UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE (IFRO)

5480-B3-3F25; Practicing Interdisciplinary Field Research on the Environment

Livelihood Strategies in Sugan, Sarawak, Malaysia

Anushka Jayesh Kargathara (znq321), Amalie Prehn Selsmark (gvp802), Carlos Julia Sanchez (wfm744) , Aia Jacobsen (kfr837), Terez Gyimoti (cnj322)

Supervisors: Ole Mertz, Lorenzo Rossi, and Xiaoye Tong

Date of Submission: March 27th, 2025

Number of words: 10718

Abstract

This research investigates the drivers and the social and environmental impacts of changing livelihood strategies in Sungan, Sarawak, Malaysia. An interdisciplinary, mixed-methods approach is employed to capture a holistic view of the changes occurring in a context where changes are often looked at independently. This study focuses on observed changes in livelihood strategies, namely agricultural intensification marked by the increasing adoption of cash crops like oil palm and shifts away from agriculture towards wage labor outside of Sungan. To understand these changes, the following drivers of change are explored: land access, infrastructure, education and economic aspirations, social networks, technology, and cultural identities. This study finds that agricultural intensification has led to significant land-use changes with environmental implications, including biodiversity loss, soil degradation, and reduced carbon stocks. Additionally, social and cultural transformations are evident in the slow decline of ethnobotanical knowledge, changing household dynamics, and shifting human- land relationships. The results of this study are analysed through Ribot and Peluso's (2003) Theory of Access framework to encapsulate how mechanisms of access interact to shape the drivers of livelihood strategies we identify. Overall, this research underscores the importance of understanding livelihood strategies and their influence on human- land relationships.

Acknowledgements

First and foremost, we would like to extend a big thank you to the people of Kampung Sungan. We are grateful to the Headman, Mr. Jebenis, for allowing us to stay in the village and making our fieldwork experience a memorable one!

In addition, we would like to thank the SLUSE coordinators from UNIMAS, Dr. Wong and Prof. Dr. Jeff, for making this fieldwork a success. Throughout the fieldwork, we received guidance and support from our lecturers, Dr. Mertz, Dr Tong and Dr. Rossi, and continuous insights were bestowed upon us by Mr. Kelvin Egay.

Lastly, we want to thank our colleagues from the University of Sarawak, Malaysia, UNIMAS, who provided us with insights and knowledge on Bidayuh customs, and traditions. We would also like to thank our translators, Penny and Firna for their patience during tiring and taxing fieldwork sessions as well as their knowledge that helped to assist our research.

Table of contents

List of Tables and Figures......5
1. Introduction...... 6
2. Theoretical Overview...... 8
3.1.1 Operationalisation......11
3.1.2 Site description......13
3. Methodology......15
3.1. Household Survey...... 15
3.2. Interviews...... 15
3.2.1. Key Informant Interviews......15
3.2.2. Semi-Structured interviews...... 16
3.3. PRA- Participatory Rural Appraisal......16
3.3.1. Transect Walks......16
3.3.2. Resource Mapping...... 17
3.3.3. Timeline......18
3.3.4. Resource Ranking......19
3.3.5. Focus Groups......20
3.3.6. Participant Observations......21
3.4. Environmental Assessments......22
3.4.1. Biodiversity, biomass, and soil quality......22
3.4.2. Water Sampling...... 26
3.5. Ethnobotany......28
3.5.1. Ethnobotanical Forest Assessment......28
3.5.2. Ethnobotanical Focus Group...... 28
4. Results and Analysis......29
4.1. Changes in Land Use - Agricultural Intensification......29
4.2. Drivers of change in livelihood strategies......30
4.2.1. Land and infrastructure......30
4.2.2. Agricultural Inputs......32
4.2.3. Education and Economic Aspirations...... 34
4.2.4. Technology...... 36
4.2.5. Social Relations......37
4.2.6. Land-based and cultural identities (Adat)...... 38
4.3. Environmental Impacts......39
4.3.1. Biodiversity...... 40
4.3.2. Soil quality and degradation......42
4.3.3. Carbon Stock...... 44
4.3.4. Water......46
4.4. Social and Cultural Impacts......49
4.4.1. Changing relationships to the land...... 49
4.4.2. Household structure and labour changes......50

4.4.3. Ethnobotany and Indigenous Knowledge........51
5. Discussion........53
5.1. Discussion of results........53
5.2. Limitations........55
6. Conclusion........56
7. Bibliography........58

List of Tables and Figures

Table 1: Categories of drivers changing livelihood strategies in Sugan........13
Figure 1: The drivers of changes in livelihood strategies, the impacts of said changes, as well as the current livelihood strategies observed in Sungan........13
Table 2: List of Key Informant Interviews........15
Figure 2: Path of the transect walks........16
Figure 3: Resource Mapping with women's focus group........17
Figure 4: Resource Mapping with men's focus group........17
Figure 6: Resource ranking activity........19
Figure 7: Children's Focus Group Activity and Xiaoye's Drone........20
Figure 8: Overview of Sungan and the two study sites. The satellite image is from 2016........21
Figure 9. Study area west (a) and east (b). The satellite images are from 2016........21
Figure 10: The soil types found in the eastern and the western study area........22
Figure 11: Soil Sampling Design........23
Figure 12. Soil bulk density sampling and herbaceous species diversity assessment........23
Table 2 Different allometric equations for calculation of above and below ground biomass (AGB and BGB) were used for the oil palm and the trees in the fallow........24
Figure 13: (1.) A hampala barb captured by researchers (2.) the process of identifying species for biodiversity........25
Figure 14: Water Sampling plots........26
Figure 15: Historical timeline of Sungan........28
Figure 16: Source of Income in Sungan........29
Figure 17: Survey rankings of what you need most to improve your household........30
Figure 18: Varying education levels in Sugan........32
Figure 19: Graphs a-d showcasing herbaceous species diversity and evenness, tree species diversity (west), and tree species evenness (east)........38
Figure 20: Graphs a-d showcasing soil carbon and land-use, soil nitrogen and land-use, C: N and

land use, and pH and land use.. 39
Figure 21: Graphs showcasing tree carbon stock and soil carbon stock.. 39
Figure 22. Soil types and changes in carbon stored in soil and trees, when fallow is converted to agriculture...40
Table 3: Water quality values and associated categories..41
Table 4: Shannon index measured in the three river plots..42

1. Introduction

In addressing the complex challenges of sustainable development and livelihood security, the integration of natural and social sciences is crucial for developing comprehensive and sustainable solutions. Therefore, this report will draw on methods from the natural and social sciences, integrating them in a cohesive framework, to understand the lived reality of people on the ground in rural Malaysia. Specifically, these methods are carried out in a case study design, based on 12 days of field work in Sungan—a small Bidayuh village in the Malaysian state of Sarawak. In doing so, this report combines the breadth of an interdisciplinary methodology with the depth of case study research, contributing to the literature on land use changes (focusing on agricultural intensification) and how they impact social well-being, identity, and cultural relations to land.

In particular, this report employs the theory of access to understand the drivers of changing livelihood strategies — that is, the reasons behind the choices individuals make about how to best support themselves and their families. In doing so, the impacts of these changes are also investigated, revealing complex and interconnected social and environmental impacts. These impacts are, in turn, situated within a broader debate about agricultural intensification and culturally embedded land relations. Ultimately, the case of changing livelihood strategies in Sungan, while unique in its own right, sheds light on the interrelations between agricultural practices, cultural identity and livelihood strategies.

1.1 Problem formulation

To guide this investigation, the following question is posed:

- What drives changes in livelihood strategies in Sungan, Sarawak, Malaysia, and what are the social and environmental outcomes of these changes?

To aid with the structure of the assignment, this question is divided into the following sub-questions:

- What are the drivers of changes in livelihood strategies?
- What are the social and cultural impacts of changes in livelihood strategies?
- What are the environmental impacts (with an emphasis on agriculture) of changes in livelihood strategies?

2. Theoretical Overview

Livelihood strategies is a broad term that can be used to describe various activities and choices (and the combination thereof) that people engage in to realise their livelihood goals (DFID, 1999). While it is a useful term to denote the activities that households undertake to support their well-being, Natarajan et al. (2022) object to the static implications of the term. Specifically, they argue, "the term 'strategy' not only implies consideration and planning, but also a degree of fixity when flux is more likely" (p. 12). With this in mind, this report will use the term 'livelihood strategies', however, with a focus on the aforementioned flux by also looking at 'changes in livelihood strategies' rather than only livelihood strategies themselves. Moreover, we will remain cognizant of the context-dependence of observed phenomena and their potential for sudden change. So, for this report, changes in livelihood strategies will refer to the adaptation and modifications that households undergo in response to different socio-economic and environmental pressures (DFID, 1999; Natarajan et al., 2022).

When looking at the underlying reasons for changes in livelihood strategies, 'drivers' can help explain potential changes and their associated outcomes. While 'driver' has a plethora of meanings and applications in studies on causality, for our analysis, we rely on the definition provided by Meyfroidt (2016), who defines drivers as:

> *Factors that are typical or hypothetical causes of land or environmental change and have some evidence of association with the outcome, but for which the evidence or knowledge is not sufficient to firmly establish the causal effects and explain the mechanisms (p. 507).*

Importantly, the term 'drivers' is distinct from the term 'causes', the latter of which Meyfroidt argues is more appropriate when sufficient evidence is present to support claims of causal mechanisms of the phenomenon in question. However, as this report is discussing environmental and social impacts, for which sufficient to establish causal links might not be available, the term 'driver' was deemed the most appropriate.

There are various theories to explain what drives changes in livelihood strategies. When looking specifically at social change, understanding who can benefit from what resources can provide insights into the reasons behind such change. For this purpose, the theory of access, as elaborated by Ribot and Peluso (2003), is useful. Here, access is conceptualised as “the ability to benefit from things—including material objects, persons, institutions and symbols,” wherein the word ‘ability’ denotes power (Ribot & Peluso, p. 153). Power, in this understanding, relates both to the capacity to affect others’ practices and ideas and the social context within which such power is situated. Thus, power cannot be reduced to a singular construct, leading to Ribot and Peluso writing about “bundles of power ” instead. These ‘bundles’ provide a theoretical framework for understanding social change as the outcome of cooperation or conflict over access to resources. Within this framework, access is mediated by several mechanisms, including legal and illegal means, technology, capital, markets, labour, knowledge, authority, social identity, and social relations. By looking at these mechanisms, the theory of access can provide insights into the processes and power relations that drive social change and affect people’s livelihoods over time (Ribot & Peluso, 2003).

While comprehensive on the reasons behind social change, the theory of access does not account for the environmental impacts of such changes. To address this limitation, literature on agricultural intensification is consulted: Agricultural intensification is the process through which the productiveness and/or profitability of land is increased due to the adoption of specific strategies. In general, such strategies can be categorised into four types: 1) reduced fallow, 2) increased inputs, 3) crop change, and 4) mixed intensification (Rasmussen et al., 2018). These strategies are usually adopted due to a mix of local and global drivers influencing the way land is used in a specific place. In turn, specific outcome pathways occur, incorporating interrelated social and ecological impacts (Martin et al., 2018). Following the logic of the land-sparing hypothesis, agricultural intensification is often thought to lead to ‘win-win’ outcomes. However, Rasmussen et al. (2018) found that this is rarely the case, as negative outcomes are often observed "for at least one of the ecosystem services that may support sustained productivity in the long term" (p. 2). Moreover, Rasmussen et al. argue that the potential trade-offs experienced as a result of agricultural intensification, must be understood within their social and cultural context; the impacts of agricultural intensification are situated within specific social and cultural contexts, and may therefore have different effects on different social groups (Martin et al., 2018).

Throughout the above discussion, it has been assumed that 'drivers' will lead to changes. However, certain drivers can also influence the persistence of traditional practices. For this, the concept of cultural systems (defined as shared "webs of meaning") and their relation to agricultural practices is useful (Hodel et al., 2024, p. 973). Here, the elements of norms, practices, values, and meanings are of particular importance; these elements influence both the way that land is maintained and the resilience of a specific land system. While cultural systems can be a driver of change, more often, they act as a stabilising force, leading to the persistence of traditional agricultural practices. Specifically, Hodel et al. (2024) point to the persistence of mixed farming, fire use, and subsistence farming as culturally embedded practices; they argue, "Cultural identity, heritage and social networks, and attachment to landscape rooted in local history prevent land users from switching to more profitable strategies" (pp. 975-6). Among indigenous peoples (Bumiputera) in Sarawak, these elements are likewise found. Here, a well-established system of customary laws, called *adat,* underpins the occupation, territories and connection to ancestral lands (Bulan, 2008; Nelson et al., 2016). More specifically, Landgub (2024) defines *adat* as "native customs which include way of life, basic values, systems of belief, code of conduct, manners, conventions and cultural practices according to which indigenous society is ordered" (p. 1).

While little has been written, specifically, on current Bidayuh cultural identity and agricultural practices, early ethnographic sources do provide insights that support *adat* being important for the relations between the Bidayuh and their land. For example, writing in 1960, the

Anglican bishop Peter Howes describes the reasons a Bidayuh man gives for not converting to Christianity:

> *I have not become a Christian because I can't. You see for yourself that our adat is bound up with our work [paddy farming]. We don't worship unless it has something to do with our work. We don't work unless it has something to do with our worship. (p. 493)*

Despite the eventual, broad conversion to Christianity among the Bidayuh people, *adat* is still widely practiced and respected. While many of the traditional rituals associated with the Bidayuh religious beliefs are no longer practiced, *adat* continues to influence various agricultural practices, such as the persistence of rice farming and sustained ownership of land, even if it is not actively being farmed (Ndigang, 2005)

3.1.1 Operationalisation

To understand changes in livelihood strategies in Sungan, this report will abductively incorporate the 'mechanisms of access,' as outlined by Ribot and Peluso (2024), with observations from the field. Additionally, the concept of 'cultural systems' as identified by Hodel et al. (2024) is used to understand how *adat* continues to shape the villagers' relationship to land, even after converting to Christianity. Thus, the following categories are identified in the table below as driving changes in livelihood strategies in Sungan:

Access to land and infrastructure
Education and economic aspirations
Social drivers
Technological factors
Agricultural drivers
Cultural systems (adat) and agricultural practices

Table 1: Categories of drivers changing livelihood strategies in Sugan

For the actual livelihood strategies, several were identified during field work. These include 1) subsistence farming, 2) cash-crop farming, 3) collecting forest vegetables, 4) wage labor, 5) owning a business, and 6) receiving remittances. Importantly, there is a reciprocal relationship between the drivers of changes in livelihood strategies, the impacts of said changes, as well as the current livelihood strategies observed in Sungan. This relationship is represented (although in a simplified manner) in Figure 1.

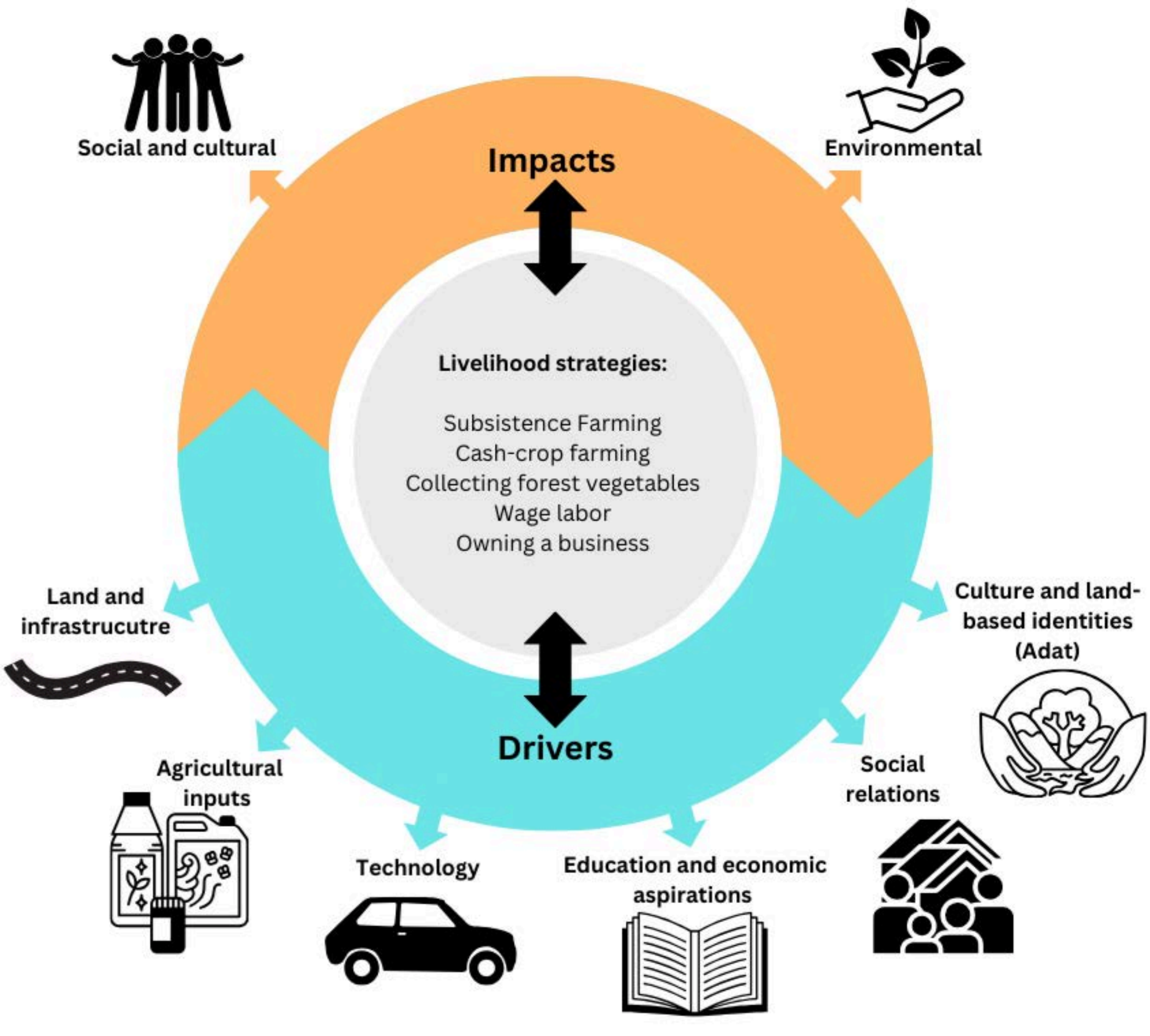


Figure 1: The drivers of changes in livelihood strategies, the impacts of said changes, as well as the current livelihood strategies observed in

3.1.2 Site description

Sungan is a small Bidayuh village located in the Tebedu subdistrict of Sarawak, Malaysia, approximately 90 km from Kuching. It has roots in the nearby Kampung Tema, from which residents relocated to the original village site known as Mawang. Residents relocated to the present-day Sungan site after an outbreak of an unknown disease in Mawang in the 1940s. The village is named after a nearby river, Sungai Sungan, although the main river flowing through the village is Sungai Kayan, which serves as a source of bathing, washing clothes, fishing and recreational activities. Until the late 1960s, the inhabitants practised Bidayuh animism, eventually converting to Catholicism after the arrival of a missionary. This subsequently impacted cultivation practices, as their old religion prohibited many practices such as planting paddy next to pepper. While the majority of the villagers today are practicing Catholics, cultural elements of the old animist beliefs remain.

Over the decades, the village has slowly experienced infrastructure developments, such as the supply of water in 2016, and the construction of multiple bridges to access farmland. Despite these developments, access to farmland remains a major challenge for some in the village, as the majority of the village's inhabitants are engaged in some form of agriculture. Alongside farming, other livelihood strategies like the selling of forest products and handicrafts, wage labor in nearby towns and cities, remittance income from family members, and owning small businesses are present.

About 70% of the village lands have been surveyed and designated as native customary rights (NCR) land, with the remaining 30% being difficult to access due to their remoteness. The process of securing native area land NAL) titles is currently underway, although no official native NAL titles have been issued, as of writing. The lack of formal titles adds to the precarity of land rights in Sungan; while NCR acknowledges the traditional connection to land based on custom, NAL provides a formal, legally recognised, and more secure form of ownership that offers greater protection against challenges from the government or commercial interests (Bulan, 2008).

3. Methodology

3.1. Household Survey

The survey consisted of thirty-one questions inquiring about demographics, income, and the well-being of village households. Households were selected through simple random sampling utilizing a list of household numbers derived through random number generation. The survey was conducted over three consecutive days at times we knew or expected the head of the household to be home. In addition, the translation of the survey was done verbally in Malay and Bidayuh as the head of the household answered the questions. In total, 42 households were surveyed (see appendix A)

3.2. Interviews

3.2.1. Key Informant Interviews

Interviewee	Reason(s) for selection	Interview topic(s)	Type of interview
Headman - Jebenis anak Kulat	Part of the decision-making body of Sungan. Was the initiator of getting the village land titles	Land-use history, local governance structure, future changes in the village.	Semi-strucutred/ Informal
Interviewee 2- Kampung Sungan resident	Multiple sources of income, varied crops.	Oral history	Semi-structured
Interviewee 3- Kampung Sungan resident	Knowledge Holder of Sungan's history	History of Sungan	Semi-structured
Tebedu Agricultural Department	Representative from the Agricultural department	Agricultural subsidies	Semi-structured
Tebedu District Office	Representative from the Tebedu district		Semi-structured

Table 2: List of Key Informant Interviews

3.2.2. Semi-Structured interviews

All farmers whose land was involved in our biodiversity and soil assessments were interviewed in the field to gather information about their land use history, as well as their practices regarding fertilizers and pesticides. Upon our arrival, the JKKK suggested several visits to various types of farms. We visited three of these farms, where we conducted interviews with the farmers, even though we did not perform biodiversity or soil assessments there. Conducting interviews directly on the farmers' land facilitated easy reference to the specific areas and crops being discussed. Our approach included semi-structured interviews, which provided a broader and more flexible framework for capturing a range of participant perspectives, while also incorporating key informant interviews to obtain focused insights from specific individuals with expertise in the field. This combination allowed us to gather comprehensive and nuanced information about agricultural practices in the region, resulting in 10 semi-structured interviews in total.

3.3. PRA- Participatory Rural Appraisal

3.3.1. Transect Walks

A transect walk is an observatory trek across the study site, during which key informants will discuss the natural and physical capital in an area and how the local people interact with these resources (Narayanasamy, 2009). During the initial days of the field work, two transect walks were conducted with informants that were knowledgeable about the local environment, culture and history. The walks were done to obtain an overall understanding of the area, both in terms of where specific resources were located along the Kayan River, as well as local customs regarding natural resource use, shown in figure 2. From the information gathered during the walks, potential points for soil and biodiversity sampling were identified. Additionally, the walks provided opportunities to learn about cocoa, pepper and belimbing farming in the area, as well as river snail gathering and crawfish catching. These activities aided in building rapport with local guides and thus formed the foundation for cooperation with the village during the fieldwork.

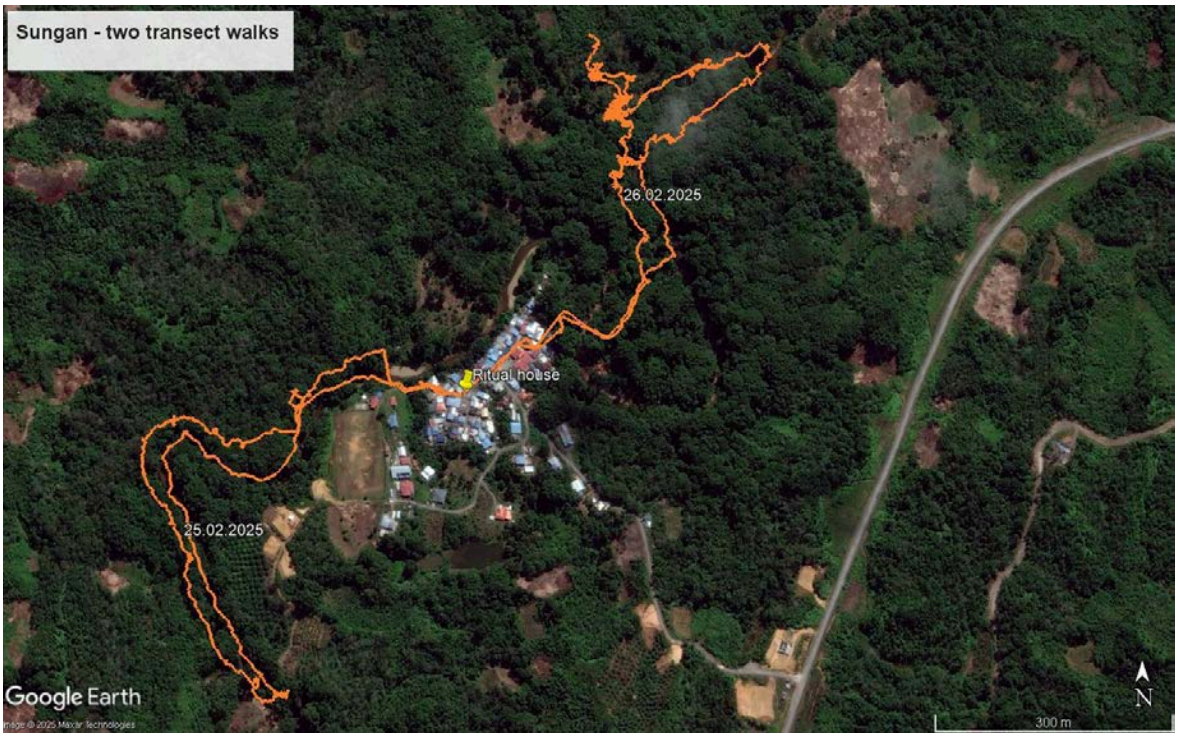


Figure 2: Path of the transect walks

3.3.2. Resource Mapping

Resource mapping sessions were held early in the fieldwork process to gain an understanding of how participants understand how land is used in the village and to visualize the locations of different crops. With the ritual house as a starting point, participants were asked to work together to draw the village, its farmland, the crops, and any other features of the landscape they deemed important. Participants were recruited through our local guide, who helped invite the participants. These sessions were conducted with both a group of five men and another of five women because of suspected gendered differences in how men and women view land and an assumption that men participate more in agricultural activities. These sessions resulted in two separate maps revealing distinct perceptions between the two groups and serving as a useful planning tool and as a reference to focus discussions in other activities.

Figure 3: Resource Mapping with women's focus group

Figure 4: Resource Mapping with men's focus group

3.3.3. Timeline

A timeline exercise provides a rough overview of the history of a group or an area and changes over time from the perspective of participants (Mikkelsen, 2005). Participants were first informed that the purpose of the timeline exercise was to gain insights into the changes in agricultural and infrastructure development in Sungan. They were prompted to think about what year the highest price for each crop they cultivated was, which kickstarted different conversations on the history of the village.

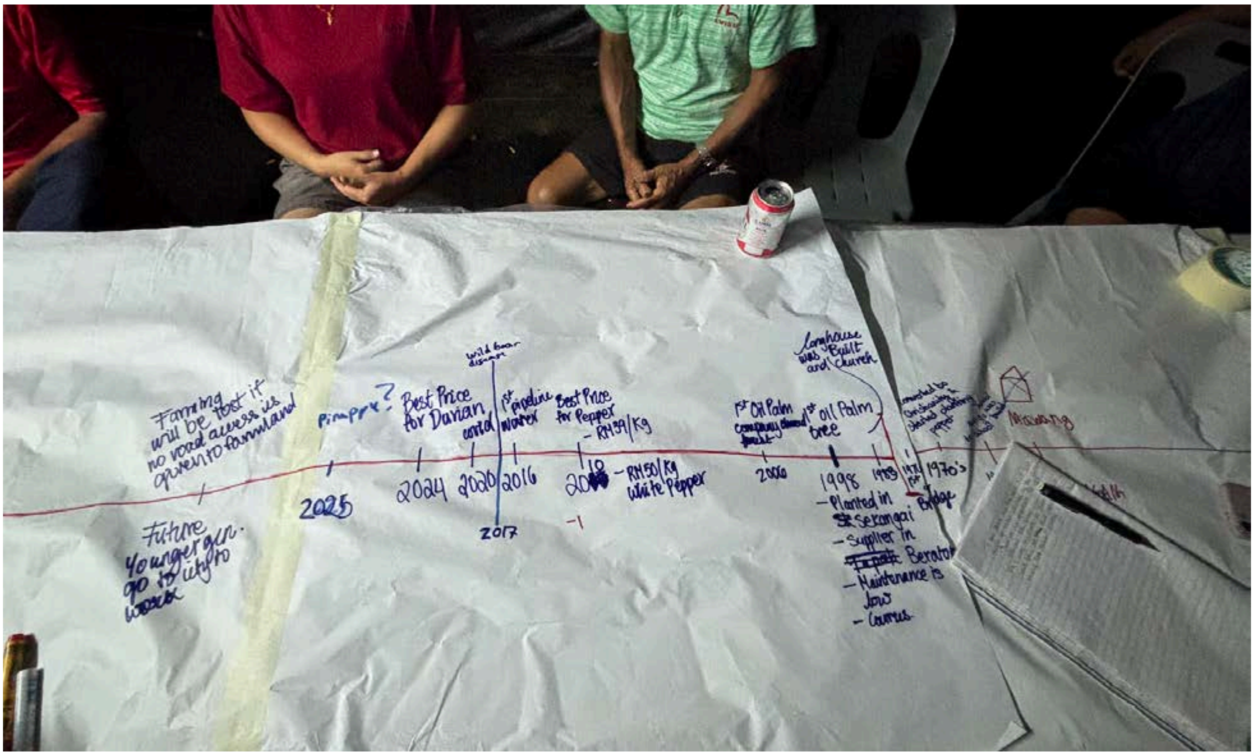


Figure 5: Timeline

3.3.4. Resource Ranking

Resource ranking, or, more specifically, matrix ranking, was used to help understand the relative importance of factors influencing the cultivation of different crops and how they compare across categories (Mikkelsen, 2005). Participants were asked to identify the most important crops grown in their village: pepper, paddy, oil palm, cocoa, dragon fruit, durian, bananas (pisang), pineapple (nanas), and stinky beans. Participants then agreed on the most important factors influencing the cultivation of the different crops: labour (manpower), food, income, land, fertiliser use, pesticide use and price stability. During the session, the category of “future land use” was added as a way to discuss possible future directions for crop cultivation in the village.

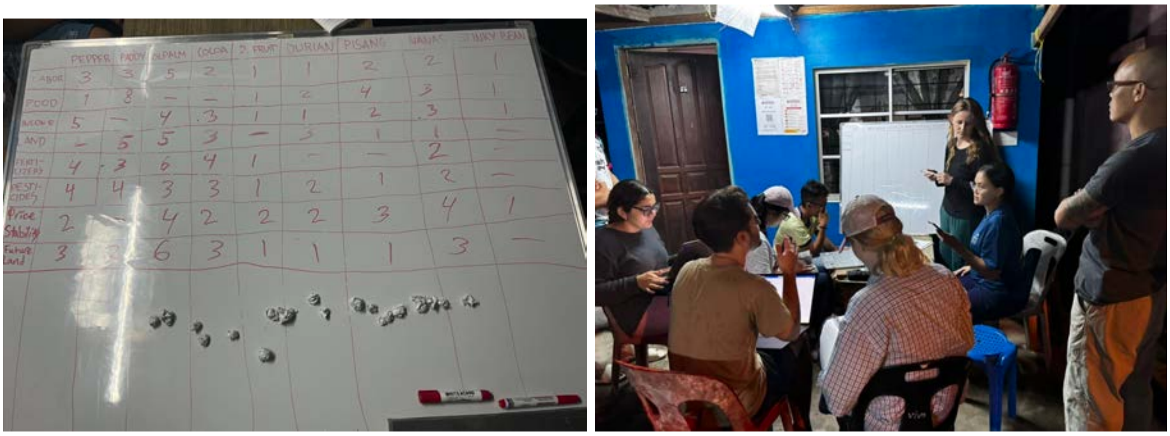


Figure 6: Resource ranking activity

3.3.5. Focus Groups

After repeated informal daily interactions with some of the village's children, a focus group discussion was organized to better understand the perspectives of the younger generation regarding things like how they view the village, their future in/out of it, and more. With other data mainly focusing on the older generations, this method allowed for a more robust understanding of the village and the trajectory of its livelihood strategies. This focus group consisted of eight children at different levels of primary school education whose parents gave consent. These children were selected as the result of informal conversations and connections made with them throughout fieldwork, allowing for a level of pre-established comfort and rapport. By weaving discussion topics into broader "fun" conversations and by discussing in a group setting, the children were able to comfortably answer questions and discuss with each other. Furthermore, this method provided an opportunity for co-learning, with researchers gaining data while the children learned more about the research process, had increased exposure to the English language (a learning objective of the school), learned about drones, and learned about the multinational backgrounds of the researchers.

Figure 7: Children's Focus Group Activity and Xiaoye's Drone

3.3.6. Participant Observations

Participant observation involves a researcher engaging in the rituals, daily activities, interactions, and events of a group of people as a way of exploring both the explicit and tacit aspects of a specific culture, along with their routines and ways of life. It is a foundational method within ethnographic research designs, as it functions both as a data collection method and an analysis tool (Dewalt & Dewalt, 2011). As part of conducting fieldwork in Sungan, participant observation was used to engage with the local community as they were partaking in everyday activities. These included going to church, preparing rice after harvesting, having informal conversations with people around the village, video chatting with villagers' family members who were not currently in the village, playing traditional music, learning the traditional dance, and other ceremonial activities. In addition to being a source of data, participating in everyday activities was pivotal to establishing a rapport with the villagers and learning about their daily lives.

3.4. Environmental Assessments

3.4.1. Biodiversity, biomass, and soil quality

Through preliminary interviews, transect walks and resource mapping it was determined that pepper, upland rice and oil palm were three of the most important crops in the village regarding income and food - and while rice production was decreasing, oil palm was increasing. To understand the environmental impact of this shift in agricultural land use, an assessment of soil quality, plant biodiversity and tree biomass was made.

Sampling design

Two study areas were chosen - one west of Sungan near the river where upland rice and pepper were grown and another east of Sungan with good road connection and less sandy soil, where oil palm was grown (figure 8). A control plot of fallow was chosen for each study area - respectively 30- and 50-year-old secondary forest in east and west (Figure 9). As the preconditions for farming oil palm, pepper and upland rice were different, they were generally not farmed in the same areas, making it necessary to choose two study areas.

Figure 8: Overview of Sungan and the two study sites. The satellite image is from 2016.

a. b.

Figure 9. Study area west (a) and east (b). The satellite images are from 2016.

By using the “feel-method”, the soil types in each plot were identified, showing a clear difference between the eastern study site and the western study sites, underlining the need for two location-specific control plots (figure 10).

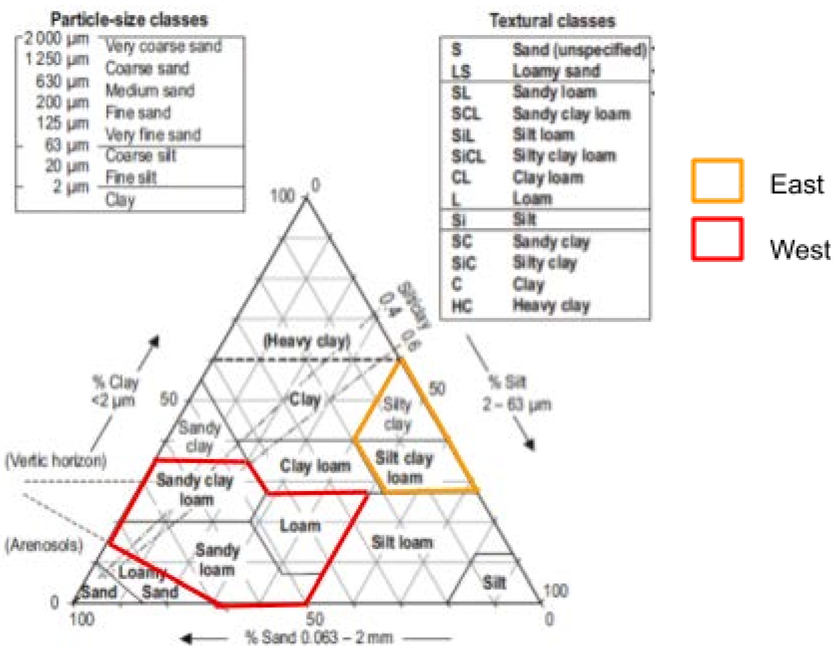


Figure 10: The soil types found in the eastern and the western study area.

For each land use a representative plot of 20 x 20 m was selected, wherein we identified all trees at species or genus level and measured their diameter at breast height (dbh) (figure 11). Trees with a diameter below 5cm were left out. The plots were selected systematically to be similar in terms of physical conditions such as soil type, topography and hydrology.

This was done to ensure that the main factor affecting differences between the study areas was land use. In the western study site, soil types varied within each field due to local differences in depositions from the meandering river. For the 50-year-old forest, three replicate plots were made to better account for the large variability in trees (Figure 11). As the oil palm plantation was uniform in terms of tree height and only had one tree species, the heights of five palms were measured and assumed to be representative of the whole plot. The density of the oil palms was determined based on satellite images in google earth.

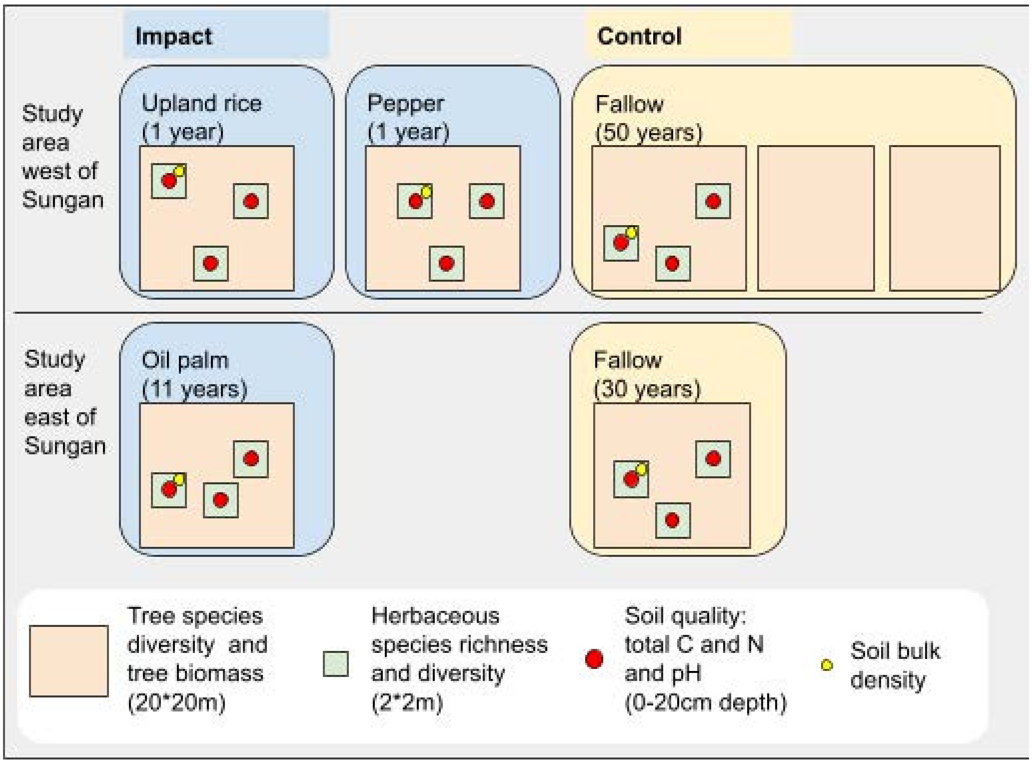


Figure 11: Soil Sampling Design

Within the larger plots three subplots of 2x2 m were randomly selected, wherein herbaceous species diversity was determined and a soil sample taken in 0-20 cm depth (figure 12). One volume-specific soil sample was taken at surface level for each plot to determine bulk density (figure 12).

Figure 12. Soil bulk density sampling and herbaceous species diversity assessment

Method of analysis

The Shannon's diversity index was used to determine both tree diversity and herbaceous species diversity, as it accounts for both species richness and evenness. Furthermore Shannon's species evenness was calculated to understand the distribution of species. To calculate tree biomass, allometric equations specific to the tree species and region were used alongside more general allometric equations (table 1).

Allometric equations		
	Above-ground biomass (AGB)	Below ground (BGB)
Oil palm	$AGB = 7.797 * H - 7.0872$	$BGB = AGB * 0,26$
Trees in the fallow	$WS = 0.313 * (dbh^2)^{0.9733}$ $WB = 0.136 * dbh^{1.07}$ $WL = \frac{125*0.124*(WS^{0.794})}{(0.124*WS^{0.794}+125}$ $AGB = WS + WB + WL$	$BGB = 0,0214 * dbh^{2,33}$
Sources for the equations		
Above-ground	round biomass (AGB)	Below ground (BGB)
Oil palm	*For oil palm, the above-ground biomass (AGB) was calculated based on Asari et al. (2013), which is*	*Below-ground biomass (BGB) was calculated with a general formula for below-ground tree biomass (Ravindranath and Ostwald 2006)*

	specifically made based on Malaysian oil palm	
Trees in the fallow	*For the fallow trees, the same equation was used for all species. ABG for the fallow trees was calculated based on equations provided by Prof. Dr. Gabriel Tonga Nowe fromthe University of Sarawak Malaysia.*	*For the fallow tree, the same equation was used for all species. BGB was based on an equation determined by Kenzo et al. 2009 specifically for secondary forest in Sarawak Malaysia.*

Table 2 Different allometric equations for calculation of above and below ground biomass (AGB and BGB) were used for the oil palm and the trees in the fallow.

To understand the impact of oil palm, pepper, and rice production on soil quality, pH, texture, total C and N and bulk density were measured. Texture and pH were used to determine whether control plots were comparable to the agricultural plots, while total C and N were used to see the impact of agricultural land use on the soils. Bulk density was used to calculate the carbon stock (C/ha).

3.4.2. Water Sampling

Four parameters of water quality were measured to assess the water quality in and around the village. Firstly, biological parameters were measured, specifically total coliform count (TCC) and fecal coliform count (FCC). Secondly, physical parameters were measured in situ using a YSI (Yellow Springs Instrument) multiparameter. Physical parameters included pH, temperature, and conductivity. Thirdly, the chemical parameters of dissolved oxygen (DO), total dissolved solids (TDS), phosphorus (P), and ammoniacal nitrogen (NH_3-N) were examined. Both DO and TDS were assessed in situ, along with the physical parameters. Phosphorus and NH_3-N were assessed in a field lab using the HACH DR890 colorimeter. Lastly, biodiversity in the sampling sites was measured by calculating the Shannon index for macroinvertebrates and fish.

1. 2.

Figure 13: (1.) A hampala barb captured by researchers (2.) the process of identifying species for biodiversity

Three sampling plots were chosen to investigate the impact of livelihoods on the water quality. The first sampling plot was located next to the village, downstream from where most daily river activities took place (e.g. washing, bathing and swimming). This plot was selected to assess the impacts of human activities, such as keeping livestock and discarding kitchen waste, on the water quality. The second sampling plot was located upstream from the village, near a tributary next to small-scale agricultural production, including a fruit orchard, paddy field and a cocoa plantation. This sampling plot aimed to evaluate the effect of small-scale farming on water quality. The last sampling plot was located upstream in the Sungan River before the Sungan and Kayan Rivers connected. This sampling plot was intended to serve as a control for the Kayan River as it is located further away from village activities compared to the other sampling plots. However, after further investigation of the area, an oil palm plantation was discovered near the sampling site, which could have a potential impact on the results of the sampling.

Figure 14: Water Sampling plots

3.5. Ethnobotany

3.5.1. Ethnobotanical Forest Assessment

An ethnobotanical assessment was conducted within the 50-year-old fallow near the 20x20m plots. Along a 2x20 m transect, we walked with a village member, who was deemed to hold great ethnobotanical knowledge. All plants that had a usage known by the villagers were registered with a photo, along with the plant's bidayuh name and abundance. The scientific names of the plants were determined with help from Professor Dr Gabriel Tonga Noweg.

3.5.2. Ethnobotanical Focus Group

To evaluate the common understandings of the plant species identified during the forest assessment, villagers were asked during focus group discussions, specifically about certain plants and their uses, as well as about their thoughts on the generational transfer of ethnobotanical knowledge. Seven species were selected, and a Kahoot quiz was made with a question about each plant. After completing the quiz, questions were discussed, and the conversation was open. Two separate focus groups were conducted, one with four male participants aged 16-23 (also referred to as the "young men's group") and another with six male participants aged 40-60. These two groups were held to determine any difference in actual and perceived ethnobotanical knowledge between generations and how ethnobotanical knowledge is valued.

4. Results and Analysis

In this section, we present and discuss our results as well as how the theory of access fits into the drivers of changing livelihoods, land use and environmental impacts.

4.1. Changes in Land Use - Agricultural Intensification

Sungan has experienced various changes to its land use, in large part because of agricultural intensification and shifting livelihood strategies. The main land-use changes occurred post-1970, as this period saw a move away from shifting cultivation to more permanent agriculture.

Traditionally part of the shifting cultivation systems, rice and pepper farming have, in the past 50 years, become more intensified. Rice is now grown for two consecutive years, followed by three years of fallow, with fertilizers applied twice per cycle. The length of time rice can be grown before the land is laid fallow varies based on the age of the fallow it replaces. Pepper is cultivated for 7-10 years, with fertilizers applied three times per year, before being left fallow for around seven years. While herbicides are used for rice, pepper fields are manually weeded. Interviews with farmers revealed an unexpected dynamic: as agriculture has intensified, farmers have been allowing more of the land to revert to old forest fallows. Without the need for shifting cultivation, the forest can grow old.

Oil palm was first grown in Sungan in 1998 and has since then marked a new transition to even more intensive agriculture. Oil palm is grown in monoculture plantations that last up to 25 years before replanting occurs in the same spots. An oil palm farmer that we interviewed explained that fertilizers were applied three times a year, while the oil palm fruit was harvested every 21 days. In contrast to other crops, oil palm plantations are not turned into fallow due to the high costs associated with rebuilding the road infrastructure created within the farms.

4.2. Drivers of change in livelihood strategies

“Drivers” are defined here, following Meyfroidt (2016), as factors which “have some evidence of association with the outcome, but for which the evidence or knowledge is not sufficient to firmly establish the causal effects.” This report does not establish strict causal links but identifies “drivers” influencing livelihood strategies in Sungan. These drivers interact in an iterative feedback process with each other as well as with their associated social and environmental impacts (Figure 1). Functioning both as an object and subject of changing livelihood strategies and environmental change. Ribot and Peluso's (2003) Theory of Access helps to analyze the varying impacts of these drivers on livelihood strategies.

4.2.1. Land and infrastructure

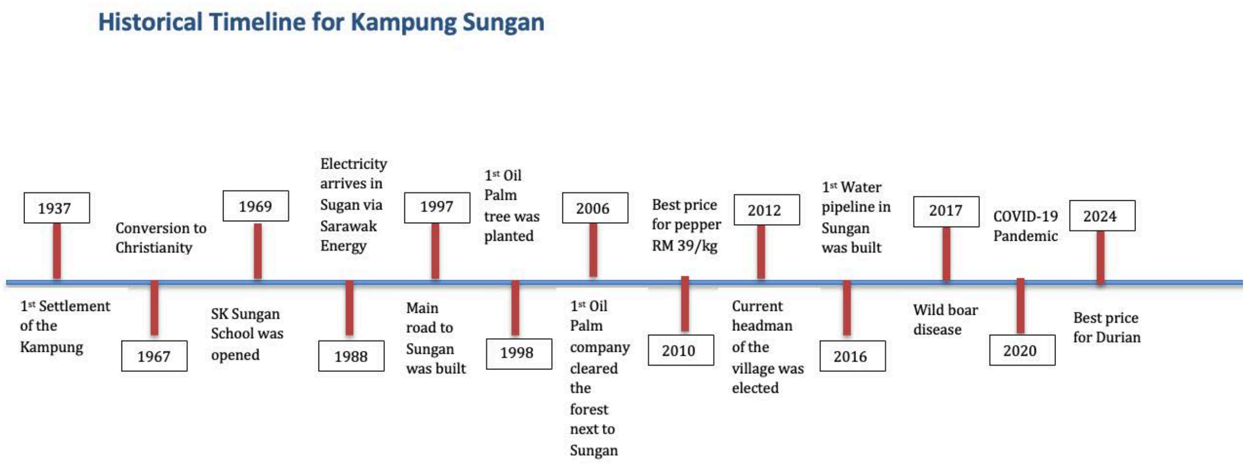


Figure 15: Historical timeline of Sungan

Access to land and infrastructure is critical in moulding many livelihood strategies observed in Kampung Sungan. From the timeline activity, we gained insights into some of the major changes in Sungan’s history. Shortly after the arrival of electricity in 1988 and the construction of the main road connecting to the Kampung, the first oil palm tree was planted (figure *15)*. Gaining access to ‘modern’ infrastructure facilitated access to broader markets, which encouraged the adoption of cash crops like pepper, durian and oil palm. The construction of the main road in 1997 diversified income sources, including the transition from farming crops to seeking wage labour in nearby towns like Tebedu. In our household survey, around 15 out of 42 respondents indicated "selling their crops to nearby villages" as part of their primary source(s) of income (Figure 16: Source of Income in Sungan). This finding was further triangulated with four informal interviews with heads of households, who pointed out that after the construction of the main road, selling their crops became easier, allowing them to diversify their household income effectively.

From our early conversations and many residents of the Kampung, we learned about the importance of formal land titles. All resident-owned land fell under the category of Native Customary Rights (NCR) statutes, meaning that they can grow crops but must continuously prove that the land is being used. In addition, we learned through conversations during the timeline activity that if NCR land is left fallow, the land risks being reclaimed by the Sarawak government. Though no evidence of such claims are found in the Sarawak Land Code, it is a constant fear of many residents who farm on NCR land. So, to ensure secured and continued land access, residents, along with the local village government, JKKK, have applied for the formal land titling process under the Land and Survey Department of Sarawak.

Within the Theory of Access framework, formal land titles fall under "rights-based access." In this case, however, there is a trend revealed through interviews with farmers in which plots of land further away from the village are increasingly left as fallow. One of the main justifications for this, especially among older participants, was that the land was deemed to be too far away from the village to use for farming. Despite the land having been used for agriculture in the past, both the increasing ability to intensify agriculture closer to the village and increased access markets to sell crops, as well as an aging population with a decreasing physical ability to access land situated far away. Characterizing this in terms of Ribot and Peluso (2003), despite having the *right* to benefit from a plot of land, the *ability* to benefit is often not present. As such, the future construction of roads, categorized as the technology mechanism in the access framework, plays an important role in expanding livelihood opportunities for the future. Additionally, access to labour is needed, which is limited by age and, in some cases, capital, decreasing one's ability to farm certain plots of land and contributing to decisions about others.

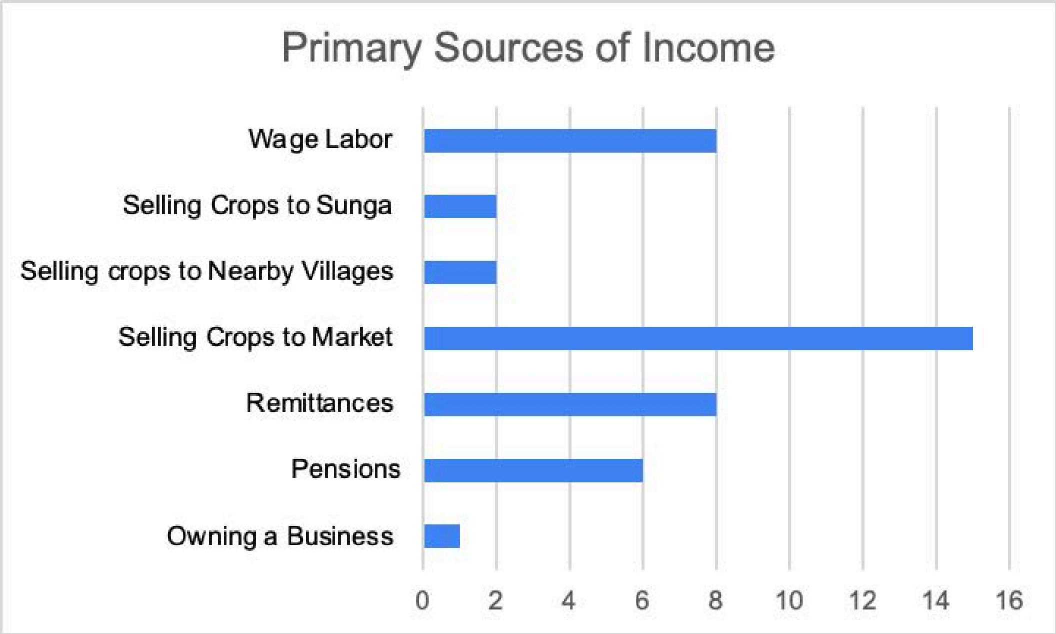


Figure 16: Source of Income in Sungan

4.2.2. Agricultural Inputs

Informal conversations with farmers in Sungan revealed that government support, or "subsidies," for their agriculture generally come in the form of agrochemicals, such as fertilizers and pesticides. The use of agrochemicals is essential for agricultural production in Sungan, particularly for many cash crops. These agrochemicals enhance soil fertility, help control pests and diseases, reduce crop losses and improve farm efficiency. When respondents were asked to rank in order of what they need the most to improve their household, 11 out of 42 ranked subsidies number one, and 24 out of 42 survey respondents ranked it number 2 (figure 17). This indicates that a consistent supply of agrochemicals is essential for maintaining long-term agricultural sustainability and economic stability for farmers in Sungan.

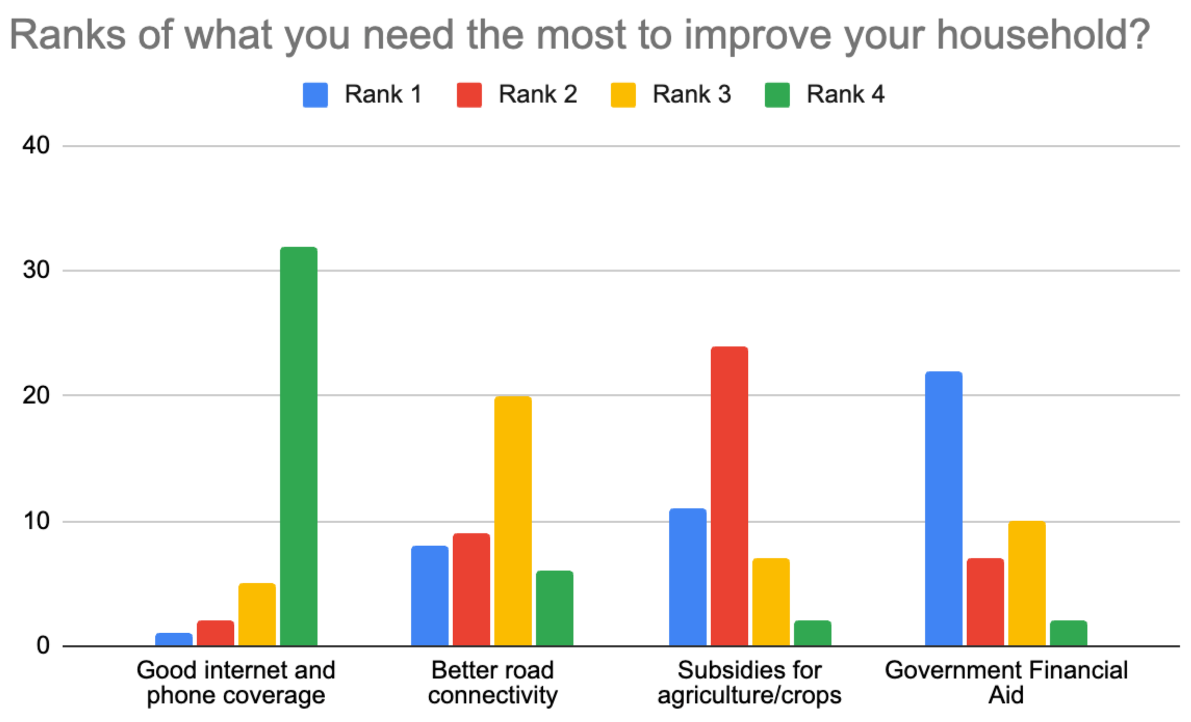


Figure 17: Survey rankings of what you need most to improve your household.

Among cash crops, oil palm is the most expensive to cultivate due to labour, seedling, and fertilizer expenses. In interviews with farmers, we learned that while fertilizers are a crucial factor in maintaining oil palm farm productivity, they are also an immense investment, costing one farmer RM21,450 for a single year's worth of fertilizer. To put this into perspective, this is higher than the average yearly household income of at least 85% of household survey respondents. For other cash crops, such as cocoa, farmers can receive yearly subsidies through the Malaysian Cocoa Board. One cocoa farmer shared that they started cultivating cocoa after receiving training, seeds, and agrochemicals from the Board, with the promise of annual supplies. Although the agrochemicals provided were insufficient, the farmer appreciated that Board representatives collected the harvested cocoa to then be sold to markets, making production and profitability more accessible. They also dindicated that they remained happy with their arrangement with the cocoa board. This is in part because a member of the Board comes and picks up the harvested cocoa rather than the farmer having to travel to the market themselves, making the profitable production of cocoa more accessible, in the farmer's view.

While access to subsidies is important, most villagers continue to produce more "stable" crops like rice and pepper[1], which also require significant agrochemical inputs. An information session with the Tebedu Agricultural Office revealed that fertilizers for rice and pepper are available through an application process. However, subsidies are only allocated for 0.2 acres of farmland when roughly 83% of those surveyed claimed to have over 1 acre of land. While applications for subsidies are processed annually, funds are disbursed only once every two years. This delay makes government subsidies unreliable for many farmers. Interviews and informal conversations indicated that many farmers do not use their own money to buy agrochemicals as they are considered too expensive. This highlights how access to capital and government subsidies significantly limits livelihood strategies of farmers, especially for crops like rice, which are not grown for sale in the Kampung.

4.2.3. Education and Economic Aspirations

The household survey revealed that over half of the participants possess either no formal education or only a primary education, making up 73.9% of the total (Figure 18). Participants noted that, during their formative years, higher education was not as prevalent as it is today. Nonetheless, transect walks, ethnobotany focus groups, and participant observation showed that villagers were extremely knowledgeable about the local environment, culture and history. By many accounts, their education in these topics was not derived from formal education but rather from their lived

[1] Though pepper prices do often have high market price variation, farmers indicated that they considered it to be "stable" because they can store it for several months if needed and control when they sell it, so they avoid selling it when they consider the price to be too low and wait for it to rise.

experiences within the Bidayuh culture and hands-on work with their family in farming and forestry.

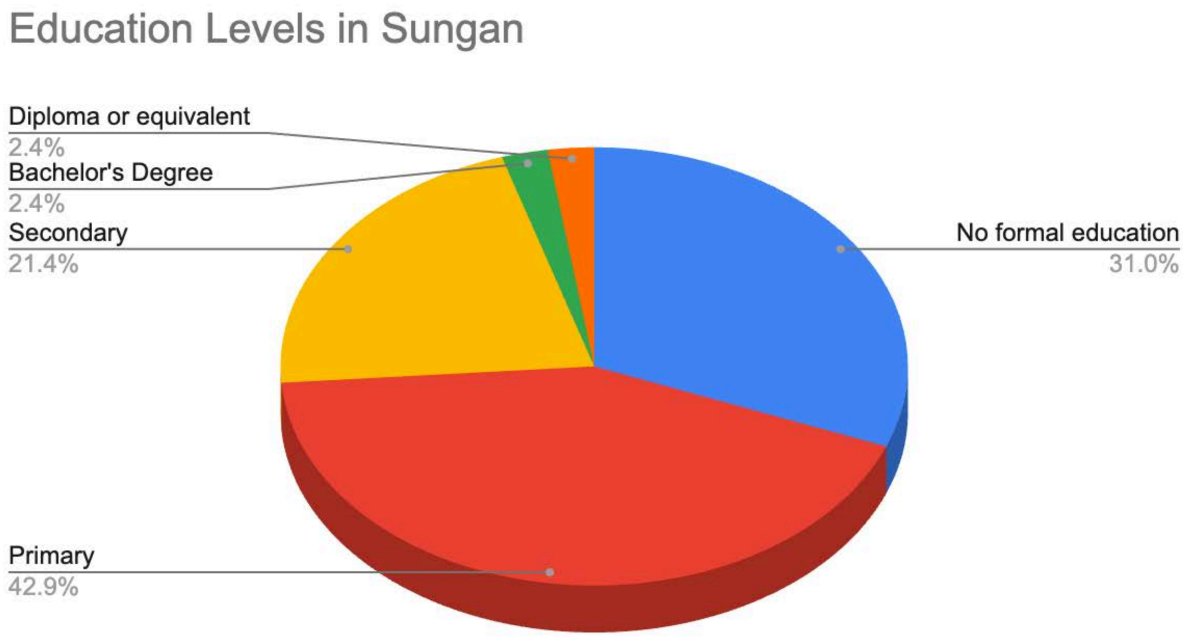


Figure 18: Varying education levels in Sugan

Formal education has become a key pillar of Sungan. Focus group discussion revealed that many residents commute not only for work but also for education. In an ethnobotany focus group with the younger generation, 2 out of 4 participants expressed a desire to pursue higher education, while one had already completed a vocational degree ('diploma'). When asked about why they were interested in advancing their formal education, the group agreed that higher education is linked to higher salaries, making income a primary source of motivation. Older generations support this pursuit, with the Headman even stating that, "it's okay if the younger generation does not want to continue farming. What matters most is that they get their education and work hard at whatever it is they want to do." Ultimately implying that hard work is highly valued as a way to higher income, principally taking the form of education for younger generations. In terms of the Theory of Access, this is in line with the access to knowledge mechanism, with education being understood as a way for younger generations to access higher wages in the future.

This economic aspiration is not limited only to the younger generations. The older generations also seek to increase their financial well-being, oftentimes by shifting towards new forms of agriculture and cash crop production. One farmer shared that they started a dragon fruit farm just 2-3 years ago after hearing that it could be profitable. Another farmer recently planted coffee, hoping it would be a valuable crop. These conversations show that farmers in Sungan are open to experimenting with new, potentially profitable agriculture while still valuing staple crops like rice, pepper, and rubber for personal consumption and profitability. Like their parents, younger generations also recognize the potential profitability of agriculture in Sungan. Alongside wanting an education and oftentimes careers outside of Sungan, younger generations also indicated wanting to return to Sungan eventually to farm cash crops like oil palm and pineapple, expressly for their high income potential. This can be understood in terms of the Theory of Access' access to labor opportunities mechanism, with people understanding their ability to use their labor to farm different cash crops as ways to extract benefits from their land.

4.2.4. Technology

Technological advancements have contributed to changes in rural livelihood strategies around the world, particularly as it relates to agriculture and commerce (Nnana et al. 2025). In Sungan, certain technologies are important for the village's livelihood strategies. For example, cars are a common sight in the village. On any given day, the designated "parking" area in front of the longhouse holds several cars, especially after the end of a working day. These vehicles often serve multiple purposes, including transportation for work, school and transportation of crops like oil palm from farm to the market, facilitating access to resources vital for livelihood strategies.

Smartphones and good internet access are also key in shaping livelihood changes in Sungan. When we asked questions about what kind of jobs they wanted to pursue in the future in an ethnobotany focus group with younger participants, one participant mentioned being inspired by TikTok and social media to become a pilot. Furthermore, we observed that it was relatively common for primary school-age children to also have access to smartphones and social media. With this increased exposure, younger generations are likely to encounter new career possibilities, like piloting, which could influence future shifts in livelihood strategies.

4.2.5. Social Relations

For this report, the 'social drivers' discussed include family, friend, and neighbor relationships both in and outside of Sungan. These relationships are strong, as observed in shared activities like helping each other, going to the river, playing badminton, or helping to keep rice dry when it rains. About 88% of survey respondents have lived in Sungan for over 25 years, and 86% were originally from the Kampung, with many having family members living nearby. Family ties influence livelihood strategies, with family members working together on farmland.

It was also observed that, in the case of several households, they have family members (generally young adults) who have moved to cities like Kuching or Kuala Lumpur, creating more distant social connections. Though questions about whether they will return arise, many of the villagers we talked to seemed confident about their eventual return. In addition, several of the younger children live with extended family while their parents work in other cities, further emphasizing the strength of familial connections. This demonstrates strong familial ties, which, in one way or another, tie people to Sungan.

Working outside of Sungan is not a recent development, as many villagers have long commuted for work. This trend has expanded social networks outside of the village. Knowing someone who works and lives in another city can open doors to similar opportunities, especially for those seeking careers outside of agriculture. This is not an entirely new phenomenon, as several 40-60-year-olds discussed having worked in the military or other fields away from Kuching before retiring with their pensions and returning to Sungan and becoming farmers. In both the children's focus group and the young men's ethnobotany group, many expressed a desire for a similar path: leaving Sungan for work before returning to farm on their familial land. This reflects how the younger generations view this path as a model of success within their community.

One key informant left Sungan in their youth to work in Kuching but returned for Gawai[2] met their future spouse and ultimately decided to settle in Sungan to farm on their family land. While not everyone returns to Sungan, this example highlights the powerful ways in which social relationships can, alongside other drivers, contribute to decisions about where people live and their larger livelihood strategies. Ribot and Peluso's (2003)'s "social relations" mechanism of access, highlights how these different relationships might bring different economic opportunities. Furthermore, Alexander (2023) demonstrates how, in certain cases, these social relationships may lead to return migration from people who have emigrated. In Sungan, this has implications especially for youths who seek higher education.

4.2.6. Land-based and cultural identities (Adat)

During an interview about land titling, the Headman stated, "The land is the sole asset of the Bidayuh people, and we are prepared to defend it." This illustrates the intricacies of identity and culture that are tied to the land in Bidayuh culture. The concept of *adat* reiterates this connection, as land is not only pivotal for livelihoods but also for maintaining the Bidayuh heritage. Focus group discussions further reinforce the notion that land is paramount, as several young individuals who

[2] A festival occurring every June that celebrates the year's harvest yields.

expressed potentially wanting to leave Sungan at some point for a career also intended to eventually return to the village to inherit their family land after retiring from their other career.

Several interviews with farmers revealed that some land is kept fallow for future generations, ensuring fertile farmland and timber for homes for the future generations to utilize. This perspective conceptualizes land as a generational asset, emphasizing individual profit as a primary consideration. This raises an interesting question about access, as cultural traditions (*adat),* rather than legal rights, determine land rights. The *adat* concept of "tree tenure" grants individuals socially recognized rights to specific trees on another person's land, which is not acknowledged in governmental land titling processes. Ribot and Peluso's (2003) access to knowledge mechanism helps to explain the access to Bidayuh natural resources as something beyond legal frameworks, which are a relatively recent development. Instead, access is moulded by social and cultural traditions, potentially leading to conflicts if cultural knowledge is not evenly passed down to future generations.

4.3. Environmental Impacts

As livelihoods are changing in Sungan, so is the land use. A major land-use change seen in Sungan, both presently and expectedly in the future, is households abandoning rice and pepper as their primary crops to grow oil palm on their land. To understand the environmental impact of this land-use change, we assess the differences in how land used for rice, pepper and oil palm affects soil quality, plant diversity and carbon storage, aiming to investigate the impact of the increase in oil palm plantations. Furthermore, we assess the impact of agriculture on the water quality in the Sungang and Kayan rivers, using the national water quality standards for Malaysia. This gives an insight into how intensified farming of crops such as rice, pepper and cocoa, impacts the water quality, but does not show the impact of oil palm, as this is mostly grown east of Sungan, away from the river.

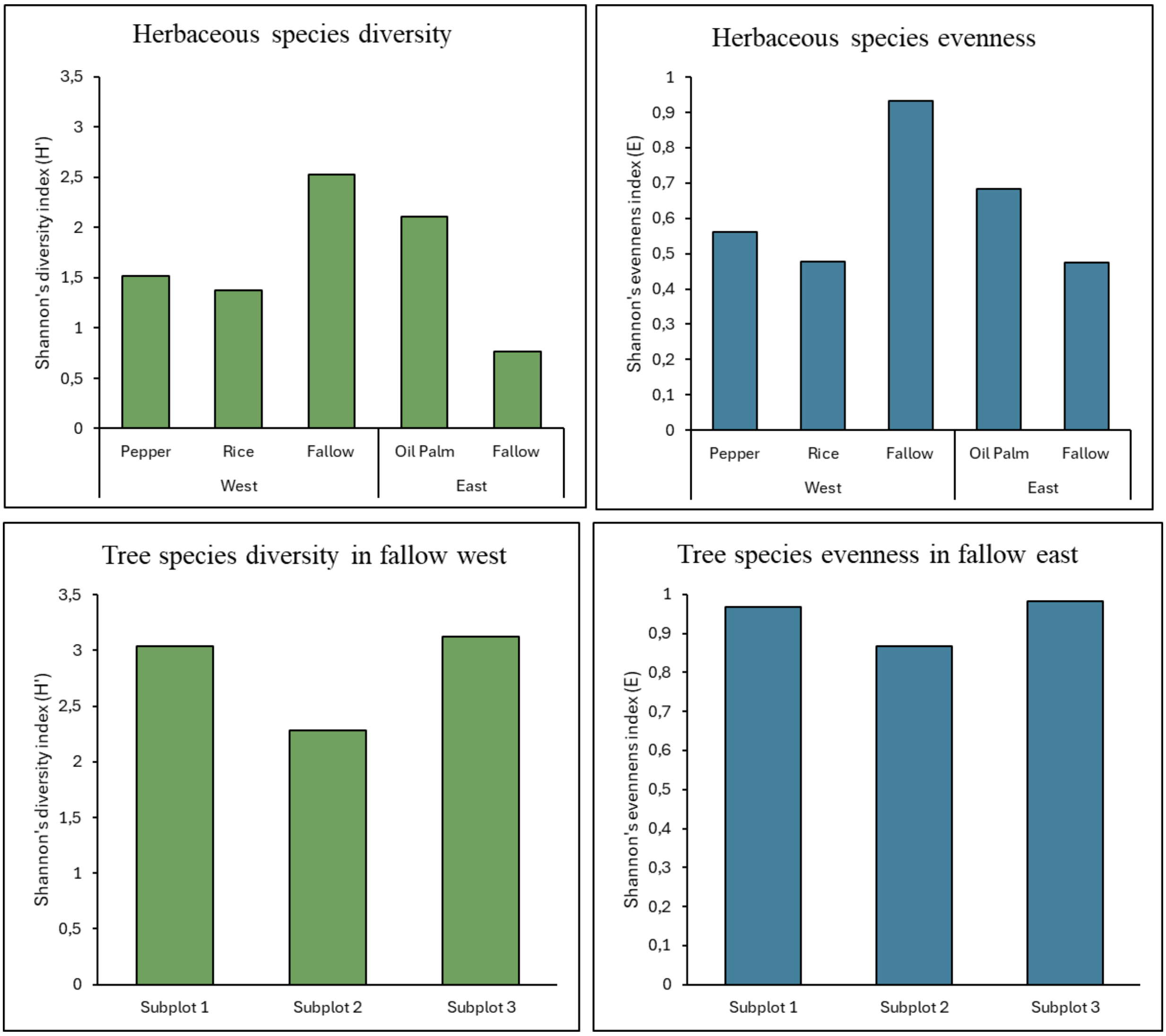
4.3.1. Biodiversity

As rice, pepper and oil palm are three very differently grown crops, the biodiversity associated with each is expectedly also different. Looking at the western study site, pepper has an herbaceous species diversity (H’) of 1.5, while rice has an H’ of 1.4 and the nearby fallow a H’ of 2.5, showing that a substantially greater herbaceous species diversity is found in the fallow land (Figure 19 a). In addition, the western fallow has an evenness close to 0.9, indicating that no one species is dominating (Figure 19 b). As it was the only plot where no repetition was found in herbaceous species within the subplots, the diversity of the western fallow has likely been underestimated. This low diversity in the rice and pepper can largely be attributed to herbicides being used on the rice fields and the pepper fields being continuously weeded, making it difficult for herbs to establish themselves. In the oil palm plantation, pesticides were also used, but a herbaceous species diversity of 2.1 was found, which is close to that of the western fallow and substantially higher than in the pepper, rice and eastern fallow. However, as the assessed oil palm plot was 11 years old, it is unlikely that it will continue to uphold an herbaceous ground cover. A key informant interviewed, working within the oil palm sector, explained that after around 10-15 years of age, the palms typically cast too much shade for any herbs to grow beneath them.
While the western fallow, which was also the oldest (50 yr) had the highest H’ and E of all assessed plots, the eastern fallow, which was younger (30 yr) had the lowest, the difference more likely seemed to be associated with land use history than age. The eastern fallow was a former rubber plantation, now abandoned and grown into a dense dark forest dominated by rubber trees and bamboo. The western fallow also had a legacy of being used for rubber, but today, the rubber trees were mixed with fruit trees and other trees, and the canopy was more open, letting light reach the understory. This underlines that fallow in itself is not a guarantee of high biodiversity, as it is closely linked to the land use history.

A key difference in biodiversity between the fallow and the agricultural lands is the tree diversity. No trees were found in the pepper and rice plots, and the oil palm was a monoculture. The western fallow showed a high tree diversity and evenness, with an average H' and E of 2.8 and 0.9 (figure 19, c and d). Still, it is worth noting that both the pepper and rice include shorter fallows in their land use cycle, which will hold tree diversity.

a.

b.

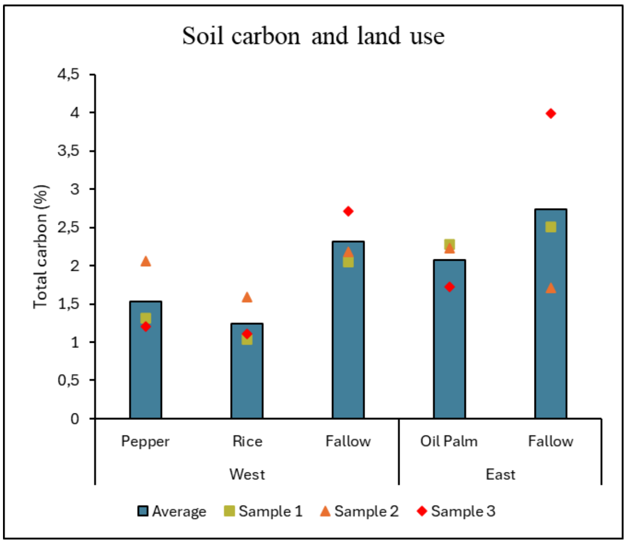


c. d.

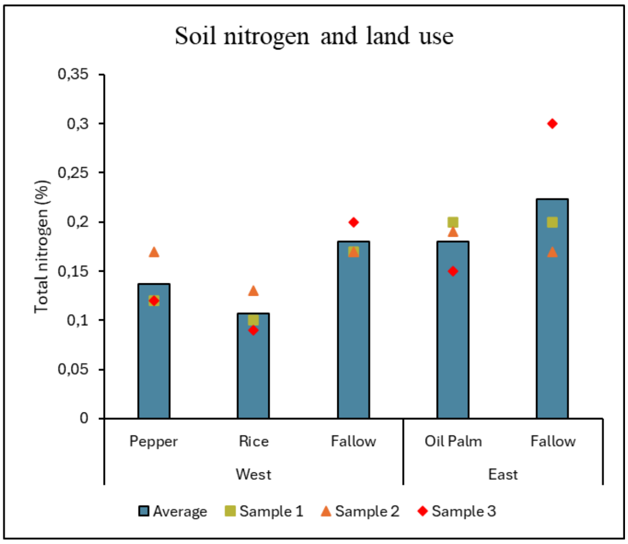
Figure 19: Graphs a-d showcasing herbaceous species diversity and evenness, tree species diversity (west), and tree species evenness (east)

4.3.2. Soil quality and degradation

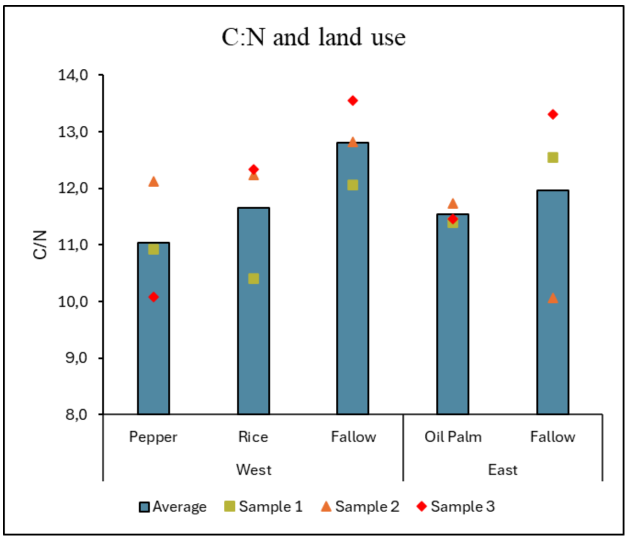
As seen in Figure 20, graph d, all soils assessed are strongly acidic, showing that the agricultural practices of burning in the rice field and liming in the pepper field do not have a noticeable impact on soil pH. The low pH is also a potential reason for the reliance on fertilizers, which was stressed by all farmers interviewed, as soils at this pH range have a low nutrient availability (Weil and Brady, 2017). The average C: N ratios all fall in the range of 11-13 (Figure 20, c), which is likely due to the organic soil pool being highly decomposed. Within this C: N ratio, a net nitrogen mobilization usually takes place, making soil nitrogen plant-available but also increasing the risk of nitrogen leaching (Weil and Brady, 2017). In both the eastern and the western survey areas, the fallow has the highest average C and N levels, indicating that organic matter is lost when the fallow is converted to rice fields, pepper fields or oil palm plantations.



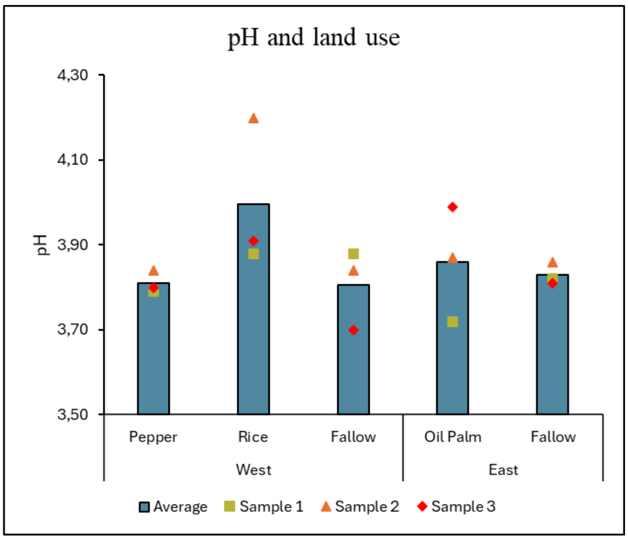
a)



b)



c)



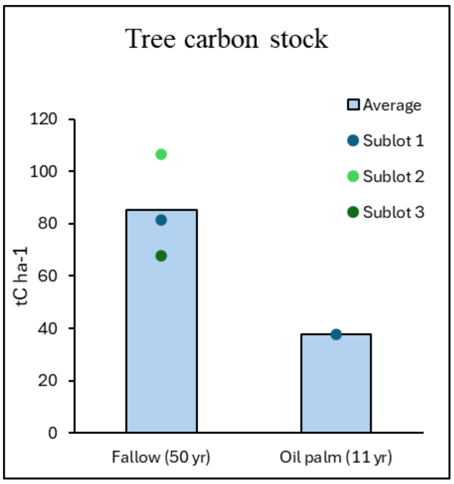
d)

Figure 20: Graphs a-d showcasing soil carbon and land-use, soil nitrogen and land-use, C: N and land use, and pH and land use.

4.3.3. Carbon Stock

Our results show a loss of carbon when fallow land is converted to oil palm plantations, both due to less carbon being stored in tree biomass below and above ground and due to a decrease in soil carbon. For all the assessed soil, the carbon stock was between 35 and 55 tC/ha (Figure 21, b). Figure 21 graph B (tree carbon stock) shows that the fallow stores approximately double the amount of carbon in its tree biomass as the assessed oil palm plantation, meaning that converting fallow land to oil palm plantations results in a loss of 48 t C/ha (Figure 21, graph a). When fallow is converted to pepper or rice, on the other hand, all 85 t C/ha are lost, as no trees are grown. It is worth noting, though, that the fallow used for this calculation is 50 years old, while rice and pepper are mostly grown on only 4-year-old fallow.

a.



b.

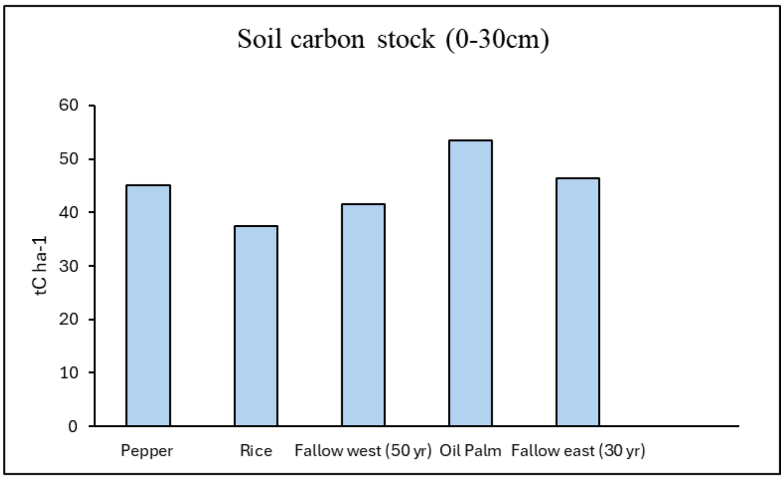


Figure 21: Graphs showcasing tree carbon stock and soil carbon stock

Looking at the soil carbon, the question of loss in carbon per ha is a bit more unclear. For both fallows, we measured very low bulk densities, even though the soil types were mineral soils (Figure

22a). As all the fallows had an organic surface layer (O horizons), the bulk densities taken at the surface level are likely underestimating the actual bulk density of the topsoil layer (0-20 cm), leading to low total carbon stocks (t/ha). This creates the misleading impression that carbon is gained when fallow is converted to agriculture, as is seen in figure 22. Graph d. as the O horizons with low bulk density are compared to mineral horizons with higher bulk density. In reality what is likely happening is that the O horizon is lost when fallow is converted to agriculture, leading to a loss in soil carbon. Focusing on changes in C% and N%, however, might more accurately reflect the observed decrease in organic matter with land-use change, as it avoids the bulk density issue and aligns better with our field observations. As seen in Figure 21, graph b, soil C% decreases with 32% 11 years after fallow land is converted to oil palm. All in all, less carbon is lost when fallow is converted to oil palm compared to when fallow is converted to rice or pepper - both regarding changes in soil carbon storage (%) and tree carbon stock (tC/ha).

a.

Plot	Soil type	BD (g/cm3)
Pepper	Sandy clay loam	0,99
Rice	Sandy loam	1,00
Fallow west (50 yr)	loam	0,60
oil palm	silty clay loam	0,86
Fallow east (30 yr)	Silty clay	0,56

b. c. d.

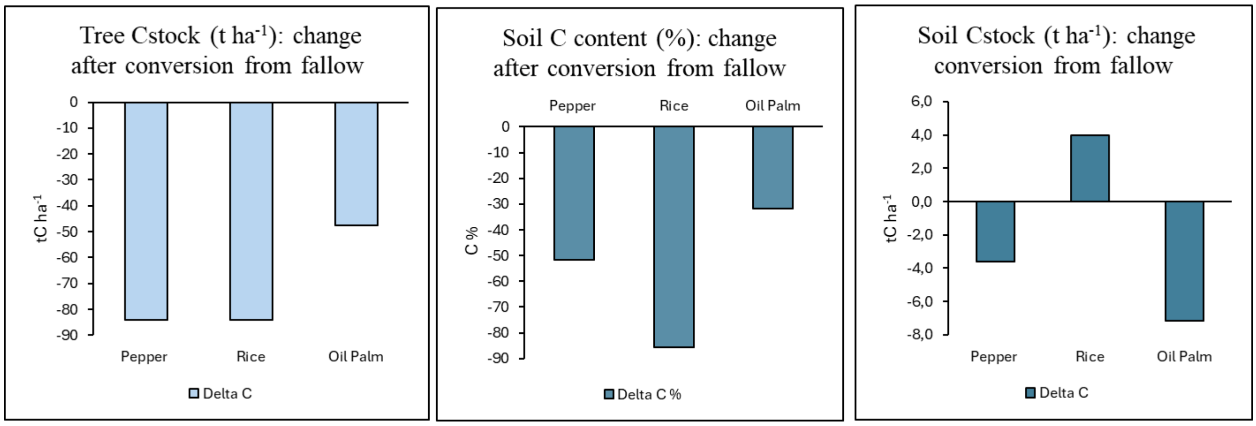


Figure 22. Soil types and changes in carbon stored in soil and trees, when fallow is converted to agriculture.

4.3.4. Water

The results of the water sampling and respective water quality categories, according to the national water quality standard for Malaysia, are listed in Table 3. As shown, all sampling sites fall into either category I or IIA for each variable, meaning the water has an overall excellent quality. Specifically, water in Class I, which is the best category, requires practically no treatment, and very sensitive aquatic species can live in it. Class IIA is the second best category, where conventional treatment is required before the water is used for drinking, but it can still support sensitive aquatic species. This implies that the current land use in Sungan has not had a substantial impact on the water quality in the areas surrounding the village. Furthermore, the H’ for invertebrates and fish shown in table 4 does not show a clear picture of which plots have the better biodiversity - while some have higher invertebrate diversity, others have higher fish diversity.

However, there is a risk that future agricultural intensification could negatively impact the water quality, if land surrounding the rivers is farmed more intensively, with increasing inputs of fertilizers and herbicides, in that case. One risk is increased levels of phosphorus, which, in turn, could lead to eutrophication (Boyd, 2015). Interestingly, an example of this phenomenon can be observed from the sample data provided in Table 3. Here, increased levels of Phosphorus are observed in plot 2 and plot 3, compared to plot 1. Both plots 3 were located closer to farming sites, and thus closer to potential agricultural runoff. The location of plot 3, close to an oil palm plantation was, only noticed after the sampling was done, making it a questionable control plot, albeit a good plot to indicate impacts of oil palm farming on water quality.

Parameter		Plot 1 (Kayan - downstream)	Plot 2 (Kayan - upstream)	Plot 3: Control (Sungan)
Temperature (℃)	Value	24.3	23.9	24.1
	Category	I	I	I
Dissolved oxygen (mg/l)	Value	5.45	5.65	5.80
	Category	IIA	IIA	IIA
Conductivity (mS/cm)	Value	0.37	0.12	0.15
	Category	I	I	I
Total	Value	81.03	80.4	96.42

Dissolved Solids (mg/L)	Category	I	I	I
Salinity (SAL ppt)	Value	0.06	0.06	0.07
	Category	I	I	I
pH	Value	6.95	7.07	6.92
	Category	I	I	I
Total phosphorous (mg/L)	Value	0.30	0.42	0.43
	Category	N/A	N/A	N/A
Ammoniacal nitrogen (mg/L)	Value	0.06	0.02	0.01
	Category	I	I	I
E. Coli colonies (count/100 ml)	Value	27	22	8
	Category	IIA	IIA	I

Table 3: Water quality values and associated categories

	Plot 1 (Kayan - downstream)	Plot 2 (Kayan - upstream)	Plot 3: Control (Sungan)
Invertebrate (H')	2.02	2.26	2.34
Fish (H')	0.732	1.04	0.562

Table 4: Shannon index measured in the three river plots.

4.4. Social and Cultural Impacts

4.4.1. Changing relationships to the land

Throughout the history of Kampung Sungan, the association between residents and their land has shifted, influenced by changes in farming practices, religions, and changing notions of land tenure. Through our field observations and resource ranking exercise, we learned that many farmers are relying less on paddy/rice farming, instead prioritizing cash crops, like oil palm, due to higher revenues. Further emphasizing this, the younger generations also expressed wanting to grow cash crops like oil palm, never mentioning paddy. In this way, we see that, though the identity of being a farmer is attached to the land and remains prominent, the goal of generating income has reshaped its significance.

Furthermore, the importance of owning land is also seen to be changing. Interviews with the Tebedu District Office as well as with Sungan's Headman indicate strong desires from both parties to establish legal land titles in the village, demonstrating a shared perception of land ownership's importance. One interview with an owner of a local village shop revealed a strong hesitancy towards selling land, viewing it as an essential part of their legacy. Similarly, one key informant emphasized that they would never sell their land, only considering renting it to someone trustworthy if their children did not return to Sungan to maintain it. Parallel conversations with younger generations revealed they were willing to sell the land in cases of extreme financial hardships or if their future children had no interest in keeping the land. This reflects a gradual shift in traditional views, with an increasing openness to selling land due to an increase in job-opportunties in nearby cities.

Traditionally, *adat* imposed strict rules and restrictions on the use of land and natural resources, such as not entering the forest if a certain frog sound was heard. However, adherence to *adat* has weakened, as farmers no longer worry about some of these restrictions in "modern" intensified agricultural production. While some traditions remain, much has faded due to religious change and socio-ecological changes evolving alongside other influencing drivers. As *adat* declines across generations, people's relationship to land and its cultural values continue to shift. Decisions about land in Sungan lie centrally to livelihood strategies but remain complex as they are shaped by access to land, infrastructure, technology, education, economic opportunities, and social relationships.

4.4.2. Household structure and labour changes

As noted from focus group discussions, there is an increasing ability to pursue varied careers both in and out of Sungan, influenced by access to education, infrastructure, technology, and social networks. There is also a growing desire and ability to pursue more profitable cash crop agriculture. These changing livelihood strategies are reshaping household structures and labour relations in the village.

A key informant noted that wage labour became more common after the construction of the main road. One interviewee shared that their partner, who spent months away for construction jobs, can now commute due to the increased car access. Allowing them to earn higher incomes while staying connected to family and village life. Furthermore, several children live with extended family while their parents work in other cities. These trends suggest that leaving Sungan for work does not lead to permanent relocation. Instead, many commuters can maintain strong social and familial ties to the village.

The future of these household dynamics is uncertain, particularly with agricultural intensification and expansion of oil palm. Many children in focus groups expressed interest in farming oil palm due to its profitability. Young men in the 15-25 year age group equated working family land to “owning their own business”, emphasising a shift in farming perceptions- from subsistence to a lucrative profession. In a case like this, where oil palm cultivation expands significantly, fewer people may seek labor opportunities outside of Sungan.

Such a shift toward cash crop production could reshape cross-village labour relations. In the resource ranking exercise, oil palm was identified as both being the most labour intensive, and the crop most likely to occupy more land in the future. When discussing how households would manage to keep up with the labour demands of oil palm, participants agreed that it would require hiring more local wage labour, particularly young people within Sungan, as well as using their increased access to capital to hire labourers from other villages to commute and help farm. This would impact livelihood strategies both within Sungan and in surrounding communities.

4.4.3. Ethnobotany and Indigenous Knowledge

Indigenous ethnobotanical knowledge demonstrated by different generations reflects how sociocultural ties to the land have changed. In ethnobotany focus groups, the 40-to-60-year-old group had profound knowledge of plants found in the forest and their traditional Bidayuh uses. However, despite knowing the medicinal uses of a plant, they use them less due to increased access to modern-day medicines. This shift suggests that technology and infrastructure are driving a departure from ethnobotanical knowledge. Nevertheless, participants emphasized the importance of passing on ethnobotanical knowledge to preserve their culture, indicating a disconnect between its cultural and its practical use.

Furthermore, when asked about whether they thought their children would inherit this knowledge, the older aged group expressed concerns about the younger generation's lack of interest. Despite this, the younger generation displayed significant knowledge about plants and their uses including bamboo species and medicinal plants, and expressed interests in learning more. This level of knowledge and interest suggests that the older generation's perception of the younger generation's knowledge and interest in plants is not entirely accurate.

Overall, the level of, and interest in, indigenous knowledge among the 15-25 year olds remains substantial. Despite this, their level of knowledge and interest in ethnobotany appears to be slightly lower relative to that of the older generation. While, to a certain extent, a difference in the generational levels of knowledge is expected due to their age differences, what is more relevant to note is the difference in the way the different generations discussed their experiences obtaining indigenous knowledge. The older generation discussed learning it from their parents, spending significant time with them on the farm when they were children, while the younger generation discussed how they have learned some things in a similar way, but do not often go to the farm with their parents, and thus are exposed to this knowledge less often. This change has been driven by education and economic aspirations, and agricultural intensification, reducing the need for the younger generations to engage with the forest. Additionally, the rise of social media and recreational activities contribute to this downward shift of interest in ethnobotanical knowledge. However, the cultural importance of land, particularly for the younger men who wish to use land to cultivate cash crops like oil palm, counterbalances these changes to some extent. This suggests that though ethnobotanical knowledge may continue to be passed down, its significance will likely diminish slowly over time with intensive and cash-crop focused agriculture.

5. Discussion

5.1. Discussion of results

Throughout the results and analysis section, several environmental, social and cultural impacts of changes in livelihood strategies have been uncovered. Looking at the environmental impacts, it was evident that oil palm plantations hold more biodiversity and store more carbon than both pepper and rice fields. These results might indicate that the shift towards oil palm in Sungan has an overall positive impact on the environment. However, the dynamics of fallow land must also be taken into account. While oil palm is a permanently grown crop with no fallow, rice and pepper both need to be left fallow, leaving room for both carbon storage and biodiversity in the fallow years. On the other hand, looking at the land-sparing hypothesis, one might argue that agricultural intensification, as seen when farmers transition from pepper and rice to producing oil palm, can lead to the preservation of areas of high biodiversity and carbon storage (Martin et al., 2018). However, as described by Rasmussen et al. (2018), agricultural intensification rarely has purely positive outcomes, even when looking solely at environmental indicators. This is, potentially, because land is not, in fact, ‘spared’ by agricultural intensification—instead, more land is simply being cultivated more intensely as part of agricultural intensification schemes.

Looking at Sungan, anecdotal evidence was provided to support the land-sparing hypothesis. When asked in a focus group if participants thought that agricultural intensification on the environment, the reply was no’, because fallow areas were left fallow longer, thus preserving their environmental benefits. However, participants did acknowledge the negative environmental impacts of a nearby large-scale oil palm plantation, indicating that maybe it is not oil palm as a crop that is the problem, but more so large-scale monoculture plantations. Overall, more data would be needed to conclude whether agricultural intensification has had positive or negative impacts on the environment in Sungan.

In addition to the environmental impacts of agricultural intensification, Rasmussen et al. (2018) and Martin et al. (2018) argue for the importance of considering social and cultural factors. In the case of Sungan, several trends were observed, especially when looking at relationships to land, household structures and labour changes, and ethnobotany and indigenous knowledge. The most notable impact of changes in livelihood strategies has been the shift towards cash-cropping and waged labour, as opposed to subsistence farming. While income data from before infrastructure developments (e.g. the construction of the main road and several bridges) is inaccessible, it is conceivable that overall income levels have increased along with the adoption of these practices. This would be in line with other findings on agricultural intensification. For example, Rasmussen et al. (2018) found that "agricultural intensification tends to positively affect local food production and income" (p. 2).

The impact on villagers' relationship to land and ethnobotanical knowledge is more difficult to assess. In the case of Sungan, an incremental shift in the relationship to land was observed; slowly, agricultural practices are becoming less embedded in ritual practices, although this change has been occurring over many decades—at least since the conversion to Christianity in 1967. This means that the importance of paddy farming is decreasing in the village, and a greater focus is put on the cultivation of cash crops. A similar incremental shift was seen in intergenerational ethnobotanical knowledge, albeit, even more slight. Here, the younger generation was perceived to have less knowledge about indigenous plants and their traditional uses compared to older generations, although we failed to substantiate this claim during an ethnobotanical focus group. Finding causal relationships between agricultural intensification and social and cultural change can be difficult as all these changes take place in a complex setting. While it might not be possible to completely avoid over-simplifications when tracking causal mechanisms of agricultural intensification, some conclusions can still be drawn. This study showed that even though changes in livelihoods are likely to have social and cultural impacts, cultural identity and social relations did not seem to be easily changeable in Kampung Sungan. This shows the resilience of communities in a changing agricultural landscape.

5.2. Limitations

Several limitations were encountered during the field work. First of all, different cultural backgrounds meant that participants did not always understand the questions asked. This was especially prominent while doing the household surveys, as categories such as "income" or "well-being" were not always understood. We attempted to mitigate this by clarifying the concept at the moment or asking for follow-up questions when needed. This, however, adds a level of interpretation to the survey data, as it was often the case that researchers and translators interpreted the answers given by the participants. Secondly, recruiting a diverse range of people proved to be difficult, as we mainly relied on snowball sampling; that is, we asked our guides to recruit potential people for PRA activities. This meant that some of the same people showed up multiple times. This could present an issue for the data generation, as the same people are likely to prioritise the same topics during conversation. Lastly, a limitation that affected all the environmental results was the difficulty of choosing plots. Since soil is the foundation of all other life in an ecosystem (De Deyn & Kooistra, 2021), choosing control and impact plots with comparable soil types was of great importance to the biodiversity, carbon stock and soil assessment. However, due to the impact of the meandering river, the soil type varied drastically within short distances, making it hard to find comparable impact and control plots. Even when we actively tried to choose plots with similar soil types we ended up with some variation between control and impact plots, which have likely affected our results. Choosing a representative control plot for the water sampling also turned out to be a challenge. The control plot we chose turned out to be located near an oil palm plantation, which might be the reason behind it having a higher phosphorus content than one of the “impact” plots. This clearly shows the challenge of choosing an accurate control plot in an area where land close to the rivers and villages is generally used as farmland.

In addition to the limitations of our methodology, several challenges also came up during the analysis process: The household surveys were structured in such a way that only ordinal and nominal data was collected. This limited the possible statistical tests, as common analysis methods such as t-tests, ANOVA, and regression analyses were not possible. Instead, chi-square tests, Fisher’s exact test and Spearman’s rank correlation coefficient were attempted. However, likely due to the small number of data points (42 in total, divided across several categories), no test provided a statistically significant result. Moreover, it was not possible to conduct statistical tests on the environmental variables, as the sample size was too small (3 in each plot). Therefore, it is not known if what we observed is an actual trend or simply due to chance. One could also discuss how valid our biodiversity assessment is since we only assessed how many species were found and not whether these species were rare, normal or invasive. As Hill et al. (2005) argue: “Particular care must be taken in interpreting the results of richness and diversity assessments,” as areas can have high ecological value but still be species-poor. Comparing our data with a primary forest would have been ideal to avoid this issue, but it was not possible under the circumstances.

6. Conclusion

Ultimately, this study finds evidence to suggest that agricultural intensification in Sungan will continue in the form of increasing cash crop production, chiefly oil palm, as a popular livelihood strategy. Wage labour outside of Sungan, in a variety of career fields, also appears to be an increasingly prominent livelihood strategy. Importantly, the two strategies are not necessarily mutually exclusive, with some wanting to have careers outside of Sungan, then return to Sungan to farm cash crops on their family land. The six drivers of change identified, each influenced by Ribot Peluso's (2003) mechanisms of access, work together to shape decision-making about livelihood strategies.

These changing livelihood strategies and trajectories have important social implications. It is expected that there will be a gradual generational decline in both adherence to *adat,* the way familial land is valued, as well as in ethnobotanical knowledge. Furthermore, while effects on household structures are largely inconclusive, shifting labour patterns and changes in access, may suggest that permanent outmigration from Sungan will become less common.

When looking at the environmental impacts of these livelihood strategies, namely agricultural intensification, we see that oil palm holds a greater plant diversity and carbon storage than traditionally and more extensively farmed crops such as pepper and rice. But to draw any final conclusions further assessments of how the expansion of oil palm affects the fallows is needed. If increasing land used for oil palm leads to a reduction in fallow lands, it might result in a total decrease in carbon storage and biodiversity, while an increase in fallow can have positive impacts. Generally, water quality was found to be quite good according to various indicators.

These findings leave us with a complex understanding of Sungan and the ways that livelihoods are evolving alongside the environment and community. Future research should further explore what "wellbeing" means to the people of Sungan and how feelings of this evolve alongside livelihood strategies. Furthermore, while the Theory of Access was used as an analytical tool to help frame our findings, a deeper study into local power relations as determinants of access could have interesting implications.

7. Bibliography

Alexander, R. (2023). Who returns? Understanding experiences of graduate return to rural island communities. *Journal of Rural Studies*, *103*, 103112-. https://doi.org/10.1016/j.jrurstud.2023.103112

Asari, N., Jaafar, J., Md.Khalid, M., & Suratman, M. N. (2013). *Estimation of Above Ground Biomass for Oil Palm Plantations Using Allometric Equations*.

Boyd, C. E. (2015). *Water Quality : An Introduction* (2nd ed.) [Online PDF]. Springer. http://ndl.ethernet.edu.et/bitstream/123456789/75235/1/Water%20Quality-%20An%20Introduction.pdf

Bulan, R., & Locklear, A. (2008). *Legal perspectives on native customary land rights in Sarawak.*

De Deyn, G. B., & Kooistra, L. (2021). The role of soils in habitat creation, maintenance and restoration. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *376*(1834), 20200170. https://doi.org/10.1098/rstb.2020.0170

DeWalt, K. M., & DeWalt, B. R. (2011). *Participant observation : a guide for fieldworkers* (2nd ed.). Rowman & Littlefield.

DFID (1999) Sustainable Livelihood Guidance Sheets.
https://worldfish.org/GCI/gci_assets_moz/Livelihood%20Approach%20-%20DFID.pdf

Hill, D., Fasham, M., Tucker, G., Shewry, M., & Shaw, P. (2005). *Handbook of Biodiversity Methods: Survey, Evaluation and Monitoring*.

Hodel, L., le Polain de Waroux, Y., & Garrett, R. D. (2024). Characterizing culture's influence in land systems. *Nature Sustainability*, *7*(8), 973–982. https://doi.org/10.1038/s41893-024-01381-z

Howes, P. (1960). Why some of the best people aren't Christian. *SMJ*, IX(15-16), 488-495.

Martin, A., Coolsaet, B., Corbera, E., Dawson, N., Fisher, J., Franks, P., Mertz, O., Pascual, U., Rasmussen, L. V., & Ryan, C. (2018). Land use intensification: the promise of sustainability and the reality of trade-offs. In *Ecosystem Services and Poverty Alleviation. Trade-offs and Governance*.

Kenzo, T., Ichie, T., Hattori, D., Itioka, T., Handa, C., Ohkubo, T., Kendawang, J. J., Nakamura, M., Sakaguchi, M., Takahashi, N., Okamoto, M., Tanaka-Oda, A., Sakurai, K., & Ninomiya, I.

(2009). Development of allometric relationships for accurate estimation of above- and below-ground biomass in tropical secondary forests in Sarawak, Malaysia. *Journal of Tropical Ecology*, *25*(4), 371–386. https://doi.org/10.1017/S0266467409006129

Langub, J. (2024). Native Customary Rights Land: Indigenous perspectives. *Journal of Borneo-Kalimantan,* 10(1), 1–10. https://doi.org/10.33736/jbk.7261.2024

Mainstone, C. P., & Parr, W. (2002). Phosphorus in rivers — ecology and management. *The Science of the Total Environment*, *282*(1–3), 25–47. https://doi.org/10.1016/S0048-9697(01)00937-8

Meyfroidt, P. (2016). Approaches and terminology for causal analysis in land systems science. *Journal of Land Use Science*, *11*(5), 501–522. https://doi.org/10.1080/1747423x.2015.1117530

Mikkelsen, B. H. (2005). Participatory Methods in Use. In *Methods for Development Work and Research* (pp. 87–123). SAGE Publications India Pvt, Ltd. https://doi.org/10.4135/9788132108566.n3

Narayanasamy, N. (2009). *Participatory Rural Appraisal: Principles, Methods and Application* (1st ed.). SAGE Publications India Pvt, Ltd. https://doi.org/10.4135/9788132108382

Natarajan, N., Newsham, A., Rigg, J., & Suhardiman, D. (2022). A Sustainable Livelihoods Framework for the 21st century. *World Development*, *155*, 105898. https://doi.org/10.1016/j.worlddev.2022.105898

Nelson, J., Muhammed, N., & Rashid, R. A. (2015). An Empirical Studyth on compatibilitythe of Sarawak forest ordinance and Bidayuh Native customary laws in forest management. *Small-scale Forestry*, 15(2), 135–148. https://doi.org/10.1007/s11842-015-9313-y

Ngidang, D. (2005). Deconstruction and reconstruction of native customary land tenure in Sarawak. 東南アジア研究, 43(1), 47–75. https://kyoto-seas.org/pdf/43/1/430103.pdf

Nnanna, U. A., Mohammed, A. U., Abubakar, T. T., Yunus, J., Eleke, U. P., & Sennuga, S. O. (2025). The role of technology in transforming rural social systems: An insightful review. *J. Nutrition and Food Processing, 8*(1). https://doi.org/10.31579/2637-8914/281

Rasmussen, L. V., Coolsaet, B., Martin, A., Mertz, O., Pascual, U., Corbera, E., Dawson, N., Fisher, J. A., Franks, P., & Ryan, C. M. (2018). Social-ecological outcomes of agricultural intensification. *Nature Sustainability*, *1*(6), 275–282. https://doi.org/10.1038/s41893-018-0070-8

Ravindranath, N. H., & Ostwald, M. (Eds.). (2008). Methods for Below-Ground Biomass. In *Carbon Inventory Methods Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production Projects* (pp. 149–156). Springer Netherlands. https://doi.org/10.1007/978-1-4020-6547-7_11

Ribot, J. C., & Peluso, N. L. (2003). A theory of access*. *Rural Sociology*, *68*(2), 153–181. https://doi.org/10.1111/j.1549-0831.2003.tb00133.x

Stone, N., Shelton, J. L., Haggard, B. E., & Thomforde, H. K. (2013). Interpretation of water analysis reports for fish culture. *Southern Regional Aquaculture Center*, SRAC Publication No. 4606.

Weil, R. R., & Brady, N. C. (2017). *The Nature and Properties of Soils* (15th ed.). Pearson Education. ISBN: 978-0133254488.