Photo: Aitana Aizpurua Soto

Balancing the frontier: Smallholders, Sawit, and livelihood diversification in Sebemban

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Abstract

This study examines the factors that influence a diversification or concentration of livelihood strategies employed by the rural community in Sebemban, Sarawak, Malaysia. We ask the question *"What are the drivers of livelihood diversification or concentration in Sebemban?"* The study aims to investigate the socio-cultural, economic, environmental, and institutional factors that act both as drivers and outcomes of livelihood decisions, and discuss their relation to one another.

To do so, an interdisciplinary field study was conducted over a period of ten days in situ, employing a mixed-methods approach. The study combines participatory social science methodologies of participatory observation, interviews, focus group discussions and questionnaires, with the natural science methodologies of soil sampling, herbaceous species biodiversity assessment and water quality assessment.

The key results of the study finds that Sebemban maintains a diversity of agricultural livelihoods, with many people integrating oil palm cultivation into diversification strategies rather than replacing diversification. Socio-cultural, economic, environmental and institutional factors are found to shape possibilities for livelihoods in many ways, and are in turn shaped by livelihoods. These interlinkages are discussed through an interdisciplinary lens of sustainability, livelihoods and economics. As a case study, this project invites further study into the implications of smallholder oil palm and livelihood diversification in Sarawak, and in tropical land systems.

Key words: livelihood strategies, agricultural diversification, land use changes, outcomes, Sarawak

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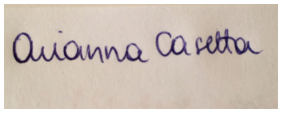
Arianna Casetta	WFS602	
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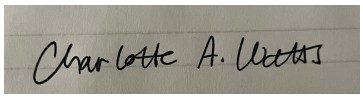
Charlotte Watts	NXM107	

Definitions and acronyms

Land use change: Changes in how land is used and managed through human activities, and changes in the physical properties of vegetation on the land surface (Meyfroidt, 2016)

Pulau Galau: Forested land that is intentionally preserved by a community or collection of communities; access to which is shared only by blood relatives of the communities.

Sustainable livelihoods: livelihood that "can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets while not undermining the natural resource base" (Scoones, 1998)

Tuai Rumah: Headman of an Iban longhouse

Wild meat: Meat from animals not associated with the forest, but wild animals and agricultural pests found in cultivated lands

NCL: Native Customary Land. Category of land classified by Sarawak Land Code, occupied by native communities and managed with their customs.

NTFPs: Non-timber forest products

SALCRA: Sarawak Land Constitution and Rehabilitation Authority

Sawit: Iban word for oil palm

Biodiversity and Soil Sampling sites acronyms:

HOP: Hill Oil Palm

ROP: River Oil Palm

PG: Pulau Galau

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1. Introduction

"Once you see an oil palm in a paddy plantation, that's how you know it's the last paddy that will ever be planted there." (Farmer in Sebemban).

The ability of smallholders to adapt to fluctuating economic and agricultural trends while fueling rural development is a key element in the Malaysian state of Sarawak. Iban communities constitute 30% of the total population of Sarawak, and have traditionally engaged in shifting cultivation while deriving their livelihoods from a variety of activities. These include the collection of forest products, garden cultivation, wage labour, logging, crafts made from non-timber forest products (NTFPs), as well as oil palm, pepper, and rice (Ichikawa, 2007).

Today, Iban lands are mosaic landscapes. Secondary forests intermingle with vegetation and farmland, as well as some remaining traditional cultivation strategies that have a role in conserving ecosystems and biodiversity (Ichikawa, 2007). Land use strategies are supported by the Iban social organisation, *adat*, which operates within the domain of a longhouse or village community. The *adat* is an expression of Iban culture and laws, encompassing decision-making processes and rules defining the access to and ownership of land and natural resources. *Adat* refers to native bodies of customs including the tradition and culture of the indigenous people (Sarawak Council For Native Customs And Traditions). Therefore, although considered part of the Iban tradition and culture, *Adat* is only partially recognized by the state. This means that in order for native lands to have a legal standing or be enforceable in a court of law, they must be officially acknowledged and given legal effect through specific legislative processes. This means if someone were to sell their land belonging to Native Customary Land (NCL) to a private company, the transaction would not be legally binding, as it belongs to the state.

The government of Sarawak provides a pathway to formal land title through the Sarawak Land Consolidation and Rehabilitation Authority (SALCRA), which was established in 1982 and focuses on poverty reduction through developing rural areas (Banerjee & Bojsen 2005). Currently, the primary means is oil palm development. Through SALCRA, landowners lease out

their unregistered NCLs for a period of 25 years, in return for dividends and legal title at the end of the term.

1.3 Study site

Figure 1: Map of Sebemban. Source: Google Earth

This research project is a single case-study of Sebemban, an Iban village located in the Malaysian state of Sarawak. Notable for a wealth of fruit orchards and vegetable gardens alongside oil palm, pepper, and rice, Sebemban stands out for its agricultural diversification, as opposed to other villages in the region where oil palm is predominant. Therefore, Sebemban serves as an ideal setting to explore crop diversification in the face of oil palm expansion.

1.4 Purpose

By investigating the decision-making factors and outcomes of livelihood strategies in Sebemban, this report contributes to the discussion of livelihood diversification and

concentration. It adds knowledge about local natural resource governance and community wellbeing. The socio-cultural, economic, institutional, and environmental dimensions of livelihood strategies are studied. Future development policies should consider these dynamics.

By means of analyzing the current livelihood strategies in Sebemban, this study aims to provide an answer for the research question: “What are the drivers for livelihood diversification or concentration in Sebemban, Sarawak?” In this way, the study will explore the link between decision-making factors and outcomes of the chosen livelihood strategies, building a circularity to their relationship. We analysed four macro-categories: socio-cultural, economic, institutional, and environmental.

1.5 Background

The 1970s witnessed the dawn of the cash crop economy in Sarawak, although it was not until the 1990s that cash crops gained ground as large scale plantations increased and smallholder cash crop production was promoted by the government (Mertz et al., 2012).

Cramb and Sujang (2011; 2013) explain that in the face of rapid economic development, native customary landowners understand that their lands are considered “idle” by the state. Oil palm becomes an opportunity to avoid this perception, allowing them to increase their income while asserting autonomy over their land. What were once marginal lands, are now well connected to markets, jobs, and services, particularly health and education. Through the development of transport infrastructure, “idle” lands now attract people who want to be closer to facilities. Moreover, these shifts in land use and livelihood strategies have major implications in the scope of land legitimisation and entitlement.

In contrast, Leha and Wong (2023) explain how economic diversification serves as a means of alleviating poverty and improving the overall well-being of rural communities. They refer to rural communities as being both the beneficiaries and the agents of change, while diversification is a mechanism to adapt to change. They define diversification as a means by which rural communities undertake agricultural and non-agricultural activities in order to make a living and earn money. In fact, smallholder production and commercialization of perennials and

tree crops has been promoted by the World Bank to reduce rural poverty (World Bank 2007, Snelder and Lasco 2008).

Notwithstanding, as explained by Cramb and Sujang 2013, this process overlooks the existing crop diversity of rural communities, as well as the inequalities that it entails. Li (2009) and Rachman et al. (2009) specifically point at the failure of the World Bank (2007) to recognize the rural impoverishment that can result from the processes of agricultural commercialisation, as farmers may lose access to land and other resources.

At the same time, the ability to adapt to change is reflected in Scoones' definition of livelihood, which is sustainable when "*it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets while not undermining the natural resource base*" (Scoones, 1998). Livelihoods are epistemologically positioned to recognize the agency and capabilities of communities, and emphasizes the role of natural resources by recognising the reliance on the environment. Preserving natural resources and diversifying their livelihood activities allows communities to secure long term sustainability of their livelihoods, strengthening their adaptive capacity and ensuring the continued productivity of natural resources over time (Natarajan, 2022; Scoones, 1998).

2. Methodology

This research project is grounded in interdisciplinary practice, and uses a mixed-methods approach of social and natural science methodologies to best gain insights into the wider scope of the research problem (Krishnan, 2009). The methodologies employed ranged from the structured and formal to the more informal methods, and as far as possible, we aimed to root our work in rural participatory appraisal within the timeframe given (DeWalt & DeWalt, 2011).

2.1 Participatory Observation

Participatory observation is a key element of the study, as it was actively used throughout the whole research. From day one, we took part in the daily activities of the villagers. This

helped build a relationship with the community, valuable not only for research but also from a personal and emotional point of view. By sharing our time and space with members of the community, we were able to understand their daily actions and choices, as well as their culture and points of view, trying to move away from any assumptions or expectations we had naturally set before our arrival (DeWalt & DeWalt, 2011). We participated in numerous activities with different members of the community, including cooking, playing with children, swimming in the river, being guests in their homes, trying on traditional clothes, taking part in celebratory events, listening to or singing their music; but also accompanying them to their plantations and harvesting rice. Participatory observation was especially helpful in understanding ethnobotanical practices; almost every day we ate meals from wild vegetables and fruits and sometimes wild meats, and alongside our hosts we picked fruits and vegetables from gardens and forests for group consumption, furthering our understanding of their ethnobotanical significance. Indubitably, participatory observation helped us to gain insights that complement information collected through other methodologies.

2.2 Interviews

Interviews were a primary source of information for our study. The goal was to gather both specific data and also allow villagers to share their knowledge on broader topics with us.

2.2.1 Unstructured Interviews

Unstructured interviews consisted of informal conversations and spontaneous discussions with members of the community. These allowed for conversational flexibility, establishing rapport and enabled the collection of relevant information regarding Iban culture, daily life activities, food procurement practices, changes in the landscapes and fauna over time, as well as current concerns and hopes for the future. Information about these topics was gathered during night conversations that took place when sharing meals and/or drinks, walking through town, in social gatherings, and in the longhouse, among others. In this way, unstructured interviews served as a strong base for our research and guided the selection of other methodologies (Jamshed, 2014).

2.2.2 Semi-structured Interviews

Semi-structured interviews took place throughout the fieldwork, but were more frequent at an intermediate stage, as we narrowed down specific topics we wanted to investigate. The introductory interview with Tuai Rumah Moss on the first day after our arrival was very important, as it allowed us to gain a preliminary understanding of the village (Appendix C1: I1), such as the history and its economic characteristics. Another semi-structured interview session concerned the consumption of NTFPs, foraging of forest resources, and gardening to investigate the role of the primary forest in the daily life of the villagers. For this session, 3 people were interviewed (Appendix C1: I2). We found semi-structured interviews to be more suitable because, compared to structured interviews, they give more space for dialogue, allowing interviewees to explore topics relevant to them (Brinkmann, 2020).

2.3 Questionnaire

A questionnaire (Appendix 4), was completed by 40 households belonging to all three longhouses. It was divided into three sections: section (A) includes the occupation and estimated income of respondents; section (B) is focused on their detailed economic profile and the sources of their income; and section (C) contains some perception questions (Rea & Parker, 2014) about their living standards. With this method, we aimed to capture the diversity of the livelihood strategies adopted by members of the community in a quantitative way. The questionnaire was conducted using a convenience sampling method. Data from the questionnaire was used in SPSS and Excel. We created summary graphs of the frequency of different livelihood activities. Statistical tests were performed to understand the relationship between livelihood diversification and income. These were chi-square tests, and an ordinal logistic regression. We chose these tests because the income data we had was categorical.

2.4 Focus groups

Focus groups were created for the matrix ranking exercise and the participatory community mapping exercise. These groups provided a good setting to analyze the social interactions of community members. By paying attention to how people discussed, justified, and

created consensus around a topic, valuable insights about agriculture and land use were gathered. Focus groups were used in these methodologies in order to establish a deeper understanding of local issues and opinions.

2.4.1 Matrix Ranking Exercise

Matrix ranking is an exercise that reveals preferences on the basis of multiple criteria (Martin, 2004). We used it to understand the considerations behind choosing to do a livelihood activity. As shown in Table 2 (see section 3.1), the top row of the matrix has different decision-making dimensions. The left-hand column lists the different livelihood activities that are present in Sebemban. For each combination of livelihood activity and decision-making factor, the participants were asked to assign a consensus score of 0-5. 0 indicating the lowest value, importance, or intensity, and 5 indicating the highest. We opted to score them in this way instead of ordinal ranking for two main reasons. The first is that two activities could have the same value, so to rank them ordinally would cause ambiguity. The second is that we had started with 5 predefined activities, and after the exercise was completed with these, we wanted the participants to add any other activities they considered relevant. These are shown in blue on the left-hand column. Ordinal ranking would make this impossible as all the activities would have to be re-ranked given the new set of activities. Taking this approach made the exercise more participatory in nature and we ended up with a comprehensive list of all the livelihood activities that are considered relevant in Sebemban.

2.4.2 Follow up focus group interview

Following the ranking exercise, the participants were invited back to discuss the results. This led to a focus group interview which generated the bulk of the information gathered from this exercise. We also asked the participants to score each decision-making dimension based on their relevance when deciding whether to do a livelihood activity. This is shown through the blue stars in each cell of the top row. Likewise, we asked them to score each livelihood activity based on its importance to the community. This gave us a firmer “ranking” and an understanding of what the core and peripheral activities are in Sebemban.

2.4.3 Community mapping

We chose to do community mapping in order to gain an understanding of how the community understood and prioritized their lands, assets, and resources in relation to a drawn map (Taliep and Ismail, 2023). The process of creating the maps facilitated discussion and surrounding livelihoods and the history of the community. There was an emphasis on past land uses, and understanding the dynamics of changes and transitions in agriculture and livelihoods.

The exercise produced three maps. Participants from all three longhouses were invited, and three separate but simultaneous mapping exercises were conducted in one large common area, where participants were grouped according to their longhouse. This was done in order to eliminate some of the potential biases, as we could then gain more equal perspectives from all members of the community, without one longhouse being more or less heard.

2.5 Ethnobotanical guided walk

To understand the ethnobotanical practices of Sebemban, we arranged a participatory guided walk focusing on food gathering practices and NTFPs (Vogl, 2004). The walk spanned multiple land use types, with the guide explaining both specific species and their use as well as explaining land management practices, land rights, and inheritance. The walk focused on the ethnobotany of the community, identifying plants and trees that are utilized as timber and NTFPs, as well as cash crops, vegetable gardens, fruit orchards, and rice fields. With a participatory focus, this methodology allowed for open-ended data collection through conversation with our guide, and gave us firsthand experience, as we along the way participated in picking rice and collecting plants to bring home for dinner.

2.6 Natural science methods

Figure 2: Map of the four repeating sample sites for soil, biodiversity, and water quality assessments, as well as WS1, the site for the first water sample. The rivers are included to accompany the two water sampling sites. Source: Google Earth

2.6.1 Biodiversity Assessment

A biodiversity assessment was conducted to investigate the potential environmental impacts of land use change. The goal was to compare the presence and diversity in different land use areas using the Shannon Diversity Index (Hill, 2005), focusing on herbaceous species given the importance they have been found to play in the health of overall forest ecosystems (Gilliam, 2007). We considered all the land use types occurring in the area, and identified the three most relevant for our study: a forested area to act as a "control" in representing biodiversity that is typical of undisturbed land in the region, a pepper farm to represent a less intensively cultivated and often intercropped land use, and two oil palm plantations representing a more intensively cultivated, monocropped land use.

Representative plots of 10x10 meters were selected at 4 sites we were able to gain access to (a dense forest, a smallholder pepper plantation, and two smallholder oil palm plantations of

similar size - one of which we had presumed was more intensively managed than the other) to examine how these land use changes may impact biodiversity. The forested area we visited was land intentionally preserved by the village, called ‘Pulau Galau’ and the selected plot was near to the gravity feed water supply for the village. This location was far from any agricultural cultivation.

Within a 10x10 m area at each site, two subplots of 2x2 m were chosen - with the goal of together being somewhat representative of the different densities and arrays of herbaceous species in the zone. In each subplot we then identified and documented every herbaceous species that was visible, and counted how many individuals of each species were present within the subplot. When we encountered a species that so densely populated the subplot (to a degree which it would be impossible to count every individual), we used a technique of counting the number of individuals of that species within three 20x20 cm squares within the subplot to capture examples of high, medium and low density. We then estimated the percentage of the sample plot covered by each density level, and used those counts alongside the percentages to calculate the total count of the species present in the sub-plot. This was necessary for four species, Hill Oil Palm SP1-S8 and SP1-S9 and River Oil Palm SP1-S3 and SP1-S4. The full calculation for each of the four species is shown in Appendix C.11.2 and C.11.3. For calculating biodiversity, we matched up the species at the sub-plots for each area to eliminate duplicate species, and calculated the Shannon index of the entire 10x10 plots, shown in Appendix C.11.4.

2.6.2 Soil Assessment

We collected soil samples from the same subplots as the biodiversity assessments. The goal of our soil analysis is to examine the impact that various land use types and crop management styles may have on soil fertility. Beyond our own curiosity, the residents of Sebemban expressed some concerns about the impact oil palm may have on soil health, in both smallholder and large scale contexts.. As we were unable to access SALCRA lands, we chose to work with smallholder plots, and were able to compare two local oil palm plantations, one on a hillside and another near a river.

At the Pulau Gulau, Pepper and Hill Oil Palm sites we collected soil samples from two separate 2x2 m subplots, and at the River Oil Palm we collected from a single subplot due to time constraints. Using an auger, within each subplot we collected soil from three soil pits at two depths (0-20 cm and 20-40 cm), and combined the 3 upper samples and, separately, the 3 lower samples to create a composite sample (Anderson and Ingram, 1993).

For each area of 10x10 meters, the steepness of the area was measured on a vertical run of 8 meters, except for the River Oil Palm, which was determined to be flat. The slope was found by measuring out the 800 cm horizontal "run", holding the measuring tape level from the highest point, and then measuring the vertical "rise" from the ground to the measuring tape. The slope was calculated in radians using the function ARCTAN (rise/run) and converted to degrees to express the angle of elevation.

For analysis, we conducted texture analysis testing on site in Malaysia (Thien, 1979), and using Munsell Soil Color Charts were able to make inferences about organic matter content. Laboratory analysis was conducted at the University of Copenhagen to analyze ammonium, nitrate, phosphorus, and pH levels, as well as Carbon and Nitrogen percentages. (Appendix C.14 details the methods for conducting each test). We were interested in looking at these measures as indicators of soil fertility.

2.6.3 Water Sampling

Water sampling was conducted to understand how agricultural activity impacts water security. Two locations were sampled; a downstream segment of a river, next to a rice field being converted to oil palm (WS1 in Figure 2), and a reservoir upstream (WS2 in Figure 2), also the source of the gravity feed water supply for the village(S3 in Figure 2). A YSI ProSolo Digital Water Quality Meter was used in-situ to directly measure the applicable parameters. Laboratory analysis was conducted at the longhouse with water brought back from each site. The UNIMAS team conducted lab analysis to determine Biochemical Oxygen Demand (BOD), phosphorus and nitrate parameters. Each test was run 3 times per site, and the results averaged. To measure the

prevalence of total and fecal coliform count we grew the bacterial colonies from agar plates for 48 hours, and counted the amount of colonies (Pelletier et al., 2006). The results are analyzed against the Malaysian national water quality standards (Appendix 7).

Table 1: Water testing parameters

Water testing parameters	
In-situ	*Laboratory Test*
pH	BOD_5@20°C (mg/L)
Dissolved Oxygen - DO (mg/L)	Phosphorus (mg/L)
Temperature (°C)	Nitrite (mg/L)
Conductivity (µS/cm)	Total Coliform Count (TCC) (count/100 mL)
Salinity (ppt)	Fecal Coliform Count (FCC) (count/100 mL)
Total Dissolved Solid (mg/L)	

2.7 Geospatial mapping

With the help of our UNIMAS partners, we used a handheld GPS to record the geoposition of the relevant sample plots for our soil sampling, water sampling, and biodiversity assessments, shown in Figure 2. All GPS points were imported as KML files into google earth to use for analysis. This geospatial data was recorded with the aim of being used for visual analysis and to cross reference with maps of soil types and agricultural compatibility of the area, helping us understand how the geo-biophysical environment can affect our results.

3. Results

This section is divided into five subsections and presents the results of the different methodologies conducted during the field study. The first subsection introduces the core

livelihoods and land uses of Sebemban. Subsection 2, 3, 4, and 5 explore the drivers of choices and practices in the community, as well as measured and perceived outcomes of how these choices affect changes for the four respective themes of socio-cultural, economic, environmental, and institutional factors.

3.1. Introduction to Land Uses and Livelihoods in Sebemban

This subsection introduces the results that explore the diversity of past and present livelihoods and land uses in Sebemban.

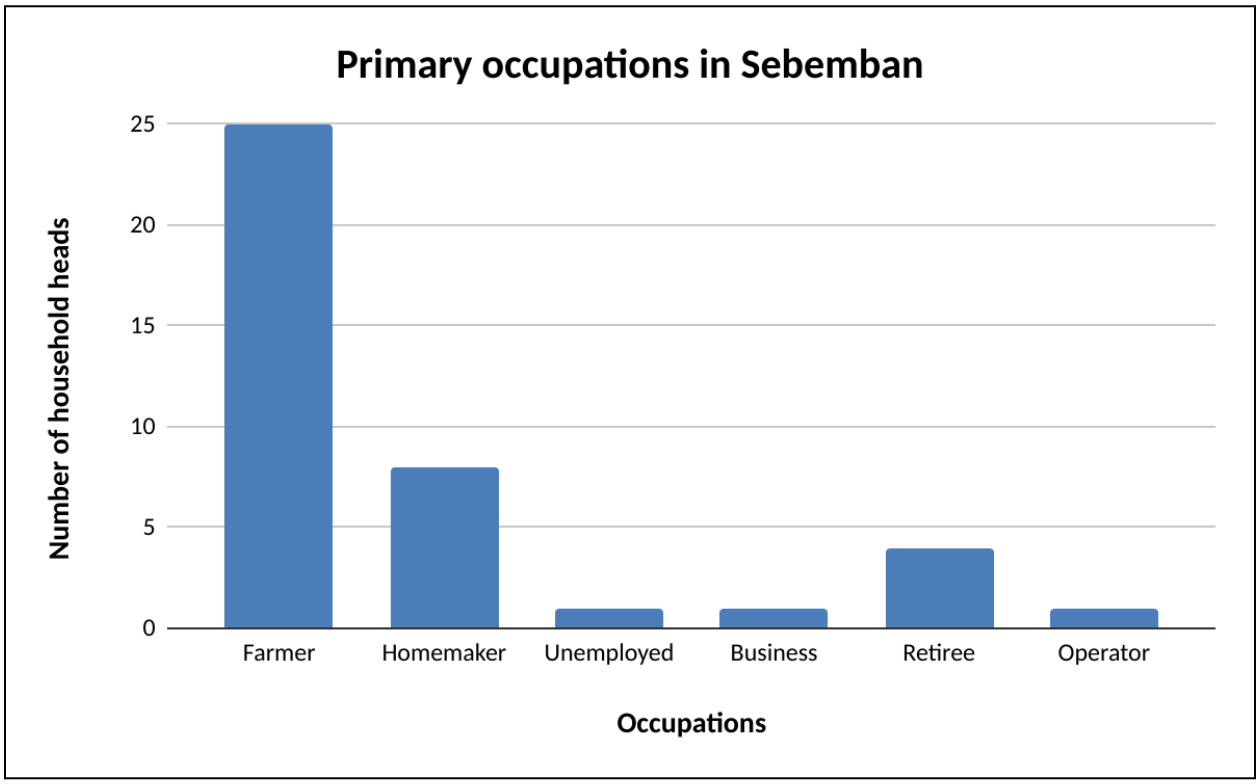


Figure 3: Main occupations in Sebemban. Data are from the questionnaire, section A.

Through interviews, questionnaire results and participation in some of the daily activities of Sebemban, we were able to confirm that the primary livelihood activity for the residents in Sebemban remains farming (see Figure 2). Some members of the community work outside of the

village, or have in the past participated in off-farm labour (i.e. oil/gas, cleaning, construction, factory positions, small business, public service, etc.) or doing wage labour in oil palm plantations.

Table 2: Matrix Ranking Exercise

	Economic value *****	Own consum-ption ***	Labour ****	Mainten-ance *****	Risk *****	Environ-mental impact *****	Location *****	Subjective Rank Of Importance
Oil palm	*****		*	*****	*****	*****	*	*****
Pepper	****	*	***	*****	*****		***	*****
Paddy	***	****	****	****	*****			*****
Vegetables	**	*****	*****	*	****		*	****
NTFPs	*	***	*					****
Fish farming	***	****	*	****	****	*	*	***
Swiftlet farming	****		*	*****	****	*	****	***
Livestock rearing	****	*****	***	****	**	**	*	****
Fruit orchard	*****	*	***	**	**		**	*****

See Appendix C3.2 to read the explanation of each dimension and further notes about the exercise.

Note: Labour should be interpreted as high score = low labour cost/intensity; low score = high labour cost/intensity The reverse logic applies for other dimensions

At the end of the exercise, we asked participants to score each individual livelihood activity based on their overall importance to the community. This gives us a general ranking.

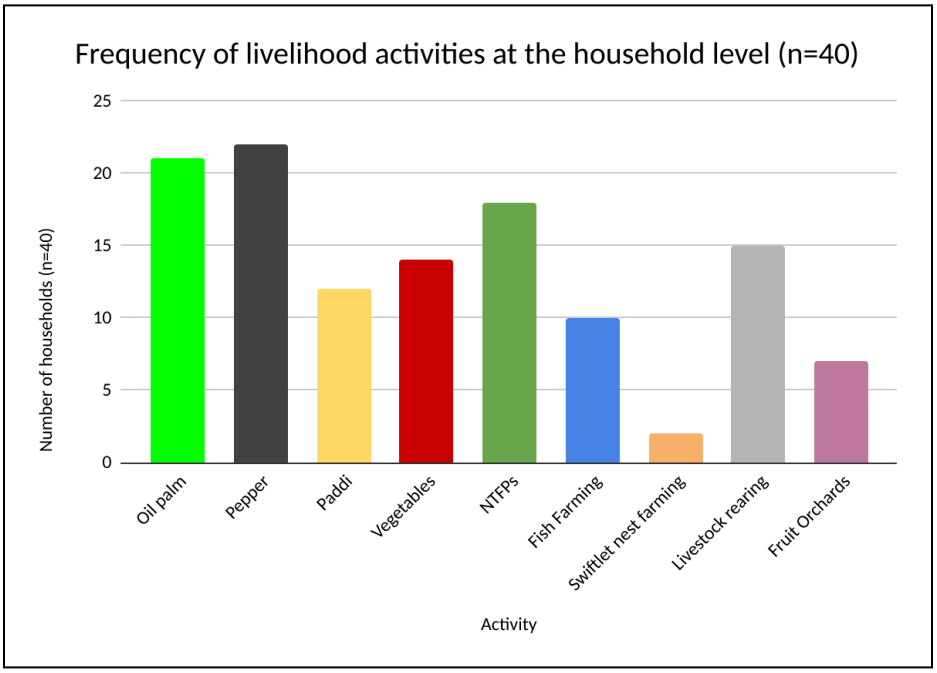


Figure 4: Frequency of livelihood activities at the household level (Appendix C5)

Livelihood activities are listed in Table 2, together with the score in different dimensions, awarded by the focus group during the Matrix Ranking Exercise (Appendix C3.2). Here, we found that the main activities are oil palm, pepper and paddy. The frequency of livelihood activities are illustrated in Figure 3. Along with the above mentioned three main crops, other activities are carried out, mostly growing vegetables and livestock, as well as collecting NTFPs. These other activities are mainly for own consumption and as a source of supplementary income (Table 1).

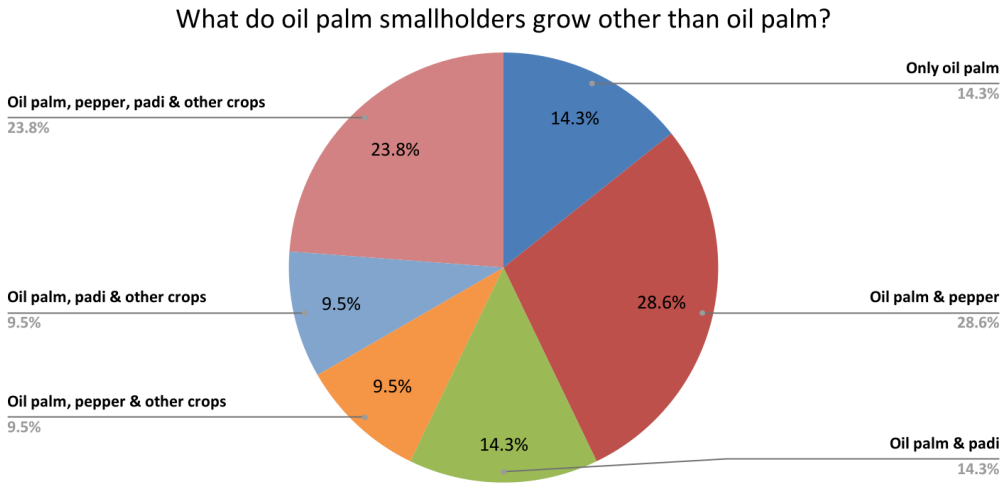


Figure 5: What oil palm smallholders grow other then oil palm (Appendix C5.2)

Palm oil is the largest source of income in the village. We analysed the degree of diversification of livelihood strategies of palm oil farmers, to see if they tend to concentrate on this crop. Surprisingly, we saw that only 14.3% cultivate only palm oil. Overall, oil palm smallholders have a diversified agricultural strategy: 28.6% cultivate oil palm and pepper, and 23.8% have oil palm, pepper, paddy and other crops (Figure 4). In any case, these data represent only the smallholders' oil palm and not the land managed by SALCRA, so that the full land use is not included in this specific analysis.

The participatory community mapping exercise allowed for the understanding of the community's perception of the village and its surroundings. They outlined houses, roads, rivers, forests, fields, and plantations, as well as demarcating the land that belonged to each household. In this way, the exercise sheds light on land ownership and land boundaries that were often defined by natural resources, in particular rivers. Conducting a community asset mapping revealed new information about the history and evolution of livelihoods in Sebemban, and triangulated our existing knowledge. This included new information about current livelihoods, such as pig raising and agricultural transitions, as well as information about the past location of the village longhouses.

Through this exercise, we were able to obtain a historical view of land use changes. We found that fields that were previously used to plant rubber have become smallholder oil palm plantations over the past few years, which illustrates oil palm expansion in the area. Paddy fields are still present in the area, although not as much as before. In addition, new houses have been built to accommodate newcomers and growing families. Churches have also been built in Sebemban, the Anglican Church, the New Testament Church and the Seventh Day Adventist Church.

We also learnt about the existence of a helicopter landing site that was used to bring villagers to the hospital, as there were no roads. With the construction of new roads in the 1970s that were financed by either logging or oil palm companies, villagers are now connected to hospitals and other facilities that they might need, and the helicopter landing pad does not exist anymore. Before the road construction, the only way to reach Pantu was by boat via the river. This highlights the remoteness of the village and the lack of infrastructure around it, which can currently only be financed through private companies, illustrating a transactional relationship driving development.

Figure 6: Community Mapping Exercise, Map 1 (Drawn by Tuai Rumah Larry's longhouse). The map shows Sebemban and its houses, roads, and crops. Houses are centred in the middle of the map. Crops were specified with the type of cultivation in the present (in blue) and in the past (in red). In addition, for each piece of land, the name of the owner was assigned. Rivers are drawn in blue, and bridges in orange. More specific details are also present, such as the cellphone tower and the helicopter landing pad.
See Appendix for other 2 maps.

Figure 7: A group of community members working on their map. Photo: Arianna Casetta.

Overall, the three maps displayed similar characteristics, such as the longhouses, roads, the 'naked' cellphone tower, rivers, and plantations. It can also be observed that oil palm is the prominent crop in all three maps.

However, in comparing the three, some differences were found. Map 1 (Figure 6) was the only map to show land use transitions, mainly from previous rubber to current oil palm; it also provided very detailed and insightful land boundaries. This map also included swiftlet farming, and paid attention to the areas too swampy for cultivation. However, it included no rice fields, whereas Map 3 (Appendix C.3.1) had many. Moreover, the SALCRA site on Map 2 (Appendix C.3.1) is representative of how SALCRA comprises a part of livelihood diversification today, and a long term strategy for owning the land, corroborated through interviews (Appendix C1: I1, I4).

None of the maps depicted vegetable gardening or fruit orchards. Despite this, interviews and participatory observation implicate these strategies as be important components of livelihood

diversification (Appendix C.3.3; C.3.1) In assessing the land-based subsistence strategies for accessing food in the community, we can distinguish five main categories of livelihood activities, shown in figure 8: Gardening, foraging, farming, hunting, and fishing. Note that this is representative only for a time frame of two weeks, during one specific season, and these are locally produced food sources only; External sources of food, such as trading with other villages and buying from nearby markets like Lachau, are not included in Figure 8.

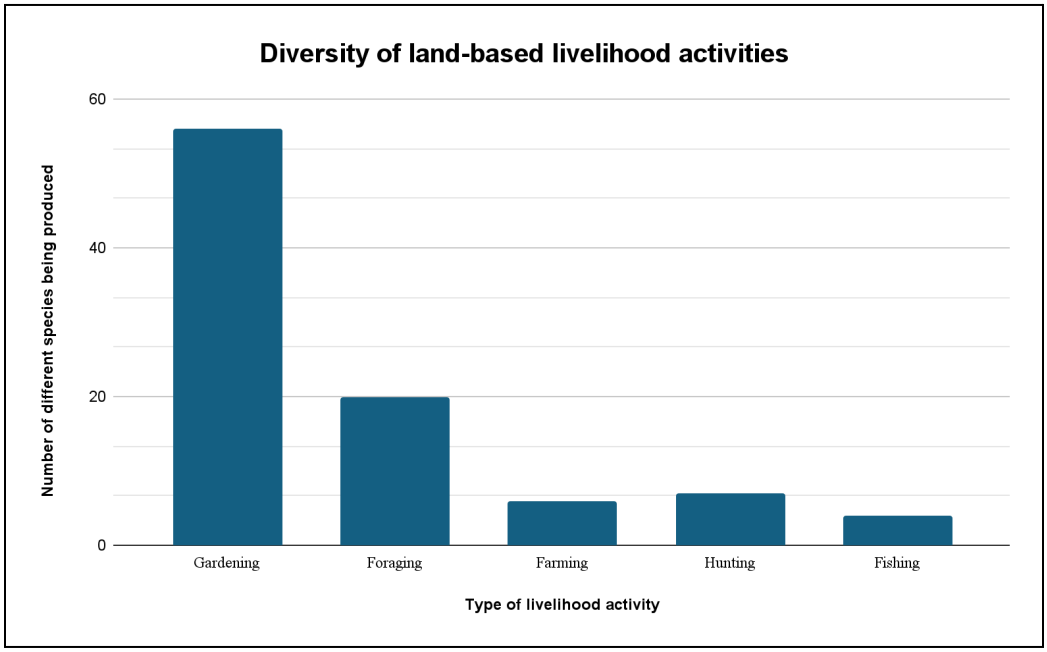


Figure 8: Amount of internal modes of accessing food practiced in Sebemban, ordered by type of sourcing. The full breakdown of livelihood activities is found in Appendix C.12 & C.13

Gardening represents a major food source for the community: Through a mixture of home gardens, small fruit orchards, intercropping on fields, and gardening on fallows, over half of all the different food sources internally produced in Sebemban are gardened. Furthermore, the community is able to supplement their diets with food hunted or collected from the wild. In the forest, people hunt for wild meat and collect fruits, vegetables, and edible plant species (NTFPs). And while some of the bushmeat would be considered NTFP, many sources of meat are non-forest bushmeat, which we can simply consider wild meat. Examples of wild meat include rodents and pythons from oil palm plantations, and *burung pipit*, a finch considered a pest for

rice cultivation. Figure 8 shows how foraging and hunting together make up 29% of the internal food sources. This practice allows the community to supplement their diets with sources of meat and greens. In this way, the forest and its resources take on a gap-filling function (Angelsen&Wunder, 2003).

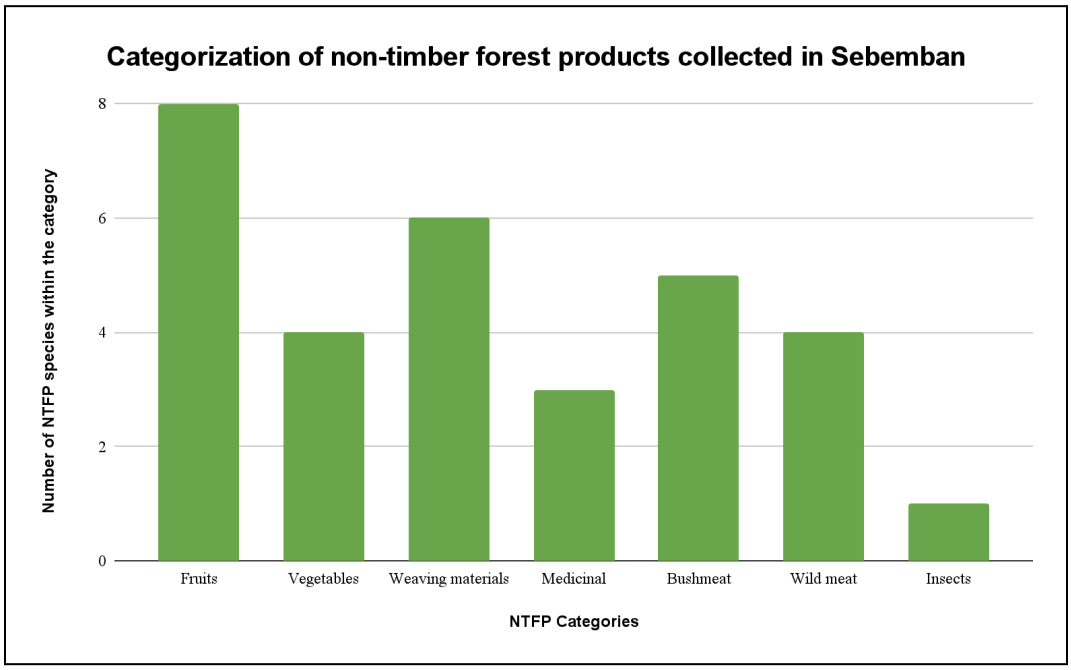


Figure 9: Overview over the amount of different NTFPs gathered in Sebemban, subdivided into type of NTFP

As is seen in Figure 9, the two most prevalent NTFPs are fruits and wild meat, even excluding the category "wild meat". Weaving materials also play an important role in the village's culture, as we will see in the following sections (see section 3.2).

In Sebemban, as with other food systems based on intercropping and agroforestry , there is often no clearly delineated difference between which fruits and vegetables are grown or gathered. Several kinds of NTFPs, such as jackfruit and *uchong*, are managed wild plants, and in some cases even planted and grown purposefully. In one case, a family grew their own *bemban*, traditionally a NTFP, by transplanting seedlings from the forest onto their own land. Similarly, there is a loose distinction between gardens, intercropping, orchards, and fallows. Some fallows are used for growing vegetables, and many pepper plantations are intercropped with gardens.

3.2. Socio-cultural drivers

3.2.1 Traditional crops

Rice cultivation has a significant role in Iban culture, and maintaining this crop is a way of sustaining their culture. It was one of the first crops in the village, as well as an early Bornean agricultural activity on which Iban subsistence is centred (Appendix C1: I1). It constitutes a substantial part of the villagers' diet, and it is present in every meal of the day. Rice is cultivated mainly for subsistence, but is also traded within the village, and in other towns when there is a surplus in the yield (Appendix C1: I6; I7; C.3.2, C12). Also pepper is traditionally grown in Sebemban, and in Sarawak it has been farmed for about a century. For some residents it is a leisure activity, and it is used both as a means of exercise to keep one active, or to relax and spend some time in their garden.

The current expansion of oil palm plantations has substituted rubber plantations and has also decreased the number of rice and pepper farms. Rice is no longer a cash crop in Sebemban, but rather a crop for self-consumption. Some members of the community have completely given up rice cultivation, and rely on local markets to get rice. In the face of rapidly expanding oil palm plantations, the cultural value of rice and pepper is jeopardized.

3.2.2 Cultural value of forest and NTFPs

Forests have a cultural value for the community. The presence of the Pulau Galau, for example, reflects the spiritual value of the forest embedded in the Iban tradition. Some interviewees stated that they have a strong connection with the forest, both for cultural reasons and for its role as a source of food and income (Appendix C1: I2 - Answer 1; I5). This connection is also expressed in figures 8 and 9, showing the breath of products gathered from the forest. Respondents also highlight the importance of preserving the forest in order to be able to rely on it when needed, but do not express concern about the impact of a potential agricultural expansion on preservation. The land that Sebemban occupies through NCL is vast. In this area, a

lot of land remains untouched and the forest will be preserved as long as agriculture expands close to the village (Appendix C1: I2 - Answer 1; I5).

The collection and craft of NTFPs such as bemban, bamboo, and ratan by women plays an important role in the Iban culture, and has been passed on through generations. Women make crafts that accommodate the needs of everyday life (See Box 1). These items are made for personal use, but sometimes they are also sold within the village.

Traditional Iban handicrafts include big baskets to carry on the shoulders and collect fruits, vegetables, or to transport their knives or tools; smaller baskets to be tied around the waist and carry the rice collected in the fields (Figure 11, 12); a sort of open basket in which they dry pepper or shake to get the rice grains out; carpets in which they dry the rice or use for sleeping; cone hats made with *akah*, used by women to collect the harvest (Figure 10); and different crafts for decorating their houses (Appendix C1: I2, I5, I7).

Figure 10 (above): traditional cone hats made with akah, used to protect against the sun while collecting the harvest

Figure 11 and 12: To the left, a PVC basket used to collect the harvest. To the right, the same baskets, but made of bemban.

Box 1: Traditional Iban handicrafts. Photos: Arianna Casetta (PVC basket and hats); Kenneth (bemban baskets).

Today, the production of these handicrafts has declined, with a lack of vertical knowledge transfer, as the knowledge is in the hands of older women. Young women in the community expressed that they have no interest in learning about these practices as they are very time

consuming and require skills. In addition, bemban and ratan are being replaced by PVC strips, as these are cheap, colourful, and easy to procure. As a result, the crafts and carpets decorating the houses of Sebemban are now made out of PVC (Appendix C1: I7).

3.3 Economic drivers

3.3.1 Economic: Core and supplementary income sources

Oil palm is a major source of income in Sebemban. Its high economic value drives the concentration of this crop (Appendix 6.1). At the time of writing, smallholders in Sebemban receive 680 RM/mt for oil palm fruit (Appendix C1: I1). Oil palm is not as location-sensitive as other crops. One individual is converting his paddy field to oil palm as the paddy was failing in the swampy conditions (Appendix C1, I13). This is why the matrix ranking participants scored it low for the location dependency dimension. Oil palm has a very high yield per unit of land. It takes 3 years to start fruiting and thereafter can be harvested twice per month, year round. These considerations make oil palm cost-effective relative to other crops.

Pepper is primarily grown as a cash crop. From the questionnaire data, 21/24 pepper farmers grow it for selling (Figure 3). Its low market price at 12-14 RM/kg coupled with high maintenance costs disincentivizes production. Paddy is mostly grown for personal consumption, but there is still a market for it, both within the village and in other nearby towns. Both pepper and paddy can only be harvested once per year. The relative economic value of these core activities is illustrated in the Ranking Matrix (Table 1).

Other livelihood activities act as supplementary income sources. As we learned from some interviews (Appendix C1: I5), the forest plays an important role as a source of income. Specifically, wild fruits and products from fruit orchards have high market value, comparable to oil palm. Fruits like durian, *akar kubal* and *dabai* can be sold at a very good price on the market given their seasonality and, in the case of *akar kubal*, rarity (Appendix C1: I6). Swiftlet nest farming is highly profitable, with a price of ~1000 RM/kg, but is a challenging and unreliable income source. Only a few people in the village practice it.

Interestingly, while rubber is not actively being tapped in Sebemban, there is at least one plantation that we know of which is being kept on reserve in case profitable rubber prices ever return.

While remittances and off-farm income sources were not the focus of the study, some results suggest they are significant sources of funds and investment opportunities. During conversations with questionnaire respondents, some mentioned receiving remittances from family members. In a focus group interview, an elderly lady told us how her son is a tour guide in Indonesia, and has a hardware business in Kuching. For older villagers, leasing their land to SALCRA is common because they cannot work the land anyways. However, this lady is not doing so because her son envisions opening a palm oil mill there using his wealth generated from off-farm activities (Appendix I.5).

A macroeconomic challenge facing Sebemban is high fertilizer prices (Appendix 6.2). Oil palm requires more fertilizer the older and bigger it gets. Farmers already spend more on fertilizer each year due to volume requirements; increasing fertilizer prices compound this, making oil palm less profitable. One interviewee commented that because swidden cultivation is no longer practiced, more fertilizer is necessary than before, as this process resulted in natural fertilization (Appendix C1: I3). Government fertilizer subsidies do exist to alleviate some of this pressure (Appendix C2: I1).

3.3.2 Diversification and economic outcomes

Concentration of oil palm is perceived to have an economic risk due to the permanence of plantations. When asked about what would happen if the market for oil palm crashed, interviewees said that those who can afford it would clear the land and plant something new. Less wealthy people would be harmed greatly because they would be unable to clear the land (Appendix C1, I3). During the matrix exercise, participants corroborated the importance of recyclable land. The reason why they gave oil palm a high score for environmental impact is

because of how the roots stay in the soil, making it difficult to convert the land. The economic implications of recyclable land are specified in the discussion section.

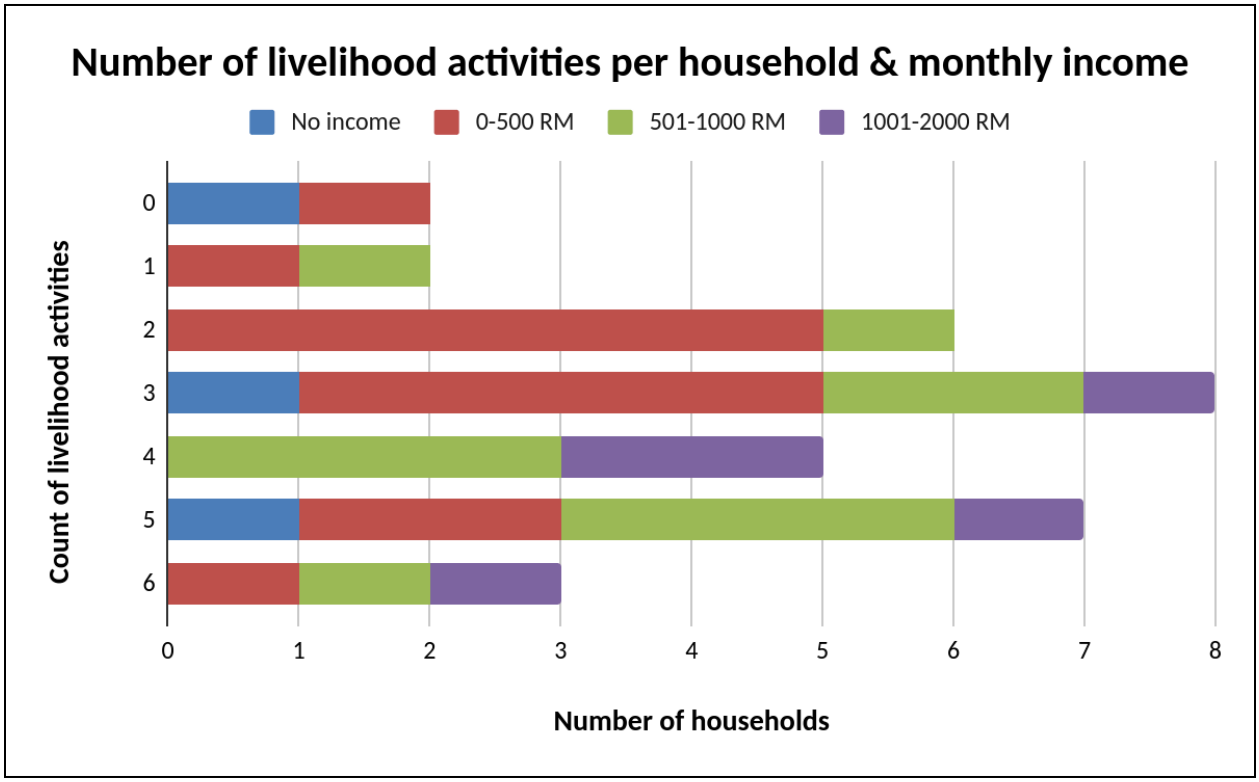


Figure 13: Visualization of income levels in relation to the number of livelihood activities

Using the questionnaire data, we wanted to understand whether livelihood diversification influenced income. Figure 13 shows the distribution of livelihood diversification, and how income levels change proportionally as diversification varies. From this visualization we find that the proportion of higher income households rises with livelihood diversification. For example, at 2 activities, 83% of households make less than 500 RM/month. At 4 activities, all households make over 500 RM/month, and 40% make 1001-2000 RM/month. Interestingly, at 3 and 5 activities, 13.3% of households do not earn any income, while another 13.3% earns 1001-2000 RM/month.

With income data gathered as a categorical variable, we were constrained in how we could statistically assess the impact of livelihood diversification on income. Two tests were performed: a chi-square, and ordinal logistic regression.

Observed values

Income level	Diversification level 0	1	2	3	4	5	6	
No income source	1	0	0	1	0	1	0	3
<500	1	1	5	4	0	2	1	14
501-1000	0	1	1	2	3	3	1	11
1001-2000	0	0	0	1	2	1	1	5
	2	2	6	8	5	7	3	**33**

Expected Values

Income level	Diversification level 0	1	2	3	4	5	6
No income source	0.1818181818	0.1818181818	0.5454545455	0.7272727273	0.4545454545	0.6363636364	0.2727272727
<500	0.8484848485	0.8484848485	2.545454545	3.393939394	2.121212121	2.96969697	1.272727273
501-1000	0.6666666667	0.6666666667	2	2.666666667	1.666666667	2.333333333	1
1001-2000	0.303030303	0.303030303	0.9090909091	1.212121212	0.7575757576	1.060606061	0.4545454545

P-value: 0.4905760838

Figure 14: Chi-square test for association between income and livelihood diversification

The 7x4 chi-square test yielded a p-value of 0.49. We fail to reject the null hypothesis that income and livelihood diversification are not associated. However, this result is unreliable as expected values should be at least 5 in 80% of the cells for the test to be accurate (McDonald, 2014).

Observed values

	0-3 activities	4-6 activities	
<500	13	4	17
501-1000	4	7	11
1001-2000	1	4	5
	18	15	**33**

Expected values

	0-3 activities	4-6 activities
<500	9.272727273	7.727272727
501-1000	6	5
1001-2000	2.727272727	2.272727273

P-value: 0.02774482667

Figure 15: 2x3 chi-square test

Observed values

	0-3 activities	4-6 activites	
<500	13	4	17
501-2000	5	11	16
	18	15	33

Expected values

	0-3	4-6 activites
<500	9.272727273	7.727272727
501-2000	8.727272727	7.272727273

P-value: 0.00912517766

Figure 16: 2x2 chi-square test

Due to this limitation, we performed two more chi-square tests. One was a 2x3 matrix which grouped livelihood activities into two ranges, and consolidated the "No income" category

with <500. This gave us a statistically significant p-value of 0.0277. The next was a 2x2 matrix which consolidated income further, with a 501-2000 range. Statistical significance increased with a P-value of 0.009. The trade-off of lumping categories together like this is that it masks variations. However, because it gives us the data requirements needed for the chi-square model, we obtain an accurate result. From this, we find an association between income and livelihood diversification, but we do not know the strength of correlation.

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	41.344			
Final	28.931	12.414	6	.053

Link function: Logit.

Pseudo R-Square

Cox and Snell	.314
Nagelkerke	.343
McFadden	.152

Link function: Logit.

Figure 17: Ordinal logistic regression with income as dependent variable, livelihood activities as independent

Ordinal logistic regression also revealed association between income and number of livelihood activities. The p-value was 0.053. Given our small sample size (n=33) among other limitations that increase the uncertainty in our results, it would be reasonable to use a wider confidence interval of 90%. Using this we would reject the null hypothesis that income and diversity of livelihood activities are unrelated. The McFadden R^2 nevertheless indicates that livelihood diversification only slightly explains income variation. This is expected because the analysis does not consider the type of livelihood activities, only the count.

3.4 Environmental drivers

While Sebemban expresses concern for environmental issues, there is generally little concern for the future of livelihood strategies in the community. The main exception is the cultivation of oil palm, which is widely perceived to have more environmental impacts, and many express concerns about soil degradation due to oil palm hindering future agricultural possibilities (appendix I.4; C.3.2). Oil palm plantations are also mentioned as a cause when

discussing loss of fauna biodiversity and changing animal patterns. Yet these concerns are tempered by the sheer amount of land in Sebemban – one interviewee said that as there is still plenty of unused land, future generations will be able to grow whichever crops they wish (Appendix I.5). In this way, the abundance of land is an environmental driver of both agricultural diversification and concentration.

In the follow up focus group discussing the matrix ranking (Appendix C3.2), several environmental factors were discussed, and location was considered to be very important in land use decisions, ranked at a value of 5. For swiftlet nest farming, the placement of the warehouses is highly influenced by the environment. With the exception of one warehouse, all the farms are placed in the hills, away from the main settlement.

At times, environmental factors affecting land use and livelihood choices are driven by their historical background. This is especially true when considering how previous generations of the Sebemban community grew crops and managed their lands, as these choices influence today's land uses. Scattered throughout the lands in and around Sebemban are trees established by the previous generations of the community. These trees have specific important functions, either being old fruit trees, like durian, or important species for artisanal timber logging.

3.4.1 Water security for forest conservation

Water security was expressed to be an important concern, and a driver for the community to conserve forested lands. A gravity feed reservoir, the source of Sebemban's tap water, is located in the Pulau Galau. When on the water sampling hike, an informant discussed the concern around agriculture activity polluting the water. For him, the water sampling was important to see if it is safe to drink.

Table 3: Water sampling results

Parameter	WS1: Stream next to plantation	WS2: Gravity feed reservoir	Remarks

In-situ			
pH	6.74 (Class II)	6.34 (Class II)	• Slightly acidic water
DO (mg/L)	4.80 (Class III)	5.84 (Class II)	• 18% lower in Site 1
Temperature (°C)	24.20	24.10	• Normal temperature for tropical weather
Conductivity (µS/cm)	83.90	84.30	• Low conductivity levels
Salinity (ppt)	0.04	0.04	• Low salinity levels
Total Dissolved Solid (mg/L)	54.60	54.60	• Low TDS levels
Laboratory Test			
BOD5@20°C (mg/L)	2.7 (Class II)	3.14 (Class III)	• Higher levels in Site 2 can be explained by organic build-up in reservoir
Phosphorus (mg/L)	0.08 (Class II)	0.05 (Class II)	• Low phosphorus levels
Nitrite (mg/L)	0.06 (Class II)	0.09 (Class II)	• Low nitrite levels
Total Coliform Count (TCC) (count/100 mL)	3475.33 (Class II)	583.50 (Class II)	• 86% higher in Site 1
Faecal Coliform Count (FCC) (count/100 mL)	107.50 (Class IIB)	54.83 (Class IIA)	• 96% higher in Site 1

Table 4: Malaysian water quality standards classes (Department of Environment Malaysia, 2021)

Class I	As a water supply: Practically no treatment necessary Suitable for very sensitive aquatic species
Class IIA Class IIB	As a water supply: Conventional treatment advised. Suitable for sensitive aquatic species Recreational body contact
Class III	As a water supply: Extensive treatment advised, livestock can drink Tolerant aquatic species

There are notable variations between the two locations. While inconclusive, the results indicate that water quality in Site 2 is favourable. For instance, TCC and FCC were significantly higher in Site 1. For the gravity feed reservoir, the only parameter that is Class III was

Biochemical Oxygen Demand. This parameter does not have direct relevance for drinking water safety (Jouanneau et al., 2014).

3.4.2 Biodiversity

In interviews, participants discussed biodiversity loss in terms of decreased wildlife and availability of NTFPs like bushmeat, fruits and vegetables. One respondent told us biodiversity is a key concern for preserving natural forests, expressing that it is a matter of survival. Numerous sources echoed the idea that deforestation caused by oil palm and timber logging has resulted in biodiversity loss and a negative impact on livelihood strategies such as hunting, fishing and foraging (Appendix I.3; I.5; I.8; I.11). The community has observed a significant decline in different species such as orangutans, wildcats, porcupines, and binturongs, among others. Moreover, this argument was supported by the participatory observations performed during walks through the village, plantations, and forests, in which rotting fruits and vegetables were found on the floor as they weren't being eaten by animals (Appendix I8). Hunting is no longer considered an economic option, as there are not enough animals anymore. This is perceived to be caused by disturbances from human activities, through intensively transforming activities such as clearing the land for logging and oil palm plantations (Appendix I8).

In contrast, other wild animal populations remain stable, such as monkeys (long tail macaques in particular), mouse deers, black leopards, gibbons, slow loris, otters, common palm civets, and flying squirrels (Appendix I8).

Notably, although wild game has significantly declined, the prevalence of some species have increased. Oil palm plantations attract porcupines. Porcupines eat the leaves of recently planted oil palm, destroying the plant. A member of the community claimed that 200 or her oil palms were eaten by these animals. There has also been an increase in pythons, as fallen palm fruit attracts rodents, and these attract snakes, which are caught and eaten by the community (Appendix I8; I.11). So while biodiversity loss is an externality of oil palm, it has also resulted in a new food source.

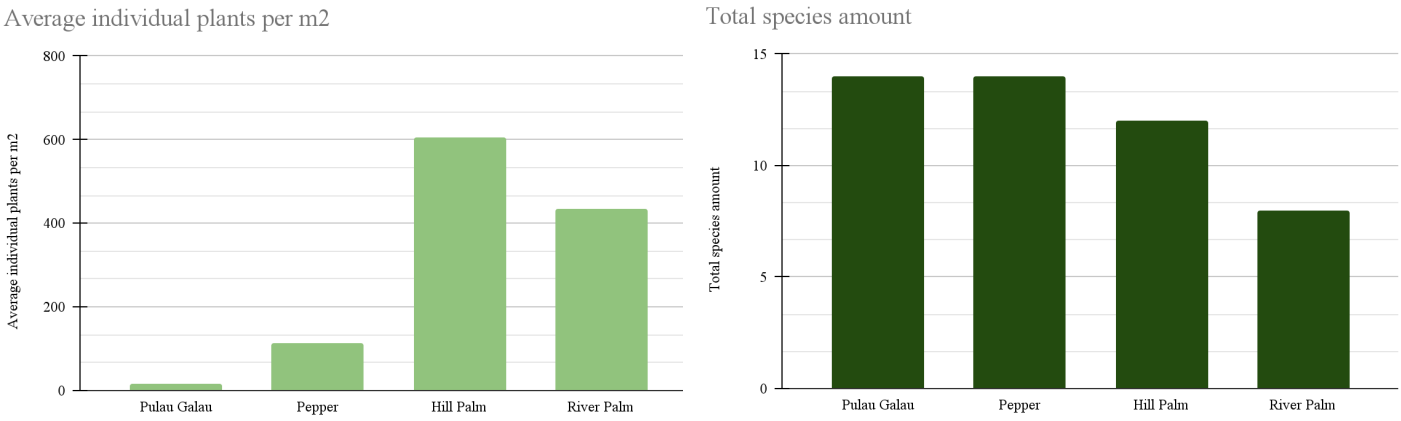


Figure 18: To the left, The amount of counted plants calculated to individual plants per m2

Figure 19: To the right, Total amount of species counted at the four different sites

Figure 18 and 19 show how the oil palm plantations are simultaneously the plots with highest amount of herbaceous plants per m2 yet also the plots with the lowest species diversity. Meanwhile, the pepper and Pulau Galau have the highest count of individual species, each at 14, but have markedly fewer individual plants per m2. This is further expressed considering that the tables don't include some species from Pulau Galau, which were removed upon discovering they were tree saplings as opposed to herbaceous plants (Appendix C.11.5). However, if taking these species into account, the Pulau Galau becomes the land use with the highest number of different species, and the lowest total count of plants.

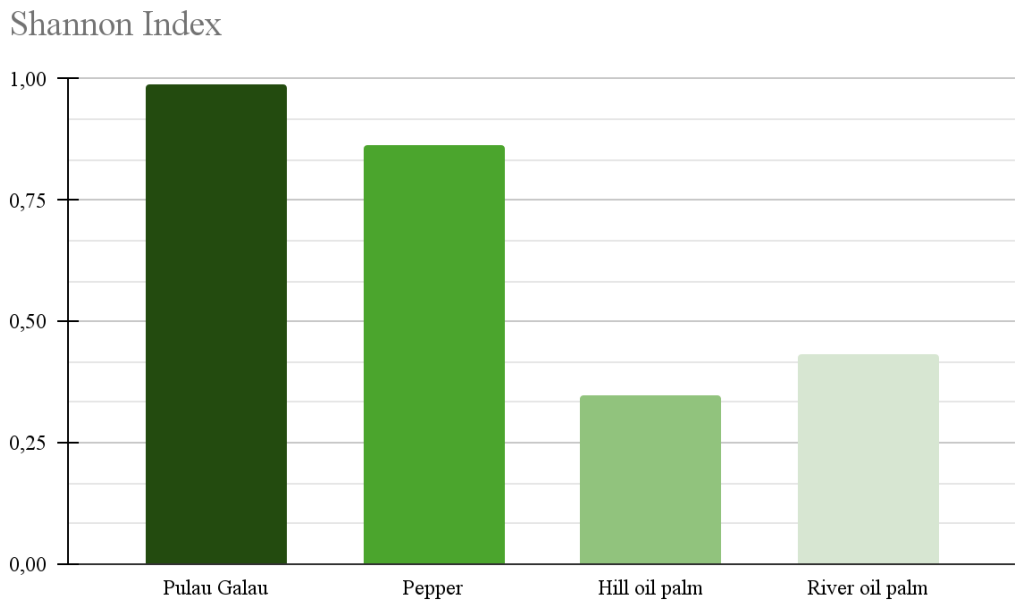


Figure 20: Shannon index of herbaceous species biodiversity on different land use types

To understand the biodiversity of herbaceous species, a Shannon index is calculated for each of the four sites, shown in Figure 20. This calculation elaborates on the pattern identified in Figures 18 and 19, as it illustrates how biodiversity is a factor of not only total plant amount, but also distribution of individuals across species count. What is discovered is that the Pulau Galau has the highest biodiversity and Hill Oil Palm and River Oil Palm have the species lowest biodiversity, despite having the highest individual plant counts (figure 18), which is expected, as oil palm support low species diversity (Savilaakso et al., 2014). Both plots are both managed with pesticides and clearing of the underbrush along continuous fertilizer application, as opposed to Pepper, which is cleared less, and the Pulau Galau, which grows wild. The low species diversity but high plant count suggest pioneer species that are able to quickly establish and spread on cleared land, which again is corroborated by Savilaakso et al. (2014), who find community composition changes on Oil Palm plantations.

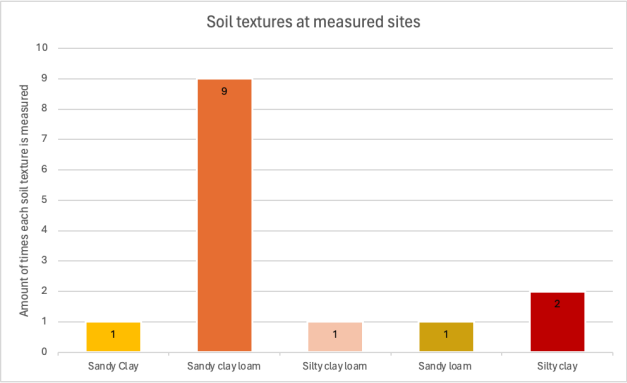
3.4.3 Soil

Several community members expressed concerns over soil quality and especially about soil degradation in relation to oil palm cultivation, explaining how oil palm makes the land

unsuitable for other crops. Choices surrounding agriculture and land uses are often influenced by soil quality, whether real or perceived. This subsection explores how soil can drive livelihoods, as well as the outcomes of land use choices on soil health.

Table 5: Characteristics of the four soil sampling sites

Sample Plot	**Location**	**Soil Series**	**Soil Texture**	**Terrain and slope**
SP1	Pepper	Jagoi, Oxisol	Sandy clay & sandy clay loam	Slope: 4^{O}
SP2	Hill oil palm	Jagoi, Oxisol	Sandy clay loam & silty clay loam	Slope: 7.8^{O}
SP3	Dense forest	Tarat, Oxisol	Sandy clay loam & sandy loam	Slope: 9.1^{O}
SP4	River oil palm	Sedau, Alluvial Soil	Silty clay	Not measured - flat



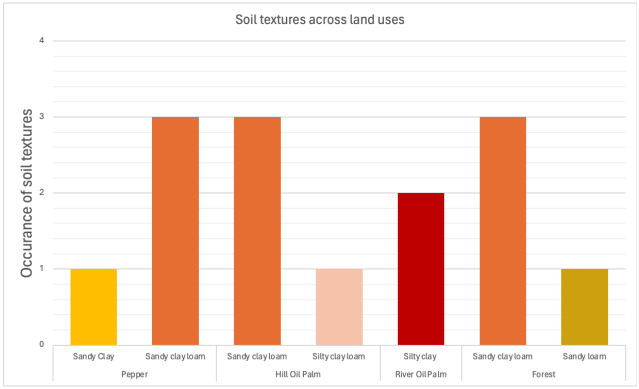


Figure 21: On the left. Prevalence of the five measured soil textures in Sebemban in complete numbers
Figure 22: On the right. Occurrence of soil textures as they are identified on different land uses

The soils in Sebemban are predominantly sandy clay loams, as Figure 21 shows how 9 out of the total 14 soil samples were identified as sandy clay loam. This is true across most types of land uses measured, which is shown in Figure 22. The only exception to this pattern is the soil

from the River Oil Palm, which is a silty clay. Comparing the soil textures to the soil map below in Figure 23 reveals how this site is classified as Sedau in the Malaysian soil series system (Table 5); a clayey alluvial soil common to floodplains and similar wet landscapes.

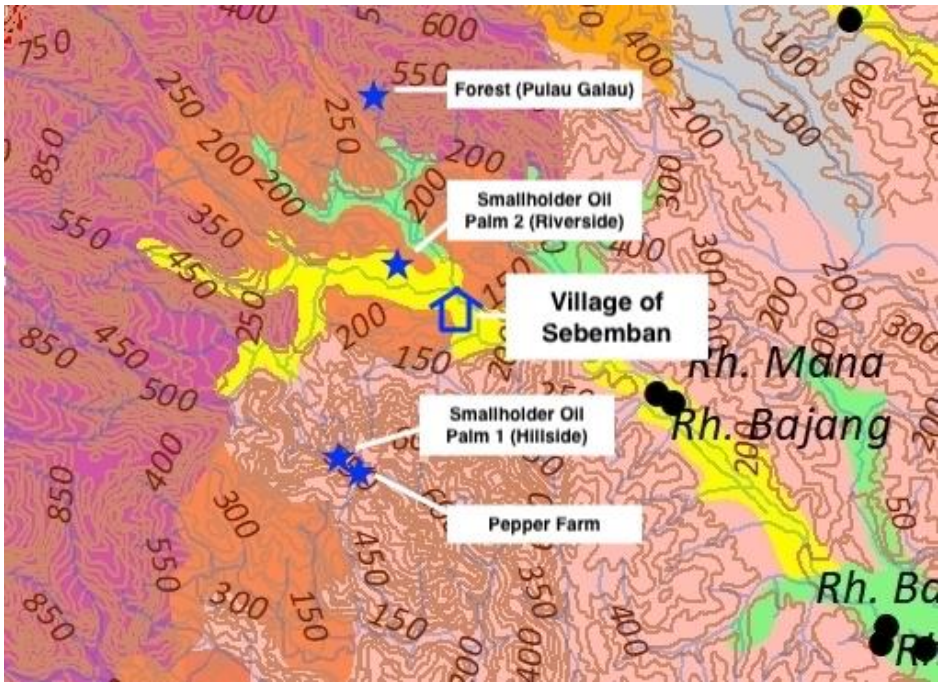


Figure 23: Soil map of Sebemban and the four sampling sites. See Appendix 8 for the full map of Pantu district. (Dept. of Agriculture, Sarawak, Soil Management Division. 2024).

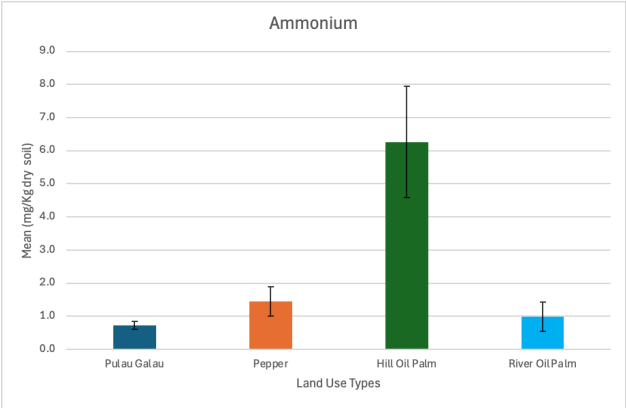
Table 6: Legend of soil series and characteristics accompanying the soil map in figure 23. See Appendix 8 for full legend. Source: Dept. of Agriculture, Sarawak.

Symbol	SERIES	FAMILY (GROUP)	MAIN CHARACTERISTIC	TERRAIN	CAPABILITY (LIMITATIONS)
Jgi	*Jagoi*	SERIN (Oxisols)	Clayey; 20-25% Gp. III oxides; red/dark red; acid igneous	Moderately steep to steep hills and mountains	Class 3 to 5 (slope, erosion hazard)
Sdu	*Seduau*	SEDUAU (Alluvial Soils)	Clayey; non-calcareous; sedimentary rocks; yellow	Flat to undulating floodplains and levees	Class 2 to 4 (wetness, inundation)
Trt	*Tarat*	TARAT (Oxisols)	Clayey; dark red; intermediate to basic igneous rocks	Moderately steep hills and mountains	Class 2 to 4 (slope, erosion hazard)

Figure 23 and Table 6 show the four sample sites on a soil map of Pantu district. Sample 1 and 2 located on Jagoi soil, and sample 3 on Tarat soil. Both soil types fit in the Oxisol soil

order, characteristic for rainforests in the intertropical regions (Ashraf, 2017). The only exception is the Sedau soil found at SP4, which follows the shape of the river (Figure 23), fitting for an alluvial soil, characterized by the prevalence of deposits from river beds and floodplains. If there is indeed a presence of alluvium deposits, it could indicate those lands to be more fertile lands than the surrounding hills.

Oxisols are a highly weathered soil order, and occur under hot tropical conditions (Sellan et al., 2019). The two oxisols Tarat and Jagoi are characterized by moderately steep hillsides, and are prone to weathering through erosion (Table 5), which contribute to the general weathering conditions along with the wet rainy conditions, as nutrient leaching and topsoil erosion are known factors for slopes (Ashraf, 2017).



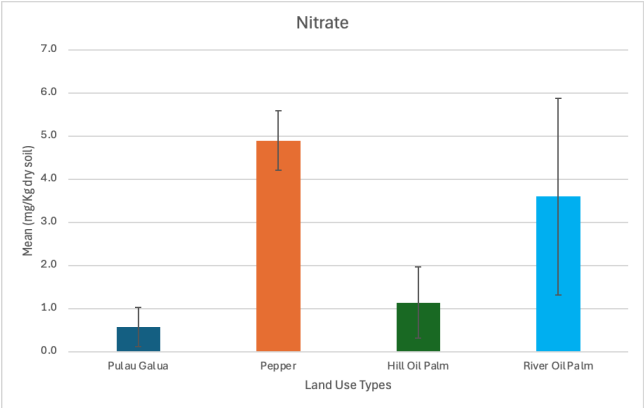
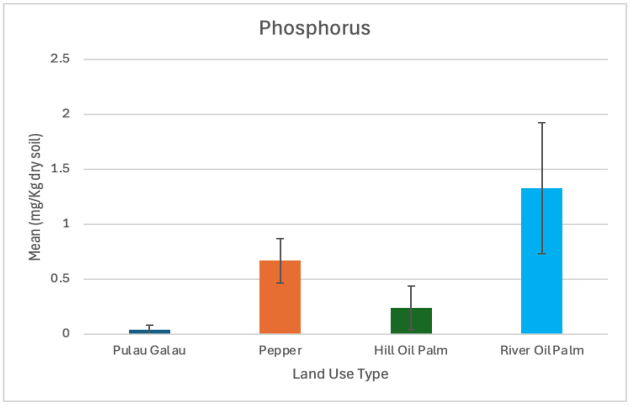


Figure 24 (left): Ammonium levels in the four sample sites

Figure 25 (right): Nitrate levels in the four sample sites



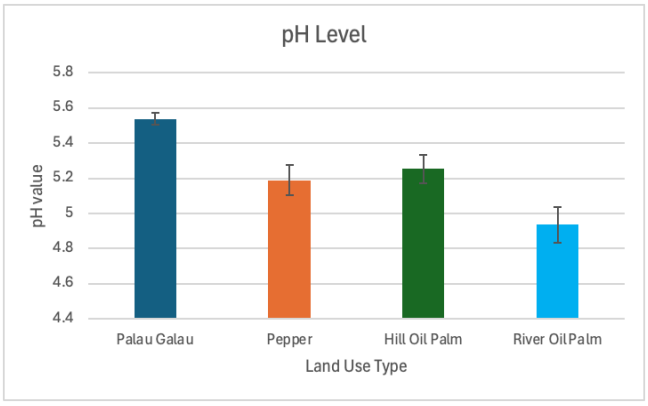


Figure 26 (left) Phosphorus levels in the four sample sites
Figure 27 (right): pH levels in the four sample sites

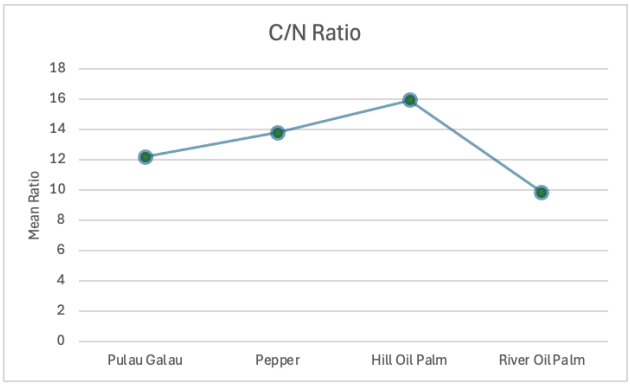
Phosphorus, nitrate, and ammonium are closely related to soil fertility, constituting crucial elements for biological productivity. Nitrate and ammonium together constitute the plant available Nitrogen - by measuring Nitrate and Ammonium concentration on land use types, we use those numbers to understand the soil nitrogen availability. Typical ranges of soil ammonium levels of tropical soils are generally below 10 mg/per kg soil, and alluvial soils typically have levels between 6.65-4.54 mg/kg (Sellan et al, 2019). Our results then clearly demonstrate low levels of ammonium - the site with the highest level is Hill Oil Palm, at 6.27 mg/kg, is also the only site measuring above 3 mg/kg. Conversely, this site has comparably low levels of nitrate and phosphorus. Nitrate levels below 10 mg/kg soil are “low”, but expected in tropical oxisols and alluvial soils (Sellan, 2019). This fits with the analysis, which finds nitrate levels below 6 mg/kg soil at every site. For phosphorus, levels are considered low when they go below 5 mg/kg soil (ibid.)

The Pulau Galau has starkly low levels of all three indicators, and is also the site with the highest pH value. This could indicate its nutrients being tied up in fresh organic matter. With the high amount of biomass in the Pulau Galau, combined with fast addition and breakdown of organic matter in the tropical temperatures, the speed of the nutrient cycling is likely very high - the very low values of ammonium, nitrate and phosphorus might be a result of this very fast consumption of nutrients. This also fits a larger pattern, as tropical soils typically have a very

low cation exchange capacity (IAFN/RIFA, 2014), meaning a low ability to retain nutrients. While we did not measure the CEC, this low nutrient levels might corroborate this general trend. Phosphorus levels in the forests of Sarawak can decrease over time when not cultivated (Hattori et al., 2019), which might be a similar phenomenon as to what we found in the Pulau Galau.

The pH in Sarawak tropical forests typically ranges between 4.5-5.5 (Tanaka, 2007), falling within our findings spanning from a pH of 4.8 at the lowest to 5.6 at the highest. In Sarawak, alluvial soils typically have even lower pH, with values around 4.5 (Sellan, 2019), corroborating our finding of the River Oil Palm site as the most acidic of the three, at 4.9 pH. With tropical soils being more acidic, farmers choose to lime their agricultural soils (IAFN/RIFA, 2014), which is also practiced in Sebemban through the use of dolomite for liming or revitalizing soils (Appendix I.2.3; I.3; I.10).

Despite the differences between the sites, they are all similar through their staggeringly low nutrient levels. Interestingly, this implies the oil palm plantations have little significant impact on the soil health, based on the indicators of nitrate, ammonium, and phosphorus. These low levels can have several causal factors. Some might have been influenced by sampling and analysis methods, clarified in the discussion section. Furthermore, during the rainy season, farmers typically don't fertilize due to runoff from rain (Appendix C2:I10), leading to lower overall nutrient levels. After a whole season of heavy rains and multiple instances of flooding (Appendix C3.1, Discussions), the nutrients have likely been further leached (Sellan, 2019).



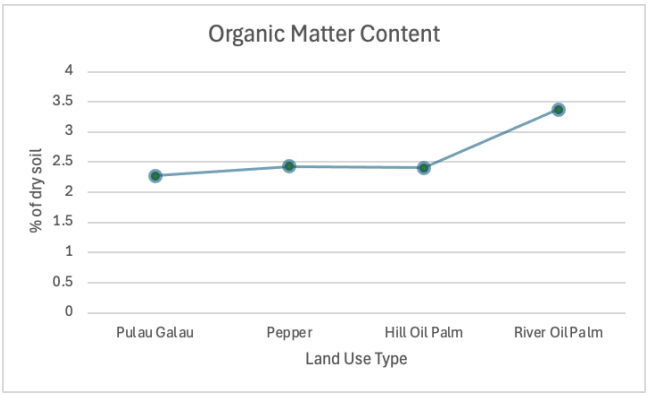


Figure 28 (left): C/N ratio in the four sample sites

Figure 29 (right): Organic Matter Content in the four sample sites

We did two basic tests to estimate the organic matter (OM) content of the soils. The in field testing estimating level of organic matter based on soil color revealed low to medium levels of OM across all land use types. Later lab testing produced estimated levels of organic carbon percentage, which when multiplied by a factor of 1.72 (Van Bemelen Factor) provides an estimate of OM. This is shown in Figure 29, and further suggests low levels of OM (Ross, 1993).

In terms of soil drivers and impacts, we can conclude the following: oil palm plantations are perceived to make land unsuitable for other future crops due to soil degradation and thick root nets, allowing only for cultivation of certain hardy species like durian and rambutan on soils that previously held oil palms. However, the soil analysis doesn't find any significant difference in soil degradation between the oil palm plots and pepper and forest.

3.5 Institutional drivers

Figure 30: A road divides the SALCRA oil palm plantation from the Pulau Galau. Photo: Michael Crha.

Local and regional institutions govern how people can use land (Box 2). We investigated the Pulau Galau, a community forest that is kept undisturbed through institutional controls. There are many wild fruits in this area, but nobody is allowed to forage without blood ties to the community (Appendix C1: I12). There are also large timber trees ideal for construction, and to fell a tree, the entire community must agree to it.

Villagers sell produce between themselves. A problem that can occur is when there are too many sellers of the same good, there is fierce price competition and nobody profits. A local institutional solution was implemented whereby farmers growing the same crop must stagger their sowing and harvesting schedules between each other. This results in a balanced distribution of produce throughout the year, preventing oversupply which occurs if everyone harvests at the same time (Appendix C1, I12).

Box 2: Managing supply through a local institution. Photo: Arianna Casetta.

A dominant institution influencing oil palm concentration is SALCRA. Secure land ownership is crucial to the goals of the community. Being able to sell land is important because private companies can hire people from the community at a competitive wage. This is needed to keep people in Sebemban (Appendix C1, I1). Thus, land title is linked to the long-term survival of the community. While dividends from SALCRA or the opportunity to work on the site can be sources of income, it is the land title that is the primary motivation for the people of Sebemban to engage with SALCRA (Appendix C1, I1;I15). In turn, this drives a trend towards higher oil palm concentration.

Figure 31: The beams in the Anglican church were made using timber from Pulau Galau (source: Robin Rawben, 2022)

Sebemban has not engaged in JVCs, with one reason being the perception that they will lose control over *all* the land in their village (Appendix C1, I.12).

The road further shows the transactional relationship between external institutions and locals. It was initially created in 1983 by a timber company that was given a permit to operate in the area. In exchange for a road, the community had to allow logging. In 2012, the road was improved through paving– on the condition that Sebemban increases its oil palm development (Appendix C1, I1).

4. Discussion

This section answers the research question through the discussion of the results presented in section 3, by contextualizing them in a larger framework in relation to one another. The first part of the discussion will delve into the feedback mechanisms between drivers and outcomes, recognizing how economic and socio-cultural decision-making drivers exist within and are shaped by a broader institutional landscape. The second subsection conceptualizes the economic rationale of livelihood diversification. Lastly, the third subsection will discuss the limitations of the study.

4.1 Linking outcomes with drivers

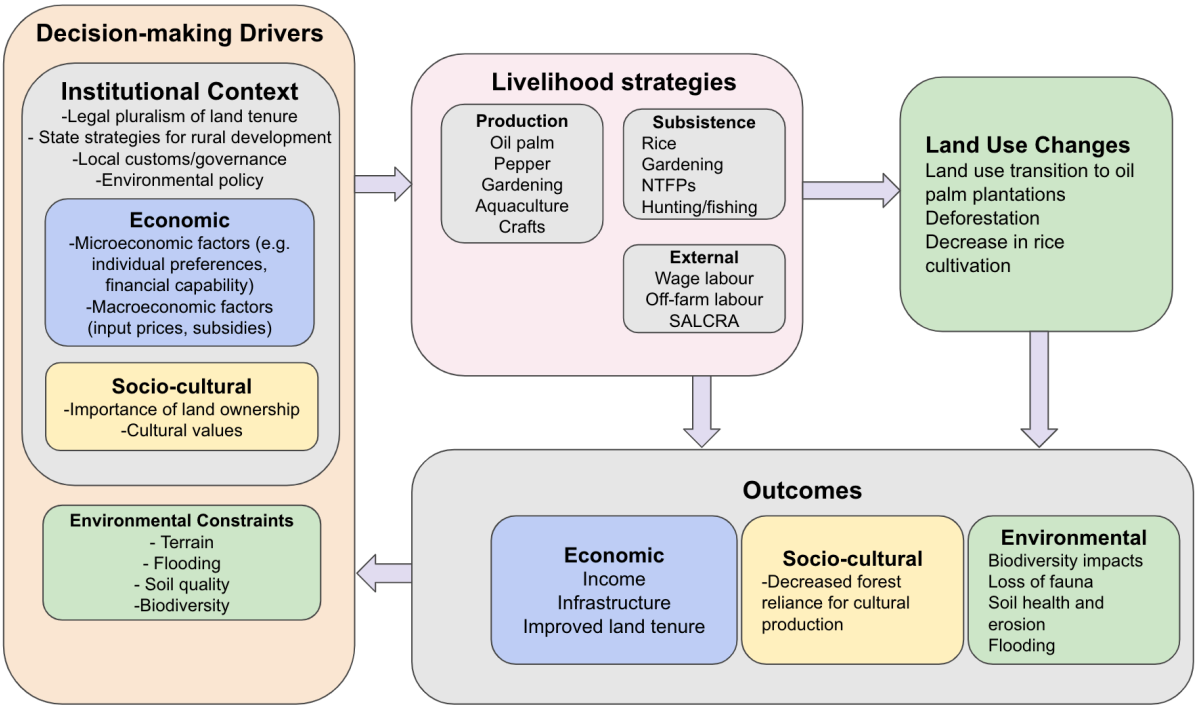


Figure 32: Model presenting the circular nature of how outcomes feedback into decision making factors, resulting in a co-production of environment and livelihoods on the local scale.

The model in Figure 32 expresses the connection between the results framed on two theoretical approaches; combining the flow of causal mechanisms and outcomes from the causal

chain analysis (Meyfroidt, 2016), with the epistemological positioning of agency and capabilities from the sustainable livelihoods framework (Scoones, 1998; Natarajan, 2022). Based on the findings, it shows the flow of drivers and outcomes as a cycle, continually co-producing. This cyclical framing highlights how livelihood decisions are influenced by internal economic and socio-cultural drivers like financial capabilities and the cultural value of ex. pepper plants, while leaving space for external factors like geophysical realities and the institutional landscape, such as governance of land rights. It illustrates how the outcome of these livelihood choices and land use changes affect future decision-making drivers, as shifts in cultural norms or environmental practices can lead to different capabilities or preferences in livelihoods.

To illustrate Figure 32, one can discuss the connection between environment and livelihoods. Land clearing is causing decreased biodiversity and shrinking rivers. Hunting and fishing used to be viable economic livelihood options, but the loss of wildlife biodiversity, including the loss of wild boar from the African swine fever (Weston, 2024), means the community has fewer sources of bushmeat available. With NTFPs and hunting both being important components of the livelihoods in the community, the decline of wild meat has led people to grow more vegetables both for consumption and selling. This is a tangible example of livelihood changes necessitated by environmental changes that came as a result of land use decisions, influenced by an additional external shock - in this case, land clearing and monocropping leading to animal biodiversity loss. Environmental change has then interacted with an external environmental factor, in this case the African swine fever, and together had enough of an impact on the decision-making drivers that they have changed the livelihood strategies of Sebemban, leading to a strong emphasis on gardening for fruits and vegetables as part of their diversified livelihood strategies.

4.2 Implications

The four factors of sustainable livelihoods are their resilience in the face of shocks and stresses, independence from external support, long-term productivity, and not undermining the livelihoods of others (Scoones, 1998). Here, the resilience aspect is relevant to our findings, connecting the livelihoods framework to portfolio theory of diversification - the diverse livelihoods potentially

insulate against unexpected shocks, like economic crises and other systematic risks, by reinforcing the adaptive capacity of the community. In this way, the community can maintain a long productivity of their natural resources.

Market forces are a strong external determinant of livelihood activities. The question remains why individuals use their land for less profitable activities given the option of investing exclusively in the highest return activity. For instance, keeping a rubber plantation that currently generates no income as opposed to converting it to oil palm. In finance, diversification is a means of optimizing return on assets within an acceptable level of risk, which in agriculture mainly refers to negative economic consequences caused by factors like adverse weather, pests, and global market conditions (Markowitz, 1952). As an alternative to investing in one high risk, high return asset, a portfolio of assets mitigates this risk at the trade-off of lowering return. We argue that similar logic can be applied to understand livelihood "portfolios" in Sebemban. Relating portfolio theory to horticulture, Paut et al. (2019) show how diversified crop production systems can reduce risk as much as 77%. Appendix C10 provides a simplified mathematical model.

Beyond crop production, Leha and Wong (2023) find that economic diversification supports higher household income. This is loosely supported by our questionnaire analysis. They argue that livelihood diversification also creates a buffer against adverse environmental or market conditions. The nationwide allure of oil palm is high return, but it comes with risks-including the challenge of land conversion. We know through Sebemban's history that cash crops come and go. Cocoa and rubber had their days of boom and bust and land use transitions, but oil palm presents a unique challenge. Recyclable land, i.e., crop rotation capacity, and alternative income sources is insurance against the potential downswing of palm oil prices. Inversely with the rubber on standby, the landowner is hedging against the chance of profitable rubber prices returning.

The unique challenge of palm oil is the community's concern with the effect of oil palm on soil degradation, making land unrecyclable. However, the overall conclusion of the soil analysis implies that the oil palm plantations seemingly had no significant impact on the soil

health. This finding goes against studies establishing oil palm as a driver of soil degradation (Afandi, 2017), as well as the knowledge expressed by the community in Sebemban, who claim the same. As both plantations sampled were smallholder cultivation, the result implies a difference in impact of large scale and smallholder oil palm plantations. This implicates the current soil quality to be an outcome of current agricultural diversification, considering smallholder oil palm a diversification strategy, but opens the possibility of it to be a future driver towards agricultural concentration. Further study is needed before drawing conclusions.

The system of decision making is not a closed loop. External institutions and macroeconomic factors feed into the process. Sebemban's institutional arrangements have driven livelihood activities in both directions of concentration and diversification. Land tenure institutions like the Land Code and local laws shape livelihood choices and their feedback. This is seen in how the Pulau Galau buffers the impact of agricultural expansion on the community's environmental needs, and how policies can limit or incentivize specific activities, like the Environmental Quality Act limiting large scale burning to clear land or fertilizer subsidies encouraging certain crops. However, as land title is a key goal of Sebemban in attaining security of land tenure, land has been leased to SALCRA, driving the concentration of oil palm.

Global market pressures also affect livelihoods, seen when rubber prices pressured smallholders to change production strategies, leading to the current cultivation patterns. Today, Sebemban doesn't engage with JVCs due to the perception that doing so would result in ceding autonomy over all their land, concerns which are validated by Cramb (2013). Communities under JVCs experience monoculture, as the sole objective is commercial oil palm development (Cramb, 2013). This reluctance towards JVCs is a potential driver towards diversification rather than concentration, as smallholders retain the discretion to diversify their land use when they control their lands. Another significant macroeconomic pressure today is high fertilizer prices. With pepper being fertilizer-intensive and low margin, this pressure could cause some pepper farmers to transition to more cost-effective activities, either diversifying to small low-cost cultivation or intensifying to higher-margin oil palm.

4.3 Limitations

The methodologies employed in this project are associated with limitations. Identifying these is important for understanding the practical implications and true scope of the research.

Translation is considered an inherent limitation, as certain details might get lost in translation. This led to situations like the matrix ranking, where participants understood concepts like “environmental impact” differently from our intention.

4.3.1 Questionnaire

We were limited in the statistical tests we could do given our questionnaire data. With income collected as a categorical variable, we could not perform a linear regression showing the relationship between livelihood diversification and income. The low observation number makes our chi-square tests unreliable. In the dataset for statistical analysis, all crop production was lumped together as a single activity. So, if someone grew oil palm, rice, and pepper but nothing else, they would have 1 livelihood activity, but a person with rice and fish farming would have 2. This prevented us from being able to analyze the impact of oil palm specifically on variables like income and livelihood diversification. Lastly, the variables clarifying the crop production diversity were not properly linked to the rest, as the questionnaire lacked an identifier, excluding it from statistical analysis.

We attended an Anglican church service and afterwards invited people to take the questionnaire. There might be social differentiation between churches, and so this sample may have been biased. In addition, a survivorship bias - that is, the ability to interview only people who are available - might have occurred given the convenience sampling, which could have excluded off-farm workers who migrated to the city from the survey (Rea&Parker, 2014).

4.3.2 Limitations constraining analysis of soil, water, and biodiversity

Water and soil assessments were limited by conducting the study during the rainy season. During the rainy season, no crop inputs are applied (Appendix I.10). This hinders the investigation of how fertilizer or pesticides impact water security and soil nutrients in agricultural sites. With field testing conducted at the tail end of the rainy season, the studies were done after months of hard rains, diluting all results and raising concerns of indicators being washed away. Further limitations for the laboratory testing are related to the freshness of the samples, and for soil nitrate and ammonium calculations, we averaged the top and bottom numbers, potentially resulting in lower levels, as nitrate and ammonium levels are generally lower the deeper the sample is taken (Sellan, 2019).

The initial plan to measure the biodiversity of forest/fallow plots to compare the biodiversity of differently managed forest/fallow plots was hindered by time and availability constraints. The sample plots were chosen by convenience sampling, affected by the willingness of landowners to allow assessments on their lands. Only one forest plot was assessed, which means that the biodiversity found there cannot be compared to any other forest plots. Lastly, as we conducted biodiversity assessments, we became more proficient at identifying separate plant species, and as such, the accuracy of our assessments may differ between plots. However, without the ability to control for this limitation, we must trust that the data is as accurate as possible.

4.3.2 Sampling strategies

We primarily employed convenience sampling for our methods. We argue this is reasonable given the duration of our study, which constrained us from implementing more complex strategies. The study was conducted during 10 days of one specific season, which means information about food sources and agriculture is only representative of that season. Typically the Tuai Rumah would call people together if we needed a group, and often it involved the same participants. It is possible that different perspectives were overlooked.

5. Conclusion

We investigated why livelihood activities become concentrated or diversified. Our study site, Sebemban, is an agrarian village in Sarawak. While following the Malaysian trend of oil palm concentration, it maintains a diversity of livelihood activities and land uses. We employ participatory social science methods to understand local perspectives, and natural science to investigate biophysical outcomes. We find that socio-cultural, economic, environmental, and institutional factors constrain, incentivize and govern livelihood options. Our results exemplify the ways in which they influence decision-making. Our discussion examines their interlinkages.

The strong economic incentive to grow oil palm, as well as the opportunity to obtain land title through SALCRA is driving oil palm expansion and transforming livelihood strategies in Sebemban. However, diversification creates economic and environmental security. Socio-cultural aspects such as food and craftsmanship also demonstrate the value of natural forest and traditional agricultural activities.

It is difficult to judge whether diversification is being consciously maintained in Sebemban, or if oil palm concentration is simply occurring less rapidly relative to surrounding villages. Future research could involve returning to the study site after a period of time to see whether Sebemban remains a final frontier for oil palm.

Figure 33: Oil palm seedlings grow in a Sebemban paddy plantation. Photo: Mike Crha.

References

Afandi, A. M., Zuraidah, Y., Nurzuhaili, H. Zulkifli, H., Yaqin, M. (2017) Managing Soil Deterioration and Erosion under Oil Palm. Oil Palm Bulletin 75, p. 1-10

Anderson, JM., Ingram, JS. (1993). *Tropical Soil Biology and Fertility - A Handbook of Methods*. CAB International.

Angelsen, A., & Wunder, S. (2003). Exploring the forest-poverty link: key concepts, issues and research implications. CIFOR occasional paper, 40, 1-20.

Ashraf, M.A., Othman, R., & Ishak, C.F. (Eds.). (2017). Soils of Malaysia (1st ed.). CRC Press. https://doi-org.ep.fjernadgang.kb.dk/10.1201/b21934

Banerjee, N., & Bojsen, KPM (2005). Negotiability and limits to negotiability-land use strategies in the SALCRA Batang Ai Resettlement Scheme, Sarawak, East Malaysia. Geographical Journal , 105 (1), 17–28. https://doi.org/10.1080/00167223.2005.10649523

Brinkmann, S. (2020).Unstructured and Semi Structured Interviewing, in Patricia Leavy (ed.), The Oxford Handbook of Qualitative Research, 2nd edn, Oxford Handbooks (24 pages).

Cramb, R. A. (2013). Palmed Off: Incentive Problems with Joint-Venture Schemes for Oil Palm Development on Customary Land. World Development, 43, 84–99. https://doi.org/10.1016/j.worlddev.2012.10.015

R. A. Cramb & Patrick S. Sujang (2013). The mouse deer and the crocodile: oil palm smallholders and livelihood strategies in Sarawak, Malaysia. *The Journal of Peasant Studies, 40*(1), 129-154.

https://doi.org/10.1080/03066150.2012.750241

De Neergard et al., 2008. Soil erosion from shifting cultivation and other smallholder land use in Sarawak, Malaysia. https://www.sciencedirect.com/science/article/pii/S0167880908000042

Department of Environment Malaysia (2021). National water quality standards for Malaysia. Retrieved from: https://www.doe.gov.my/wp-content/uploads/2021/11/Standard-Kualiti-Air-Kebangsaan.pdf

DeWalt, & DeWalt, B. R. (2011).What is participant observation and Fieldnotes, in *Participant observation a guide for fieldworkers* (2nd ed.). Rowman & Littlefield. (20 pages).

Cramb, R. A. (2013). Palmed off: Incentive problems with joint-venture schemes for oil palm development on customary land. *World Development*, *43*, 84–99. https://doi.org/10.1016/j.worlddev.2012.10.015

Cramb, R. A., & Sujang, P. S. (2011). 'Shifting ground': Renegotiating land rights and rural livelihoods in Sarawak, Malaysia. *Asia Pacific Viewpoint 52* (2), 136-147. https://doi.org/10.1111/j.1467-8373.2011.01446.x

Cramb, R. A., & Sujang, P. S. (2013). Mouse deer and the crocodile: Oil palm smallholders and livelihood strategies in Sarawak, Malaysia. *The Journal of Peasant Studies*, *40*(1), 129–154. https://doi.org/10.1080/03066150.2012.750241

Soil Management Division, 2024. Soil map, Sri Aman, Pantu. Department of Agriculture, Sarawak.

Gilliam, FS. (2007). The Ecological Significance of the Herbaceous Layer in Temperate Forest Ecosystems, *BioScience*, 57(10), 845–858. https://doi.org/10.1641/B571007

Hattori, D. Kenzo, T. Shirahama, T. Harada, Y. Kendawang, JJ. Ninomiya, I. Sakurai, K. (2019). Degradation of soil nutrients and slow recovery of biomass following shifting cultivation

in the heath forests of Sarawak, Malaysia. Forest Ecology and Management 432: 467–477. DOI:10.1016/j.foreco.2018.09.051

Hill D, et. al. (2005). *Handbook of Biodiversity Methods: Survey, Evaluation and Monitoring*. Cambridge University Press. https://doi.org/10.1017/CBO9780511542084

IAFN/RIFA. (2014). Understanding Tropical Soils. Accessed on Apr 4, 2025. https://analogforestry.org/understanding-tropical-soils/

Ichikawa, M. (2007). Degradation and loss of forest land and land-use changes in Sarawak, East Malaysia: a study of native land use by the Iban. *Sustainability and Diversity of Forest Ecosystems: An Interdisciplinary Approach*, 403-413.

Jamshed S. (2014). Qualitative research method-interviewing and observation. J Basic Clin Pharm. (4):87-8. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4194943/

Krishnan, A. (2009). Five Strategies for Practising Interdisciplinarity. ESRC National Centre for Research Methods NCRM Working Paper Series

Leha, S., Wong, S. (2023). Enhancing Rural Wellbeing: Unravelling the Impact of Economic Diversification in Sarawak. *Journal of Production, Operations Management and Economics, 3*(6), 21-28.

https://doi.org/10.55529/jpome.36.21.28

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, *7*(1), 77–91. https://doi.org/10.2307/2975974

Martin, G. J. (2004). *Ethnobotany : a methods manual*. Earthscan. https://doi.org/10.4324/9781849775854

McDonald, J.H. (2014). *Handbook of biological statistics* (3rd ed.). Sparky House Publishing.

Mertz, O., Egay, K., Bruun, T. B., & Colding, T. S. (2013). The Last Swiddens of Sarawak, Malaysia. *Human Ecology*, *41*(1), 109–118. http://www.jstor.org/stable/23353205

Meyfroidt, P. (2016). Approaches and terminology for causal analysis in land systems science. Journal of Land Use Science, 11(5), 501-522.

Natarajan, N., Newsham, A., Rigg, J., Suhardiman, D. (2022) A sustainable livelihoods framework for the 21st century. World Development, Volume 155, 105898. https://doi.org/10.1016/j.worlddev.2022.105898

Ngidang, 2005. Deconstruction and Reconstruction of Native Customary Land Tenure in Sarawak. Southeast Asian Studies, Vol. 43, No. 1.

Paut, R., Sabatier, R., & Tchamitchian, M. (2019). Reducing risk through crop diversification: An application of portfolio theory to diversified horticultural systems. *Agricultural Systems*, *168*, 123–130. https://doi.org/10.1016/j.agsy.2018.11.002

Pelletier, G. J., Chapra, S. C., & Tao, H. (2006). QUAL2Kw–A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration. Environmental Modelling & Software, 21(3), 419-425.

Rawben, R. (2022). Picture taken from google maps. Link: https://maps.app.goo.gl/YhNHvzACdGChMEtt6

Rea & Parker, Ch. 9: Selecting a Representative Sample. In: Rea, L. M.,& Parker, R. A. (2014). Designing and conducting survey research: A comprehensive guide. John Wiley & Sons. P. 147-163

Ross, S. M. (1993). Organic matter in tropical soils: current conditions, concerns and prospects for conservation. *Progress in Physical Geography: Earth and Environment*, *17*(3), 265-305. https://doi-org.ep.fjernadgang.kb.dk/10.1177/030913339301700301

Savilaakso, S., Garcia, C., Garcia-Ulloa, J. et al. (2014) Systematic review of effects on biodiversity from oil palm production. *Environmental Evidence*, 3, 4.

https://doi.org/10.1186/2047-2382-3-4

Sellan, G., Brearley, F., Titin, J., & Majalap-Lee, N. (2019). Differences in soil properties among contrasting soil types in Nortern Borneo. Journal of Tropical Forest Science 33(2): 191–202. https://doi.org/10.26525/jtfs2021.33.2.191

Scoones, I. (1998). "Sustainable rural livelihoods: A framework for analysis", *IDS Working Paper, 72,* Brighton: Institute of Development Studies.

Tanaka, S. Wasli, ME, Kotagawa, T. Seman, L. Sebang, J. Kendawang, JJ. Sakurai, K. Morooka, Y. (2007). Soil properties of secondary forests under shifting cultivation by the Iban of Sarawak, Malaysia in relation to vegetation condition. *Tropics.* 16 (4). https://www.jstage.jst.go.jp/article/tropics/16/4/16_4_385/_pdf

Taliep, N., Ismail, G. (2023). Community Mapping Method. In: Liamputtong, P. (eds) Handbook of Social Sciences and Global Public Health. Springer, Cham. https://doi.org/10.1007/978-3-030-96778-9_57-1

Thien, SJ. (1979). A flow diagram for teaching texture-by-feel analysis. Journal of Agronomic Education. https://doi.org/10.2134/jae.1979.0054

Vogl, C. R., Vogl-Lukasser, B., & Puri, R. K. (2004). Tools and Methods for Data Collection in Ethnobotanical Studies of Homegardens. *Field Methods*, *16*(3), 285-306. https://doi-org.ep.fjernadgang.kb.dk/10.1177/1525822X04266844

Willmott, H. (2015). Why Institutional Theory Cannot Be Critical. Journal of Management Inquiry, 24(1), 105-111. https://doi.org/10.1177/1056492614545306

Weston, P., (2024). ‘The pigs have disappeared’: swine fever threatens food source for millions as disease hits wild herds. The Guardian. https://www.theguardian.com/environment/2024/jan/19/african-swine-fever-asian-wild-pigs-borneo-aoe?ref=upstract.com

Appendix

Appendix A: Synopsis

Appendix B: List of applied methodologies

Methodology	**Amount**
Participatory observation	Ongoing throughout the study
Unstructured interviews	11
Semi-structured interviews	5
Questionnaire	41 respondents
Focus group interviews	
Community mapping	3 maps (1 drawn by each longhouse)
Resource ranking exercise	1 - followed up by a focus group
Guided tours	2
Water quality and aquatic life assessment	2 sites
Biodiversity Assessments	4 sites
Soil sampling and laboratory testing	4 sites - pH, ammonium, nitrate, phosphorus, C, N

Appendix C: Results and discussion

Appendix C1: List of interviews

Index	**Type of interview**	**Topics**

I1 (Tuai rmu moss 1st day)	**Semi-structured**	**History of Sebemban, current and long-term goals (TR Moss), tour of gardening**
I2 (Home gardening interview)	**Semi-structured**	**NTFPs, foraging of forest products and home gardening 3 total conducted**
I3 (Interview with joe while water sampling)	**Semi-structured**	**Water quality, fertilizer pressures, swidden cultivation, oil palm crashing, hunting, biodiversity loss, converting land after oil palm**
I4 (Lian whe we went to terrace pkantation)	**Unstructured**	**Oil palm, converting land after oil palm, SALCRA, gardening, pepper**
I5 (interview at Marinas house)	**Unstructured group interview**	**Biodiversity, Pulau Galau, forest preservation, agricultural expansion, ideas for the future of Sebemban**
I6 (foraging walk with Ikun)	**Unstructured**	**During foraging walk; NTFPs, gardening, land customs**
I7 (Group interview with some old ladies at the beginning)	**Unstructured group interview**	**Land use, food sources, SALCRA, handicrafts**
I8 (Aitana fauna)	**Unstructured**	**Fauna**

I9 (interview on Udin's plantation)	**Unstructured**	**Oil plantation practices, use of pesticides and fertilizers**
I10 Marinas pepper and oil palm plantation	**Unstructured**	**Agricultural practices, soil liming, fertilizer use**
I11 (Interview with men in the kitchen on march 6th)	**Unstructured**	**Interview about pest animals, food preferences, and hunting for wild meat**
I12 (interview with grandpa)	**Semi-structured**	**Spontaneous discussion circle with small group community members after taking our Surveys: Discussed why the community prefers SALCRA over JVC's. Also discussed impact of infrastructure development, how internet would change agricultural activities, Pulau Galau, land tenure institutions, economic decision making**
I13 (TR moss taking us to his rice field)	**Unstructured**	**Swidden cultivation, conversion of paddy field to oil palm and history of the plot, beginning of SALCRA in the village**
I14 Tr Moss fish pond	**Unstructured**	**Tour to tilapia fish pond, livelihood challenges**
I15 (TR moss plantations first day)	**Unstructured**	**SALCRA, how oil palm grows,**

Appendix C2: Interview notes

I1

Questions:

1. Can you tell us the story of Sebemban? (when, how and why the village established there)
2. How do you become Tuai Rumah?

3. How do you decide to join SALCRA?
4. Why did you decide to join SALCRA?
5. Native Customary Land: can you tell us more about it?
6. What was there before SALCRA oil palm plantations?
7. What would you like to do with the land after the 25 year-old period when you obtain ownership?

The village was once a **primary forest** . Currently the third generation of villagers is inhabiting the place. In 1921, 2 people were established in the place: Bayang and Buli. One of them was a cousin of Lawin, an ancestor of Moss. Reason why they open up the area: they went up to the river and built a temporary shed, nobody was there so they decided to settle. Initially, they planted rubber, then also paddy. They went back and collected people to join them to establish the place. Other siblings decided to stay in the original place (on the other side of the river). In this place, swidden cultivation was not used. In total 22 families went there. Buli brought people to this place, such as Lawin, the brother of Bayang's wife. They named the village after the river, Sebemban. in turn, the river is named after the plant bemban, which now people use to make artifacts such as matts and baskets for harvesting.
The TR becomes such with election: people of the longhouse vote, and the elected person has to send a motivation letter where the agenda is stated, to the district to get governmental approval.
The community split up into 3 longhouses with 3 different TR (why? Different ideas).
In total there are 68 houses and longhouses, 20 of which are under Moss administration (142 people). People who move out to work remain still under his administration. Therefore, they need to be consulted for any land change.
SALCRA: how do you decide to join it? In Kuching there is an office managing oil palm plantations. It operates by calling a logging company to clear up the area and then start planting. In Sebemban: the zone where there are SALCRA plantations right now was once a rice cultivation. People stopped it and let it go fallow 20 years. The villagers didn't have the machinery and transportation (capital) to manage the fellow (clean up the area and start the cultivation), so they decided to join SALCRA to take care of it.
NATIVE CUSTOMARY LAND: all land patches here do not have a title. They belong to the state. They joined SALCRA mostly because after a 25 year period joining the project, they gained the ownership of that land. In this way, they can do what they want with it: cultivate, sell it etc. A neighboring village decided not to continue with SALCRA because the dividends are unpredictable. Probably after SALCRA the TR will decide to plant his own palm oil. SALCRA operates in a big area of land, which is made by small land patches "belonging" to all of the villagers. Dividends are earned according to the size of your patch of land. After 25 years, you can choose to continue with the contract or not. This is possible because roads and infrastructures needed are already being built.
SALCRA has financial mismanagement issues: They take too many subcontractors from too many companies, and because they have to pay all of them, they have less to give out in dividends. Claims they are in debt to many of these companies.
Smallholder palm oil:
- 10 tons of fruits from one harvest (Tr Larry's plantation, the biggest in Sebemban)
- Collect fruits twice a month
- Tr Moss collects 800 kg fruit from one harvest
- The current price is **680 RM** per ton

Salcra has management issues because of financial issues: it established too many subcontracts (for example a subcontract with a company to build roads). The money doesn't flow back, because of too

many debts. In this way, the dividends for the villagers are too low. The main goal of the villagers however is to obtain ownership. For example in another community they own the land, planted bamboo so all the villagers can work there, in a land managed by them and earn money from production.
In Sebamban when the villagers obtain the ownership, they would like to start a coffee project in a different section of the village. They aim to manage the plantation because they can sell coffee beans to a factory that is processing them and receive money for that. Why coffee? Because the coffee supply in Sarawak is very low. If demand is growing, the price is gonna increase (the culture of coffee shops is increasing also here, they have noticed)
Cont. interview, on a walk through Sebemban, showing us vegetable gardening:
People use fertilizers that came from government subsidies. Younger people no longer follow traditions – they will go out and harvest even when the omen birds are singing. They don't do the traditional ceremonies for good harvest, but they will instead do Christian prayer.

I2:
Questions:

1. What do you grow in your home garden (and beyond)?
2. Do you go to the forest to collect forest products? If yes, what do you collect?
3. Do you have livestock?
4. Do you have fruit trees on your land/garden?
5. Where do you take food sources that you do not produce?
6. Do you sell products of your garden?
7. Do you know how to make traditional handicrafts?

I.2.1 - Answer 1:
In her farm she produces the following: Brirjel, Chili, Yam, Sweet leaves, Paddy, Oil palm, Pepper, Durian, Mawang

In her backyard: Dabai, Stinky beans, Engalak, Sikup, Bua langka, Langsak, Utsua

What she grows in the garden she shares with the community, doesn't sell it. In town she buys other things, such as vegetables that she doesn't grow, ensabi, chicken, noodles etc. She doesn't have livestock, only fish. She has a fish farm,and in the past she used to sell some of the fishes. Now she doesn't because the quantity is less, she doesn't add new ones (does not take care much of it now). She has Black Tilapia. Before she used to go to the forest to collect vegetables such as bamboo shoots, daun sabung etc. in the forest she also hunted little animals: water snails, frogs, shrimps, and fishes. She goes at night because fishes are easier to catch. She uses a gun. Now she doesn't go often. It depends on the weather and the season, for example in the dry season she goes more often.
Before they noticed way more animals than now. Some animals are decreasing because of diseases such as the swine flu. Some others like the fox are disappearing because of the changes in landscape, which in turn changes their habitats. This causes less hunting. They still go hunting at night during night walks but less than they used to do before. They are quite concerned about it, because animals are a source of food as well. How do they cope with it? They buy meat from the market. If they collect (hunt) enough animals they can also sell it.

She sells rice hats to the village. She's the one who is making them, using a material called Akah. She is also making bemban mats, but just for her household. Her daughter in law doesn't know how to make them. She doesn't sell it in other places. In the Iban tradition, if a woman can cook and knit, they are considered smart, strong and independent. Kumang is the reference: an Iban spiritual character.
She collects materials from the forest. She has a strong connection with the forest, both because of cultural reasons and because it is a source of income and food. Thus, she feels that it is important to preserve it. She is not concerned about the expansion of agriculture. The land with forest cover is located away from the village, and therefore will be preserved.

I. 2.2 - Answer 2:
In her garden she grows: ensabi, eggplant, sour plant, chillies (for sambal), benli, papaya, bringel, pomelo, small mangoes, and dragon fruits.

She has been cultivating yam for 5 months - this is her first year doing this. She also grows other vegetables both for own consumption and to sell them within the community. Sometimes she shares with the community, sometimes she sells them for 2 ringgit per piece. Vegetables: she grows sweet leave, bitter gourd, bendi, long beans. Also has a pepper farm with 600 to 800 pepper trees. Oil palm is her main source of income, pepper second. She planted oil palm in 2019. Oil palm does not require high maintenance. Good because fertilizer is too expensive. She grows oil palm but decided to keep pepper and other vegetables because they grow better in that land. Hiring employees for oil palm plantations is expensive. Flatness of the land is good to grow pepper. High price of fertilizer, low price of pepper. However, she wants to preserve pepper farming to preserve tradition. Pepper farming comes from ancestors, and is part of their cultural identity. She sells pepper in Pantu town. She is also worried that pepper farms will disappear. Market fluctuations play a big role as well. The land where she currently grows pepper has always been used to grow pepper. Pepper trees in flat areas last 2-3 years; in hill areas 3-4 years; then need to replant. They fertilize the soil every day. Pesticide damages soil. She can recognize soil quality through the color of the leaves. Yellow signifies bad quality. Due to lack of time, her rice field was left to fallow land. She buys rice from the market. She collects from nearby forests (pulp, mushrooms). She also collects non-timber forest products (bemban, rattan). She recognizes the forest, knows which spots to go to. She goes near the Suna Kura, and always goes with someone (safety reasons). Younger generations also know about the forest but they have a more limited knowledge. Rattan is harvested for own consumption. Bamban to make carpets. Kids and grandkids don't want to learn, fear that this tradition will be lost. Tattoos are part of the Iban cultural identity. Tattoos used to have a meaning related to the Iban culture. Both men and women have tattoos. Back in the days the ink was made of the ashes from burning timber. She does not use fertilizers in her home garden. She also collects impunok to make baskets. Bamban, rattan, impunok are for self consumption. They used to sell them before, but now the demand is low.

I.2.3 - Answer 3: Older couple
Results of the interview:
They grow oil and pepper as farming. Oil is their primary source of income
Oil: Several different plots

- 130 trees, 12 yrs old

- 130, 9 years
- 200, 7 year
- 70, 1 year 4 month

He harvest once a month - we go to visit tomorrow at 7/8am at his intensely managed spot
He has some in the hills which has sandier soil, and one in the flat swampy area. He says they grow better in the flat swampy area, bc of the soil and the slope
Pepper: 500 trees, 4 years/new
Previously, 2000 trees, but now they're dying. 6-7 years after he planted pepper, because they got too old and he stopped taking care of them
Fruits and vegeatables:
Rambutan, durian, crystalfruit: They have about 20 fruit trees, total. They grow their fruits on the lands behind the river (where we walked yesterday) - these lands are good for growing. For the past three years, the durian fruit production is decreasing because it rots and is attacked by worms. They sell their fruits. They sell them from people who come here to buy, and sometimes in Lachau. Costumers include Iban people from other villages and also people from other countries, like China and Taiwan. Fruit sales depend on the fruiting season. When it's fruiting season people come here to buy, and if they have fruit and nobody come here, they go to Lachau to sell
Plant vegetables for own consumption: Vegetables they grow: Sweetleaves, terung iban, terung asam, yam, ginger (ginger just for eating). All vegetables are for own consumption, but if there are too many they sell them. Ginger production is very low right now so it's all for own consumption. If it's planted on a flat area, there's a risk of flood killing the plants. The rest of the food they eat they buy in Lachau and Serian
Forestry: In the past, they went to the forest to collect foods, but they don't anymore because they have health products. If someone collects opa lale from the forest, they will buy it from them (Opa lale - a type of shoot they eat). They don't harvest any other forest products
Bemban and mat-making: The wife made the mats we're currently sitting on from bemban. The process of making a bemban mat: First they cut harvest the bemban. Then they skin it, to use the skin of the stalks. Then they dry the skins, which makes them shrink. After they're dried, they soak them, which makes them expand a bit and make them more pliable. After the soak, they scrape off the remaining flesh. Then they pull them, and then they weave them.
They still harvest bemban - They planted the bemban themselves here in the area. They plant it by harvesting bemban seedlings and planting them in their own lands, Between their fruit and their pepper there's a swampy area where they plant their bemban. The people who make a business out of selling mats, they have a lot more bemban than these guys do. She only weaves mats, she doesn't know how to weave hats, the people who weave other items squire their own materials
Livestock:
They have chickens, previously ducks but not anymore. The person at the last door in this longhouse has pigs. The person at the end of the road before the Anglican Church also has pigs. Both only have young pigs currently. In 2021, a woman in town had pigs but she sold all of them to other people in the village. To raise a pig, it takes 15 months, and it can reach 100 kg. But during covid, 2020-2021, the pigs around the village all died from disease. The house across the road is their swiftlets farm - they've had it for 6-7 years. The bird nest production is low, because not a lot of birds are coming to this location, because the sea area is far away from Sebemban - There are four people who have swiftlets - marina, Judy, tuong, and this couple. This man is the one who started the swiftlet farming here in Sebemban

I3

-amount of fertilizer needed increases with the age of the oil palm
-joe confirms that the river is shrinking because it is getting hotter, and because of erosion
-hunting/fishing is no longer possible as an economic livelihood option. The fish and animals have decreased as a result of land clearance. Biodiversity loss. Same with NTFPs
-wild boar used to be an important game, but disease has caused their population to decrease
-for joe water sampling is important because he wants to know about any harmful things in the water
-joe thinks its really important to test the water next to oil palm because he wants to know whether there is pollution
-joe confirms that they leave the gravity feed area undisturbed to keep the water clean
Interview with Joe
-amount of fertilizer needed increases with the age of the oil palm
-joe confirms that the river is shrinking because it is getting hotter, and because of erosion
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-for joe water sampling is important because he wants to know about any harmful things in the water
-joe thinks its really important to test the water next to oil palm because he wants to know whether there is pollution
-joe confirms that they leave the gravity feed area undisturbed to keep the water clean
-Have to use much more fertilizer now than before, because swidden cultivation is no longer practiced, which would keep the soil fertile.
-what happens if the market price for oil palm crashes? What do you do with all the land that is currently oil palm?
- Those who can afford it will clear the land and plant something new, the less wealthy people will be harmed greatly because they won't be able to clear the land
-joe used to hunt wild boar in the past, but now there are no more because of the african swine flu outbreak which happened at the same time as COVID.
- he would sell half the meat he hunted, but it wasn't so important for his livelihood. It was primarily a hobby.
- People used to rear domesticated pigs in the village, but no more because the swine flu wiped them out.
-everything is becoming more costly and harder to do business. Price competition within the village and outside markets makes it difficult to profit
-when you see oil palm in a rice plantation, thats how you know its the last rice that will be planted there. Once you convert to oil palm, its very hard to convert the land for other purposes. Mainly because of the roots in the ground you have to deal with, but also because of soil health. There are ways to bring the soil back to life, particularly dolomite

The water supply of the village. It is in a protected area, where the forest in undisturbed because they do not want to pollute the water. We are doing water sampling here to determine whether it is safe to drink, because there have been some concerns.

I4

He is a villager that works for a company in Kuching and has land in Sebemban. he lives 4 days there and 4 days in Kuching. Plantation is a secondary source of income. He plans to retire in 2 years, the plantation will become his first source of income.

- Terrace plantation, because it is too sloppy and terraces makes it easier to fertilize.
- 230 oil palms
- 3 acres of land

Land was burned in June last year. Before that, he had rubber trees. Burning process: starts burning from the top of the hill, so that the fire is going down. The fire is being monitored, because it shouldn't expand especially because this land is on the boundaries with SALCRA plantation. Decided to switch to oil palm because they were influenced by other people of the village, and because rubber demand dramatically decreased. In addition, oil palm is easier to take care of, easier to fertilize and the market price is currently profitable. Before starting with oil palm, they established a garden of veggies. Veggies are both for own consumption and a cash crop. They sell it in Kuching, Lian's wife has a friend ordering it for her and picks it up. She sells the orange eggplant at 10 RM per kg. Veggies are temporary: when oil palm will grow, they will not survive. They have another piece of land but it is not easily accessible. So he decided to give it to Salcra. Salcra offered to take over this piece of land but he refused because dividends are too low. What is the perception of SALCRA? Employment opportunity. But if the land is close to their house they prefer to manage it on their own. Hiring workers to work in the plantation is expensive: it costs 60 RM per day. He plans to split the revenue (50-50) with a person who could work in the plantation: this strategy is even more convenient than leasing it to SALCRA (whose wage is 15 RM per day). Indonesian workers work only with SALCRA because they get benefits included in the wage, i.e. housing, bills etc.
The EU put some sanctions on palm oil, but there is a new market in international trade, that is the Arabs. The price of palm oil is increasing thanks to this. The price is established by the Malaysian government. The highest price that the palm oil market has ever experienced is 1200 RM per ton.
There are different levels of quality: if the fruit is red, the quality is gonna be higher.
He also has pepper but wants to cut it off because of high maintenance costs. Pepper to him is like a hobby right now, he takes care of it in his free time and also sells it to the market. Now he prefers to focus only on oil palm. The roots of oil palm make it difficult to grow pepper. Land after oil palm is not suitable for any other crop, except for fruit trees such as durian and rambutan. Therefore, oil palm is a long-term commitment. After 25 years he has to decide whether to continue with SALCRA or not or plant a different crop. He thinks land ownership is important for new generations so that the state doesn't steal it back.

I5

Participants: in total 5 people, all women.

One of them (the youngest) speaks about the importance of biodiversity: if it rains, water quality becomes very low and toxic especially because of palm oil fertilizers. That's why the gravity water is far away from the plantations and the village.
All of them have oil palm.
Opinion of oil palm? One of them is a bit concerned, but old ladies are not because there are other lands far away (untouched land such as Pulau)
Opinion about conserving Pulau? It's very important and they share it with the whole community. So to make a decision they need the consent of everyone. They feel that there is no conflict about it: there is only one person that doesn't want to conserve it (it's like 1 vs 100). From Pulau they get mostly fruits (such as durian), not really medicinal plants.
If you want to get timber you should have permission to discuss it with the rest of the community. To take timber anywhere else (not only Pulau), needs the permission of TR and the owner of the land.
Rice wine moment: one of them knows how to make it and will teach it to her son when he grows up. But they prefer the industrial one. Rice production of the village is not enough to produce rice wine. To make it, they buy the rice in the market.
Business proposal by one interviewee: they would like to bring tourism in Sebemban, for example a tourist trekking in Pulau Galau. But now they can't do it because they don't have internet access. This would be a job opportunity for people to let them stay in the village. As long as it brings benefits with the villages, the old ladies agree with her.
In the case of the old lady, they didn't lease the land to SALCRA. Their kids preferred to manage it by themselves. Their plans concern not only farming: they would like to open a processing mill of palm oil. If he opens the mill, job opportunities will be created.

I6 - Ethnobotanical guided walk
Knowledge about land ownership passing through families, as learned through an interview in a. This field belongs to her and her siblings, passed down from their parents. Her fathers grandmas siblings: two women, one man. The land given to the girls is inherited to the grandchildren's generation (her, her brother, another grandchild of the sister has oil palm. The man's grandchildren has the land that isn't cleared and is fallow right now. They ask for permission from each other to harvest on each others lands over the walkie. The wife's parents are divorced, and so don't share their land anymore, but each have a patch of land here too - her father gave her mother part of the land before the divorce. Her brother is the one taking care of the parents original house, so he is the one inheriting the house and the land the parents have separated. The father of her grandfather was the berimba (the one who clears the land is the one who owns it) was named juman, and her brother took that name after he died. Bibi also has some land here, an oil palm plantation this oil palm, down by the very tall durian tree.

- Forest is close to the village, and you have to pass thorugh it to go to the paddy.
- Tekalong: a tree used in the past to hunt birds. People used its "resina" in some sticks. They put them close to a tree from which birds are eating and they get stuked in the sticks. This method was used in the past for food security. Now people do not clim trees anymore and prefer to hunt birds with guns.
- Akar kubal: another tree where they harvest fruits. During fruit season (june, july) they sell these fruits on the market. Now it became very hard to find this fruit, that's why people do not want to clear up this forested area.

- We passed through the area were the frst people established before the construction of the first longhouse.
- Kmantan tree
- We passed the forest and now we ended up in the land of TR' wife's brother. They used to have paddy here, both wet and hill paddy. Now they planted multiple veggies and roots after having burned the area. Some palm oil are also planted. The veggies are treated with pesticides otherwise they wouldn't survive. When oil palm will grow, they will leave also the veggies.
- Ginger: there is a kind of ginger that was used for women after giving birth. The extract is being spread on the skin to protect the pores, because they are vulnerable to diseases. The malay peopl eare using this on the forehead.
- Red mushroom: is used for newborns if they have skin problems during bath time.
- History of the land: land was given in inheritance to all of the 3 siblings. So they divided it into smaller parts. Now it is distributed to them and their grandchildren.
- In a palm people can find a type of worm that can be eaten.

I7

Participants: 3 elderly women.

Women cultivate pepper, paddy, and veggies. They stopped with the rubber in the 90s. Paddy is only for consumption, in the village you can find both wet rice and paddy (hill rice). Sparrows are the main threat to the paddy. Pepper is both a cash crop and for its consumption. The main pests are insects. They have to invest a lot in fertilizers and pesticides for pepper. Oil palm is only a cash crop. Rodents (squirrels, porcupines) are eating small plants so that only a few survive.

Salcra: they pay workers 45 RM per day, while smallholders pay from 70 to 100 RM per day, depending on the amount that they harvest. For this reason, villagers do not work for SALCRA, the pay is too low. Salcra hires mostly Indonesian immigrants.

Vegetables: mostly corn and pumpkin. For their own consumption and sometimes they sell it in Pantu market, which is 30-40 min away by car.

TR's wife is selling baskets made with a synthetic material. It is a product that was once made with bemban. She sells them online and goes to Pantu for the internet. Rattan and bemban are used just for their own use. The new generation does not make it anymore because the process is too complicated. Skill is gone for the bemban mat. People nowadays would rather buy the plastic substitute because it is way easier and faster. Other people in the village also sell baskets to generate some income. Once per month they go to the market to buy additional products (sugar, salt, oil…).

I8

Participants: 7 members of the community, both men and women

There used to be more wildcats, not anymore. There are lots of monkeys, long tail macaws especially. Mouse deer can be found in the forest too. Leopards can be found up the river we swam in, they are black. Gibbons are present too. They eat the rodents in their plantations, the ones in the forest as well. There were orangutans around Sebemban before Tuai Rumah Moss was born, now there are not; he thinks it's bc of logging. A lot of slow loris can also be found nowadays, also a lot of otters. They also eat porcupines, but there are not as many as before. 200 oil palm trees from a member of the village were

eaten by porcupines. People also eat civets, these are common palm civet that live in the palms. These civets eat palm oil and chicken. They eat binturong as well, but the population has decreased. Flying squirrels can be found in forested areas. Wildlife decreasing, fruit falls and no animals eat it. Pigs and wild wolves disappeared bc African swine fever. Villagers stated that the expansion of oil palm has resulted in the decrease of wildlife. They also eat bats, they are delicious and sweet bc they only eat fruit; old generations never killed bats because they were pollinators, but new generations shoot them to eat. They hunt for animals during the dry season.

I9

Interview with Oil Palm owner concerning his oil palm plantation

In 2020, he was in the hospital in a coma for three days. He had inhale too much weedicide spray. He wears mask when spraying, which consists of a cloth dipped in water, but that didn't stop him from getting sick from the amount he inhaled. He tells us a story of coma for 3 days after inhaling too much spray - herbicide. He was already sick with a flu. This happened during covid era. Says he didn't get covid- he was getting poisoned. His kids brought the chemicals to the hospital so the doctors could better treat him and know what the problem was

Pesticides:

Brand of the one that poisoned Udin: Alai

He mixes two weedicides to kill the big trees on his plantation land: Paladang - weed killer and Romansul- Rachun hitam. We can see on the bottle that this is a Systemic weedicide. It contains Glyphosate.

The oil palm plot we visited: 130 trees, 5 years old

Doesn't work here himself, hires people for it - when the fruiting is high he hires 4 people, sometimes 3. Harvest once a month. 3 tons per month. Harvested last Saturday.

Koompassia -

Visiting another one of his plots:

5 yrs old

70 trees

Tells about a thunderstorm which knocked one over but it grew back. Looks funny now.

In the midst: sour turung (eggplant), yam, chili pepper

Tapang tree

Plantation:

5 yrs old

130 trees

1x/month

Hires 4 ppl to harvest

3 tonnes

28 , 29 ft between the oil palms

The plantation was paddy before, for 3 yrs

When he first started the plantation he used the paddy fertilizer here, also the chemicals he showed us to clear the big trees— now uses oil palm fertilizer. And, uses racun hitam - (glyphosate?) Acomik - herbicide
After planted the paddy, lots of yam and bamboo. He burned it to clear it for oil palm.
Weeds are about a week old now - One month ago fertilzer

Count of plants at ROP:
Sp1 - roundridges - 8ish bc vine
Sp2 - pointyridges – 9
Sp3 - tiny pointy flowery
10% high denisty - 23
25% medium - 6
65% low- 3
Sp4 - tinypointy no flowers
15-% high density - 29
25% medium - 14
50 % low – 6
Sp5 - broadleafgrass 49
Sp6 - mimosas 4
Sp7 - tree seedling 2
Sp8 - skinny grass 106
Sp9 - pointy 2

I10 - Interview with workers and landowners during biodiversity sampling on Pepper and HOP

1. Swallow nest: they have a farm of bird nests. They sell the nests to the chineses because in the chinese medicine it is used as a cosmetic againts aging (somehow you can drink it).

- Swallow nest is sold at a price of 5800-4800RM per kg. the price depends on the quality. Since it is new, they havent earned revenues yet. They sell it to some factories in Kuching and other places.
- In sebemban there are 3 swallows nest farms.

2. Pepper (150 pepper plants)

- Biodiversity assessment: 2 plots of 2x2m. observe the plantation first and notice the differences; decide where to put the plot areas, possibly in different spots to capture diversity. We put one in a less green area, one in a more green one. Count the species.
- Soil sampling: in the plot area, select 3 spots for soil sampling (random but also considering diversity). Sample first 0-20 cm, and mix the 3 samples together in one single sample. In the same holes, take samples of 20-40 cm, and mix them together. Then take one sample fot soil for bulk density.

3. Oil palm
   Same as the above.

I11 - Unstructured interview with a group of men in the kitchen, late in the evening

Cangkung - vegetable by the water, seen on morning walk on Wednesday 6th
PEST
Fruit: nr 1: squirrels. nr 2: monkeys. bats and civets are also a pest,
Rice: nr 1: sparrows, the Malaysian field mouse are also bad, but not as bad as pipit (sparrows). but in other places it's monkeys (long tailed macao monkey), but there are not many monkeys here now
In the 1940s-50's, pepper arrived to Sebenmvan
As far back ad TR Moss remembers, people cultivated both pepper and Rice
Pepper has to grow on a Hill, because it's sensitive to mold and needs a lot of drainage and fresh air. And also because the hills mean less weeds, if you grew ok flat you would have to cut weeds every day.
The men in the kitchen also prefer the taste of red rice over white rice
Eat rodents from the forest and plantations, but not the ones from the houses, because they're considered more dirty. The snakes eat rodents, and when workers see a snake in the plantations, they shoot them for meat. Lots of wild cats before, but not anymore. Mouse deer, the one we had the first day. They went out hunting for it, shot four of them in the kampong (secondary forest)

I12

Is there any land that has not already been "claimed" here?
Yes! There is some land that is untouched.. Sebemban is BIG (biggest village in nearby area?), so there is a lot that is untouched.

How is new land acquired here?
IN THE PAST:
Whoever can clear forest and plant claims it as theirs.

NOW:
Inherited. Whoever takes care of the parents of the family gets most of it. Still some for other siblings.

Have to communicate! Whoever has land (anyone else has some), must all agree. Meet in Moss's longhouse for these discussions. His is the 'home' for all 3 longhouses.

2 scenarios if there is a dispute. One if the land is not part of SALCRA, the land is marked as "under dispute" and it can't be used until dispute is solved. Two, if the land is part of SALCRA, then if a dispute they must reach a negotiation.

Recent history of SALCRA:

SALCRA came to the village, gave a presentation. Did a land perimeter survey of all of Sebemban. Once done, everyone could decide whether to give or not. (up to individual land owners). River we bathed in – land beyond that no one surrendered that to SALCRA. SALCRA is willing to subdivide the land.

In contrast, if a JV company was to come here, the people I'm chatting with state 'they are going to force the whole community to give over the entire land.' They explain, that's why we don't want to work with any other companies. And, prefer to work with SALCRA.

As a side note they mention that they have been partnered with SALCRA for a long time, first was cacao, now oil palm. They mention that in the 1980's the government stopped updating their information.. and that there is a sign near entrance to the village (along highway?) that still says they are farming cacao.

They explain a bit about the Palau Galau.. say "all villages nearby know the boundaries" and that "it's never been developed." When SALCRA came the community wanted to continue to preserve so drew the boundary for SALCRA land and did not surrender that land (with Balai Mayas). They say it would have been "messy" anyways, as it is owned by many villages. A primary reason for preserving it they say was to preserve the many fruit orchards within. Durian, wild dabai, kemayau, kepayang, jackfruit, uchong. Also tapang trees within (which are a protected species), and terminalia catappa (spelling?). They exclaim.. there are far too many species in the Palau Galau to note them all!!

Pulau Galau – can only access if blood lineage of local communities. Also of note, a 4WD vehicle has been required to harvest / transport. They wanted the road that SALCRA is building around the area to make it a bit easier. (The land they surrendered for oil palm to SALCRA is all around it).

When the price of a commodity is too low, there is oversupply, how do farmers respond? Do they all start switching to different crops or is there more of a coordinated effort?
-when everyone has the same type of crop, and they sell it, everyone in the village can buy it even though they have the same type. They plant at different times in the year so that all the supply is not at the same time

OBJ
-Lenggain: king of fruit, dabai and kemayau. It is very hard to grow, it is not seasonal, so if you want to collect and sell it, you have to get it from Pulau Galau
-is it overharvested in Pulau Galau? It has become extinct due to logging. The timber companies intentionally cut this tree because the timber is great, and the tree is big.
-is there any protection? The local community made the decision to fine people very high if they cut down this tree. You need special permission.

How has access to markets through better roads impacted agriculture? What are the costs and benefits? For example does it decrease the price but provide greater demand?
-

How have better roads impacted your agricultural activities?

-give them a better life, in the past they used boats to access markets (Pantu) it took four hours to get there.
-access to markets give them more people to sell
-no negative impact

Why is it important to have telecommunications?
-emergency cases
-need to call

How would access to telecommunications change their agricultural activities?
-there are people selling their goods online
-handicraft like baskets
-easier to sell goods, can do it online, such as wild fruits. In terms of major agricultural commodities, it would make the process easier, but not necessarily in terms of placing orders online. Just in terms of communication.
-Pepper board is where they sell it to

I13

Swidden cultivation vs bulldozing
-slash/burn is illegal on a large scale, it is respected on a smaller scale. Illegal because of environmental pollution Smallholders do have to bulldoze larger plantations.
-slash/burn is much cheaper, a bulldozer is 130 ringet/hour
-also keeps soil fertile
-much easier/quicker
-fire started in a dry

He's converting the paddy to oil palm because the paddy was a failure. Too swampy in the area, oil palm will do fine. It was converted from rubber to paddy in 2022
The salcra area started as cacao, was later converted to oil palm. Initially workers were hired from the village, for a wage of around 2 ringet/day.

I14

Visit to a fishing pond with Tuai Rumah Moss, Wednesday 6th

Still new, fish babies were put out this January. The fish are red Tilapia
Owned by a relative of TR Moss named REDACTED – maybe a cousin. These fish are for selling at the wet market in Lachau, not for self consumption. Moss also had a fish pond that he stopped running. Its quite high maintenance, so he decided to stop in 2019
They need to put up a big fence to keep out otters and monitor lizards. Feed the fish three times a week when they're small, and less often when they grow to adult
Conversation about the Pulao Galao: One of the TR and his households wants to let a logging company clear it. It is a native customary land, so they cant sell it – the company is offering a compensation of 1.000 ringgit per household in return for being allowed to clear the forest there
Moss and Larry don't want that - Pulao Galao needs consent from everyone in the community to make decisions about the management, as they are traditional spaces of conservation forest. Typically, they are

used mainly for artisanal logging, as the trees there are allowed to grow larger than in short fallows, and one needs permission from the entire community at a meeting

I15

Headmans oil palm
How productive are they 12 years on?
-not so productive, 1800kg every month

Main benefits of official title:
-you can sell the land
-the government must compensate you for the land itself and not just whats growing on it
-if someone sells NCR land, the sale won't be recognized by the government because it is still considered state land

Ex-headman planted pepper until 2008
-patty was probably planted before

OBJ
Terrace going to be used for oil palm

OBJ

OBJ
Invasive fern, associated with poor soil, opening up land

Oil palm often requires a lot of fertilizer, dependent on the soil

If trees are not productive, why replant oil palm?
-comparatively, its much easier to take care of oil palm
-don't need as much pesticides

Palm oil seedlings
OBJ
Why isn't the pepper producing?
-soil isn't good
-patty was grown here before and it was productive
-hard to maintain so he isn't putting much work into it
-plan is to let the area fallow
OBJ
Palau land, forest reserved for the community

-not recognized in the land code, but there is an ongoing movement to have it included
-chose to include this land in palau because they cannot farm on it anyways

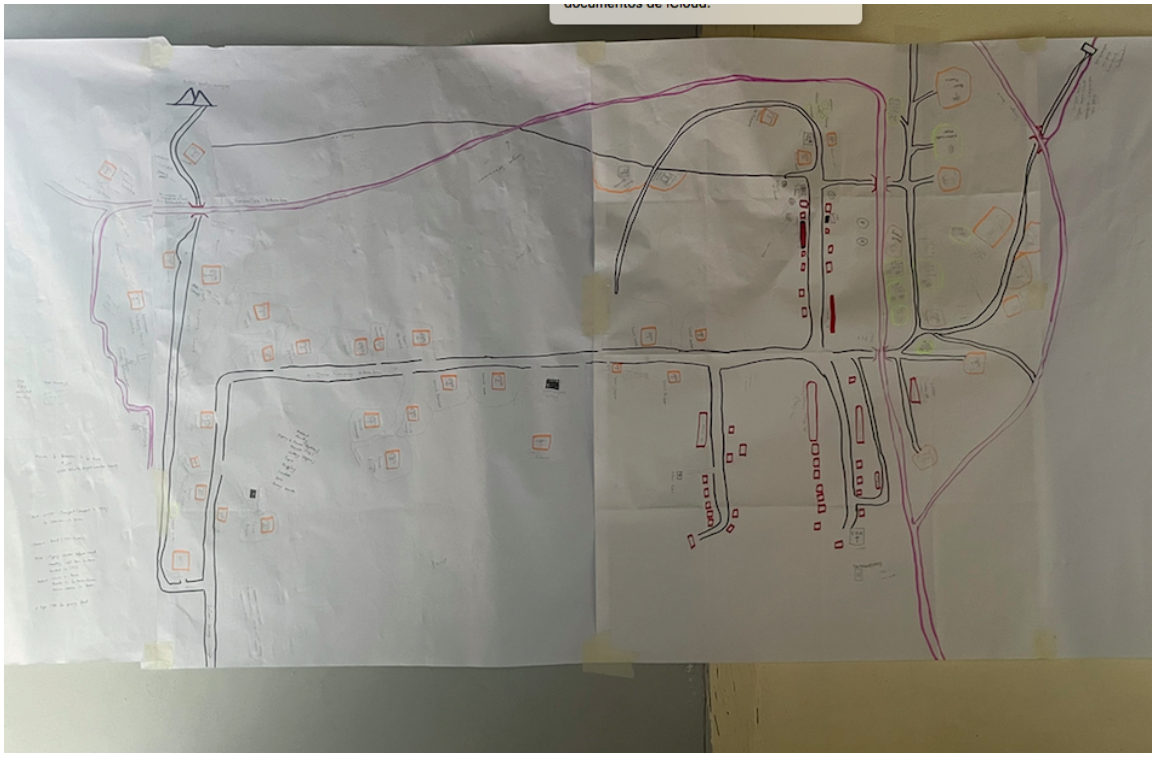
When you talk about rights, it becomes conflict.
-siblings will physically fight each other to determine who gets lanD

Why renew contract with salcra?
-owners are too old to tend to the land
-younger people are not interested in taking it over

Appendix C3: Focus group discussions

Appendix C3.1: Participatory Mapping exercise

Community Mapping Exercise, Map 2 (Drawn by Tuai Rumah Moss's longhouse)



Community Mapping Exercise, Map 3 (Drawn by Tuai Rumah Jilum's longhouse)

C.3.1

Tuai Rumah Moss' longhouse map discussion

17 years old
-he will stay in Sebemban and work
-he works on many oil palm fields
-balai ri high school
-pepper
-vegetables in a farm
-cucumber, corn, bringo (eggplant)
-takraw is his hobby
How has sebemban changed
-more houses, but the population has stayed the same
-families move out of the longhouse and have their own place in the village
-the land they use for farming has expanded a lot

The area we are in now used to be fallow land
-2005 they started developing houses more
-before then they were still living in wooden longhouses, tembawai— old settlement
-across the river, it was all primary forest.

-they moved because it was always getting flooded

OBJ

-flooding has increased in this area because of oil palm development
-oil palm development started early 2000s, they moved because of flooding in 2005
-flooding in the area has increased since 2021. Bibi thinks because of oil palm development
-NEW SALCRA DEVELOPMENT IN 2021, that has caused the flooding
-they wanted to find an area where they didn't have to live on wooden stilt houses, thats how they dealt with the flooding historically
-they old settlement was way better before the road was developed, they were taking better care of the environment, there was more biodiversity
-flooding didn't get worse in the old settlement, it was always like that. They moved because they had the option of building better houses. The old settlement wasn't suitable for electricity
-the government provided electricity
-they had to write a letter to the government to bring electricity into the village, got it in 2015
-No plan to deal with the flooding

Any other impacts aside from flooding as a result of oil palm development?
-climate change
-its become hotter
-they are aware that oil palm development is causing climate change
-the river is becoming smaller, which impacts their economic activities like fishing
-fishing used to be a main economic activity, because the river was the main transportation method
-fishing is not done at all. Because of the logging/deforestation
-forest kept the river cool in the shade, logging happened, river dries up

What did the fishermen start to do instead of fishing?
-changed to hunting
-before logging, they hunted a lot more, deforestation caused less animals,
-Sebemban eats less fish and meat than in the past
-vegetable consumption has increased
-plants that they grow in the garden, and collect from the forest

-vegetable farming has increased because of:
1. personal consumption
2. Cash crop
-they have business/access to markets to sell their vegetables
-longbean, cucumber, baby corn, bittergourd, bringel (eggplant)
-everyone grows vegetables
-people who have less labour capability plant bringel because its wild and you dont need to maintain it,

- more able bodied people, have a variety of vegetables because they are more labour intensive
-pepper is still a more important cash crop, vegetables are a supplementary income source

What are some issues in the community you think we should research?
-its a good thing to study water because it is the main thing they use in their daily lives, we don't know if its contaminated
-mini-hydro
-propose what needs to be done to ensure the water quality is secure.
-they want feedback. Water is critical, everyone needs it.

What do you think are concerns we should investigate?
1. There is too much supply of cash crops being sold within the village. Too many market participants and its becoming hard for people to earn a living because the price falls. People need to leave the market. Competition too strong, race to the bottom
2. Things related to oil palm and pepper, maintenance is too high. Pesticide and fertilizer are too expensive. Many people cannot afford it, this results in decreased yields, lower income
3. Road/internet. Road is not good enough, lots of potholes, some parts aren't paved yet, erosion, hard to drive on.
-Ma and her ladies said the same thing

The trirumas cousin discussed the importance of our research helping the community by taking the information to the district officer/higher authority, so that they can understand the issues in the community and provide support. Especially with internet.
-health care is a big concern, distance to clinic is about 1 hour

They used to have a helicopter come in the past, don't need it anymore because of the road.
-the reason she is doing the red dots in the river is because it is very sandy
-it has always been sandy, but before they could use boats more. Now, erosion from oil palm has caused the sand to build up

C.3.2 Tr Larry's longhouse discussion

C.3.3: Tr Jilum's longhouse discussion

People start drawing roads and houses (including the names of the people inhabiting). Mostly men are participating at this stage.

Then they draw the river; Fish farms of households and outside the village; Churches; Land with names of owners.

Very accurate in drawing all houses and pieces of land

They draw the old longhouse that now does not exist anymore. It is the original longhouse of the village, and was left 20 years ago.

They only draw the land belonging to the village, not the one belonging to salcra.

Young people are participating. It looks like they are putting an effort in making everything accurate, especially with lands and roads. They are the sons of a couple who are contributing a lot to the exercise.

TR was among those who started the activity and is helping the young people in the details.

Map was expanded to include every detail

They include pulau galau. Last logging activity: 1988

Before the road they used to go to the town in pantu with the boat, using the sebamban river. The road was built in the 70s.

20 years ago rubber was everywhere instead of palm oil and pepper.

Churches are all relatively new (they are 3) and were built in the last few years/decade.

Overall, the village expanded a lot in the past years. Churches were built, fish farms, and new houses: before there was only a longhouse. All the others came after, they are less than 20 years old.

Before the 70s, they had cows but they were ruining the crops. So now they just have chickens and goats.

Appendix C3.2: Notes from Ranking exercise and the follow up focus group

- *Economic value:* They did economic valuation based on whether they can sell the product and the market value, taking into account the prices and the festive season for sale of fish and pigs.
- *Labour*: Labour captures the intensity of the work they have to put for each of the activities.
- Consumption
- *Maintenance*: They think about the difficulty level keeping plants and animals alive and the loss they might get based on weather, pests, etc, and the amount of fodder and fertilisers and or pesticides they need for each activity.
- *Risks*: The risks are the same as above.
- *Environmental* impact: the impact is the land where they do activity, taking into consideration if they are able to grow other crops (crop rotation) after planting a certain crop. The other factors are about loss of nutrients to the land and whether the animals might cause any pollution to land, water etc.
- *Location*: they rank the location based on difficulty to find a suitable location, for example if it is easily accessible (like vegetables garden behind their house)

<u>Discussion of the factors influencing decision making:</u>

Economic Value:

Oil palm: five stickers under economic value. it's the main source of income for many in the community, it's economically important they have a lot of oil palm
Pepper is also important but it's the second economic source so not as pepper

Own consumption:
They don't consume oil palm, only cash crop. That's why it's zero

Why people put oil palm and fruit as same economic value:
Economic value is equal bc within the community they have many and various fruit orchards, so when they have a high amount of fruit they have income from the many variety. The fruit orchard is seasonal crop, so if the whole community only has dabai, which has a very high value, then the can sell it for a good price because other villages don't have it. The high variety increases their competitiveness compared with other villages

The economic importance of rice:
If you're a person with a lot of rice fields and a high quantity of rice, you'll sell it. They'll sell it to outside, typically Lachau. For example in Sri aman white rice is 15 kg per kilo, but black is 18 ringgit. So their smallholder rice is valuable. For Lian, he sells it in Kuching (but maybe only him)

Livestock rearing risks: the pigs has swine flu, the chicken can have chicken flu

Environmental impact:
The community puts no environmental impact for pepper, rice, and veggies. The land they use for these crops can always be recycled and used for other crops, so they are no considered destructive for the environment in terms of future production.
The reason why environmental impact for palm oil is so high is because the land can't be recycled for other crops after the oil palm. This is because of the roots of the oil palm.

Maintenance of oil palm and pepper. The cost of the maintenance of the two is the same - pesticide and fertilizer.

Risks of oil palm and pepper: The risks are similar to each other. Oil palm is easy to gain disease, susceptible to fungal oil palm disease, and pepper to pepper fungal disease. For rice, the high risks is especially related to pests.
Risks involved in growing vegetable:
Vegetables get eaten by animals, if not properly fertilized it doesn't grow or it becomes yellow. They use pesticides in the vegetables. They want to keep worms away
Alica- name of the pesticide for vegetables and pepper
For oil palm, it's a different pesticide

Environment impact of swiftlet best farming:
The only reason for swiftlet farming is because of swiftlet lice that has disease that can spread among the people. That's why they build those farms further away from the village. For fish, when the water is very hot, the fish can die.

The reasons they make these kinds of decisions for economic value is not affected by harvest festival, but influenced by how they want to become successful in the near future, but also their income and livelihood style

Ranking of the factors influencing decisions:
Location
Location is very important. It was ranked five. Worth noting is that the community has a different understanding of the location factor than we did

Economic Value:
Economic is important, but the group of women say that location is more important. Knowing the location is important to make sure you know you grow your crops on your own land. Because if you grow something on someone else's land without permission, that crop is then theirs to own. Economic value is ranked five

Labor:
Labor gets four. The reason it gets four is because they hire people to work for them. It's important because they need to know which land they want to grow the different crops on.

Own subsistence use:
They at first we're discussing putting own consumption on zero, but then they started discussing that it's important to them to grow things like rice, and also they both sell and consume things like veggies and fruits

They say it's difficult to rank the factors because the factors are very important for oil, rice and pepper, but everything else is more of a hobby or side income or cultural

Maintenance:
The reason they want to rank maintenance high is because it's ranked highly in the whole exercise

Environment:
Environmental factors is ranked five
The reason environmental impact is ranked five is because when it is flooding, the flood influences all the crops. Especially in the flat areas where it's prone to flooding

Own consumption:
Ranked three

Ranking of resources:
Fruits:
Durian, rambutan, banana. Fruits are very important because they can sell it to other towns and use it for own consumption. The balance of both is very important to them

Livestock:

Livestock reasons like the orchards. Bc you can sell and consume it. But for pigs, they kill it to sell it. 1kg is 38 ringgit, import to Lanchau. It's not as important as the rest because they've already sold all their pig.
They sell chicken for 70 ringgit. Chicken village is a very natural and organic and sweet and better than Chinese chicken. It's a high price because it's delicious. They don't sell often bc they eat it themselves. They sell them in Serian and Lanchau

- Only one person raises goats

The pigs are dead and sold. The remaining pigs are only babies. Pig is very expensive nowadays. Before swine flu, they sold very often. They can sell it for many money now because it's hard to procure.

- They also raise duck, only for their own subsistence use

Swiftlet nest farming:
70% of the village don't do swiftlets that's why it's only 3. But it's not lower bc the price is good, it's 1000 ringgit for only 1 kg. The location needs to be in the hills, bc the flats don't attract birds

Fishing:
Fish is similar reason as to birds. Not everyone has fish

Non-timber forest products
NTFPs Export to Singapore. State initiative where the state will be able to export mirin to Singapore. Way before, if the mirin is located in this area, people can always collect it. But now, if it's located on someone's land, you have to ask permission, so you can't just collect from anywhere. Cassava, sweet leaf, Pulp of different palms. Wild banana pulp is cooked and eaten. Lalis pulp is sold for a good price, 2 stems sold for 10 ringgit.
There are porcupines in the oil palm plantations, they eat the fallen palm fruits. In this there's not only pour up one eating the oil palm, but also squirrels and rats and general rodents.

Vegetables:
Vegetables are important food for eating and selling both

Oil palm, pepper and rice:
These three are all in the top are important because they're the income sources. The sell both the pulp and oil from oil palm.

AppendixC4

Questionnaire

Date: _____ Time: _____

Questionnaire Sebemban (Household-Level)

Code:

Section A: Respondent's Information				
A1	Longhouse/*Rumah Panjang*: _____			
A2	Gender/*Jantina*:			
	☐ Male/*Lelaki*	☐ Female/*Perempuan*		
A3	Age/*Umur*: _____			
A4	Do you reside here full-time (**≥ 6 months**)?/*Adakah anda menetap sepenuh masa (≥ 6 bulan) di kampung/tempat ini?*			
	☐ Yes, How many years/*Ya, Berapa tahun*:		☐ No/*Tidak*	
A5	Is this your original village/*Adakah ini kampung asal anda?*			
	☐ Yes/*Ya*	☐ No, Original Village/*Tidak, Kampung Asal*: _____		
A6	Main occupation / *Pekerjaan utama*:_____ ***(please go to Question A10 if you are a student, homemaker, unemployed or retiree)*** ***(sila pergi ke soalan A10 jika anda seorang pelajar, suri rumah, penganggur ataupun pesara)***			
A7	Nature of Employment/*Jenis Pekerjaan*:			
	☐ Waged Employment/*Kerja Bergaji*		☐ Self-employment/*Kerja Sendiri*	
	☐Both/*Kedua-dua*			
A8	Occupational Sector/*Sektor Pekerjaan*:			
	☐ Government/*Kerajaan*	☐ Private/*Swasta*	☐ NGO	☐ Not Relevant/Tidak Releven
A9	Occupational Status/*Status Pekerjaan*:			
	☐ Full-time/*Sepenuh Masa*		☐ Seasonal-based/*Ikut Musim*	
	☐ Covenience-based/*Ikut Kesenangan*		☐ Others/*Lain-lain*:	
A10	Household Income Source (can choose **more than one** answer) *Sumber Pendapatan Isi Rumah (boleh pilih **lebih daripada satu** jawapan)*:			
	☐ Fixed Income/*Gaji Bertetap*		☐ Income from Selling Activities/*Gaji Penjualan*	
	☐ Remittance/*Wang Kiriman*		☐ Money from Social Welfare/*Wang Bantuan*	
	☐ Others/*Lain-lain*: _____			
A11	Estimated Monthly Household Income Source/*Anggaran Pendapatan Isi Rumah Sebulan*			
	☐ No Income Source/*Tiada pendapatan*		☐ RM 2,001 – RM 3,000	
	☐ <RM 500		☐ RM 3,001 – RM 4,000	
	☐ RM 501 – RM 1,000		☐ RM 4,001 – RM 5,000	
	☐ RM 1,001 – RM 2,000		☐ > RM 5,000	
A12	Calculation of Income Source/*Pengiraan Pendapatan*:			
	☐ Monthly basis/*Secara bulanan*		☐ Not Fixed/*Tidak tetap*	
A13	Additional Notes/*Nota Tambahan*			

Date: _____ Time: _____

B2 Household Expenditure/*Perbelanjaan Isi Rumah*:

No	Types of Expenditure/ *Jenis Perbelanjaan*	Estimated Expenditure/ *Anggaran Perbelanjaan*	Expenditure Frequency/*Kekerapan Perbelanjaan*			
1	School expenditure for kids/*Persekolahan anak-anak*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
2	Food stuff & Kitchen/*Makanan &masakan dapur*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
3	Electricity bill/*Bil elektrik*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
4	Water bill/*Bil air*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
5	Attires and shoes/*Pakaian dan kasut*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
6	Personal hygiene/*Sabun, shampoo, berus gigi, ubat gigi*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
7	Medical/*Perubatan*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
8	Transportation/ *Pengangkutan*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
9	Phone & Internet/*Telekomunikasi/telefon bimbit/internet*		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
10	Others 1/*Lain-lain 1*:		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
11	Others 2/*Lain-lain 2*:		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*
12	Others 3/*Lain-lain 3*:		☐ Daily/*Harian*	☐ Weekly/*Mingguan*	☐ Monthly/*Bulanan*	☐ Not fixed/*Tidak Tetap*

B3 How many vehicles owned/*Pemilikan Kenderaan*

Car/*Kereta*:

Boat/*Bot*: _____

Motorcycle/*Motorsikal*:

Bicycle/*Basikal*: _____

None/*Tiada* : ☐

Other forms of asset ownership?

- ☐ Radio
- ☐ TV
- ☐ Telephone
- ☐ Computer
- ☐ Fridge
- ☐ Washing machine
- ☐ Electric fan

Other

Date: _____ Time: _____

B4 Detailed Economic Profile/*Profil Ekonomi Terperinci*

No	Category/*Kategori*	Involvement/*Penglibatan*		List the activities you engage in (Senaraikan aktiviti yang terlibat):	State if it is a source of income, own consumption, or both (Nyatakan sama ada aktiviti tersebut adalah sumber pendapatan, kegunaan sendiri atau kedua-duanya)
1	Agriculture/*Pertanian*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.
2	Livestock Rearing/*Penternakan*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
3	Small Business/*Perniagaan Kecil*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
4	Handicrafts/*Kraftangan*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
5	Aquaculture/*Akuakultur*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
6	Swiftlet Farming/ *Pengusahaan Sarang Burung*	☐ Yes/*Ya*	☐ No/*Tidak*		1. 2. 3.
7	Fishing/*Memancing Ikan*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
8	Hunting/*Pemburuan Haiwan Liar*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
9	Collection of Forest Resources/ *Pengutipan Hasil Hutan*	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.
10	Others/*Lain-lain* (specify/*nyatakan*)	☐ Yes/*Ya*	☐ No/*Tidak*	1. 2. 3.	1. 2. 3.

B5 According to the activities listed above, which one is your main source of income? (Berdasarkan senaraikan di atas, mana satu aktiviti yang menjadi sumber pendapatan utama?) _____

Date: _____ Time: _____

Which one is your second source of income? (Aktiviti mana satu yang menjadi sumber pendapatan kedua?) _____

Date: _____ Time: _____

Section C: Livelihood Strategies & Perceptions	
C1	What would be the aspects needed to be improved for your household? (Aspek apa yang perlu dinaiktaraf dalam keluarga anda?)
	☐ Good celluar coverage and internet connection for my house (Jaringan internet yang bagus)
	☐ More financial assistance and subsidies for agriculture (Bantuan kewangan dan subsidi tanaman)
	☐ Better road connectivity (Jaringan jalan raya yang baik)
	☐ Other (Lain-lain):

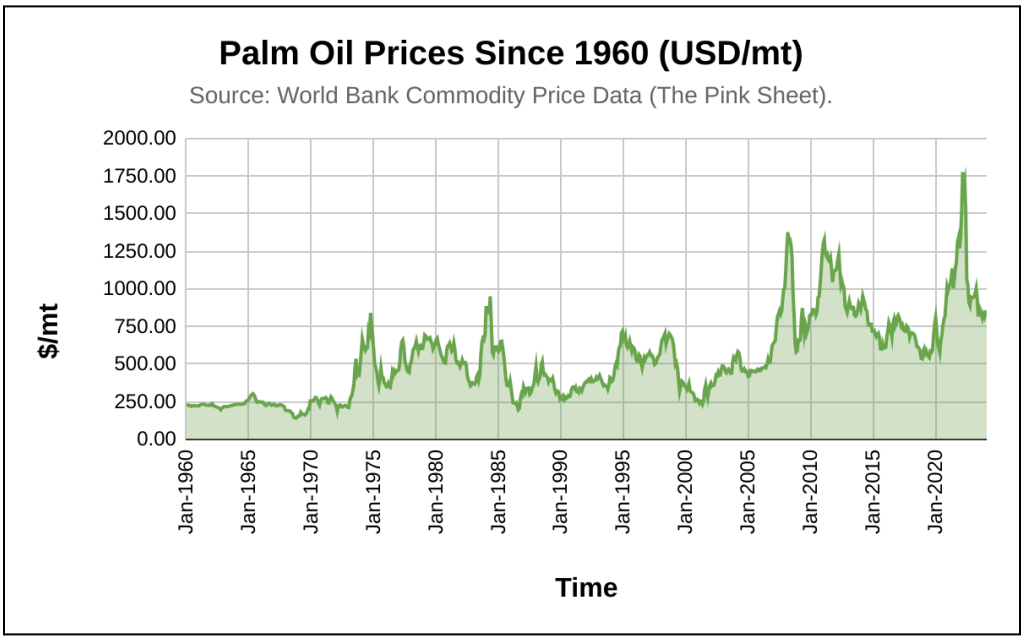
Appendix C5:

Format in terms of ranking matrix		
Activity	**Number of households (n=40)**	**Percentage**
Oil palm	21	52.50%
Pepper	22	55.00%
Paddi	12	30.00%
Vegetables	14	35.00%
NTFPs	18	45.00%
Fish Farming	10	25.00%
Swiftlet nest farming	2	5.00%
Livestock rearing	15	37.50%
Fruit Orchards	7	17.50%

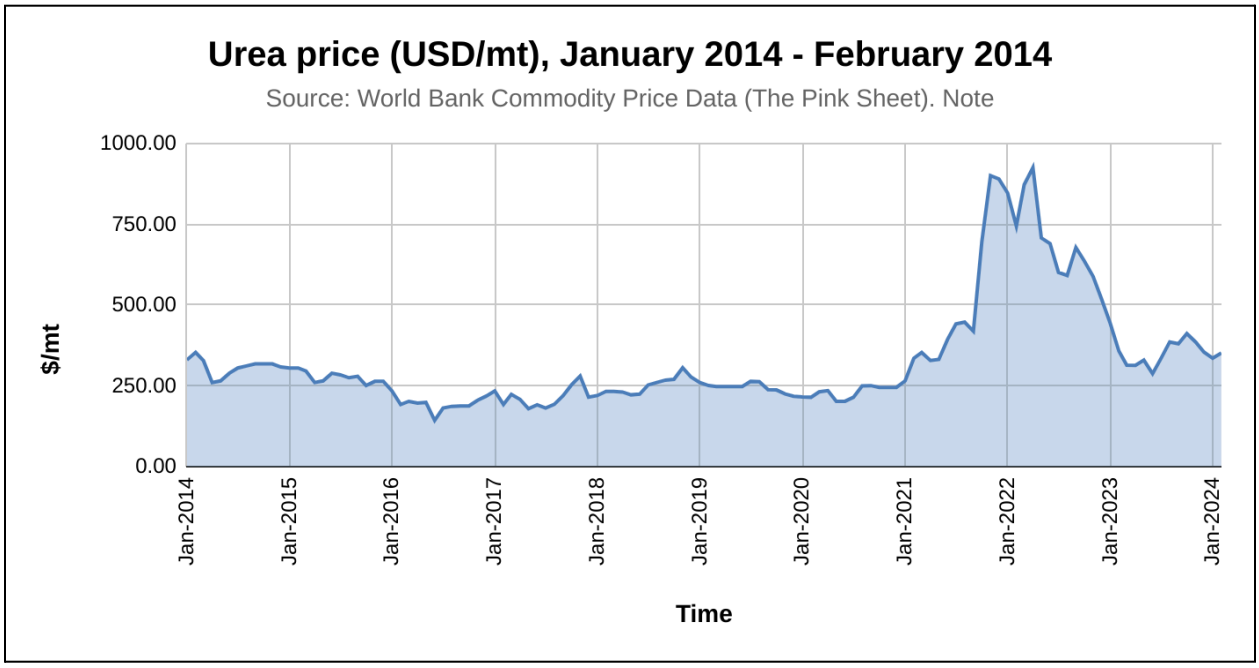
Appendix C5.2

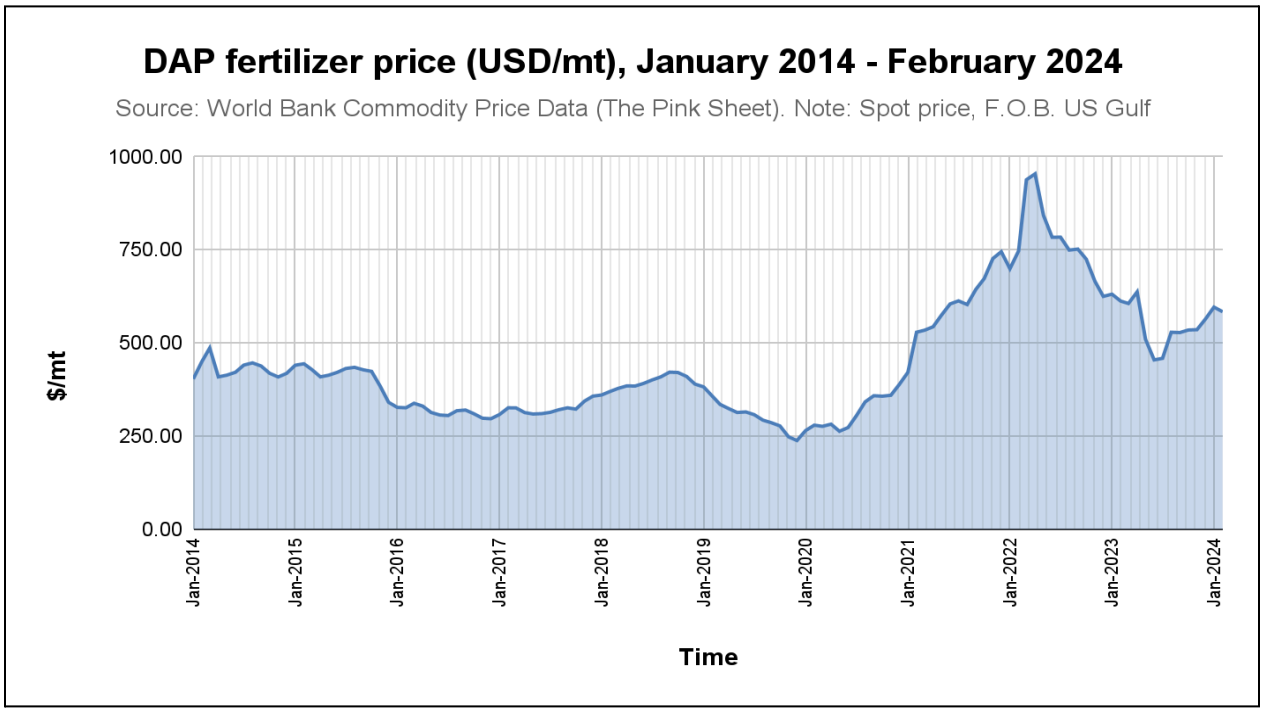
How many oil palm farmers grow additional crops? (n=21)		
	Number of households	**Proportion**
Only oil palm	3	14.29%
Oil palm & pepper	1	4.76%
Oil palm & padi	8	38.10%
Oil palm & other crops	0	0.00%
Oil palm, pepper & padi	0	0.00%
Oil palm, pepper & other crops	1	4.76%
Oil palm, padi & other crops	3	14.29%
Oil palm, pepper, padi & other crops	5	23.81%
Total oil palm & additional crops	**18**	**85.71%**

Appendix C6.1: Historical palm oil prices



Appendix C6.2: Historical fertilizer prices





Appendix C7: Malaysian national water quality standards

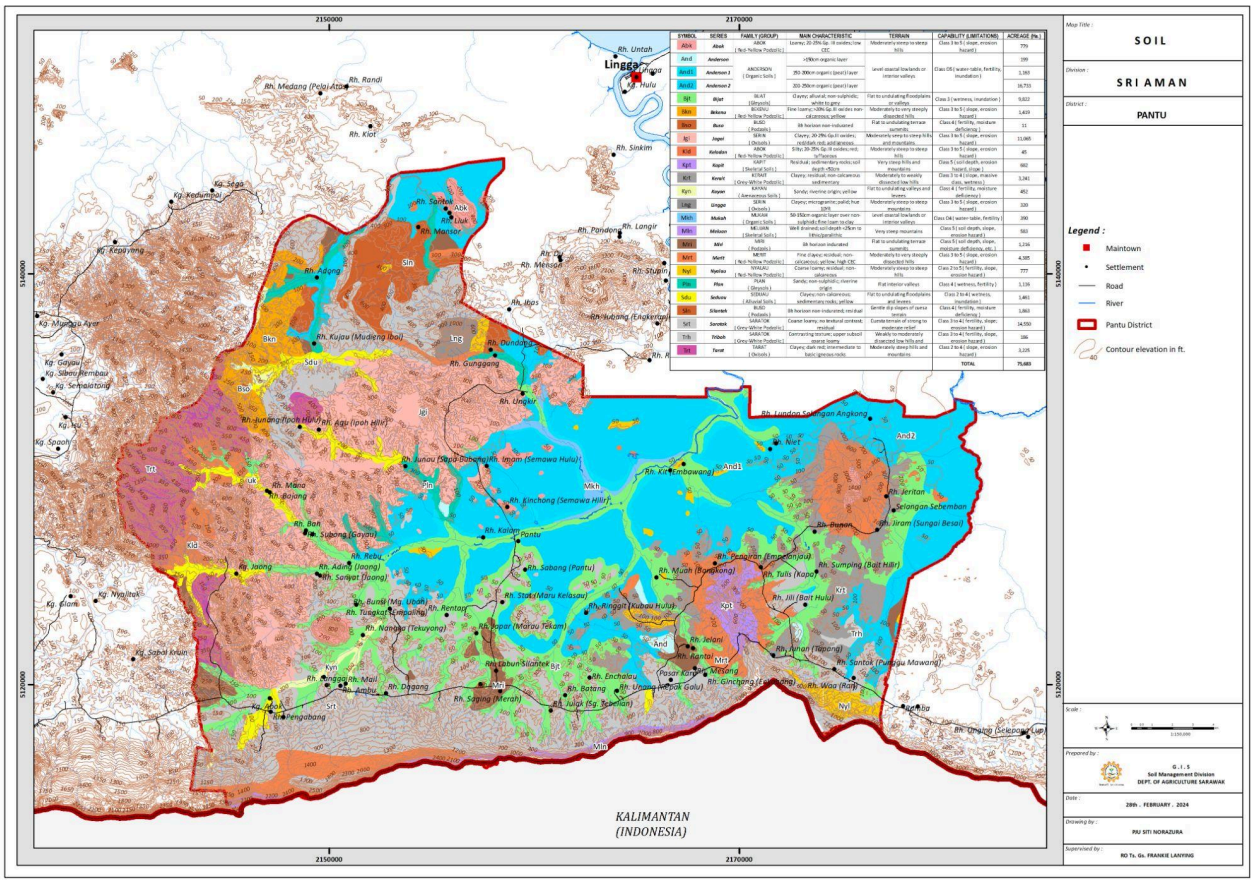
Source: Department of Environment Malaysia (2021). National water quality standards for Malaysia. Retrieved from: https://www.doe.gov.my/wp-content/uploads/2021/11/Standard-Kualiti-Air-Kebangsaan.pdf

PARAMETER	UNIT	CLASS				
		I	IIA/IIB	III[#]	IV	V
Al	mg/l	NATURAL LEVELS OR ABSENT	-	(0.06)	0.5	LEVELS ABOVE IV
As	mg/l		0.05	0.4 (0.05)	0.1	
Ba	mg/l		1	-	-	
Cd	mg/l		0.01	0.01* (0.001)	0.01	
Cr (VI)	mg/l		0.05	1.4 (0.05)	0.1	
Cr (III)	mg/l		-	2.5	-	
Cu	mg/l		0.02	-	0.2	
Hardness	mg/l		250	-	-	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	
Fe	mg/l		1	1	1 (Leaf) 5 (Others)	
Pb	mg/l		0.05	0.02* (0.01)	5	
Mn	mg/l		0.1	0.1	0.2	
Hg	mg/l		0.001	0.004 (0.0001)	0.002	
Ni	mg/l		0.05	0.9*	0.2	
Se	mg/l		0.01	0.25 (0.04)	0.02	
Ag	mg/l		0.05	0.0002	-	
Sn	mg/l		-	0.004	-	
U	mg/l		-	-	-	
Zn	mg/l		5	0.4*	2	
B	mg/l		1	(3.4)	0.8	
Cl	mg/l		200	-	80	
Cl_2	mg/l		-	(0.02)	-	
CN	mg/l		0.02	0.06 (0.02)	-	
F	mg/l		1.5	10	1	
NO_2	mg/l		0.4	0.4 (0.03)	-	
NO_3	mg/l		7	-	5	
P	mg/l		0.2	0.1	-	
Silica	mg/l		50	-	-	
SO_4	mg/l		250	-	-	
S	mg/l		0.05	(0.001)	-	
CO_2	mg/l		-	-	-	
Gross-α	Bq/l		0.1	-	-	
Gross-β	Bq/l		1	-	-	
Ra-226	Bq/l		< 0.1	-	-	
Sr-90	Bq/l		< 1	-	-	
CCE	µg/l		500	-	-	-
MBAS/BAS	µg/l		500	5000 (200)	-	-
O & G (Mineral)	µg/l		40; N	N	-	-
O & G (Emulsified Edible)	µg/l		7000; N	N	-	-
PCB	µg/l		0.1	6 (0.05)	-	-
Phenol	µg/l		10	-	-	-
Aldrin/Dieldrin	µg/l		0.02	0.2 (0.01)	-	-
BHC	µg/l		2	9 (0.1)	-	-
Chlordane	µg/l		0.08	2 (0.02)	-	-
t-DDT	µg/l		0.1	(1)	-	-
Endosulfan	µg/l		10	-	-	-
Heptachlor/Epoxide	µg/l		0.05	0.9 (0.06)	-	-
Lindane	µg/l		2	3 (0.4)	-	-
2,4-D	µg/l		70	450	-	-
2,4,5-T	µg/l		10	160	-	-
2,4,5-TP	µg/l		4	850	-	-
Paraquat	µg/l		10	1800	-	-

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	ppt	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

CLASS	USES
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

Appendix C8: Soil map with legend of Pantu district, Sarawak



Appendix C9: Results of field testing for soil texture, soil color, and OM content

Soil	Samplin	Texture	Color	Color	Organic	Notes

	g depth		code		matter content	
P-SP1-20	0-20	Sandy Clay	10yr, 5/4	Yellowish brown	Medium	
P-SP2-20	0-20	Sandy clay loam	10yr, 4/4	Dark yellowish brown	Medium	
P-SP1-40	20-40	Sandy clay loam	10yr, 6/8	Brownish yellow	Low	
P-SP2-40	20-40	Sandy clay loam	2,5y, 6/6	Olive yellow	low	
Hill-SP1-20	0-20	Sandy clay loam	2,5y, 5/4	Light olive brown	Medium	
Hill-SP2-20	0-20	Sandy clay loam	2,5, 6/6	Olive yellow	Low	
Hill-SP1-40	20-40	Sandy clay loam	2.5, 7/8	Yellow	Low	
Hill-SP2-40	20-40	Silty clay loam	2.5, 7/8	Yellow	Low	
PG-SP1-20	0-20	Sandy loam	10yr, 6/6	Brownish yellow	Low	Large sand grains, particulate content. Organic chunks.
PG-SP2-20	0-20	Sandy clay loam	10yr, 4/4	Dark yellowish brown	Medium	
PG-SP1-40	20-40	Sandy clay loam	10yr, 6/8	Brownish yellow	Low	
PG-SP2-40	20-40	Sandy clay loam	10yr, 5/6	Yellowish brown	Medium	Sand grains and particulate, several small rocks, organic particles
River-SP1-20	0-20	Silty clay	2,5y, 6/6	Olive yellow	Low	Thick root mat, a lot of organic debris in the sample
River-SP1-40	20-40	Silty clay	2,5y, 6/6	Olive yellow	Low	Underground water at this level. Lots of organic debris at this level

Appendix C10: A simplified, hypothetical model of how diversification of crop production can reduce risk

You have $1000 to invest.
Assume oil palm has a return on investment of 25%. However, there is a 30% *risk* that the market for palm oil crashes and this return cannot be realized.

Since there is a 70% chance of achieving the return of 25%, the expected return of the oil palm investment is 0.7*0.25 = 0.175 = 17.5%
If you invest the full $1000 into oil palm, your expected profit is $175

Now assume you can also invest in pepper. Pepper has a return on investment of 10%, with a 15% *risk* that the crop will be destroyed by pests and the return cannot be realized.
The expected return is 0.85*0.1 = 0.085 = 8.5%
If you invest the full $1000 into pepper, your expected profit is $85

Now let's assume you invest $700 into oil palm and $300 into pepper.
You expect to profit $700*0.175 = $122.5 from the oil palm.
You expect to profit $300*0.085 = $25.5 from the pepper.

Total expected profit from the $1000 investment is $122.5 + $25.5 = $148
This is lower than the amount you could earn by investing solely in oil palm, but because pepper is a much less risky asset, higher expected profit is traded for increased security:

Amount allocated to oil palm: $700/$1000 = 70% (0.7)
Amount allocated to pepper: $300/$1000 = 30% (0.3)
Portfolio risk: 0.7*0.3 + 0.3*0.15 = 25.5%

Compared with only oil palm, diversifying with pepper decreases risk from 30% to 25.5%

Appendix C11: Biodiversity Assessments

C11.1: All species counted in calculating biodiversity and Shannon index. Rows highlighted in yellow are count estimates - calculations are shown in C.11.2 and C.11.3

Location	Area	Sample Plot	Species	Amount	amount %	log amaount	Sum	Description
Pulau Galau A1-SP1	A1	SP1	S1	5	0,14706	-0,83251	-0,12243	fern
	A1	SP1	S2	8	0,23529	-0,62839	-0,14786	thin leaves
	A1	SP1	S3	3	0,08824	-1,05436	-0,09303	short round
	A1	SP1	S4	1	0,02941	-1,53148	-0,04504	Brown shoots
	A1	SP1	S8	3	0,08824	-1,05436	-0,09303	Tall grass
	A1	SP1	S10	5	0,14706	-0,83251	-0,12243	woody stem
	A1	SP1	S11	3	0,08824	-1,05436	-0,09303	large lily
	A1	SP1	S12	1	0,02941	-1,53148	-0,04504	small lily
	A1	SP1	S13	1	0,02941	-1,53148	-0,04504	red leaf shoot
	A1	SP1	S14	1	0,02941	-1,53148	-0,04504	thorny vine
	A1	SP1	S15	2	0,05882	-1,23045	-0,07238	baby dark fern
	A1	SP1	S16	1	0,02941	-1,53148	-0,04504	flat thin leaves
Pulau Galau A1-SP2	A1	SP2	S1	7	0,20588	-0,68638	-0,14131	fern 1
	A1	SP2	S2	10	0,29412	-0,53148	-0,15632	Apeng
	A1	SP2	S3	8	0,23529	-0,62839	-0,14786	Oval pointy
	A1	SP2	S4	1	0,02941	-1,53148	-0,04504	Redan
	A1	SP2	S6	8	0,23529	-0,62839	-0,14786	Fern 2

Location	Area	Sample Plot	Species	Amount	Amount %	Log amount	Sum	Species description
Hill Oil Palm A1-SP1	A1	SP1	S1	42	0,01951	-1,70979	-0,03335	orchid
	A1	SP1	S2	3	0,00139	-2,85592	-0,00398	long leaf green
	A1	SP1	S3	2	0,00093	-3,03201	-0,00282	palm oil sprout
	A1	SP1	S4	3	0,00139	-2,85592	-0,00398	red
	A1	SP1	S5	2	0,00093	-3,03201	-0,00282	lily pad like
	A1	SP1	S6	6	0,00279	-2,55489	-0,00712	flower
	A1	SP1	S8	1675	0,77798	-0,10903	-0,08482	round ridges
	A1	SP1	S9	420	0,19508	-0,70979	-0,13846	pointy small
Hill Oil Palm A1-Sp2	A1	SP2	S1	28	0,10487	-0,97935	-0,10270	Flowering grass
	A1	SP2	S2	18	0,06742	-1,17124	-0,07896	Tall grass
	A1	SP2	S3	10	0,03745	-1,42651	-0,05343	fern
	A1	SP2	S4	42	0,15730	-0,80326	-0,12636	Star plant
	A1	SP2	S5	161	0,60300	-0,21969	-0,13247	leaf
	A1	SP2	S6	6	0,02247	-1,64836	-0,03704	round herb
	A1	SP2	S7	2	0,00749	-2,12548	-0,01592	Curly leaf

Location	Area	Sample Plot	Species	Amount	amount %	log amaount	Sum	Species description
MP	A1	SP1	S1	45	0,141065830	-0,85057816	-0,11998751	grass
	A1	SP1	S2	76	0,238244514	-0,62297709	-0,14842087	purple flower
	A1	SP1	S3	51	0,159874608	-0,79622050	-0,12729544	bright green
	A1	SP1	S4	21	0,065830721	-1,18157138	-0,07778369	grass 2
	A1	SP1	S5	11	0,034482758	-1,46239799	-0,05042751	big oval
	A1	SP1	S6	2	0,006269592	-2,20276068	-0,01381041	round leaf
	A1	SP1	S7	67	0,210031348	-0,67771588	-0,14234157	little fern
	A1	SP1	S8	23	0,072100313	-1,14206284	-0,08234308	long leafy green
	A1	SP1	S9	2	0,006269592	-2,20276068	-0,01381041	ridged leaf
	A1	SP1	S10	1	0,003134796	-2,50379068	-0,00784887	big flower
	A1	SP1	S11	2	0,006269592	-2,20276068	-0,01381041	long lily pad lead
	A1	SP1	S12	7	0,021943573	-1,65869264	-0,03639764	dandelion-ish
	A1	SP1	S13	11	0,034482758	-1,46239799	-0,05042751	ridged round
MP	A1	SP2	S1	7	0,053846153	-1,26884531	-0,06832243	short leafy
	A1	SP2	S2	30	0,230769230	-0,63682209	-0,14695894	Star herb
	A1	SP2	S3	52	0,4	-0,39794000	-0,15917600	mimosa
	A1	SP2	S4	26	0,2	-0,69897000	-0,13979400	Thin grass
	A1	SP2	S5	1	0,007692307	-2,11394335	-0,01626110	Flat grass
	A1	SP2	S6	14	0,107692307	-0,96781531	-0,10422626	Pink herb

C.11.2: Calculation for estimation of species S8 and S9 in Hill oil palm, explicitly showing the mathematical methodology behind the calculation of the estimates

S8							
Density	Percentage cover	Amount		Estimate = Sum of (Species count x 100 x percentage cover)			
High	25%	26					
Medium	50%	18					
Low	25%	5					
S9					**S8**		**S9**
Density	Percentage	Amount		26 x 100 x 0.25	650	1 x 100 x 0.45	45
Low	45%	1		18 x 100 x 0.5	900	3 x 100 x 0.05	15
Medium	5%	3		5 x 199 x 0.25	125	6 x 100 x 0.5	360
High	50%	6	Sum:		1675		420

C. 11.3: Calculation of estimation of species S3 and S4 in the River palm oil sample site

S3		
Density	Percentage	Amount
High	10%	23
Medium	25%	6
Low	65%	3
S4		TOT
Density	Percentage	Amount
High	15%	29
Medium	25%	14
Low	50%	6
	S3	**S4**
	230	435
	150	350
	90	300
Sum	470	1085

C.11.4: Tables of species occurrence of each site, with sample plot 1 and 2 merged together, for the purpose of calculating the Shannon Index

Location	**Species**	**Amount**	**amount %**	**log amount**	**Sum**	**Species description**	**Shannon Index**
Pepper	S1	45	0,10022	-0,99903	-0,10013	grass	
	S2	90	0,20045	-0,69800	-0,13991	purple flower	
	S3	81	0,18040	-0,74376	-0,13418	bright green	
	S4	47	0,10468	-0,98015	-0,10260	grass 2	
	S5	11	0,02450	-1,61085	-0,03946	big oval	
	S6	2	0,00445	-2,35122	-0,01047	round leaf	
	S7	119	0,26503	-0,57670	-0,15284	mimosa	
	S8	23	0,05122	-1,29052	-0,06611	long leafy green	
	S9	2	0,00445	-2,35122	-0,01047	ridged leaf	
	S10	1	0,00223	-2,65225	-0,00591	big flower	
	S11	2	0,00445	-2,35122	-0,01047	long lily pad lead	
	S12	14	0,03118	-1,50612	-0,04696	dandelion-ish	Sum * (-1)
	S13	11	0,02450	-1,61085	-0,03946	ridged round	**Shannon**
	S5	1	0,00223	-2,65225	-0,00591	Flat grass	0,864886174
Hill Oil Palm	S1	70	0,02895	-1,53836	-0,04453	Cerulian flaxlily	
	S2	3	0,00124	-2,90634	-0,00361	Melastoma malabathricum L.	

	S4	3	0,00124	-2,90634	-0,00361	red	
	S5	2	0,00083	-3,08243	-0,00255	lily pad like	
	S6	6	0,00248	-2,60531	-0,00646	flower	
	S8	1836	0,75931	-0,11958	-0,09080	Spreading false pimpernel	
	S9	420	0,17370	-0,76021	-0,13205	pointy small	
	S2	18	0,00744	-2,12818	-0,01584	Tall grass	
	S3	10	0,00414	-2,38346	-0,00986	fern	
	S4	42	0,01737	-1,76021	-0,03057	Star plant	Sum * (-1)
	S6	6	0,00248	-2,60531	-0,00646	round herb	**Shannon**
	S7	2	0,00083	-3,08243	-0,00255	Curly leaf	0,348895569
Pulau Galau	S1	12	0,17647	-0,75333	-0,13294	fern	
	S2	8	0,11765	-0,92942	-0,10934	thin leaves	
	S3	3	0,04412	-1,35539	-0,05980	short round	
	S4	1	0,01471	-1,83251	-0,02695	Brown shoots	
	S8	3	0,04412	-1,35539	-0,05980	Tall grass	
	S10	5	0,07353	-1,13354	-0,08335	woody stem	
	S11	13	0,19118	-0,71857	-0,13737	apeng - large lily	
	S12	1	0,01471	-1,83251	-0,02695	small lily	
	S13	1	0,01471	-1,83251	-0,02695	red leaf shoot	
	S14	1	0,01471	-1,83251	-0,02695	thorny vine	
	S15	2	0,02941	-1,53148	-0,04504	baby dark fern	
	S16	9	0,13235	-0,87827	-0,11624	flat thin leaves	Sum * (-1)
	S3	8	0,11765	-0,92942	-0,10934	Oval pointy	**Shannon**
	S4	1	0,01471	-1,83251	-0,02695	Redan	0,987969
River Oil Palm	S1	8	0,00462	-2,33571	-0,01078		
	S2	9	0,00519	-2,28456	-0,01186		
	S3	470	0,27121	-0,56670	-0,15369		
	S4	1085	0,62608	-0,20337	-0,12733		
	S5	49	0,02827	-1,54860	-0,04379		
	S6	4	0,00231	-2,63674	-0,00609		Sum * (-1)
	S8	106	0,06117	-1,21349	-0,07422		**Shannon**
	S9	2	0,00115	-2,93777	-0,00339		0,431151

C.11.5: Five species removed from the original assessment of biodiversity in the Pulau Galau, as they were discovered to be tree saplings rather than herbaceous

Removed due to being tree seedlings rather than actually herbacious plants							
Area	Sample Plot	Species	Amount	amount %	log amaount	Sum	Description
A1	SP1	S5	1	0,0294118	-1,5314789	-0,0450435	avocado like
A1	SP1	S6	1	0,0294118	-1,5314789	-0,0450435	eaten leaves
A1	SP1	S7	1	0,0294118	-1,5314789	-0,0450435	shoots by stem
A1	SP1	S9	1	0,0294118	-1,5314789	-0,0450435	spiky edges
A1	SP2	S5	2	0,0588235	-1,2304489	-0,0723793	Oval pointy 2

Appendix C.12: Ethnobotanical table

Name	Plant	Purpose	Cultivation	Notes
Engkabang	Fruit	Extract oils for cooking	NTFP, gathered	
Poko Kara	Fruit	Not edible. Attracts birds for hunting	NTFP	A traditional style of catching birds. Still practiced today, but less than before.
Akar Kubal	Fruit, growing on a vine	Eaten, sold	NTFP	High economic value due to it being a rare fruit in the region
Kemantan	Fruits		NTFP	
Ensabi	Vegetable		grown	
Eggplant	Vegetable		grown	
Terung assam (sour eggplants)	Vegetable	Eaten, sold	Grown	Easy to grow, and requires little maintenance
Terung pipit	Vegetable	Eaten	Grown	Similar to terung assam, but smaller
Ginger	Root	Medicinal	Grown, intercropped	Used as post-partum medicine. Made into tea or topical ointment
Ginger	Root	Eaten	Grown, gardened	Eaten and cooked. Unclear if this is the same or different from the other ginger
Sour Plant	Leafy vegetable	Eaten, cooked with meat to remove game flavor	Gardened	

Chillies	Vegetable	Eaten	Gardened & intercropped	
Benli	Vegetable	Eaten	Grown, garden	
Papaya	Fruit	Eaten	Grown, garden	
Brinjal	Vegetable	Eaten, sold	Grown, gardened & intercropped	
Pomelo	Fruit	Eaten	Grown, gardened	
Small Mangoes	Fruit	Eaten	Grown, gardened	
Dragon Fruit	Fruit	Eaten	Grown, gardened	
Wild bananas	Fruit, vegetable	Eaten, cooked as vegetable	NTFP	
Bananas	Fruit	Eaten	Gardened. Farmed	
Bitter Gourd	Vegetable	Eaten, sold	grown	
Long Beans	Vegetable	Eaten, sold	grown	
Dabai	Fruit	Eaten	Grown, garden	
Stinky Bean		Eaten	Grown, garden	
Langsat	Fruit	Eaten	Grown, garden	
Engkala	Fruit	Eaten	Grown, garden	
Sikup / Mangosteen	Fruit	Eaten	Grown, garden	
Buah Nangka / jackfruit	Fruit	Eaten	Grown, garden	Not a true jackfruit, but referred to as one
Uchung	Fruit	Eaten	Grown, NTFP	

Yam	Vegetable, roots	Eaten as vegetables	Grown, farmed	Both shoots and roots are edible. Shoots are harvested to encourage growth of larger roots
Durian	Fuit	Sold, eaten	Grown, gardened, farmed	Sold in Lachau. Some of the durian trees are very old, planted by their ancestors but still maintained today
Rambutan	Fruit	Sold, eaten	Grown, farmed	Sold in Lachau
Mawang	Fruit		Grown	
Rice (paddy)	Grain	Eaten	Farmed	Three types: Hill rice, swamp rice, wet rice
Pepper	Black and white pepper berries	Cash crop - sold	Farmed, sometimes intercropped	Some people told us they eat their pepper, some people don't
Cangkuk Manis (sweet leaf)	Leaves	Eaten	Grown, gathered	
Dionella ensifolia	Fruiting flower	Medicinal	NTFP	Used casually as topical ointment for minor scrapes
Kechala	Flower	Eaten, cooked	Grown	
Salak	Fruit	Eaten		Sour and sweet fruit
Lenggain	Fruit	Eaten		Commercially logged
Bemban	Grass canes	Weaving	NTFP, grown	
Bamboo	Grass canes	Weaving	NTFP	
Sago	Palm	Eaten as vegetables	NTFP	The palm shoots and palm hearts are eaten as vegetables
Pandan	Monocot, leaves	Flavoring rice wine	NTFP - managed	
Letup	Fruits	Eaten as vegetables and fruits	Grown, gardens and intercropping	Young leaves, shoots and unripe fruits are eaten as vegetables. Ripe fruits are eaten raw as fruit, taste like passion fruit. Their flower can be used for fun, as they make a loud popping noise when inflated and

				popped against the surface of a persons skin
Okra/ladies fingers	Vegetables	Eaten	Gardened	
Cassava/Tapioca	Vegetable	Eaten	Gardened	
Rubai	Vegetable	Eaten	Grown, intercropping	Leafy vegetable
Abok	Roots	Eaten	Grown	Root vegetable. Spread vigorously if not managed
Midin	Fern shoots	Eaten, raw and cooked	NTFP	
Oil palm	Palm, plan fruits	Cash crop - Sold for palm oil production	Grown, plantation	
Corn	Grain	Eaten	Grown	
Pinang / betel nut	Nut			
Kemayau	Nut	Eaten	Grown	
Soursop	Fruit	Eaten	Grown	
Calamansi (limes)	Fruit	Eaten	Grown, gardens and intercropped	
Rambai (Baccaurea motleyana)	Fruit	Eaten, sold	NTFP, grown	Sweet and dry sour fruit
Tarap	Fruit	Eaten	Grown, NTFP	Sweet fruit in the same family as jackfruits
Wild pineapple	Fruit	Eaten	NTFP, gathered	There is also cultivated pineapple in the area
Tublian	Tree	Timber		Used for house construction
Potolah	Vining plant with loofahs	Loofah	Gardened	

Palm fronds	Palms	Weaving	NTFP	Used for weaving small shapes for celebratory purposes (at the 1 year birthday)
Rubber	Rubber	No longer in use	Cultivated	Rubber tapping no longer practiced. Some people keep their rubber plantations as backups for if the price becomes better
Duan engkerbai	Leaves	Medicinal	NTFP	For rashes and small blisters
Rattan	canes	Weaving	NTFP	Generally no longer collected, as it is too labor intensive
Rajang		Eaten	NTFP	
Coconut	Fruit	Eaten	Grown	
Cucumber	vegeatble	Eaten, sold	Gardened	
Lemongrass	Vegetable	Eaten	Gardened	
Mustard Green	Leafy vegetable	Eaten	Gardened	
Kristal Matoa	Fruit	Eaten, sold	Gardened	
Langsat	Fruit	Eaten, sold	Gardened	
Orange mushroom	Mushroom	Medicinal, for baby skin conditions	NTFP	
Tekalong	Tree sap	Defunct; used to catch birds	NTFP	
Mulberry	Berry	Eaten	Gardened	
Engkili	Leafy plants	Eaten	Gardened	
Pisang kepok (Savory banana)		Eaten, used for banana chips	Gardened	
Cacao	Cacao fruits	Unknown	Gardened	
Guava	Fruit	Eaten	Gardened	
Lemon	Fruit	Eaten	Gardended	

Orange squash	vegetable	Eaten, sold	Gardended	Very productive - will sell at market and also give away
Akah		Crafts, making cones	NTFP	
Kepayang	Fruit	Eaten	NTFP	Fruit is poisonous when
Terminalia catappa	Nut	Eaten	NTFP	
Tapang tree (honeybee tree)	Honey and bee eggs	Cultural	NTFP	Cultural value, protected species. unclear if people gather honey from it
Empunok	Cane, similar to bemban	Crafting	NTFP	

Appendix C.13: Table of protein sources

Name	Animal	Purpose	Source	Notes
Ulat mulong/ulat sago	Worm	Eaten	NTFP	Lives inside cut down sago palm trunks. Mostly a cultural tradition today
Tilapia	Fish	Sold	Raised in aquaculture	
Home fish	Fish	Eaten, sold	Raised in home ponds	There may be some overlap between aquaculture and home raised fish
Chicken	Livestock	Sold, eaten	Raised in the village	High economic value
Pigs	Livestock	Sold, eaten		Currently only piglets in town. Reestablishment from the effects of the swine flu
Pythons	Snake	Eaten	Hunted	Hunted, mostly incidentally, from oil palm plantations
Squirrel	Squirrel	Eaten	Hunted, NTFP	
River fish	Fish	Eaten	Fished from river ntfp	Gathered through recreational fishing
Duck	Livestock	Eaten	Raised in the village	The ducks are for own consumption only
Mouse deer	Wild meat	Eaten	Hunted, NTFP	Hunted for meat
Poko Kara Birds	Wild meat	Eaten	Hunted, NTFP	Traditionally caught with sap, today shot with guns

Burung pipit (the birds that bother the rice farmers)	Wild meat	Eaten	Hunted,	Shot and eaten when acting as pests in rice plantations
Porcupine	Wild meat	Eaten	Hunted	Hunted from oil palm plantations
Rodents	Wild meat	Eaten	Hunted	Pests in oil palm plantations, hunted
River snails	Insect	Eaten	Fished from river. NTFP	
Shrimp	Aquatic		Fished	
Frogs	Frog		Fished	From river and from the forest

Appendix C14:

Soil laboratory analysis tests were conducted as follows; ammonium and nitrate were analyzed by combining 10g of soil from each sample with 40 ml of 1M KCl solution, shaken for 60 minutes, then filtered and measured on the flow injection analyzer (FIA). Plant available phosphorus was measured by combining 2.5 g dry soil with 50 ml of a sodium hydrogen carbonate solution, shaken for 30 minutes, and run through filter paper. Then, 1.5M sulphuric acid was added to 5 ml of the filtered solution, rested overnight and then measured on the FIA. Soil pH was analyzed using a pH meter and a 1:2.5 soil:water solution. Lastly, the percentages of Carbon (C) and Nitrogen (N) were determined using Isotope-Elemental Analysis.