions.



How does the transition from subsistence farming into oil palm affect people's livelihoods in GD?

What are the main factors leading to land-use change in GD?

- *What are the proximate and underlying drivers of land use change for the community members in GD?*
- *How do power relations affect those shifts in traditional agriculture practices to oil palm practices?*
- *What are the advantages and disadvantages of the shift from traditional agricultural practices towards oil palm cultivation for the community members in GD?*

How do these changes influence the socioeconomic and environmental conditions of the local community?

- *What are the socioeconomic consequences of the change in land use? (Be more specific in relation to power relations when we know more)*
- *How has the transition of oil palm affected livelihoods?*
- *What are the environmental consequences of the change in land use?*

Study Site:

The field study for data collection will take place in GD in Sarawak, Borneo, Malaysia. GD is located around 158 kilometers southeast of Kuching.

Satellite image 1. Overview of Gua Dungatt (N 1.074527°, E 111.282726°)

Research Design:

This research study is designed as an interdisciplinary case study. Our paper will examine social and environmental factors leading to land use changes in GD, utilizing mixed methods to gain a comprehensive understanding of the community and their choices regarding land use for oil palm plantations. It will investigate the proximate and underlying drivers and consequences of land use change through methods such as focus group interviews, semi-structured interviews, and natural tests for environmental consequences of oil palm plantations.

Analytical Framework:

To explore both proximate and underlying factors influencing changes in land use, this study will employ methodologies and terminology derived from causal analysis within the field of land system science to analyze the research question (Metroid, 2016). In addition, we will borrow some themes from the Sustainable Livelihoods Framework to analyze socio-economic effects on the community. Specifically, the framework's livelihood capitals (natural, physical, human, social, and financial) can aid us in quantifying well-being while avoiding biases (Ellis, 2000).

Methodology:

Literature Review and Historical Analysis

A literature review will help to get an insight into the historical context of traditional practices in GD and similar areas in Sarawak. Also, the study will look into existing studies, reports, and articles that discuss the decline of traditional agriculture and its impact on communities. This can help to identify wider key factors associated with the decline, such as urbanization, globalization, changing consumer preferences, environmental factors, and government policies.

Questionnaire

The report will also, through a questionnaire, use a representative sample of people from the community members to gather social, economic, and environmental data to investigate the effects of oil palm cultivation in GD. The sample will consist of at least one participant from each household (most likely the head of the household). This can be characterized as a stratified sampling method, as the population is divided into subgroups (their respective households), with one representative answering the questionnaire. This method ensures that

each household is adequately represented in the sample. Due to the time limitation, we anticipate not gathering answers from each household. Therefore, we prepared to change our method to convenience sampling, where we select individuals who are ready and available to participate in the survey. The downside is that certain groups might be over- or underrepresented.

Soil Sampling

The analysis of soil quality due to agricultural land use change is crucial to understanding the resulting environmental effects. Therefore, the report will identify a site within GD and its surroundings for soil sampling and use factors such as land history, topography, and soil variability. This is to determine the level of nutrients that can be expected within natural forests and oil palm plantations. This data should give an idea of how the soil is being changed, if at all. The method will be implemented with 3 replicated from a sample from the top 30 cm of soil, with 3 samples coming from natural forests and 3 from oil palm plantations. The samples will be collected at random plots owned by the community of GD. This information can be integrated with socio-economic and environmental factors later in the analysis and see the difference in soil fertility and soil quality in the area of GD.

GPS Assessment and Satellite Data

To comprehend the distribution of changes in land use, infrastructure development, and environmental degradation, we will conduct a GPS mapping. This involves recording GPS coordinates for essential features like agricultural fields, crop types, forest boundaries, settlements, and infrastructure. Also, we will map different land use types such as croplands, pastures, and fallow lands and identify areas under traditional agricultural practices. The use of satellite data can help to objectively measure changes in land cover and general land use change.

Species and Biodiversity Assessment

To comprehend the impact of environmental changes from the transition to oil palm plantations, we will compare biodiversity in a tropical forest and oil palm plantation. This will aid us in our discussion of agricultural land use changes and its impacts on biodiversity. We will conduct measurements on designated plots, (3 plots in natural forest and 3 in oil palm plantation) including the count of tree species, the diameter of trees at 1.3 meters height, and the height of trees. These measurements will allow us to determine carbon stocks (estimated biomass using allometric equations) and assess biodiversity through two key indicators:

species richness (the total number of tree/plant species in a specified area, both canopy and ground) and species evenness (the abundance of each species). These aspects of biodiversity will be measured using the Shannon index.

Participatory Timeline Mapping

This methodology will allow community members to physically map the transition to large-scale oil palm production, providing crucial background information on the region and developing rapport. This method will be done with the head woman and/or with the elderly community members to determine the land use changes over time and how it impacted their socio-economic factors, such as food security.

Semi-Structured Interviews

We will use semi-structured interviews throughout our research to investigate the causes and effects of shifting agriculture practices. We can coordinate these interviews in common spaces during meals or when community members are free from work obligations. The semi-structured interview is an appropriate method as it allows the interviewee to speak freely as we gain valuable context and information. We will interview stakeholders of oil palm plantations to determine their perceptions of how oil palm plantations have impacted their lives through time. If we get the opportunity, we will also try to conduct a semi-structured interview with the head woman of GD to investigate the hierarchy of GD and local government officials to get a better understanding of the economic factors driving oil palm production in the area.

We aim to conduct 5-10 interviews due to the time limitations in the transcription phase. Additionally, the relevant landholder participants will be chosen based on our unstructured interviews and field observations. We will most likely use a snowball sampling strategy where participants refer to additional relevant persons of interest.

Field Observation

Throughout the research period, we will spend time in the community observing agricultural activities, infrastructure, and interactions among community members. Community members can work together to map areas where resources are utilized and document cultural and traditional land management practices. This collaborative effort aims to integrate indigenous perspectives into the mapping process and will help to gather stories about the uses of different plants in the community.

Transect Walks

This method will provide an on-the-ground approach while aiding in a comprehensive understanding of the landscape, community dynamics, and cultural elements. Transect walks also allow us to build a well-rounded relationship with the land and interviewee. We intend to find an older community member who best knows the area for the most success in this method.

Photovoice

Photovoice can enhance the research on the resulting power relations of declining traditional agriculture by providing a visually compelling and participatory approach while eliminating biases. We intend to ask community members to bring a photo that exhibits their closest relationship, explain this relationship, and if it has been impacted by changes in the land. We may also ask the subjects to bring a photo of their environmental concerns and why.

Limitations and Challenges:

Cultural Differences

There will be challenges related to working across different cultures due to different learning methods, work ethics, and problem-solving. To mitigate this, we will talk with our Malaysian counterparts to explain our project so they can explain their view on our project.

Timing

The initial time plan is designed with flexibility in mind, considering the need to quickly adapt to the context and specific opportunities.

Working in Interdisciplinary Groups

Working across disciplines can be challenging; therefore, it is important to address differences in approaches. The study will include both social and natural science methods, so everyone in the group will contribute with their respective background knowledge.

Language Barriers

Many different languages are involved in this study, creating a risk for misunderstanding. Therefore, interpreters will receive a briefing before interviews begin, emphasizing the importance of asking questions for clarification if anyone is uncertain about the meaning. This briefing is particularly important during interviews.

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Synopsis Appendices:

Appendix A: Research Matrix

Overall Research Objective: Investigate the cause and effects of declining traditional agriculture in GD.					
Research Questions	**Sub-Research Questions**	**Data Required**	**Methods**	**Data Analysis**	**Limitations**
What are the main factors leading to land-use change?	What were the primary agricultural practices prior to "cash crop" production?	Past crop species/ technique Crop motivation	Historical analysis/ literature review Semi-structured interviews/ transect walks (GPS assessment) Participatory timeline mapping	Triangulation between interviews/ transect walks and past literature Code and analyze interviews (Nvivo)	Sourcing historical data Establishing trust with interviewees
	What are the economic factors driving palm oil production?	Global economic data and demand for oil palm Information on joint venture oil palm schemes Economic structures in GD	Historical analysis/ literature review Structured interviews with government officials Focus group interviews with past and current citizens of GD Participatory Timeline Mapping	Triangulation between interviews and economic data Code and analyze interviews (Nvivo)	Sourcing historical data Interviewing outside GD

How do these changes influence the socioeconomic and environmental conditions of the community?	What are the resulting power relations after the transition of agricultural practic by es?	Investigate power hierarchies in town Palm oil stakeholders' information	Semi-structured (community members) and structured (headwoman) interviews Photovoice Field observation	Code and analyze interviews and field notes (Nvivo)	Sensitivity of topic/gaining trust Measuring abstract concepts such as power
	What are the economic benefits or detriments of this transition?	Labor data Financial data	Questionnaire Semi-structured interviews Historical analysis/ literature review	Code and analyze interviews (Nvivo) Triangulation between questionnaire/ literature and government/ NGO reports	Sourcing data Measuring income in subsistence economies
	What are the environmental effects of this transition?	Biodiversity Soil quality Forest cover loss	Species assessment Soil sampling Satellite information and GPS assessment	Comparison of biodiversity and soil quality in a tropical forest and oil palm plantation	Too few samples/not truly representative

Appendix B: Interview Guides

Method:
This paper will utilize semi-structured interviews for data collection. This interview structure will help us gain an in-depth understanding of the issues associated with Joint Venture Agreements from various perspectives and interests. This includes addressing issues relating to historical events, present circumstances, and future outcomes. By employing the qualitative method, there is an opportunity to delve into the participants' attitudes and understanding of the expansion of oil palm plantations through their lived experiences. Semi-structured interviews enable the preparation of themes and questions in advance which can serve as guidelines during the process, while also allowing for adaptation and modification if necessary. Therefore, enabling the possibility of follow-up questions and digging deeper into other interesting topics that may arise during the conversation (Kvale & Brinkmann, 2014).

To improve the quality of the data, the interviews will be conducted through an interview guide. Initially, the questions are formulated as research questions and then translated into easily understandable questions. This transition is done to avoid overly academic language ensuring the interviewee feels most comfortable and not "quizzed" on their intelligence (Hurst, 2023). This involves initiating the discussion by posing general questions about the participants' perspectives, providing them with the opportunity to start reflecting on the topic (Kvale & Brinkmann, 2014). The questions will then become more specific to gather information about GD's unique circumstances. Lastly, the interview will be concluded with a question about whether the participant has any further thoughts or perspectives on the topic.

Purpose:
Our primary objective is to gain a comprehensive understanding of the land use changes in GD, with a particular focus on the transition from traditional agriculture to oil palm cultivation. Therefore, we seek insights into various aspects of the transition. This includes the historical background of agricultural practices in the area, the factors driving agricultural change, and the socioeconomic and environmental consequences on the local communities' livelihoods.

Furthermore, we are interested in exploring the dynamics of power relations in GD and how these affect land-use decisions, particularly in relation to JVAs. Here it is relevant to understand the involvement of authorities such as LCDA, SALCRA, and generally, the collaborations with a private investor. We aim to investigate the different perspectives of the community members on these agreements, including both challenges and opportunities they might face regarding land ownership and resource access. Therefore, the goal is to gather insights into the complex interplay of factors shaping GD's land-use transitions and to understand the implications of these changes on their respective livelihoods.

Smallholder Interview Guide		
Information Required	**Main questions**	**Follow-up questions**
Make the interviewee comfortable and aware of the research collection A brief introduction to us, our fields of research, and the topic of the project.	Is it ok that we record this interview? Would you like a pseudonym, so you remain anonymous? Can you briefly tell us about yourself? Do you have any involvement in oil palm or JVA?	
Personal background information Historical background information	Can you please provide some background information about yourself? This may include your age, occupation, and the duration of your residency in GD. Can you provide some historical context on the traditional agricultural practices that have been practiced in GD?	How have these practices evolved over time? Were there any traditional crops that later changed? Were your ancestors primarily engaged in subsistence farming? Do the development projects affect Native Customary Land for this specific area?
Factors driving oil palm production Socioeconomic effects	What factors have influenced your decision to change your land use from traditional agriculture to oil palm cultivation? In your opinion, what are the primary factors contributing to the decline in traditional agricultural activities in GD? How has the transition to oil palm cultivation impacted your livelihood, income, and overall economic well-being? How has the expansion of palm oil	How did the changes affect you personally? Can you share your personal experiences or observations regarding traditional farming activities in the community? Market dynamics? How do you perceive development through oil palm plantations? Please describe, how has development projects affected local landholders here at GD.

	plantations affected local employment opportunities and income levels? Can you describe any challenges or benefits associated with the transition from traditional agriculture to oil palm cultivation?	How have government policies influenced the promotion of palm oil cultivation?
Community perspectives	What challenges do community members face due to changes in farmland use, and how do they cope with these challenges? Are there any opportunities emerging from the new patterns of land use? Have there been any internal conflicts among and within longhouse communities?	
Environmental impacts	How do you perceive the environmental consequences of shifting from traditional agriculture to oil palm cultivation?	Are there concerns about issues such as deforestation, biodiversity loss, or changes in water quality?
Power relations and land-use decisions (top-down tendencies)	What role do you think “power relations” play in influencing land-use decisions in the community? Can you provide insight into the joint-venture oil palm project's social responsibility to the community? Has the decision-making on introducing oil palm projects undergone randau (Iban version of dialogue, open discussion, community-wide consensus)?	Are there any consequences if you reject a Joint Venture Agreement? Can you discuss whether LCDA or SALCRA has taken care of your interests related to Joint Venture Agreements? What private investor has taken part in the JVA? Are there any consequences if you reject a Joint Venture Agreement?

	What are the shares of the JVA, and do you think that is fair? Do you trust the authorities? Why/why not?	Are foreign labor forces hired to work in the JVCs? Are you satisfied with your earnings from working in the oil palm plantation? Do you have fears that the land won't be given back to you after the 60-year lease?
Final questions	Is there anything else you would like to share regarding the changes in farmland use in GD or any perspectives that we haven't covered?	

References:

Brinkmann, Svend, and Steinar Kvale. InterViews. Sage Publications, 2014.
Hurst, Allison. Introduction to Qualitative Research Methods. Oregon State University, 2023.

Transect Walk Interview Guide		
Information Required	**Main questions**	**Follow-up questions**
Land use changes	What traditional agricultural practices do you notice in this area, and have there been any changes over time? What differences do you observe in the landscape compared to areas with traditional agriculture? Can you identify any areas with abandoned farmlands or where traditional agricultural practices have declined? What reasons might be contributing to this decline?	How has the introduction of large-scale oil palm plantations affected the visual aesthetics and overall feel of the community? How do you think the abandonment of certain farmlands has impacted the community's dynamics?
Community habits	Let's visit communal spaces related to farmland use, such as gardens or meeting areas. How have these spaces changed, and what role do they play in the community?	In your opinion, how do these communal spaces reflect the community's relationship with farmland use?
Social Cohesion	Have there been any changes in community dynamics as a result of land-use change?	Has there been better community cohesion or have there arisen new conflicts because of land-use change? Why?
Livelihood Diversification	How have changes in land use affected the diversity of livelihood strategies?	
Spontaneous conversations about farmland use and changes in the community		

Appendix C: Draft Questionnaire

https://www.survey-xact.dk/LinkCollector?key=MTD523J8SJCP

Appendix D: Preliminary Timeplan

Date	Subject	Activity	Place	Responsible Group Member	Equipment
3rd of March		Finalize plans for field work with UNIMAS	Kuching	All	
4th of March		Observation Find out who we should be with us on the transect walk/ timeline mapping / GPS Asking community members if they can participate in photovoice	In the community all day	All All Gabriela	Notebook
5th of March	All from the community	Observation Transect Walk + GPS? (finding places to collect soil and biodiversity assessment) Find out who we should include in the timeline mapping	In the community all day	All Group All	Notebooks, paper/pen /computer, GPS,
6th of March	Relevant people from the community One member from each household	Participatory Timeline Mapping Questionnaire Preparation of presentation	Evening? Throughout the day / In the community Evening	 One person or groups of 2 per household All	Notes, paper/pen /computer Tablet Computers

7th of March	One member from each household	Presentation Questionnaire	Longhouse at 8-9.30 Throughout the day / In the community	All Group	Tablet
8th of March		Interviews Photovoice Soil sampling		All	Recorder Tools for soil sampling: - Plastic bags - Soil rings - Soil core - Spade
9th of March		Interviews Photovoice		Group	Recorder
10th of March		Interviews Photovoice		Group	Recorder
11th of March		Interviews Biodiversity		Group Group	Recorder Tools for biodiversity assessment: - Inclinometer (Vertex) - Meter stick (to measure the diameter of trees) - Handheld GPS
12th of March		Buffer day			

13th of March		Prepare presentation	Pantu District Office	All	
14th of March		Presentation		All	
15th of March		Departure from community to Kuching		All	

Appendix 2: Table of Applied Methods

Research Methods	
Social Science Methods	**Number**
Transect walk	1
Questionnaires	30
Semi-structured Interviews	6
PRA mapping	2
Participant observations	12 days
Natural Science Methods	**Number of Sites**
Biodiversity assessment	3
Water sampling	3
Macroinvertebrates Assessment	2
Soil bulk density	3
Ethnobotany	4

Appendix 3: Broad Interview Guide

Appendix 4: Interview 1

Appendix 5: Interview 2

Appendix 6: Interview 3

Appendix 7: Interview 4

Appendix 8: Interview 5

Appendix 9: Interview 6

Appendix 10: Questionnaire Outline

Appendix 11: Questionnaire Result

Appendix 12: Unstructured Field Notes

Appendix 13: Natural Data Results