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Land Use Transition in Kepayang

Bridging Perceptions and Physical Environmental Change

Photo: Katrine Piester

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Authors:

Annabelle Yifei Chen Wu (qrk888)

Jasmine Vorburger (mcj364)

Juni Victoria Moe Moltubak (xjc631)

Katrine Bruun Piester (shk708)

Magnus Winther Damkær Jensen (bfc970)

Supervisors:

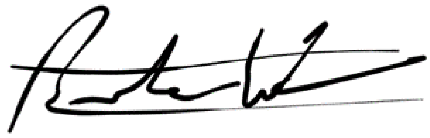
Assistant Professor Lorenzo Rossi

Professor Ole Mertz

Associate Professor Rikke Lybæk

Signatures

Annabelle Yifei Chen Wu

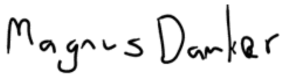


Jasmine Vorburger

Juni Victoria Moe Moltubak

Katrine Bruun Piester

Magnus Winther Damkær Jensen



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Abstract

As the world's palm oil demand becomes increasingly dependent on production from Sarawak, Malaysia, the region is witnessing drastic changes in land cover and land use, transforming the natural environment as well as local Iban livelihoods. Following an interdisciplinary approach, this case study on the Sarawak village of Kepayang aims to investigate the socio-ecological dimensions of the rapid transition towards oil palm cultivation, by taking a comparative approach in contrasting physical changes to perceived changes to the natural environment. The concept of perception is operationalized using the Societal Relations to Nature Framework by exploring narrative descriptions of the natural environment and sources of knowledge acquisition as important indicators. The physical changes are operationalized through a variety of biophysical indicators, namely land cover and use, water quality, and vegetational and aquatic diversity. The results of this analysis indicate that the local community's perceptions of changes to the natural environment are often aligned with the biophysical changes. However, there were also notable differences revealed with regard to the perceived water quality of the rivers and the identification of the primary causes of forest decline.

List of Abbreviations

ASD	Aquatic Species Diversity
BMWP	Biological Monitoring Working Party
COD	Chemical Oxidant
GEC	Global Environmental Change
GPS	Global Positioning System
JV	Joint ventures
KU	Copenhagen University
MFBI	Malaysian Family Biotic Index
PO	Participant observation
TR	Tuai Rumah
UNIMAS	University of Malaysia Sarawak
WQI	Water Quality Index

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List of Iban words

Ai	Water
Sungai	River
Bejalai	Walk / Journey
Bilik	Household
Bukit mangga	Communal forest reserve
Empangan	Dam
Getah	Rubber
Gerija	Church
Utan	Forest
Jalai	Road
Bot/Perau	Motor (specifically to boats)
Kampung	Village / forest
Lada	Pepper
Tanah temuda/ Tanah memudai	Native Customary Rights to land (NCR)
Padi	Rice
Pembalakan haram	Illegal logging
Pemereti ati	Understanding
Penemu	Knowledge
Penerang	Information
Pengangkutan	Transportation
Perusahaan	Enterprise
Rumah	Buildings / Houses
Rumah panjai	Longhouse
Sawit	Oil palm
Sesco	Electricity grid
Tuai Rumah (TR)	Headman
Words for Nature in Iban	
Alam	Nature
Alam semulajadi	The word for nature in Malay
Alam sekitar	Surrounding nature or Natural surroundings
Bengkah Menua	Which part (area / type)
Dunya	World (directly translated and a very broad term). Used when talking about changes to the world.
Menua	Village (like Kampung)
Tanah	Land

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Introduction

As global consumption grows, so does humanity's impact on the natural environment. A prime example of this challenge is oil palm, a commodity which has experienced significant growth as it supplies food and biofuel industries across the globe (UNDP, 2020). In the past 100 years, oil palm has become one of the most profitable agricultural commodities in the world (Awalludin et al., 2015), and Malaysia is the world's second-largest producer (after Indonesia), responsible for approximately 25% of global productions (Malaysian Palm Oil Council, 2024).

The scarcity of land with favorable climatic conditions allows Malaysia's oil palm industry to grow with few competitors generating income for millions of livelihoods (Unilever, 2022). However, more than 99% of the country's deforestation, between 1988 and 2012, can be attributed to oil palm cultivation (Shevade & Loboda, 2019). Land-use conversion from forest to oil palm impacts the entire ecosystems, with direct effects like biodiversity loss, pollution, and increased greenhouse gas emissions (Fitzherbert et al., 2008). Furthermore, the habitat fragmentation caused by oil palm has multiple negative spill-over effects like loss of wildlife and reduced water quality (Fitzherbert et al., 2008). This creates a wicked problem between economic development, sustainable agricultural practices, health, and the biophysical health of the natural environment.

Sarawak, one of two Malaysian states in Borneo, has experienced significant economic development and improved infrastructure over recent decades. This has acted as a catalyst for change by continuously fuelling a transition from traditional shifting and subsistence cultivation towards widespread cash crop cultivation (Cramb & Sujang, 2013). Borneo has one of the world's most biodiverse environments due to a climate that has created the foundation for fruitful livelihood opportunities but also made widespread oil palm cultivation possible (UNDP, 2023). One of the communities involved in this shift is Kampung Kepayang.

Previous studies in Malaysia have established that transitioning to monocultures rather than traditional crop practices can harm biodiversity (Hughes, 2017; Mertz, 2013), while other studies have shown how unsustainable land use can negatively impact local livelihoods (Munthali et al., 2019). However, most studies focus on the physical impact of oil palm cultivation, and do not consider the interplay between perceived changes and physically measurable environmental changes (Pyhälä et al. 2016). Understanding how perceptions of environmental changes influence the decision-making of local agents is crucial, as experience-based knowledge, accurate or not, often overrides scientific knowledge (ibid.). This creates a gap between authorities and local communities, making implementation of environmental and sustainability policies difficult (Oldekop et al., 2012).

Research Question and Objectives

This report aims to investigate changes to the physical and lived realities of the rural community in Kepayang by exploring the social and ecological dimensions of the land use transition to oil palm cultivation, contributing to existing research and providing a stepping stone into further interdisciplinary research on socio-economic and environmental sustainability.

Andrachuk & Armitage (2015) highlight the importance of considering the interplay of changes in both social and ecological systems rather than conceptualizing the changes in these spheres as separate subsystems. Building on this, this report employs a comparative approach to exploring land use change, whereby the analysis of local perceptions, investigated through social science methods, will be juxtaposed against observable changes in the natural environment, explored through natural science methods.

Through the integration of these techniques, lived experiences are compared to what is observable from an external standpoint, either reinforcing or challenging existing ideas (Bruun et. al, 2016). Following this, ecological changes in Kepayang's land use transition will be explored as *land cover*, *biodiversity*, and *water quality*, and perceived changes will be explored through the dimension of *knowledgescapes*, facilitating interdisciplinary data collection through both natural and social science methods. This has led to the following research question:

How do local perceptions compare to physical environmental changes related to the transition to oil palm cultivation in Kepayang, Sarawak?

To answer this research question, four sub-questions guide the data collection and analysis:

Physical environmental changes

1. How has land cover changed?

2. How does the land-use change impact the forest and water resources in Kepayang?

Perceptions of change

3. How does the local community of Kepayang describe changes to their surrounding natural environment?
4. From which sources of knowledge do these definitions derive?

Analytical Framework

The Societal Relations to Nature Framework (SRN) is used to "analyze human–nature relationships in specific settings [...] as well as in conflicts related to nature" (Berghöfer et al., 2022). As it explores people's relationship with nature by revealing underlying factors of human-nature entanglements, this analytical framework is suitable to operationalize the concept of *perception* (ibid.). It investigates a diversity of perspectives and values while acknowledging spatio-temporal disparities, such as historical contexts and geographical differences. Through this framework emerges the concept of *knowledgescapes,* defined as "the lens through which people perceive and understand their natural environment" (ibid.). The *natural environment* is here defined through the "global and endangered nature perspective", often associated with indigenous communities (ibid.). In this study, the natural environment is represented as a space embedded into the daily lives of the Kepayang community, through interactions with their natural environment and dependencies on local resources. Perception will be explored through the investigation of two main elements of the *knowledgescapes.* Firstly, descriptions of the natural environment and its changes provides refers to *what is known*, and secondly the processes of knowledge acquisition will be explored, referring to *how something is known* (ibid.). Through this, the SRN framework operationalizes perception and thus, guides the data collection and analysis process of the study. These elements of knowledge are only studied on the local scale and thus, exclusively capture the *knowledgescape* of Kepayang's community.

Methodology

The following section provides an overview of the methods employed during the fieldwork in Kepayang. The mixed methods approach enabled data triangulation, increasing the reliability of the findings (Mikkelsen 2005). Data collection lasted 14 days and entailed an interdisciplinary approach through the employment of a total of four natural science methods (satellite imagery/remote sensing, in-situ verification, vegetational diversity assessment, and aquatic diversity and water quality assessment) and five social science methods (focus groups, a transect walk, surveys, semi-structured interviews, and participant observations). The preliminary time schedule was altered during field work (Appendix 2).

Site Description

This study was conducted in all four Kampungs (villages) of Kepayang (Berangan, Setia Raja, Lama and String, all with their separate headmen) including the surrounding forests, rivers, and smallholder oil palm plantations. Kepayang consists of 147 households, with a primarily ethnically Iban and Christian population. A majority of the community engages in various agricultural practices, including oil palm and pepper cultivation. Rice cultivation used to be dominant in this area but has completely ceased now. Despite formerly living in traditional longhouses, the villagers transitioned to living in separate households in the late 1980s. Concerning the social structure, each Kampung follows its respective headman.

Figure 1 depicts the study area of Kepayang and the geographical scope of this research. The extent is 2.100 Ha, excluding the large-scale oil palm plantations. Kepayang has no documented borders but verbally agreed upon them with the surrounding communities based on natural borders such as mountain ridges, settlements, and large-scale plantations. 141 Ha of this is a protected communal forest reserve belonging to the community of Kepayang, from where they can gather forest products for their own consumption (Figure 2).

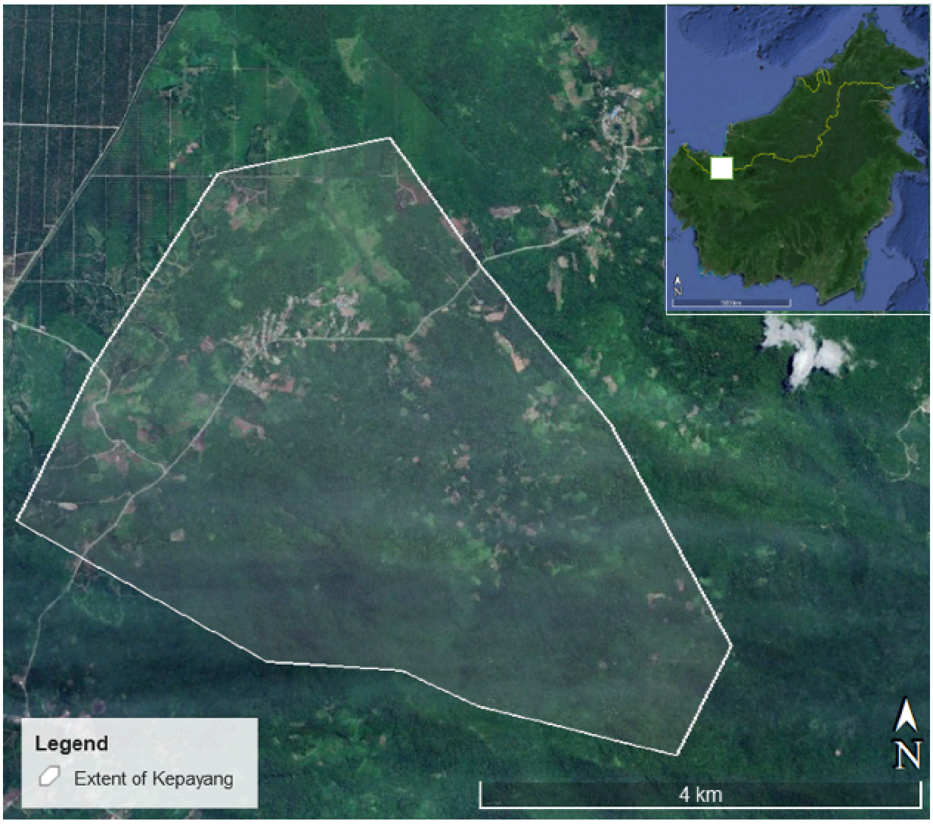

Figure 1: Map of research area

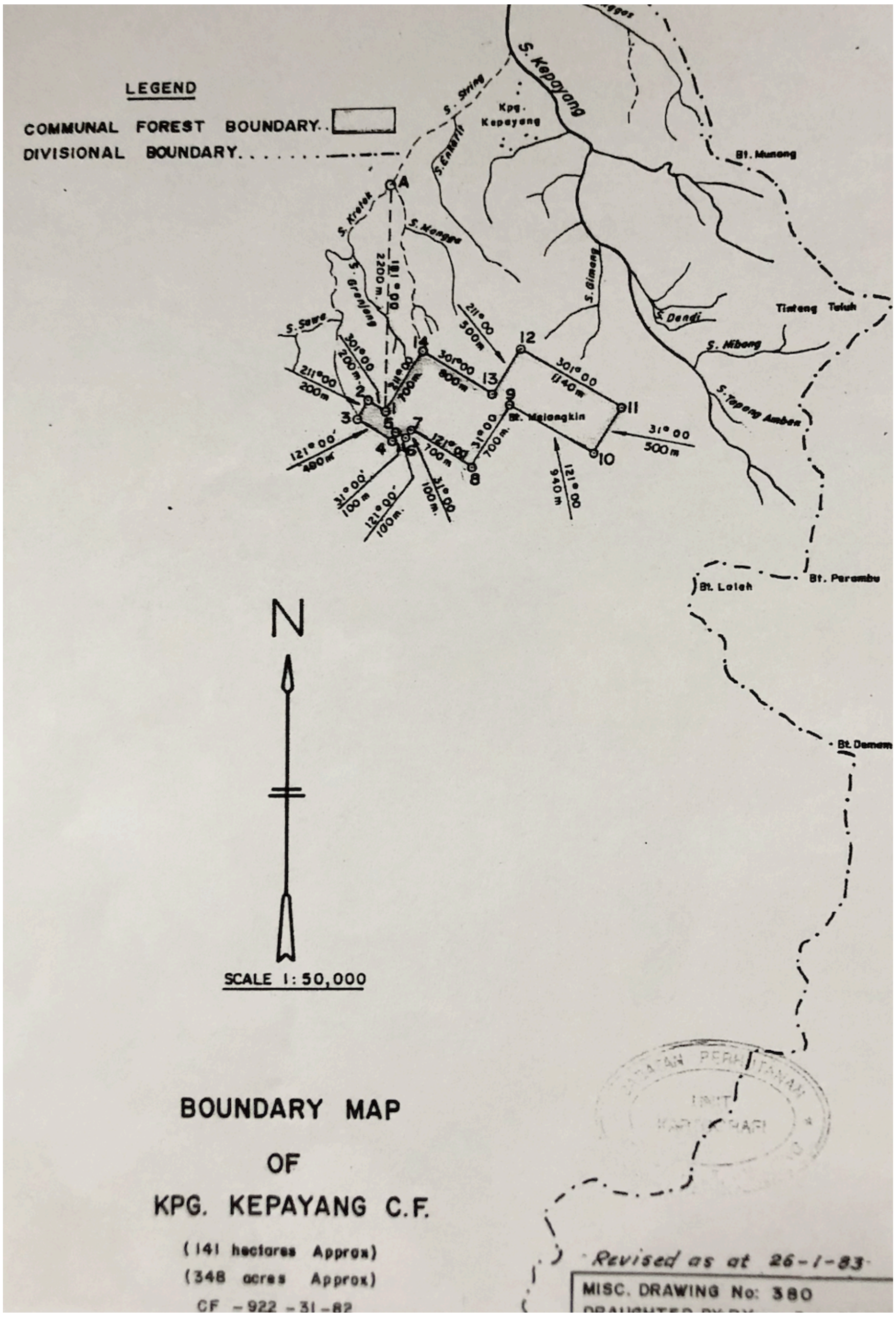

Figure 2: Boundary map of Kepayang. The marked area is the official protected forest based on an agreement between Kepayang and the Government

Natural Science Methods

Natural science methods included a historical comparison of satellite imagery, in-situ verification, and biodiversity and water quality assessments, depicted in Figure 3.

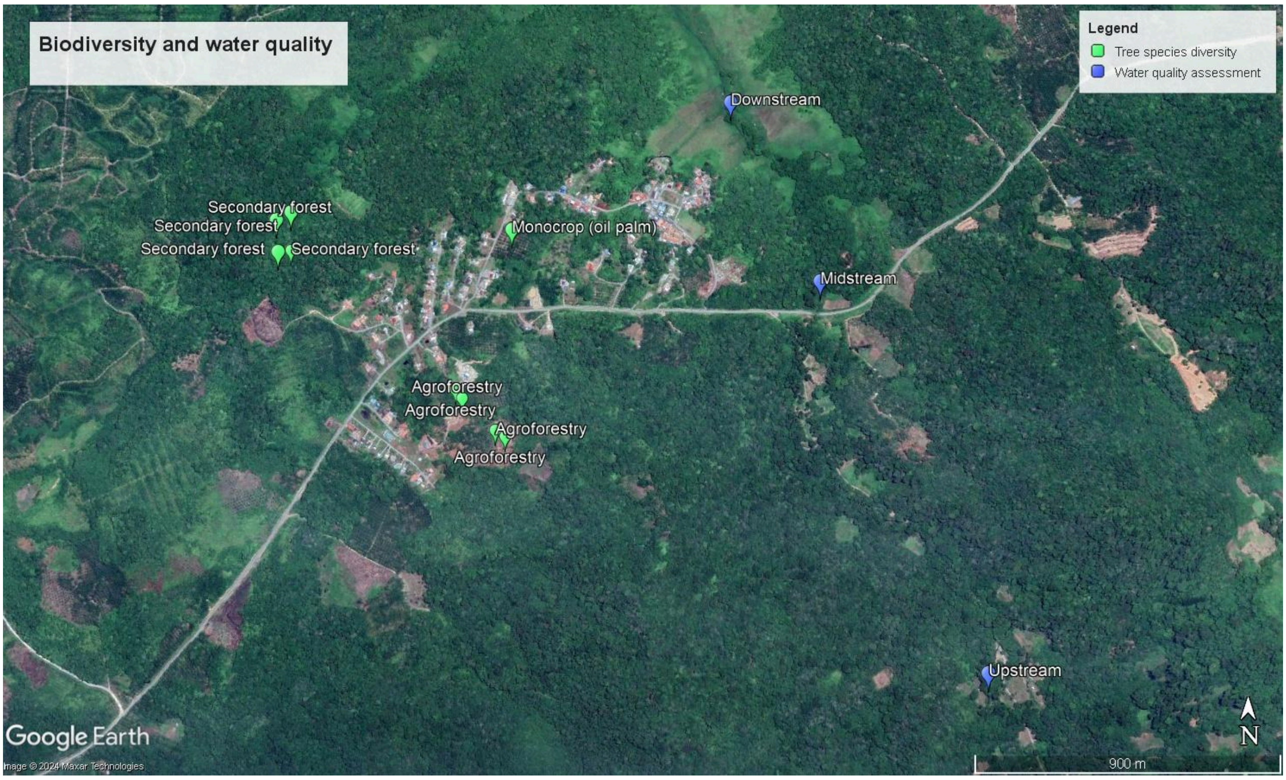

Figure 3: Natural science study sites

Satellite Imagery

To understand the large-scale land use and land cover changes that have occurred in the last 20 years, remote sensing images were analyzed to assess major transformations and identify areas of interest that needed to be confirmed in the field through in-situ verification.

Google Earth Pro allowed for a visual interpretation of Kepayang's natural environment, where the initial goal was to compare imagery from 2004 to 2024 to provide a perspective on the changes across a 20 year period. However, due to the unavailability of images from both 2004 and 2024, the years 2011 to 2021 were selected instead. Despite substantially reducing the gap from 20 to 10 years, it still provided useful information about the current land-use transformation trends.

The analysis is within the research area (Figure 1), covering 7 km², and was chosen to enable clear delineation of the plot for on-site verification, utilizing distinct features like roads. The selection of this area was guided by predefined criteria that included the entire village of Kepayang and the incorporation of areas deemed important was based on a literature review, pre-field information provided by professors and discussions with the local population. These areas included parts of the closest joint venture (JV) oil palm plantation, the closest forest area, and a region to the northeast that seemed to be previously cultivated land.

In-situ Verification

Because vegetation cover might "hide" specific land-uses, in-situ verification was performed to complement remote sensing and provide a more accurate point of comparison (Lillesand et al. 2015).

15 areas of interest were marked based on remote sensing areas that appeared unclear or were of additional interest upon arrival (points 3 and 14). In Kepayang, field surveys were done at the pre-identified areas and compared to the images from the 2021 satellite image (figure 4). What the land was currently being used for was noted, as transitions had occurred since 2021. A global positioning system (GPS) device was used for a precise location mapping to minimize error in the field.

Figure 4: In-situ verification map

Six areas (points 7, 11, 12, 13, 14, and 15) were initially inaccessible, so a second day of in-situ verification was arranged with a local guide that the Tuai Rumah (TR) provided. The guide also answered questions regarding the land use that was observed during the walk.

Figure 5: In-situ verification. Photo: Katrine Piester.

Vegetational Diversity Assessment

The Shannon-Weiner Diversity Index was chosen for the vegetational diversity assessment of tree species, as it provides a comprehensive assessment that considers both the number of species in the habitat (richness) and their relative abundance (evenness), offering a nuanced understanding of biodiversity in different environments (Hill et al. 2005). Tree species are selected to enable a comparison between the three land-uses

The qualitative vegetational diversity assessment was carried out in three different land-use classifications where subplots for each class were merged: secondary forest, agroforestry (combination of trees and crops), and monocrop (oil palm plantation). All sites were selected based on remote sensing, local knowledge, in-situ observations and accessibility. The size of the plots was determined in line with Hill et al. (2005), who pinpointed that a typical quadrant size needs to be at least 400m². Based on similar downscaling applied by Hill et al. (2005) and Li et al. (2023), the determined size subplot ended up being 10m x 10m (100m²). For secondary forest and agroforestry, two sites were randomly selected, each consisting of two subplots. The assessment of the monocrop area was conducted in one site with two subplots because it was expected to only consist of one tree-like species, namely oil palm. From a biological standpoint, oil palm is classified as a monocotyledonous species, which lacks typical characteristics of trees and is therefore not classified as a tree (Akmar & Kennedy 2001). However, oil palm was categorized as a tree in this biodiversity assessment because in-situ observations illustrated that the community referred to oil palm as trees and the triangulation of methodologies required the classification of oil palm as a tree.

Furthermore, the assessment only considered tree species to make the results comparable. Trees were deemed relevant if the diameter was ≥ 5cm in breast height to reduce the risk of distorting results, as these trees are expected to be established enough to survive nutrition competition (Hill et al. 2005). Weeds and shrubs were excluded from the assessment as these plants are removed in agroforestry and monocrop plantations.

A GPS was used to document the coordinates of the subplots center. Then, each tree species was marked and categorized by the local guide. Subsequently, the total number of trees and trees per species were collected to capture each plot's richness and evenness. Unidentifiable species were thoroughly documented by leaf samples and pictures of the crown, stem, and branches to enable identification ex-situ.

Aquatic Diversity and Water Quality Assessment

Sampling was conducted in three sites on the Sungai Rian river: downstream, midstream, and upstream, each approximately 1 km apart. The river starts from Kepayang's mountain and passes through oil palm and pepper plantations and the village. This is chosen as it represents three levels of anthropization within a gradient from limited human interference (upstream) to high human interference (downstream). The selection of sampling sites was based on remote sensing, local knowledge, in-situ observations, and accessibility. The sampling process was twofold. Firstly, water samples were collected to assess quality and compile a Water Quality Index (WQI). Secondly, aquatic species were collected to calculate a Shannon-Weiner Diversity Index, and macroinvertebrates were used as bioindicators to assess stream quality and calculate the Biological Monitoring Working Party (BMWP) (Appendix 5) and Malaysian Family Biotic Index (MFBI) (Appendix 5).

Index	Equation
Shannon-Wiener Diversity Index	$H = -\sum[(Pi \times (\ln(P1))]$
WQI	$WQI = (0.22* SlDO) + (0.19*SIBOD) + (0.16*SICOD) + (0.15*SIAN) + (0.16 * SISS) + (0.12 * SipH)$
BMWP	$BMWP = Sum\ of\ each\ species\ tolerance\ value$
MFBI	$MFBI = BMWP/number\ of\ species$

Table 1: Equations for assessing water samplings. See Appendix 4 for calculations

Three examinations were conducted preliminary to sampling: a simplified assessment of the vegetational diversity, a visual description of the turbidity to assess if sampling was suitable, and notes of any visible pollution (plastic, metal, etc..).

Aquatic diversity

For each site, one sample was collected by installing three nets for thirty minutes. Collection was conducted by the same three individuals to ensure consistent sampling strategy. They were instructed to gather samples in all parts of the river, specifically the bank, underwater vegetation and center. All species were placed in a container, documented, and counted in-situ, before being released back into the river. Any unidentified species were taken for ex-situ identification. This data is used to calculate the Shannon-Wiener Diversity Index, BMWP and MFBI.

Water quality

For each site, four samples were collected and a mean value was calculated. One sample was drawn specifically for Biochemical Oxygen Demand (BOD) and three for water quality. As advised by Al-Badaii et al. (2013), the pre-sterilized sampling containers were flushed three times to remove potential bacteria and subsequently filled and secured underwater to avoid contamination. Temperature, dissolved oxygen (DO), conductivity, and pH were measured in-situ using a YSI-meter. Phosphate, nitrate, total suspended solids (TTS), fecal coliform count (FCC) and total coliform count (TCC) were analyzed ex-situ within 6 hours of collection. TTS, FCC and TCC were passed through a membrane filter capturing the bacteria, then placed in a petri dish with added agar to grow the bacteria overnight to enable a count of the colonies within 12-16 hours. All data is used to calculate the Water Quality Index.

Social Science Methods

Participatory Rural Appraisal was employed through two focus groups, two participant observations, and a transect walk (Mikkelsen, 2005). Other social science methods included surveys and semi-structured interviews. All social science methods are elaborated upon in the following.

Figure 6: Social science study sites

Focus Groups

Focus groups were conducted on the first day of data collection and carried out in two separate exercises: community mapping and timeline mapping. These exercises emphasized a collaborative dialogue between participants with the goal of forming a collective opinion, offering nuanced information (Hurst, 2023). In each exercise, participants were selected through purposeful sampling by recruiting a group of eight community members through a local online group chat. Sampling criteria included participants being over the age of 20, born and raised in Kepayang, and cultivating at least one crop. The participant groups included both men and women. Control questions were administered to ensure all participants possessed sufficient knowledge of village events and surrounding land use transitions. Analysis followed the thematic coding key used for the semi-structured interviews (Appendix 9).

Community Mapping and Ranking Exercise

Community mapping can highlight the community's perceptions of land use transitions and environmental changes (Mikkelsen, 2005). The objective was to create two maps of Kepayang: One in present day (2024), and one approximately twenty years ago (2000). The participants were given markers of six different colors representing different categories of natural surroundings and land use. Moderating questions centered around the drawings, such as when certain areas were established, how a majority of the participants responded to changes, and why particular regions were drawn first or viewed as most important.

Figure 7: Community mapping. Photo: Katrine Piester.

After finishing the maps, the most prominent areas of change were identified for a ranking exercise, using a ranking scale (Figure 8) that highlighted the participants' attitude towards the selected areas. The first round of ranking allowed participants to choose any smiley on the scale to describe how they feel, from very positive to very negative, towards areas identified on the map. In the second round, participants were instructed to use each smiley on the scale once, thereby ranking regions in comparison to others. This was done considering economic and community value.

Figure 8: Ranking scale

Figure 9: Ranking exercise. Photo: Katrine Piester

Timeline Mapping

A historical timeline exercise can provide substantial background information from the participants' perspectives on topics such as land use and socio-cultural changes (Mikkelsen, 2005). Participants first placed a set of twenty predefined categories in chronological order. After reaching agreement on this, they created their own categories and placed them on the timeline. In the second step, participants assigned years to each category, including when specific categories stopped or changed.

Figure 10: Timeline mapping. Photo: Magnus Damkær

Transect Walk

A transect walk was carried out with two participants sampled through convenience, in order to observe, discuss, and register land use transitions, providing a deeper understanding of their perceived changes to the natural environment (Mikkelsen, 2005). The transect walk was conducted along a route intersecting through most of the Kepayang village. Participants were asked in an open-ended and informal manner to discuss the context of each area pointed out, including land use transition and reasons for the changes. To gather specific geographical data on important areas, the route was tracked as a path using a GPS and Google Earth, and narratives related to areas of land use change were recorded as field notes to later be coded into relevant categories. All collected points are illustrated on the map (Appendix 6).

Figure 11: Transect walk. Photo: Katrine Piester

Survey

A survey was conducted to obtain quantitative information on perceived changes to the natural environment and the roots of our sample's knowledge acquisition (Hurst, 2023). Inspired by Rea & Parker (2014), a questionnaire was created prior to arrival, focusing on land use, livelihood practices, perceived changes to the natural environment, and sources of knowledge. The finalized version was merged with the questionnaire developed by the Malaysian students and pilot tested in two rounds (Appendix 8). The platform SurveyXact was used to streamline the data collection.

A simple random sample was drawn from Kepayang's 147 households by numbering all households on a satellite imagery map of the village and sampling 40 households with a random number generator. A total of 36 surveys were ultimately conducted. In the process of analysis, the data was cleaned by standardizing open-ended answers and formatting the numerical answers in Excel. A comprehensive set of descriptive statistics was computed and a series of chi-squared tests of independence was performed to analyze the data.

Semi-structured Interviews

Semi-structured interviews were conducted to gain a deeper insight into local perceptions not easily observable through surveys (Hurst, 2023). Before conducting the semi-structured interviews, the interview guide was translated, whereby discussions of terms, such as "natural environment" arose. Due to a potential lack of understanding of this word in Iban, it was exchanged with a more locally accurate term of "nature". For this study "*alam sekitar*" was primarily used in translation to describe one's natural surroundings (see list of Iban words). After pilot testing the interview guide with one individual, the formulation of certain questions was simplified, and two questions were added (Appendix 9 for finalized interview guide).

Purposeful sampling was applied, considering the following criteria: gender diversity, variety of crop cultivation, and role within the village. A total of eight semi-structured interviews were completed. The names of all interviewees were pseudonymised during transcription due to sensitive information. Because the distinction between headmen and villagers emerged as an important analytical topic, the two headmen interviewed are indicated with TR to signal their position. These headmen are still anonymised to some degree, because the village of Kepayang has four headmen in total. NVivo was used to code the interviews with a set of 4 overarching theme codes and 15 thematic codes, drawing upon the indicators of the study's key concepts (Appendix 9).

Participant Observation

Participant observation was incorporated into the study to allow for further immersion into the lifeworlds of the community. This method provided insights that move beyond what people could articulate about themselves in interviews (Dewalt & Dewalt, 2011). The participants included: A woman with vast knowledge of local land use and plants, and a headman owning two private oil palm plantations. These participants were selected through purposeful sampling that took gender diversity and use of land into consideration.

Prior to the observation period, a prompt was presented to the participants. One participant was asked to guide the researchers through the forest, gathering products for lunch while pointing out and explaining anything edible or medicinal. Another participant was asked to show the researchers around a privately owned oil palm plantation, conducting a checkup of the plantation, while explaining the process of maintaining oil palm. During the observation, specific roles were divided between the participating researchers. One gathered notes on behavior and gestures, another on participant narratives, and a third directly interacted with the actions of the participants, such as gathering plants. Observation notes were compiled as narratives (Appendix 10), and the analysis involved applying the same set of codes used for the semi-structured interviews.

Figure 12: Participant observation A. Photo: Katrine Piester

Figure 13: Participant observation B. Photo: Magnus Damkær

Results and Analysis

Changes to the Natural Environment

The following will display the main findings from the natural science-based data collection. The results will be presented in two parts, answering the two sub-research questions: 1) How has land cover changed, and 2) How does the land-use change impact the forest and water resources in Kepayang. Question one will be answered using remote sensing imagery, and question two will be answered using three different indicators of the state of the natural environment: Tree species diversity, aquatic species diversity, and water quality.

Land Cover Change

Remote sensing imagery and in-situ verification

A comparison of the land cover in 2011 and 2021 using remote sensing reveals a transformation to a more fragmented landscape which can mainly be attributed to deforestation. The change has led to a conversion from forest to agricultural land-use, primarily oil palm.

The majority of these patterns differ in size and are generally observed within a close proximity of infrastructure. Comparing the two images shows the most significant transformation towards the southwestern part of Kepayang (Figure 14, 15), where large forest areas have been removed for agricultural purposes. Based on visible patterns and knowledge about current trends, it seemed likely to be a conversion into oil palm plantations. This was confirmed by in-situ verification as all areas were converted into oil palm plantations, except one, which was an agroforestry plantation. A new road has also been established in the western part, leading into a new plantation, which was identified through in-situ verification. The comparison further visualizes the emergence of a new oil palm plantation in the northwestern corner, which is part of Sarawak's large-scale JV plantations (Figure 1). Further land cover changes have occurred in the southeastern part of the area, close by the river, where small patches have been cleared, indicating small-scale agricultural practice. In-situ verification of these areas show that the fields are a mix of oil palm and pepper plantations.

Comparing the satellite image from 2021 with in-situ verifications has not only supported land-cover change analysis, but has also revealed how rapidly the land modifications occur. 11 out of 15 areas investigated in-situ have been converted into oil palm plantations (point 2, 3, 5, 7, 8, 10, 11, 12, 13, 14, 15) whereas two sites also included pepper plantations. The rest has either been converted solely to pepper (point 4, 6) or remained fallow land (point 1) since the abandonment of the rice fields (figure 4). Despite a conversion of forest to oil palm between 2011 and 2021, the forest cover remains the predominant area.

Figure 14: Map of Kepayang (2011)

Figure 15: Map of Kepayang (2021)

Impacts to Forest and Water Resources

Tree species diversity

Figure 16 shows the results of the biodiversity in the secondary forest, agroforestry, and monocrop. For the secondary forest, a total of 83 trees and 37 different species were identified, which resulted in a diversity index of 3.2 and a Hmax of 3.6 (figure 16). This means that the overall diversity is very high, as the difference between the actual diversity and the highest possible diversity, based on the sample size, is 0.4. The high index value signifies a substantial number of species as well as a relatively well-balanced distribution between the species indicating a diverse and decently balanced ecosystem, which further implies a high ecological resilience among the different species (Mangan et al. 2022). Agroforestry shows a similar result. A total number of 24 trees and 10 different species were identified, which resulted in a diversity index of 1.9 and a Hmax of 2.3. Notably, the difference between these indices is also 0.4, with a difference in the lower absolute level of biodiversity (3.2 compared to 1.9), due to the difference in land-use. However, this indicates that the trees in agroforestry are working together and utilizing available resources to support a high degree of species richness. Monocrop has a very different output. There were 4 trees in total which were all oil palm, which resulted in a diversity index of 0.0 and a Hmax of 1.4. Due to the fact that a monocrop is the antithesis of diversity and this land-use is a high intensity commercial cultivation, this result is to be expected. Noteworthy is that for this area less samples have been assessed, due to the assumption that monocrop would remain the same regardless of the sample size.

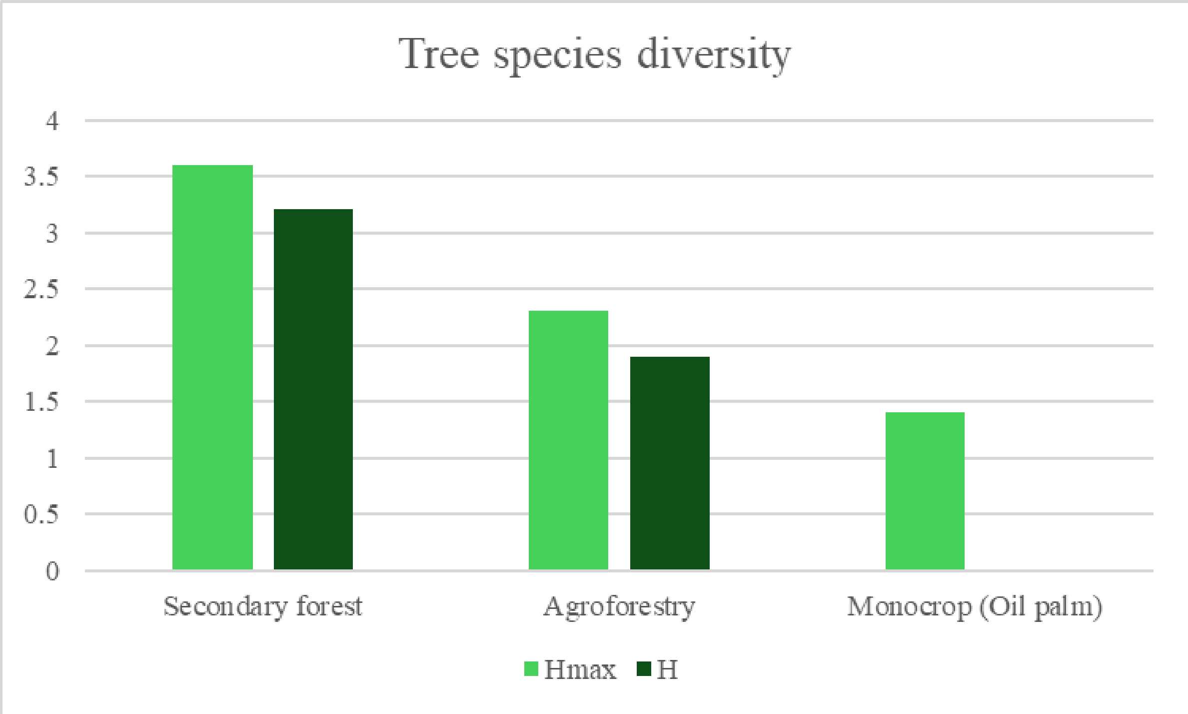

Figure 16: Tree species diversity

Figure 17: Downstream sample site. Photo: Magnus Damkær

Figure 18: Midstream sample site. Photo: Magnus Damkær

Figure 19: Upstream sample site. Photo: Magnus Damkær

Water site descriptions

The river meanders across all three sites with rocks on the riverbed. The water in the downstream is cloudy compared to midstream and stream which is very clear. All three sites had experienced recent erosion attributed to heavy rainfall. Downstream (Figure 17) is dominated by herbaceous vegetation, weeds and bamboo. Midstream (Figure 18) have varied vegetation with an increased amount of trees, bamboo and herbaceous species, especially ferns. Upstream (Figure 19) has the most diverse environment which is dominated by multiple different fruit tree species, dense areas of bamboo, and small-scale plantations.

Aquatic Species Diversity (ASD)

Figure 20 illustrates the results of aquatic species diversity in the three different locations in the river, which were downstream, midstream, and upstream. The diversity index is extremely similar across all three sites with diversity indices at 2.4, 2.5 and 2.5, and the Hmax is also similar with 3.9, 3.8 and 4.1. This indicates that each location supports a comparable level of species diversity and has an equal evenness in the distribution. A total of 29 different species were identified, with all sites having 16 different species, indicating that some species might be unique in certain sections of the river (Appendix 5). The total number of species in the upstream was 62, which is 16 more than midstream (46) and 12 more than downstream (50), indicating a slight difference in abundance. However, as mentioned above, this does not have a significant impact on the overall diversity index. The biodiversity is consistent across the sampled river sites which possibly indicates stable water quality providing a suitable habitat for a wide range of species. Upstream a slightly higher abundance of species was identified, which could be attributed to less anthropogenic disturbance.

The result of the MFBI indicates a similar pattern. Species caught downstream and upstream have a higher average water quality rating (5.9 & 6.1) than midstream (5.6). 5.9 and 6.1 are classified as 'very good' water quality. 5.6 is classified as 'good'. The water quality ratings from the BMWP are all classified as 'moderately good' despite variation in the score (Table 2). This indicates that there is a marginal difference in the water quality but the highest water quality is upstream.

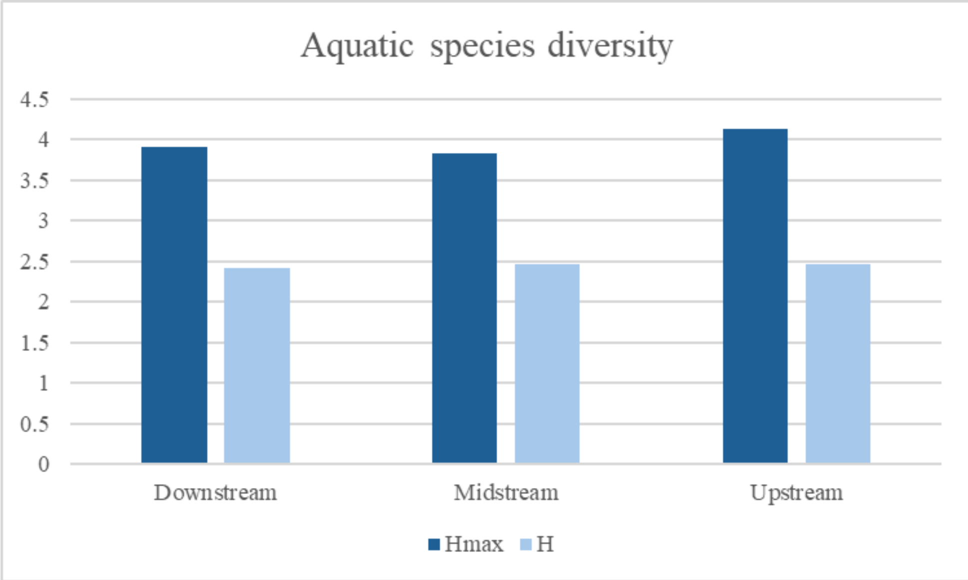

Figure 20: Aquatic species diversity in three different sites

	Downstream	Midstream	Upstream
BMWP (Total)	71	67	91
Water Quality rating (Total)	Moderately good (51-100)	Moderately good (51-100)	Moderately good (51-100)
MFBI (Average)	5.9	5.6	6.1
Water Quality rating (Average)	Very good ($\geq$ 5.9)	Good (4.5-5.8)	Very good ($\geq$ 5.9)

Table 2: Water quality assessment using macroinvertebrates as bioindicator

Water quality

Table 3 shows the WQI for the three locations based on calculations using Chemical Oxygen Demand (COD) threshold levels at three different water quality classes (I, II, III) as a variable. Higher scores indicate better water quality. The WQI are all within class II despite different COD values (appendix 4). This is similar to the results in the BMWP and MFBI which further indicate that the water quality in the river is good despite being affected by anthropogenic interference. However, there is a small difference between the three sites whereby the river has the best water quality upstream. This can be explained by more human interference midstream and especially downstream, where water from a different catchment passes directly through the village which ends up in the river just before the downstream sample site.

	Downstream		Midstream		Upstream	
COD (10)	84.9	Class II	86.8	Class II	86.5	Class II
COD (25)	82.1	Class II	84.1	Class II	83.8	Class II
COD (50)	78.4	Class II	80. 3	Class II	80.0	Class II

Table 3: Water quality index using three different thresholds of COD

In summary, secondary forest, and to some extent agroforestry, are two ecosystems with relatively high diversity despite different land-use classifications and different sample sizes. Notably, the complexity of the ecosystem in the secondary forest is significantly higher than in the agroforestry and signifies a more natural and varied ecological habitat. In contrast, areas converted from forest to oil palm have suffered a drastic alteration as oil palm plantations have a 0.0 diversity index, causing a low-tier ecological habitat, highlighting the significant impact of biodiversity caused by oil palm expansion. Meanwhile, the river system, despite anthropogenic pressures and land-use changes, generally maintains a good water quality across all three sites and supports a stable and relatively diverse aquatic ecosystem, with a slightly higher score in the less disturbed upstream.

Perceived Environmental Changes

As highlighted by the SRN framework, a community's knowledgescape fundamentally impacts how changes to the natural environment are perceived. It consists of two dimensions: *What is* *known* and *how something is known*. These two dimensions guided the data collection process and structured this analysis. The demography of this sample is introduced in the figures below. As most questionnaires were conducted with the head of the household, the sample has a male majority, and interviewee's availability resulted in age discrepancies as the sample lacks younger people. The sample of Iban ethnic majority and Christian religion mirrors the Kepayang population.

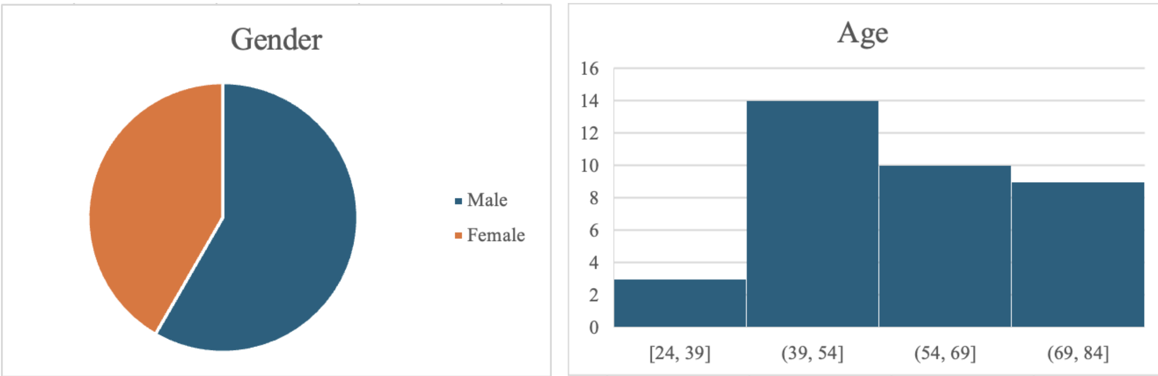

Figure 21: Gender and age distribution

Narratives of Changes to the Natural Environment

> "[…] the local village need to protect their forest […] and they don't want other people destroying their forests. Their nature." (Interview A, 00.00)

What did Jantung, a 63-year-old villager of Kepayang, mean when he referred to "their nature"? Interviewees were prompted to elaborate on what they understand as their natural environment, and the consensus emerged that it is a composition of trees, mountains, animals, and rivers. Moreover, the focus group highlighted the significant value that the forest holds to them, as it was one of the first areas to be drawn in the mapping exercise. A reoccurring perspective was the need to protect the natural environment, as participants elaborated on their reliance on natural resources like forest products and wildlife. However, the extent to which and reasons why the natural environment should be protected and what benefits can be derived from it, differed. While TR Intun, one of Kepayang's four headmen who cultivates oil palm, described available resources as abundant (Interview E, 00.10), Jantung, who cultivates pepper, described their availability as limited: "[…] instead of taking the fruits from [...] the forest, you can just take the seeds and grow it around your house" (Interview A, 00.00). By doing this, Jantung explained, benefits can be derived in a more resourceful way. Descriptive statistics from the questionnaire data showed that livelihood-related reasons, which include reliance on forest products, were often at the core of respondents' attitudes towards deforestation, further supporting the interviewees' understanding of the natural environment as a provider more than anything else.

Descriptions of the river further underscored the perception of the environment as requiring protection to safeguard access to resources. Jusit, a 46-year-old whose livelihood depends on pepper and oil palm, pointed towards the importance of waste management to keep the river clean and ensure fish supply, advising to "[…] dig the ground and throw the rubbish […] near their own house" (Interview C, 10.00). The tendency to manage waste in a manner that removes it from the immediate view indicates a prioritization of resource availability over environmental protection. During the participant observation, TR Intun further conveyed this disconnect, as he emphasized the importance of protecting the water resources, but did not view the spraying of pesticides in the vicinity of the river as problematic (Interview E, 00.30; PO B, p. 2). In contrast, Tingum, who grows fruit for subsistence, stood out as the sole interviewee to identify pesticides as a threat to environmental preservation, referring to pesticides as "poison" (Interview H, 00.00). Interestingly, the remaining interviewees mainly highlighted illegal logging activities as the primary threat to environmental degradation.

Several interviewees also emphasized the profitability of oil palm cultivation, highlighting their dependence on the natural environment for income. Agan, a 72-year-old who cultivates oil palm, was prompted to elaborate on whether he derives any other benefits from the environment other than economic, and concluded that "It just give income" (Interview B, 10.00).

However, cultural aspects were also mentioned when referring to the range of benefits the local community derives from the forest. 24-year-old Sara, who is unemployed, was the only interviewee to highlight the spiritual value of the natural environment, arguing that it is "[…] healing […] it gives something to human emotion" (Interview F, 00.00). Moreover, Jusit reflected on the socio-cultural importance of his land, emphasizing its generational legacy passed down from his father (Interview C, 10.00). In regard to the rice cultivation in Kepayang that has completely been abandoned within the past 20 years, it is interesting that both interviewees and survey respondents show a neutral attitude towards the most traditional and long lasting land use practice. While the vast majority of respondents in the survey agree that the cultivation of rice is the land use practice that has decreased the most over the past 20 years, it is also the land use change that they consider as the least significant.

Lastly, the question “If you cut down a forest to plant oil palm, is it still considered a forest?” was asked to further explore the community’s understanding of their natural environment. Nearly all interviewees argued against this statement, as the forest “[…] grows by itself, but the oil palm is planted by humans" (Interview G, 30.00). These answers suggest a prevailing perception that the definition of a natural environment is that it is relatively unaltered by human activities. TR Intun contrasted this perception, however, stating that clearing forests to cultivate oil palm does not equal forest loss because: “[…] we cut a tree, we plant a tree” (Interview E, 10.00). This unique definition of a forest is particularly interesting in light of the headmen’s role in shaping the community’s understanding of the natural environment, as will be discussed in the next section.

In conclusion, based on our data, the community collectively conveyed the perception that the natural environment primarily serves as a source of subsistence and income, with a minority highlighting its socio-cultural significance. Despite expressing concerns about environmental protection, the primary focus lies on preserving resources for subsistence rather than safeguarding the natural environment itself.

Moreover, the participants of this research agreed that land use in Kepayang has shifted significantly towards oil palm cultivation (Figure 22). This trend was also reflected in the transect walk, the focus group and in the questionnaire data, where the majority of respondents saw oil palm as having drastically increased.

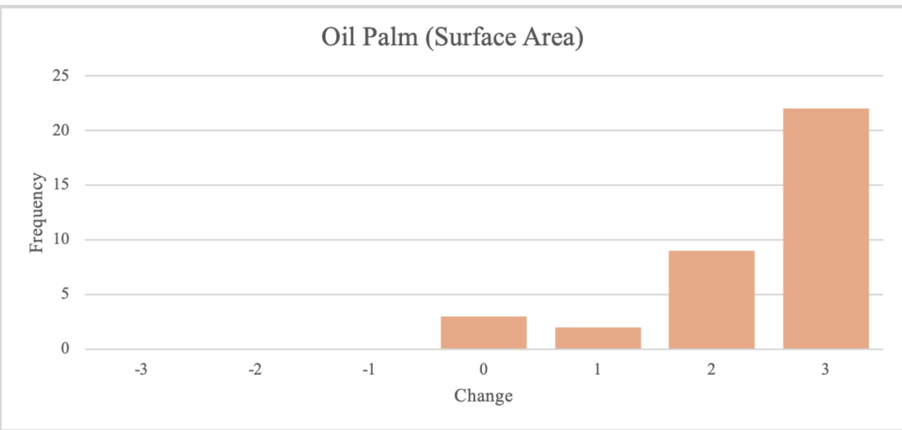

Figure 22: Perceived changes in surface area in oil palm, on a scale from -3 (significant decrease) to +3 (significant increase), where 0 indicates no change.

Moreover, questionnaire data illustrates that a majority of the respondents (28 out of 36) changed livelihood practices in the past 20 years (Figure 23), primarily shifting towards oil palm cultivation. Figure 23 below displays the time of this change, which was reflected during the transect walks and the timeline mapping (Appendix 7).

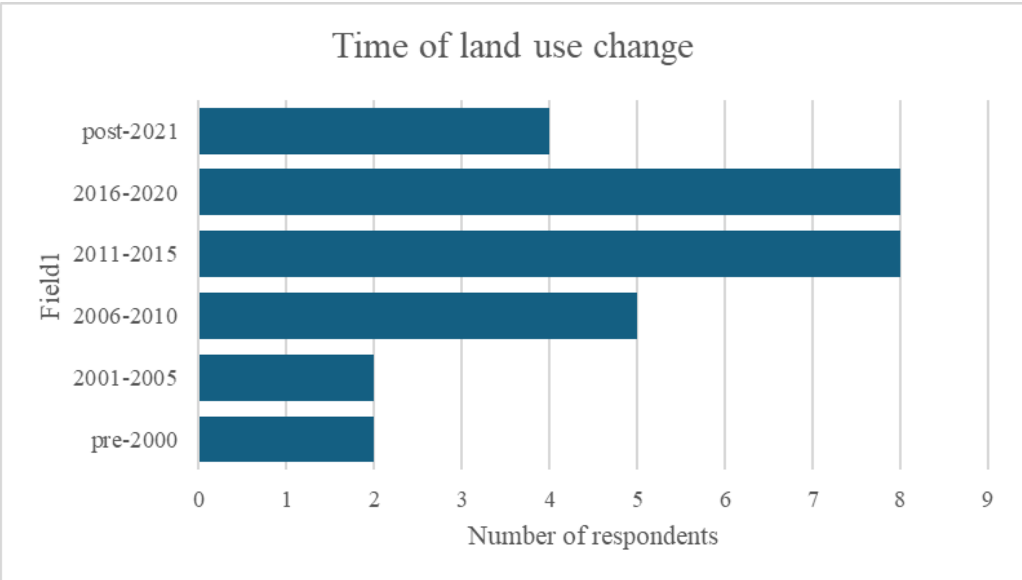

Figure 23: Respondents who have changed livelihoods in the past twenty years

During the community mapping, similar information was reflected as the first major change observed between 2000 and 2024 was the widespread establishment of JV and smallholder oil palm plantations, as seen in the maps below (Figure 24).

Figure 24: Community maps of 2000 and 2024. Both large-scale and small-scale oil palm plantations have been established, rice fields have been abandoned, and forest area has decreased.

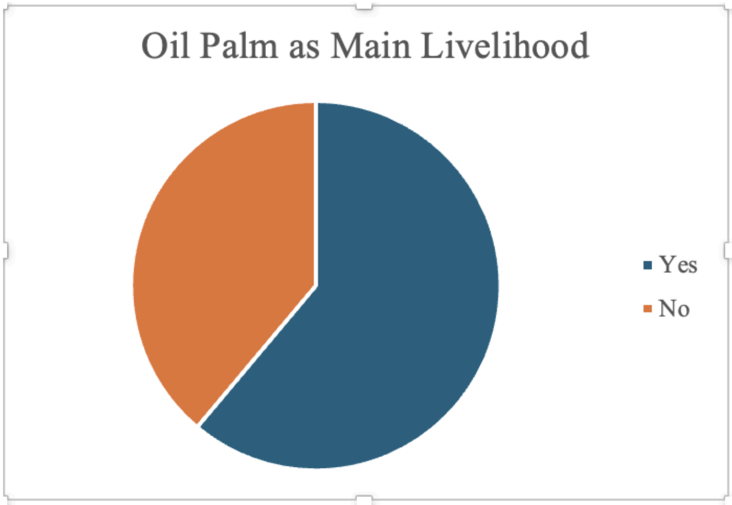

Figure 25: Respondents primarily cultivating oil palm

Tingum explained that farmers in Kepayang mainly rely on oil palm as a primary source of income because it generates the highest, most stable income and is also the most convenient to maintain (Interview B, 30.00). This is supported by descriptive statistics (Figure 25), which shows that the majority of survey respondents view oil palm as their main livelihood source. The convenient maintenance of oil palm, particularly the plantations' accessibility and low manpower requirements was also brought up during the participant observation with TR Intun (PO B, 2). Additionally, Jusit explained that another reason why people shifted towards the plantation of oil palm is due to a societal trend, as "[…] some of them follow the other people. Once the other people start to plant the oil palm, and then they just 'oh I want to plant that as well'" (Interview C, 40.00).

Questionnaire data and the focus group ranking exercise also showed the increase in oil palm as having an overwhelmingly positive impact on the community (Figure 26), mainly due to increased income (Figure 27). Muna, a 55-year-old who cultivates oil palm, said it "[…] gives her happy feelings […] because this plantation seems to improve their life here" (Interview G, 30.00).

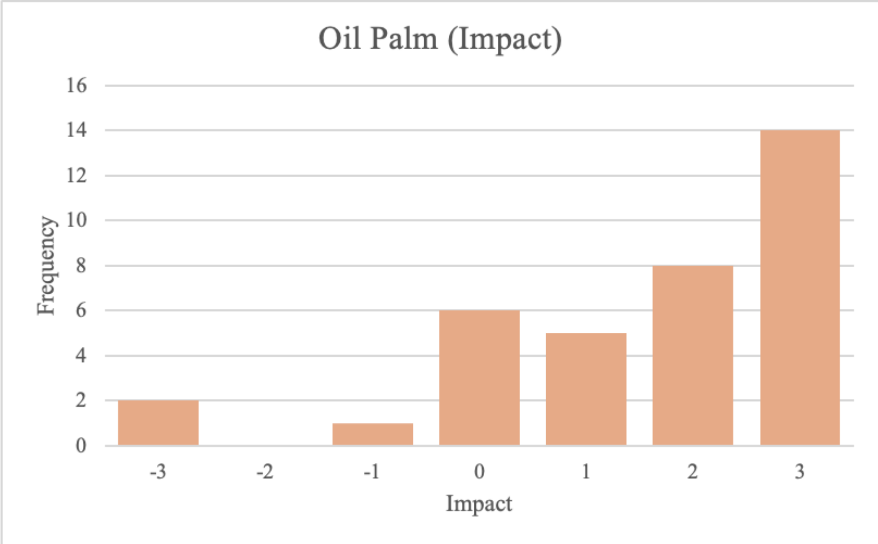

Figure 26: Impacts of perceived changes to oil palm

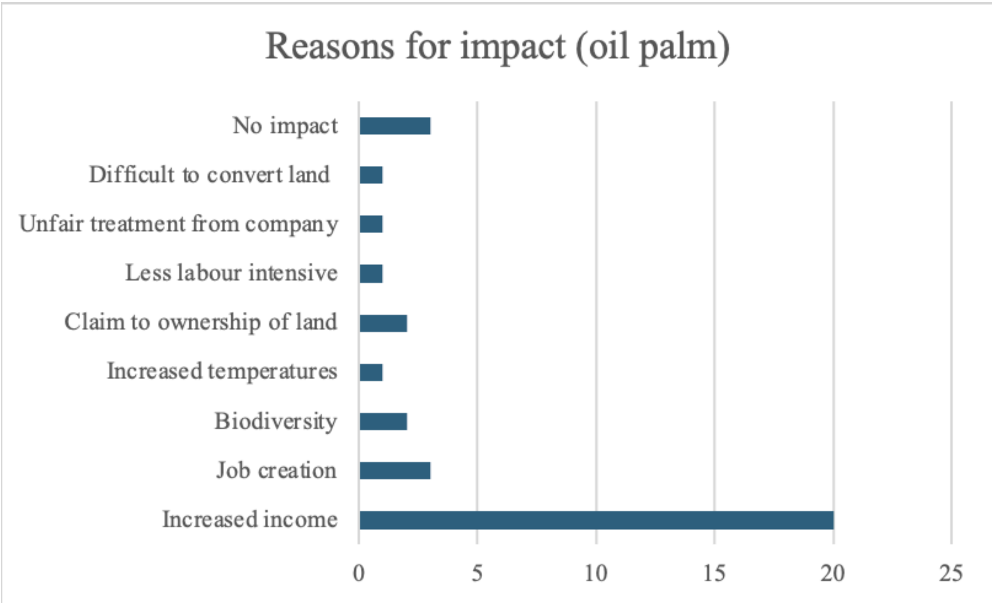

Figure 27: Reasons for positive feelings towards oil palm increase

Despite the vast majority feeling positive about oil palm expansion and TR Intun's emphasis on the fact that they "[...] have forest reserves, so they are not really affected by the oil palm" (Interview E, 30.00), certain downsides were also presented. Agan mentioned that it caused the river flow to change, which increases water temperatures and decreases fish populations (Interview B, 20.00). TR Intun, and Bujang and Janting, who guided the transect walk, also touched upon temperature changes being a negative side effect of the oil palm expansion, describing that Kepayang was much cooler 20 years ago (Interview E, 00.00; Appendix 11).

Muna expressed her frustration about how oil palm companies claim Kepayang's land, which impedes her capability to pass the land on to her children (Interview G, 50.00).

However, all interviewees except for one indicated that the benefits of cultivating oil palm outweigh the negative impacts. Notably, a chi-squared test illustrated a statistically significant relationship between income dependence and opinion on the shift to oil palm with a p-value of 0.060 at a 90% confidence level (Appendix 7). This was further supported by descriptive statistics, illustrating that people who depended on oil palm view the expansion as primarily positive (Figure 28).

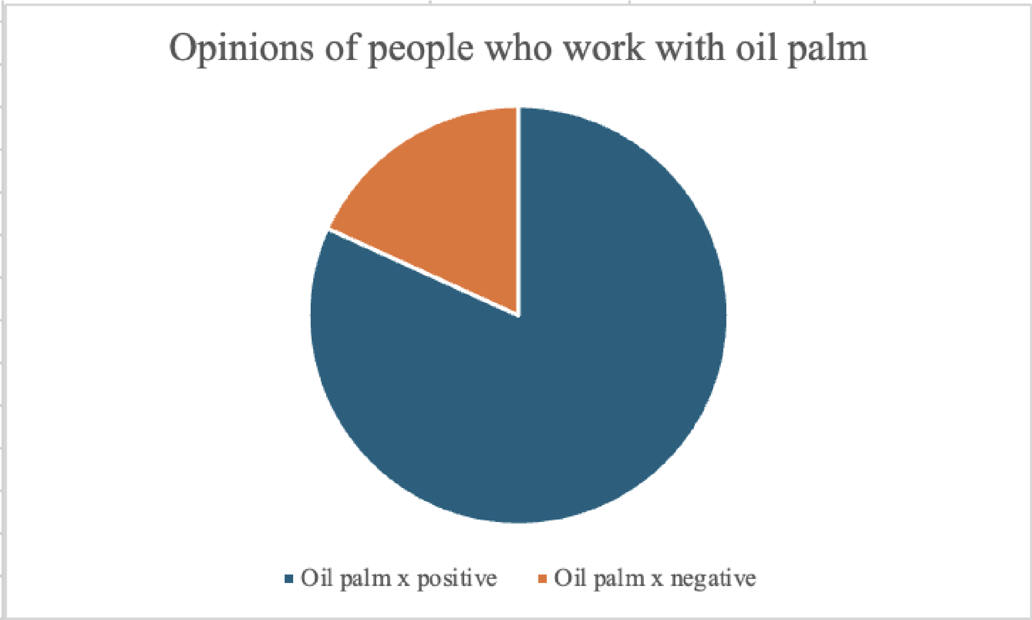

Figure 28: Opinions of people working with oil palm

The interviews illustrate a consensus that the forest is continuously decreasing, primarily attributing this development to illegal logging activities. Only when specifically prompted, the participants would mention the shift towards oil palm cultivation as a cause. The perception of a decreasing forest is reflected in the questionnaire data, as all respondents viewed the forests as either declining or neutral (Figure 29). In the focus groups, this decrease is evident between the 2024 and 2000 map, whereby the community forest was drawn much larger in 2000.

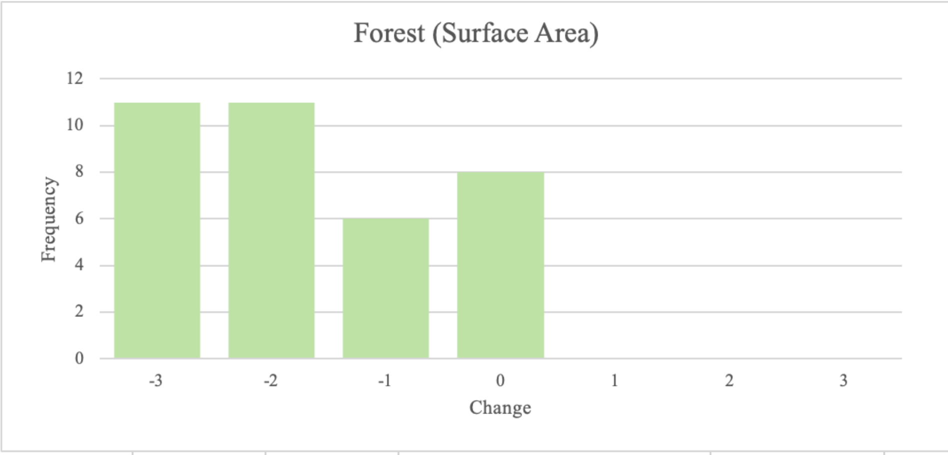

Figure 29: Perceived changes in surface area of forest

Numerous interviewees mentioned negative impacts on the river and wildlife when prompted to elaborate on the changes to the forest. Similar narratives arose in the participant observation, revolving around the significant decrease in fish supply, although the ascribed reasons differ. Jantung established a clear connection between the rise of oil palm and the decrease in fish due to pesticides as he mentioned that "[…] when you compare with the period before the oil palm, they tend to have a lot of fish but now […] it's decreasing" (Interview A, 10.00), TR Merikan, who cultivates oil palm, explained that the decrease in fish is due to visitors overfishing (Interview D, 10.00). Interviewees also expressed that non-aquatic wildlife in the forest has decreased. Agan mentioned: "[…] in the past the forest is still big so […] now they mostly cleared the land, so they are unable to see the animals" (Interview B, 00.00). Surveys further revealed that a majority of respondents viewed the decrease in forest as a negative impact (Figure 30).

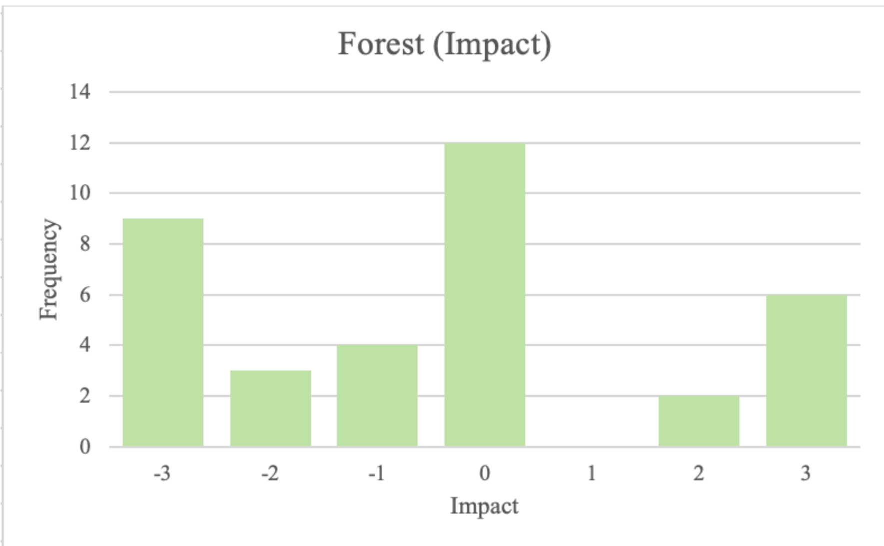

Figure 30: Impacts of perceived changes to forest

Apart from oil palm, pepper cultivation is the most prevalent; yet the area dedicated to pepper plantations is declining (Figure 31, 32).

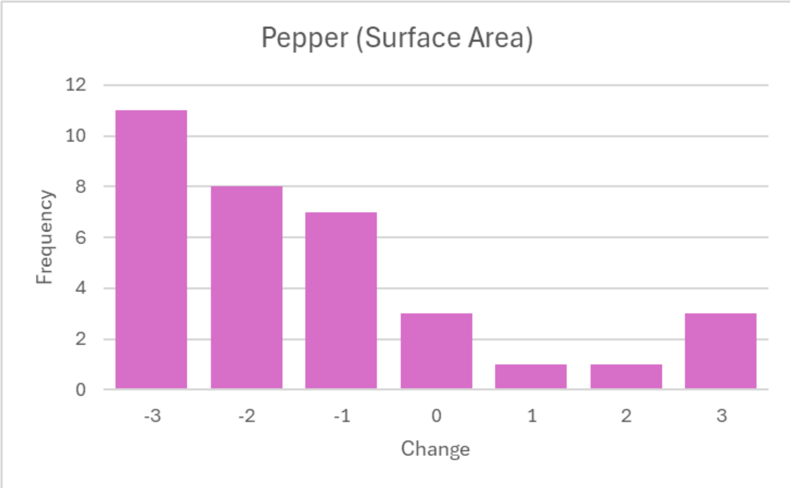

Figure 31: Perceived changes in surface area of pepper

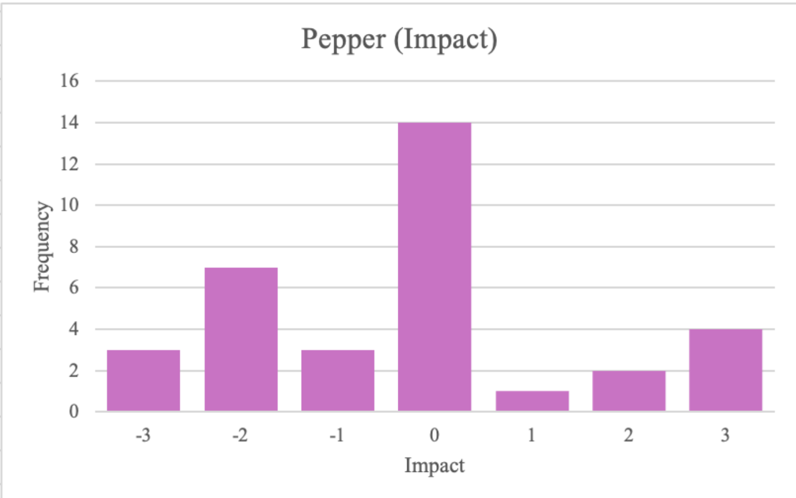

Figure 32: Impacts of perceived changes to pepper

Interviewees commonly articulated that this shift meant pepper went from being a primary source of income to a secondary one. Sara described that Kepayang was once known for planting peppers, and nowadays, only a few people are left who cultivate it, but "[…] the memories is still there of the peppers" (Interview F, 10.00). As shown below (Figure 33), there are prominent negative feelings towards the decline of pepper, with "loss of identity and tradition" and "loss of sense of community" as major reasons (in addition to more financially based reasons, like price fluctuations and alternative income source). Further, a chi-squared test shows that at a 90% confidence level with a p-value of .0884, there is a statistically significant relationship between those relying on pepper as a source of income and those who note a loss of sense of belonging as a reason behind feeling negatively towards pepper decline.

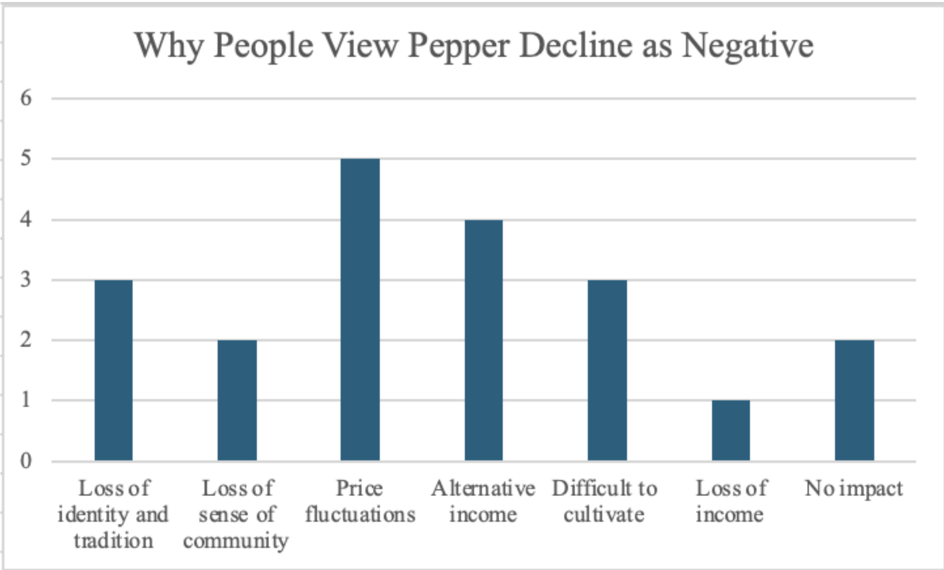

Figure 33: Reasons why respondents view change in pepper negatively (N = 20, namely all respondents that viewed pepper decline as being negative)

Jusit also highlighted drawbacks associated with pepper cultivation, namely increasing costs of fertilizers and pesticides, extensive harvesting cycles, and declining market value of pepper (Interview C, 40.00). This aligns with Figure 33, which shows price fluctuations as a common reason for viewing the decline in pepper negatively.

Acquisition and Dissemination of Knowledge

In the exploration of the community's primary knowledge sources about the natural environment, a diverse knowledge landscape was presented, including life experience, the headmen, local authorities (the district office and agricultural department), religious and cultural narratives, village elders, family members, the Internet, and scientific knowledge. Out of these sources, two were notably repeated in our interviews: The headmen and elderly villagers within the community of Kepayang.

This trend is confirmed by the questionnaire data, where the category "Cultural customs and traditions (local knowledge/narratives)", which included the headmen, was the leading source of knowledge for 55.6% of respondents (Figure 34).

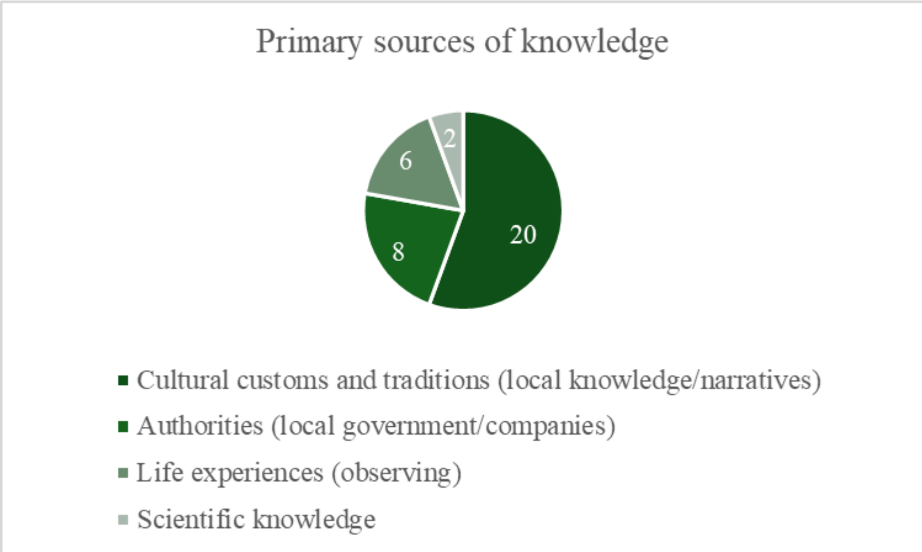

Figure 34: Respondent distribution of primary sources of knowledge

Additionally, a more accurate number of respondents listing "Cultural customs and traditions (local knowledge/narratives)" as their main source of knowledge might be even higher than this, as some researchers mistakenly recorded "headman" under the "Authorities (local government/companies)" category. Despite the downsides that come with the unintentional blurring of categories, the fact that confusion arose in this process illustrates an interesting issue: The line between the headmen's role as government-mandated authorities and as social and cultural leaders is not entirely clear-cut.

Formal knowledge

The majority of participants expressed that they seek information about the natural environment and its changes through the advice of their respective headmen. As Sara explains: "Usually, I know it from the head of the village. [...] whenever something happens like someone wants to build something here, they will tell us everything" (Interview F, 10.00). Several participants explained that they trust the headmen to transparently convey important information to the community (Interview B, 40.00).

During interviews with two headmen, TR Merikan and TR Intun, they explained that their main source of knowledge originates from the next authoritative level – the district office – from which they transfer information to the rest of the villagers (Interview D, 30.00). The community of Kepayang thereby get their formal knowledge about changes to the natural environment through a hierarchical chain of information, indicating that the headmen serve as a link between the people of Kepayang and the local government. This is further supported by observations from the community mapping focus group, as the headman present immediately took initiative to create the map when participants were instructed to draw Kepayang in 2024.

The four headmen share the knowledge they gain through town meetings in the community hall (see point H on the transect walk map, Appendix 11), which are held when relevant information is attained or issues in the community arise. Before town meetings are convened, the headmen will have a separate meeting consulting with appointed committees to ensure the validity of the information given, as Jantung explains:

> "You cannot just simply say and share any of the information, so they need to make sure that the news or the new knowledge are true or not, so they discuss first with the committees and then they let the rest know." (Interview A, 40.00)

Moreover, when making decisions about changes to the village or surrounding natural environment "[…] the headmen will bring this knowledge to the community and ask them first, before making any decisions" (Interview E, 10.00). Ensuring that all villagers' opinions are considered is expressed as an important step in Kepayang's decision-making process. Though the villagers only have access to the end result of the closed committee discussions, the majority of participants expressed that they trust the headmen to always provide the information they need. TR Intun echoed this notion by explaining that the headmen "[…] cannot just keep something *[from the villagers]*, no secrets" (Interview E, 10.00).

Crucially, when talking about the way the headmen influence how information is shared in Kepayang, Muna explains: "The headman gives a big influence in every decision because sometimes they [villagers] have disagreement and then they discuss about it and then they will eventually come to the conclusion or agreement because of the headman" (Interview G, 1.00.00). This illustrates the headmen's strong influence in decision-making: Once the headmen explain the reason behind a conclusion, the villagers will generally accept it (ibid.). Tingum also expressed the willingness of the community to follow the headmen: "Majority of the people, they don't understand about this environment, they just follow instructions" (Interview H, 00.00). The headmen's attitude towards nature will therefore affect "the village and the village folks", shaping their understanding of the natural environment (Interview A, 40.00). The system of the headmen and their committees has been in place for as long as the interviewees could recall, and the interviewees mostly expect knowledge to continue being shared in this manner (Interview A, 30.00; Interview B, 40.00).

To investigate whether other power relations might influence the knowledge acquisition and dissemination in Kepayang, a test on the relationship between the respondents' position in the household and their primary source of knowledge, as well as the relationship between respondents' educational level and primary source of knowledge, were also conducted, but no significant results or trends in the descriptive statistics were found (Appendix 7). The questionnaire data thus confirms what was shown in the interviews: the formal shapers of knowledge in Kepayang are primarily the headmen, and other potential power relations do not seem to influence what people's primary source of knowledge is.

Informal knowledge

While the headmen act as formal sources of knowledge, most interviewees regarded the village elders who regularly go to the forest as having the most reliable knowledge of the natural environment. Jantung explained that the people who taught him about his natural environment were his parents and his friend's parents (Interview A, 40.00). Sara echoed this notion and explained that whenever she wishes to learn about the natural environment she will ask "[…] the villagers here, the old people", and continued: "The people they know better, and they will explain to me" (Interview F, 10.00). The older generation as a source of knowledge and information was also mentioned extensively during the participant observation with Idina. While walking through the forest, Idina explained that she would go to the forest with her mother as a child and learn about the plants they saw, especially what plants are edible or poisonous. "We know because our parents told us" she said and soon after added that she has already started passing this knowledge on to her own children (PO A, p.2).

The knowledge gained from the older generation is circulated and shared freely amongst the community through everyday interactions. For example, Idina stopped a man biking past during the participant observation to ask for help identifying the name of a medicinal plant (PO A, p.3). The older generation of Kepayang thus operates as an informal source of knowledge about changes to the natural environment through orally transferred narratives in personal encounters.

Despite this pattern of knowledge transmission, there seemed to be a generational clash in attitudes towards concerns about the natural environment. Jantung expressed: "They *[the current headmen]* don't care about nature. The older generations were more concerned" (Interview A, 30.00). This notion was echoed later in the interview, where he continued to explain that this was due to economic dependence: "They are more concerned about the forest than the new generation, because the older generation they are completely, they rely on the forest and on nature" (Interview A, 40.00). TR Merikan added to this by suggesting that the next generation will be even less dependent on the land, and that his children might solely inherit his land for housing and not cultivation (Interview D, 40.00).

As this generational clash in attitudes towards nature emerged as a key theme in the interviews, the relationship between the respondents' age and their primary source of knowledge was also investigated quantitatively. While the chi-squared test results came out as non-significant with a weak effect size measure (Appendix 7), the descriptive statistics seem to indicate that the oldest age group relies more on culture, customs and traditions in their knowledge acquisition than the youngest age group. Building further on the findings of a generational discrepancy from the interviews, the relationship between respondents' age and their opinions about the forest decreasing was also examined. The chi-squared test came out as non-significant (Appendix 7), but the descriptive statistics (Figure 35) indicate that the generational differences brought up by the older interviewees were not reflected in the questionnaire data. If anything, out of all four age groups, the youngest age group shows the least amount of respondents describing forest decrease as positive.

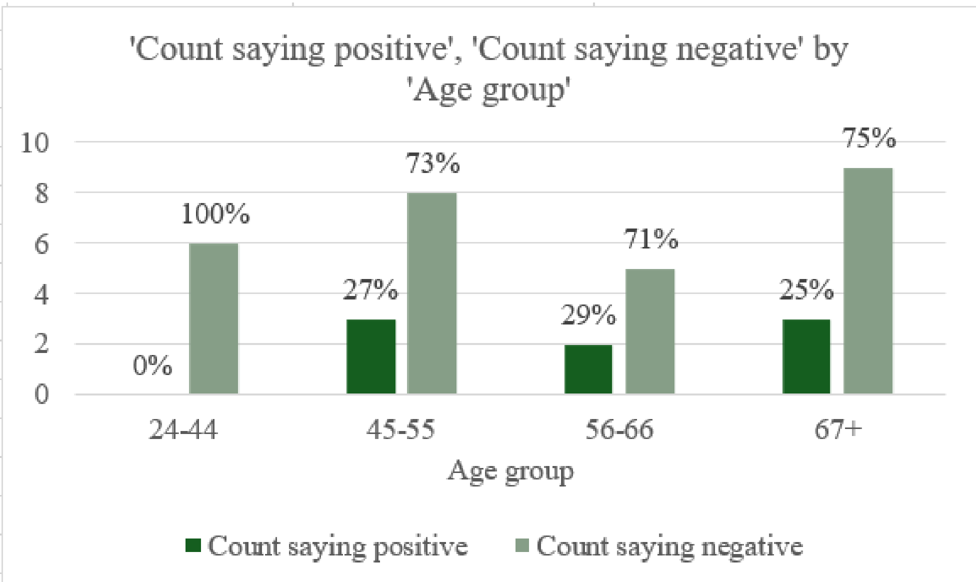

Figure 35: Distribution of opinions: whether the changes in the surrounding forest area was viewed as mainly positive or negative by age group.

During the participant observation with TR Intun in his oil palm plantation, the topic of between-village knowledge sharing also presented itself. When asked how he was introduced to the cultivation of oil palm, TR Intun shared that a woman who married a man from Kepayang moved to the village and told other villagers about the oil palm cultivation she had witnessed in her old village (PO B, p.2). TR Ismail expanded upon this during an interview, explaining that Kepayang shares knowledge with the nearby village Kedumapi, with whom they are "very friendly" (Interview E, 20.00). Despite this, no other interviewee mentioned any knowledge being shared across villages, suggesting that information shared between villages occurs on an administrative level, including only the headmen and not the villagers of Kepayang.

The Knowledgescape of the Natural Environment

Having explored Kepayang's knowledgescape through the dimensions of *what is known* and *how something is known*, the natural environment is characterized by a perception of it primarily providing resources for subsistence and income. These narratives reflect Kepayang's significant shift towards oil palm cultivation, resulting in notable changes in the natural environment, such as the decline of forests and impacts on rivers and wildlife. The shift of pepper cultivation from a primary to a secondary source of income and the complete cessation of rice cultivation illustrated another side of the perceived changes to the natural environment.

Despite the voiced concerns regarding Kepayang's negative environmental developments, primarily attributed to the community's increase in oil palm cultivation and logging activities, the underlying motivation to preserve natural resources was shown to be to uphold their potential for providing subsistence rather than safeguarding the environment itself.

These narratives of how knowledge is acquired and disseminated indicate both formal and informal structures. Specifically, the formal knowledge transmission is facilitated by the four headmen through committee discussions and town meetings, while the informal knowledge is shared through the older generation's orally transmitted narratives before it is subsequently circulated within the community.

Comparison

In light of the overarching research question, the following section explores a comparison between the observable changes to the natural environment and the community's perception of said changes.

In general, the identified changes in Kepayang's land cover and use in the remote sensing imagery match the analysis of perceived changes. Almost 80% of the survey respondents reported having changed their land use practices since the year 2000, and more than 50% changed their practices since 2010. This trend, as well as the fact that over 60% of the respondents said they cultivate oil palm today, can also be observed in the satellite images. The satellite imagery showed increased forest loss and increased oil palm cultivation in Kepayang over the past 20 years, which aligns with the community's perception of changes to the natural environment. Almost 80% of the survey sample indicated that the forests have decreased in the past 20 years, and more than 90% indicated that oil palm has increased in the same period. The fact that no respondents indicated that the forests have increased or that the oil palm plantations have decreased shows a strong connection between the measured environmental changes and the perceived realities of the local community.

The vegetational biodiversity assessment indicates a decrease in biodiversity. This is strongly reflected in the participant observations, survey data and interviews. Almost 30% of survey respondents stated loss of wildlife and forest products as reasons why they view the forest loss negatively.

The first major difference observed was with regard to water quality. In the semi-structured interviews, it was mentioned several times that there has been a decline in the amount of fish in Kepayang's river, which the interviewees attributed to decreasing water quality. However, the water sampling does not uphold this narrative. The measured water quality is high, at a class nearly suitable for drinking, and thus, assessed as a good habitat for sensitive aquatic species. Therefore, it can be assumed that perceived changes of fish supply is due to other anthropogenic factors, such as overfishing or increased recreational tourism.

Another difference distinguished in the analyses was what appears to be a missing link between the observed land and land use changes, and the perceived reasons behind said changes. In the satellite imagery, it was evident that the forest was decreasing because of oil palm, as the surrounding forest area has been largely replaced for it. The interviews, surveys, and participant observations aligned with the observation that the forests have been reduced. However, participants rarely cited oil palm cultivation as the primary cause of deforestation. When prompted, they would mention it, but mainly emphasize other factors, such as illegal logging or the increased infrastructure development, and not see the rapid forest decline as an urgent matter. This indicates a disconnect between what the villagers perceive as the cause of forest decline, and what remote sensing reveals, a notion which highlights the contradiction between acknowledging environmental degradation while denying the impact of livelihood strategies.

Discussion

The following section presents a discussion of the results, embedding it into the broader context of existing research. Furthermore, it critically reflects on the methodological process of this study, taking into account various notions of limitations.

Results Discussion

Numerous aspects underscore the importance of analyzing how local communities perceive environmental changes alongside a physical environmental assessment. Firstly, gaining insights into local perceptions can enhance comprehension of environmental changes in its diverse forms and its implications for local communities. Secondly, how people perceive environmental change determines their chosen mitigation and adaptation strategies (Pylälä et al. 2016).

The global expansion of oil palm increases at a significant rate, as illustrated by Yan et al.'s (2020) remote sensing measurements of Malaysia's land-use changes between 1990 and 2017. In less than three decades, the country's natural forest declined by 21%, with half of these areas being converted into plantations (ibid.). Hence, Kepayang's oil palm expansion illustrates a broader trend that has emerged in multiple studies (Ichikawa 2007; Mertz et al. 2013; Van Vliet et al. 2012). Alongside the importance of exploring perceived changes, the results of this study highlight the effect the oil palm industry can have on vegetational biodiversity specifically, and other natural environmental changes generally.

The far-reaching impacts of the shift towards oil palm are also reflected in participants' narratives. Participants stressed a decreasing reliance on the natural environment for subsistence, as the availability of natural resources is vanishing. Kuhnlein et al. (2006) and

Broegaard et al. (2017) highlight wild foraged foods as an overlooked impact of deforestation and argue that agricultural expansion in agriculture-forest landscapes negatively impacts the health of rural communities. Although participants did not elaborate on the health impacts stemming from forest decline, their emphasis on the vanishing availability of natural resources in the secondary forest emphasizes the importance of fostering synergies of wild and managed crops. Powell et al. (2015) further support this argument, suggesting a move away from the dichotomization of wild and cultivated food species, towards cultivation of species that complement each other.

According to Mercer et al. (2014), there is a clear correlation between water quality impacted by oil palm and poor macroinvertebrates richness and evenness, compared to natural environments with less anthropogenic interference (Al-Shami et al., 2011). However, the water quality parameters in this research indicate similar values and are quite good despite being close to agricultural sites. This can be attributed to the fragmented land use, where nearby vegetation might absorb supplements, and the relatively small size of the sites, which would limit their overall impact on water quality. If agricultural intensification continues, an increase in pollution is to be expected. This could also be explained by the the timing of pesticides and fertilizer application, as they do not apply these before heavy rain.

Interestingly, participants' perceptions of water quality differ significantly, with a tendency of perceiving the water quality as decreasing. The concept of disparities between perceived and actual water quality has been explored by Doria et al. (2009), who found that perceptions of water quality are shaped by a complex interplay of various factors, including interpersonal information.

In summary, this research illustrated the participants' tendency to classify the natural environment into distinct categories based on observation and experience rather than recognizing it as an interconnected system influenced by a set of anthropogenic factors such as land-use changes and infrastructure development. This segmented perception of ecological systems is not a unique phenomenon. Beery et al. (2023) argue that an expansion of our understanding of human-nature relations and disconnections requires further research, as they are crucial to understanding how natural resources are used. The significance of human-nature relationships varies, leading to diverse perceptions that can impact the development of sustainable policies, a factor largely overlooked in current literature (Pylälä et al. 2016). Building on Pylälä et al. (2016), who argue that too few studies delve deeper into how knowledge acquisition and dissemination impact of perceived environmental changes, how the results of the present study call for further exploration of how community's knowledgescapes impact their perception of environmental changes, and how said perceptions interact with biophysical assessments of environmental change.

Methodological Discussion

Language

Though the language barrier and issue of translation was anticipated, it posed a significant challenge during this fieldwork. During the focus groups, it proved difficult to follow the multiple conversations and grasp the formation of collective opinion. In the interviews, the language barrier occasionally resulted in miscommunication and simplifications of elaborate answers. Further, the dependency of translators to conduct the field work restricted the potential for spontaneity, which, considering the constraining time frame, presented a significant challenge.

Recollection

Recollection bias was present in most of the social science methods. In asking participants to remember and convey details of experiences and land use practices within the past 20 years, some inaccuracies must be expected in the collected data. However, as the focus of this research was on exploring narratives and experiences, the gathered data nevertheless fulfills the purpose of this study. The investigation of change presented another challenge, as the scope of this research made it impossible to establish a baseline in real time. This was overcome by, for instance, using remote sensing to create a reference point of overall land cover change.

Demography

The age disparities evident in the questionnaire sample resulted in a lack of insights from younger generations. This not only illustrates outmigration trends but also suggests that the identified narratives primarily reflect a generation that has historically depended heavily on the natural environment and directly witnessed the major shift to oil palm cultivation. It should also be taken into account that perspectives of younger generations could differ. Additionally, a majority of respondents were male, which limits the range of available gender-dependent perceptions.

Sample size

Time constraints limited the questionnaire's sample size, falling short of statistical analysis norms and limiting our ability to draw robust statistical conclusions. Although a larger sample would have been ideal and allowed for more assertive results, descriptive statistics still revealed trends that could be of interest for future research.

Water sampling & WQI

The plan was to collect the upstream water sample from the undisturbed forest area to assess the water quality closest to the original river source. The upstream sample was unfortunately conducted near a small-scale plantation as they were present along the entire river, affecting the sample by agricultural practices and influencing the results of the WQI and ASD. To have a more reliable result, a sample site with no agricultural influence would have been preferable. Moreover, the sampling was done on a day after heavy rain, which potentially impacted the results. Therefore, it would have been beneficial to sample the water before and after heavy rain to assess the potential impact of run-off. Lastly, in the process of calculating the WQI, the data for COD was found to be missing. Given that this data represents one of six crucial parameters, the values for this parameter were obtained from established literature using threshold numbers. These estimated values have to be taken into account when interpreting the calculated results. Lastly, certain identified species lacked defined tolerance levels and were consequently omitted from the BMWP and MFBI calculations. This reduced the quality of results; however, the findings align with the measured WQI, indicating the species might have an insignificant impact.

Positionality

Since forms of knowledge reflect the particular conditions in which they are produced, it is important to reflect on the researcher's position (Harraway, 1988). Due to differences in the researchers' cultural and academic backgrounds, the two groups affected the data collection differently. KU students exhibited greater confidence in social science methods, while UNIMAS students demonstrated greater confidence in natural science methods. Additionally, UNIMAS students were more confident in approaching villagers of Kepayang, having greater knowledge of local customs and norms, thereby becoming more socially embedded. The roles of the two groups resulted in the creation of partial perspectives that complemented each other during the data collection.

Conclusion

The purpose of this study was to investigate how local perceptions compare to physical environmental changes related to the transition to oil palm cultivation in Kepayang, Sarawak, Malaysia.

Perceived changes to the environment were identified through the analysis of the local community's narratives on changes to their natural surroundings, how these changes have impacted them, and how they came to obtain this knowledge. Physical changes to the environment were measured through assessing the state of Kepayang's natural environment in terms of water quality, vegetational and aquatic diversity, and land cover and use over time.

Perceptions of changes to Kepayang's natural environment were largely aligned with the observable physical changes, with certain exceptions. Notably, there was a discrepancy between observable reasons for forest loss, namely oil palm expansion, and what the community perceived as being the reasons behind forest loss. Future research should continue to explore the alignments and discrepancies between observable and perceived environmental changes more in detail and move beyond the single-case design and small sample size that limited this study.

This research has contributed to the larger body of work on the impact of the expansion of oil palm cultivation, not only on the physical environment, but also on the livelihoods of the humans interacting with it. It has also brought to light the importance of considering perceived and lived changes alongside scientifically measurable changes, thus maintaining a robust human-nature balance when working in the field of sustainable development.

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Appendices

Appendix 1: List of methods used for data collection

List of methods			
Method	**Quantity**	**Dates**	**Overall Method**
Surveys	36	6/3-13/3	Social science
Semi-structured interviews	8	10/3-13/3	Social science
Focus group	2	5/3	Social science
Participatory observation	2	12/3-13/3	Social science
Transect walk	1	12/3	Social science
Remote sensing	2 maps	20/2-22/2	Natural science
In-situ verification	15 sites	5/3-12/3	Natural science
Water quality assessment	3 sites	11/3	Natural science
Aquatic diversity assessment	3 sites	11/3	Natural science
Vegetational diversity assessment	5 sites	10/3-12/3	Natural science

Appendix 2: Preliminary & Actual Field Schedule

Preliminary Schedule	4	5	6	7	8	9	10	11	12	13	14	15
General tasks												
Travel days	■											■
Presentation preparation			■	■					■	■		■
Presentations				■							■	
Data collection tasks												
General observations & planning	■											
Participatory observation		■									■	
Biodiversity assessment					■	■	●					
In-situ verification		■	■					■				
Transect walk			■									
Questionnaires			■	■	■	●						
Interviews						■	■	■	■	●		
Focus groups									■	■		
Water & soil sampling					■	■						
Red = final potential wrap-up day												

Actual Schedule	4	5	6	7	8	9	10	11	12	13	14	15
General tasks												
Travel days	■											■
Presentation preparation			■	■						■		
Presentations				■							■	
Data collection tasks												
General observations & planning	■											
Participatory observation									■	■		
Biodiversity assessment					■	■		■	■			
Water sampling								■				
In-situ verification		■					■					
Transect walk							■					
Questionnaires			■	■	■		■		■			
Interviews						■	■	■				
Focus groups		■										

Appendix 3: Biodiversity Assessment Calculations

Biodiveristy Assessment calculations.xlsx

Appendix 4: Calculations of Aquatic Species Diversity & Water Quality

WQI, BMWP, MFBI calculations.xlsx

Appendix 5: Water Assessment Charts

Assessment of stream quality using macrointervertibrates as bio-indicators.pdf

National Water Quality Standards for Malaysia.pdf

Appendix 6: Transcribed Semi-Structured Interviews

Transcribed Interviews

Appendix 7: Questionnaire Calculation Results

Questionnaire Statistical Tests

Appendix 8: Merged Questionnaire

Consent

Introducing the study

We are a team of students participating in the SLUSE course organized by the University of Copenhagen and the University of Malaysia Sarawak.
Kami pelajar ngambi kursus SLUSE ke diadu UNIMAS enggau Universiti Copenhagen.

The purpose of our study is to investigate the influences of land use transitions on the natural environment around Kepayang, and how the local community perceives these changes.
Tuju kami ngadu kajian tu dikena kami nyiasat pengaruh ubah guna tanah ba Kampung Kepayang ditu, enggau bakani bala rakyat meda ubah tu tadi.

Right now we are doing the questionnaire section of our research.

Confidentiality and consent

In order to protect your privacy and confidentiality your name will be anonymized during data processing, and we will only use your survey responses for this specific study. If you at any time regret participating in this study, you can withdraw your participation and we will remove your responses from our data collection without any problem.
Kena nyaga maklumat peribadi, nama kita sigi dilalai. Kami sigi begunaka jawapan ke diberi kita. Enti sema ka narit diri ari kena intebiu, kita tau madah ke kami.

After hearing more about the goals and the terms of our research, do you consent to participate in this questionnaire and for your data to be used in our analysis?

(1) Yes *(Setuju)*
(2) No *(Enda setuju)*

Background information

1. Village *(Asal kampung/menua)*
   (1) Kepayang Berangan
   (2) Kepayang Setia Raja
   (3) Kepayang Lama
   (4) Kepayang String

2. Name *(Nama)*

   ____

3. Residency (*Asal)*
   (1) Original resident (*Urang asal ditu)*
   (2) Not original resident (*Urang datai)*

4. Gender *(Jantina)*
   (1) Female *(Indu)*
   (2) Male *(Laki)*
   (3) Other (what?)

5. Ethnicity *(Bangsa)*
   (1) Melayu
   (2) Chinese
   (3) Iban
   (4) Melanau
   (5) Other (what?)

6. Religion *(Pengarap)*
   (1) Islam
   (2) Christian
   (3) Buddhist
   (4) Pagan
   (5) Other (what?)

7. Age *(Umur)*

   ____

8. Marital status *(Status kawin)*
   (1) Single *(Bedau kawin)*
   (2) Married *(Kawin)*
   (3) Divorced *(Bercerai)*
   (4) Widower *(Duda/Janda)*

9. How many people live in your household, including yourself? *(Berapa iku kita sebilik temasuk diri empu)*

   ____

10. Have any people moved out of your household? If so, how many? *(Bisi bala mindah ari bilik? Berapa iku?)*

   ____

11. Position in the household *(Jawatan ba rumah/bilik)*
    (1) Head of the household *(Ketuai bilik)*
    (2) Other (what?)

12. Highest educational level *(Peninggi sekula)*
    (1) No formal education *(Nadai sekula)*
    (2) Primary school (7-12) *(Sekula rendah/primary)*
    (3) Secondary school (13-17) *(Sekula menengah/secondary)*

(4) Tertiary education (diploma and more) *(Universiti)*
(5) Trade or skilled education (carpenter etc.) *(Sekula kemahiran)*
(6) Others (what)

13. What do you spend most of your time doing for work? (rank the three main choices, maximum 3) *(Nama pengawa selalu dikereja sesari?) (Tiga bengkah pengawa)*
(1) Oil palm cultivation *(Nanam sawit*)
(2) Pepper cultivation *(Nanam lada)*
(3) Cultivation of other crops (what?) *(Betanam utai bukai)*
(4) Wage labor *(Kereja kuli)*
(5) Business owner *(Bisnis)*
(6) Retired *(Pincin)*
(7) Other (what?) *(Pengawa bukai)*

14. What are the main sources of income for your household? (rank the three main choices, maximum 3) *(Nama penatai pemisi kita sebilik)(Pilih tiga iti penatai pemisi)* *clarify the difference in oil palm
(1) Agricultural
  (a) Oil Palm (own) *(Sawit diri empu)*
  (b) Pepper *(Nanam lada)*
  (c) Livestock *(Nupi jelu)*
  (d) Other (what?) *(Pengawa bukai)*
(2) Wage Labor *(Bekuli/Begaji)*
  (a) Oil palm plantation *(Sawit kompeni)*
  (b) Service *(Servis)*
  (c) Other (what?) *(Pengawa bukai)*
(3) Remittances *(Bantu ari bala sebilik)*
(4) Pensions *(Pincin)*
(5) Other (what?) *(Pengawa bukai)*

Land use change *(Ubah guna tanah)*

15. Do you have any land that you consider as your own? *(Bisi ngembuan tanah diri empu?)*
(1) Yes
(2) No

16. How do you use your land? (choose all that apply) **for income or personal consumption (Bakani begunaka tanah?)*
(1) Agriculture (Betanam)
  (a) Oil palm (Nanam sawit)
  (b) Rubber *(Nanam getah)*
  (c) Pepper *(Nanam lada)*
  (d) Rice *(Nanam padi)*
  (e) Other (what?) *(Pengawa bukai)*
(2) Livestock *(Nupi jelu)*
(3) Leasing *(Sewa tanah)*
(4) Logging/Forestry *(Beramu)*
(5) Hunting/fishing *(Ngasu/Berikan)*

(6) Housing *(Berumah)*
(7) Other (what? e.g. recreation, shop, private business) *(Pengawa bukai) (Rekreasi, kedai, bisnis diri empu)*

17. Who are the people involved in cultivation of this land? *(Siapa enggau ngereja pengawa betanam ba tanah kita?)*
(1) Family *(Diri sebilik)*
(2) Friends *(Kaban belayan)*
(3) Employees *(Ngupah pekerja)*
(4) Other (what?) *(Utai bukai)*

18. Do you receive any source of funding / subsidy? *(Bisi nerima bantu tauka subsidi?)*
(1) Fertilizer *(Baja)*
(2) Pesticide *(Racun)*
(3) Seedlings *(Igi benih)*
(4) Other (what?) *(Utai bukai)*

19. Are your current livelihood practices different from what they were around 20 years ago? *(Pengawa ke dikerja kita diatu berubah ke enda enggau utai dikerja kita 20 taun suba?)*
(1) Yes *(Ya/Berubah)*
(2) No *(Enda)*

(if no skip to the next section)

20. If yes, what were your previous practices? *(Nama pengawa dikerja suba?)*
(1) Agriculture *(Betanam)*
  (a) Oil palm *(Nanam sawit)*
  (b) Rubber *(Nanam getah)*
  (c) Pepper *(Nanam lada)*
  (d) Rice (swamp) *(Padi paya)*
  (e) Rice (hills) *(Padi bukit)*
  (f) Other (what?)
(2) Livestock *(Nupi jelu)*
(3) Leasing *(Sewa tanah)*
(4) Logging/Forestry *(Beramu)*
(5) Hunting/Fishing *(Ngasu/Berikan)*
(6) Housing *(Berumah)*
(7) Other (what? e.g. recreation, shop, private business) *(Pengawa bukai) (Rekreasi, kedai, bisnis diri empu)*

a. Note: any changes in purpose of practice (personal consumption, income, etc.)
____

21. If yes, how many years ago did you begin to change your practices? (year) *(Enti berubah, kemaya kita ngubah pengawa ba tanah?)*

____

22. Why did your land use practices change? *(Nama kebuah utai dikereja kita ba tanah nya berubah?)*

    ____

Sustainability of agricultural practices

23. Are you planning on proceeding with your current agricultural practices? *(Adaka kita ka neruska pengawa betanam kita diatu?)*
    (1) Yes *(Ya)*
    (2) No *(Enda)*

    a. Why? *(Nama kebuah)*

       ____

24. What are the three main challenges in maintaining your agricultural practice? *(Nama tiga iti jenis penanggul maya kita ngereja pengawa betanam?)*
    (1) Aging *(Umur)*
    (2) Health *(Pengerai)*
    (3) Time *(Masa)*
    (4) Distance *(Penyauh)*
    (5) Price and cost *(Rega/kos)*
    (6) Lack of manpower *(Enda cukup urang ngereja)*

25. What are the three main motivations that have maintained your interest in cultivating crops? *(Tiga iti peransang ngasuh kita ka neruska pengawa betanam?)*
    (1) Intervention *(Bantu)*
    (3) Time *(Masa)*
    (4) Distance *(Penyauh)*
    (5) Price and cost (economic benefit) *(Rega/kos)*
    (6) Sufficient manpower *(Cukup urang ngau ngerejea/Tenaga kereja)*
    (7) Sense of belonging (attachment to area, community, culture, etc.) (

26. Is your current crop planting able to financially support the household for the next 10 years? *(Pengawa betanam diatu nya ulih enda nampung kita sebilik untuk 10 taun ila?)*
    (1) Yes (Ya/ulih)
    (2) No (Enda)

Categorization of changes to the natural environment across time

Now, we will present a scale on which you can rank the degree to which each of the three areas (forest, oil palm plantations, and rice paddies) has changed over time. For question 27 and 28, -3 is the most drastic decrease, and 3 is the most drastic increase. For question 29, -3 is the most negative and 3 is the most positive. 0 means that there has been no change.

**Note for interviewers: Place a written scale in front of the participant and ask about each location individually (ex: How much has the old forest increased or decreased?)*

27. To what extent has the size of surface areas increased or decreased for the whole village? *(Naka ni pemesai tanah bisi berubah banding suba enggau diatu?Bisi betambah tauka bekurang?)*

Old forest *(Utan)*	-3 -2 -1 0 1 2 3
Oil palm plantation *(Sawit)*	-3 -2 -1 0 1 2 3
Rice paddies *(Padi)*	-3 -2 -1 0 1 2 3
Pepper *(Lada)*	-3 -2 -1 0 1 2 3

28. To what extent has the number of plant types in (specific area) increased or decreased? *(Naka ni pemayuh jenis utai tumbuh bisi ba…… diatu? Betambah tauka bekurang?)*

Old forest *(Utan)*	-3 -2 -1 0 1 2 3
Oil palm plantation *(Sawit)*	-3 -2 -1 0 1 2 3
Rice paddies *(Padi)*	-3 -2 -1 0 1 2 3
Pepper *(Lada)*	-3 -2 -1 0 1 2 3

1. Have these changes in land use of (specific area) been positive or negative to you? *(Ubah guna tanah ba ….. tu tadi bisi enda meri kesan ngagai kita?)* **refer to answers of question 27*

Old forest *(Utan)*	-3 -2 -1 0 1 2 3
Oil palm plantation *(Sawit)*	-3 -2 -1 0 1 2 3
Rice paddies *(Padi)*	-3 -2 -1 0 1 2 3
Pepper *(Lada)*	-3 -2 -1 0 1 2 3

   a. What is the main reason you consider the changes in land use positive/negative? (leave a space blank if the answer is 0) *(Nama kebuah nuan madah ubah guna tanah tu tadi bisi meri kesan ke manah tauka enda manah?)*
      Forest *(Utan)*: __________________
      Oil palm *(Sawit)*: ________________
      Rice *(Padi)*: ___________________
      Pepper *(Lada)*: _________________

Primary sources of knowledge acquisition

**Place the answer cards in a random cluster (not a line) in front of the participant.*

29. Where do you learn about the environment and changes to the environment? (choose one)
(Bakani kita bulih penemu pasak utai ke nyadi ba alam sekitar tauka ba menua kita?)

(1) Life experience (observing) *(Pengalaman idup) (Merati ke utai nyadi*
(2) Cultural customs and traditions (local knowledge / narratives) *(Adat) (Penemu urang menua)*
(3) Authorities (local government / companies) *(Perintah/kompeni)*
(4) Scientific knowledge *(Penemu saintifik) (Berita/Surat kabar)*

30. Now please rank the following sources of knowledge from most important to least important
(Susun/ngeripih bakani chara kita ngulih ka penemu)
**write the respective numbers*

Life experience (observing) *(Pengalaman idup) (Merati ke utai nyadi)*
Cultural customs and traditions (local knowledge / narratives) *(Adat) (Penemu urang menua)*
Authorities (local government / companies) *(Perintah/kompeni)*
Scientific knowledge *(Penemu saintifik) (Berita/Surat kabar)*

Closing questions

Are there any important topics in the community you feel we have not talked about?
(Bisi enda utai bukai ke bisi nyadi ba ditu ka dikungsi kita ngagai kami?)

Can you tell us your favorite and least favorite thing about living in Kepayang?
(Nama utai paling dikerindu enggau enda dikerindu ba Kepayang?)

Do you have any questions about how this information will be used?
(Bisi utai ka ditanya nuju kami?)

Appendix 9: Semi-Structured Interview Guide & Coding Key

Semi-Structured Interview Guide

* Nature = Alam sekitar

Consent

Introducing the study

We are a team of students participating in the SLUSE course organized by the University of Copenhagen and the University of Malaysia, Sarawak.
(Kami pelajar ngambi kursus SLUSE ke diadu UNIMAS enggau Universiti Copenhagen.)

The purpose of our study is to investigate the influences of land use transitions on the natural environment around Kepayang, and how the local community perceives these changes.
(Tuju kami ngadu kajian tu dikena kami nyiasat pengaruh ubah guna tanah ba Kampung Kepayang ditu, enggau bakani bala rakyat meda ubah tu tadi.)

What we are doing right now is part of the interview section of our research.

Confidentiality and consent

In order to protect your privacy and confidentiality your name will be anonymized during data processing, and we will only use your responses for this specific study. If you at any time regret participating in this study, you can withdraw your participation and we will remove your responses from our data collection without any problem.
(Kena nyaga maklumat peribadi, nama kita sigi dilalai. Kami mina begunaka jaku saut ke diberi kita aja. Enti sema ka narit diri ari, kita tau madah ke kami.)

Participating in this study implies "informed consent", which means that you agree to participate voluntarily and that you understand the purposes of this research. After hearing more about the goals and the terms of our research, do you consent to participate in this interview, and for your data to be used in our analysis?
Laban nuan dah setuju enggau nemu nama tuju pengawa diadu kitai diadu, kitai deka neruska intebiu tu.

(1) Yes *(Setuju)*
(2) No *(Enda setuju)*

Introduction *(ask only if we don't do the questionnaire)*

1. Can you please tell us a little bit about yourself (name, age, village, role within household)?
   (Tusui ka nama, umur, enggau pengawa nuan ba bilik kita)

2. What do you do for a living? *(Nama pengawa dikereja nuan?)*

a. Is this your current primary income for your household? *(Adakah tu penatai pemisi kita sebilik diatu?)*
b. Do you have any land you consider as yours? *(Bisi ngembuan tanah diri empu?)*
c. How important is land to you? *(Beguna enda tanah nya ngagai kita?)*
    i. Why? *(Nama kebuah beguna?)*
    ii. Is your income dependent on your land? *(Penatai pemisi kita begantung enda enggau tanah tu?)*

Narratives of experienced environmental changes

3. How would you describe nature? What is nature to you? *(Uji terang ka nama runding nuan pasal alam sekitar.)*
    a. Is nature of any importance to you, besides economic benefits? *(Beguna enda alam sekitar ngagai nuan, selain meri penguntung ari segi ekonomi?)*

4. How would you describe the nature in Kepayang? *(Terangka alam sekitar ba Kepayang ditu)*

5. How is trash managed in Kepayang? *(Bakani kita nguruska sampah ba Kepayang?)*

6. Has the way you have used land changed within the past twenty years? *(Bisi berubah enda guna tanah untuk masa 20 taun?)*
    a. What was the change? *(Nama utai ke bisi berubah?)*
    b. What were the primary reasons for this change? *(Nama kebuah utama ngasuh kita ngubah pengawa ba tanah?)*

7. What do you see the surrounding land of Kepayang mostly being used for? *(Nama pengawa ke paling dikereja urang ba tanah ba menua Kepayang ditu?)*
    a. Out of these activities, which have increased the most within the past twenty years? *(Nama pengawa ke paling bisi betambah dikereja untuk masa dua puluh taun?)*
    b. Out of these activities, which have decreased the most within the past twenty years? *(Nama pengawa ke paling kurang dikereja untuk masa dua puluh taun?)*
    c. Do you think these activities have an effect on the nature around Kepayang? *(such as forest) (Ba runding nuan, pengawa ke dikereja ba tanah tu bisi enda meri kesan ngagai alam semulajadi ba Kepayang?)*

8. Have you experienced changes in the surrounding…*(Bisi enda ngasai ke utai berubah ba sekeliling….?)*
    a. Forest *(Utan)*
        i. If yes, what do you think caused this? *(Enti bisi, ba runding nuan nama punca utan kita bisi berubah?)*
        ii. What do you think about the changes? *(Nama runding nuan ba ubah tu?)*
        iii. If a forest is cut down to plant new oil palm trees, is it still a forest? *(Enti utan ditebang dah nya ditanam pun sawit, adakah endur tu tadi agi dikira sebagai utan?)*
    b. Rice cultivation *(Pengawa betanam padi)*
        i. If yes, what do you think caused this? *(Enti bisi, ba runding nuan nama punca pengawa bumai/nanam padi tu berubah?)*
        ii. What do you think about the changes? *(Nama runding nuan ba ubah tu?)*

c. Oil palm cultivation *(Pengawa nanam sawit)*
    i. If yes, what do you think caused this? *(Enti bisi, ba runding nuan nama punca utai tu berubah?)*
    ii. What do you think about the changes? *(Nama runding nuan ba ubah tu?)*

d. Pepper cultivation *(Pengawa nanam lada)*
    i. If yes, what do you think caused this? *(Enti bisi, ba runding nuan nama punca utai tu berubah?)*
    ii. What do you think about the changes? *(Nama runding nuan ba ubah tu?)*

e. Are there any other important areas that have changed? *(Bisi enda endur bukai ke bisi berubah ba menua kita?)*

Primary sources of knowledge acquisition

9. When there are changes in nature, how do you learn about it? *(Sema jaku bisi utai berubah ba alam sekitar/bisi utai nyadi ba alam sekitar, bakani kita ngulih ke penemu pasal utai ke nyadi tu?)*
    a. Has this always been like this? If not, what has caused the change? *(Sigi ari suba bakatu? Enti enda, bakani kita ngulih ke penemu?)*

10. Who do you believe has the most reliable knowledge of changes to nature? *(Ba runding nuan, siapa ke bisi ngembuan penemu ke lebih agi pasal ubah ke bisi nyadi ba alam sekitar?)*
    a. Do you have access to this source? *(Kita sigi ulih ngulihka penemu pasal utai ke nyadi ari…?)*

11. Do you feel like you share the same understanding/knowledge about changes to nature as other people in Kepayang? *(Ba runding nuan, kita bekunsi penemu enda enggau bala bukai ba Kepayang pasal ubah ke bisi nyadi ba alam sekitar/menua?)*
    a. Do you think there are differences between what your parents knew about nature in Kepayang and what you know about it? *(Sama ke enda penemu kita enggau apai indai/urang tuai kelia pasal alam sekitar ba Kepayang?)*

How knowledge is shared amongst the community

12. How is information about changes in nature typically shared in Kepayang? *(Bakani kita bekunsi penemu pasal ubah ke bisi nyadi ba alam sekitar ba Kepayang ngagai bala ba menua?)*
    a. Has this changed? *(Chara kita bekunsi penemu sama enda tauka bisi berubah?)*
    b. Do you think this will change in the future? *(Ba runding nuan, chara kita bekunsi penemu berubah ke enda dudi ari ila?)*
    c. Who usually gives advice in Kepayang about nature/changes/land use? *(Sapa ke selalu meri jaku lalau ba Kepayang pasal ubah ke bisi nyadi ba alam sekitar/menua/guna tanah?)*
    d. How do the headmen influence the way information is shared within Kepayang? *(Bakani tuai rumah ulih mempengaruh cara kita bekunsi penemu ba Kepayang ditu?)*

13. Do you talk about nature in everyday interactions? *(Bisi bejaku pasal alam sekitar enda ba randau sesari?)*

14. What are the biggest challenges faced by the community in terms of sharing knowledge? *(Nama penanggul kita maya bekunsi penemu?)*
    a. How are these solved? *(Bakani kita nyelesai ka penanggul/masalah tu?)*

15. What happens if you have a difference in understanding? *(Bakani enti penemu/runding enda sebaka enggau urang bukai?)*

16. Do people in Kepayang interact with nearby villages to share knowledge? *(Bala ba Kepayang ditu bisi enda bekunsi betemu enggau urang ari menua bukai?)*

Closing questions

Is there anything you would like to share with us that we have not talked about? *(Bisi utai bukai ti deka dikunsi/dicerita kita ngagai kami?)*

What do you wish to see for Kepayang in the future? *(Nama utai ka diarap/dipeda ka nyadi ba Kepayang dudi ari ila?)*

Do you have any questions about your participation in this research project? *(Bisi utai ka ditanya pasal bakani kami begunaka maklumat ka ditanya kami tadi?)*

Thank you for your time! *(Terima kasih)*

Coding Key

Indicator codes

A	Categorization of natural environment across time	Placing each mentioned area into one of four predefined habitats (oil palm, forest, pepper, and rice paddy) and noting a change from one habitat to another over the years. Refers to the "perceived changes of the natural environment"
B	Narratives of (no) experienced environmental changes	How participants view the environment as having changed. Refers to the "perceived changes of the natural environment"
C	Primary sources of knowledge acquisition categorized as: Life experience Cultural customs and traditions Authorities Scientific knowledge	Where participants learn about changes to the environment. Refers to "how knowledge is acquired and disseminated"
D	How knowledge is shared amongst the community	How participants circulate knowledge between one another

Thematic codes

1	Nature as a resource for income	When aspects of the natural environment are used as the basis for a participant's livelihood
2	Nature as a resource for subsistence	When aspects of the natural environment are used for personal consumption and non-income related survival
3	Oil palm - change	Increases or decreases to the practice of oil palm cultivation over time
4	Forest - change	Increases or decreases to the forest area and aspects within the forest over time
5	Pepper - change	Increases or decreases to the practice of pepper cultivation over time
6	Paddy - change	Increases or decreases to the practice of rice cultivation over time
7	Other changes to nature / land use	Increases or decreases to land cover and land use other than oil palm, forest, pepper, and rice over time
8	Positive description of change	Perceiving changes in the four predefined habitats as a positive and happy impact

9	Negative descriptions of change	Perceiving changes in the four predefined habitats as a negative or sad impact
10	Neutral descriptions of change	There is no impact from the changes to the four predefined habitats
11	Community’s understanding of nature	Local perceptions of the natural environment
12	Factors influencing understanding of nature	Elements that affect how one views their natural surroundings, including sources of knowledge acquisition)
13	Knowledge sharing	Exchange of knowledge between two or more people
14	Waste management	Disposal of rubbish and trash
15	Other	Interesting aspects not answering the research questions

Appendix 10: Participant Observation A & B

Participant Observation A: In the forest w. Idina

12th March, 09.50 - 11.30

Background information

41, wife of the household head, one of the women who cook for us at the community hall.

Context and setting

We asked Idina if we could walk through the forest with her, gathering products from the forest for our lunch. We asked her to tell us when she saw something edible and we helped her collect the forest products we came across (mostly fern shoots).

Observations and informal interview

We are walking along the asphalt road very close to the entrance of the forest when Idina starts telling us about the animals that used to be here. She is sad that there are no more animals in the forest, even though minutes earlier we just passed a "protected wildlife in this area" poster that she instantly discarded. She mentions that the wildlife should not be protected as it is here to be hunted. The disappearance of wildlife makes her sad because they used to be able to hunt wild boars, monkeys and an array of snakes. Idina further explains that there are also no more leeches in the forest now. "The leeches have followed the animals," she says, as we turn down the pebbled path that leads through the forest. We ask her why the animals are not here anymore, and while she begins to tell us about the cutting down of the forest in order to plant oil palm, she also explains that many wild animals died a few years back because of infections and that during this time, it was dangerous to eat the dead animals.

As we enter the forest we ask Idina how long she has been coming to the forest to gather fruits and vegetables and she tells us that she used to come here with her mother when she was a girl. According to her the forest used to be much larger and there were a lot more vegetables and food to find in here when she was younger. "You don't need to buy veggies, when you can just go to the forest" she says, as she explains that the forest used to be able to feed more families. Though the forest is getting smaller with fewer resources, she also explains that they now have motorbikes and cars which can take them further to other forest areas than before. It seems that this fact in a way evens out the loss of resources.

We move further into the forest as Idina tells us that she typically goes to the same spots in the forest that she has identified over the years, to gather roots and shoots. She explains that the vegetables and fruits grow very fast here, so there will often be new shoots to pick when she comes by. She mentions that her favorite things to gather in the forest are ferns, bamboo shoots and fish, and adds that she used to be able to gather much more products from the forest than now. While crossing the small bridge that leads over the river, Idina elaborates more on how much the amount of fish has decreased in this area and how they used to have a so-called "Tagang system". The system was established with the support of the government whereby the authorities provided them with fish for the villagers to breed in a pond in the river. However, a big flood led to the escape of the fish. Nowadays, they tend to go fishing during the night as it increases their chances of catching anything. We stop when the bridge ends and Idina points out the fish we can see swimming by, getting excited whenever she spots one larger than the rest.

While we walk through the forest we notice that Idina sometimes will snap the top part of a plant off. We ask her if this has a specific purpose and she smiles and explains that it will make the plant grow faster and stronger. When we ask how Idina learned about the forest and all of its resources, the conversation turns to the older generation. She explains to us that her parents taught her all she knows about which plants are edible and which ones can be used for medicinal purposes. She mentions that the medicinal plants they used to gather are almost nowhere to be found anymore which makes her sad since they cured illnesses. But at the same time she adds that "it does not matter because we can go to the health clinic now and people trust the health clinic more than the medicinal plants". We ask her whether she plans on passing her knowledge of the forest onto her children and without hesitating she says "Yes, it is very important for them to understand what is around them in nature". "They know what to eat and what to do" she says, before she picks up some more fern shoots. Later on, Idina spots a medicinal plant from around 7 meters away. She proceeds to pick it up, shows it to us and although she cannot recall its name she explains that it is used for healing wounds, infections and diabetes treatment. After a while Idina stops a man coming by on a motorbike to ask him if he can remember the name of the plant in her hands and together they come up with what it is called. She carries the medicinal plant for some time but eventually throws it away, since no one she knows is sick.

Her parents also taught her about the borders of the communal land. She goes on and explains to us that everyone is allowed to gather products from the forest from the communal land for their personal consumption. However, only the locals are allowed to sell their gathered products in addition to using it for their personal consumption. As long as they only take what they need, there will be plenty for everyone, she explains. As we pass some fruit trees, she mentions that this land is not communal land and adds that the villagers in Kepayang know exactly which land is communal land and which parts are private, and they respect these borders. "People here know" she says and elaborates on the generational knowledge that is orally passed on, "We know because our parents told us". When we ask Idina if there are ever any conflicts related to the communal land, she explains that the only conflicts over land in Kepayang is between siblings and the division of inherited land.

We continue walking through the forest on a road that was built 15 years ago by the authorities and ask her whether she prefers having the land covered in oil palm or forest. She explains to us that people prefer planting oil palm and adds that whatever people wish to do on their own land, whether it is cultivating oil palm or keeping it as a forest, is up to them. Personally, she wants to cultivate oil palm on her land but wishes that the communal forest stays like this and won't be cut down to grow oil palm cultivation.

Idina picks up a fern shoot by the side of the path and reaches her hand down towards the shoot between an empty plastic bottle and a cigarette pack that has long been emptied. We ask her what she thinks about the trash lying around and her tone of voice changes while she passionately blames the trash on the visitors who come to Kepayang to swim in the river. It makes her sad and angry that outsiders throw away trash and leave their forests dirty. When she stands back up, she lets her hands glide over a large green leaf, using the water stored there to rinse off her hands.

On our way back we spot another woman harvesting vegetables on her own land. She waves us to her and says "You can have some of my vegetables if you wish" and while we stand and talk for a couple of minutes, she harvests cassava leaves for us to take home. When we get near to the exit of the forest, Idina tells Stanley, our interpreter, that she wishes we could see the forest in the harvest seasons when all of the fruits and vegetables are ripe. She adds that the smell is overwhelming to experience and that the forest seems more inviting in this season.

List of edible plants/trees pointed out by Idina *(10)*

- Ferns (shoots)
- Bamboo (shoots)
- Engkalak tree (pink fruit)
- Kepayang tree (fruit)
- Yam (baby leaves and roots)
- Cassava (leaves and roots)
- Small fish (in the river, by the swimming place)
- Ijopk tree (can make alcohol from it, you can also eat the shoot)
- Mango tree (paoh)
- Medicinal plant (cannot remember the name of the plant, but spits it from 15 meters)

Participant Observation B: Oil palm plantation with Ismail

13th March at 01.30 - 03.00 pm

<u>Background information</u>

Ismail, 48, Head of Household and Headman of Kepayang Berangan, owns private oil palm plantations.

Context and setting

We joined Ismail, who planned to check up on his oil palms. We asked him to show us around his plantation, which consisted of two sites, located opposite of each other.

1) New plantation in a hilly area

- 4 years old
- 2 hectares
- Freshly harvested for the first time
- He used the land for rubber cultivation before
- Less profitable

2) Old plantation in a flat area right next to the river

- 18 years old
- 5 hectares
- The land was previously forest
- More profitable since harvesting can start after 4-5 years of planting

Observations and informal interview

Before we enter any of the plantations, we ask Ismail how he got inspired to start planting oil palms, and he explains that because he saw how easy it is to plant and maintain, coupled with the income it generates, it was an easy choice. As we start walking into the old oil palm plantation, Ismail explains the process of harvesting the oil palm fruits to us. With the help of his three employees, who are villagers of Kepayang, it only takes half a day to harvest the whole plantation. He mentions that he could employ people to help with the plantation soon after the first harvest. During harvesting, he monitors them and ensures the quality of their work. He explains to us that he can tell when it is time to harvest by looking at the fruit, and once they are ripe, they use a big pole to snap the oil palm fruit off from the trees. Generally, he can harvest the oil palm trees monthly, but he visits the plantation about 20 times a month to check on the trees and spray fertilizer. He mentions that it is better to spray fertilizer and pesticides on sunny days so the rain does not wash it away. We keep walking through the plantation, and he points out the newly planted oil palm trees in between the old ones, explaining that continuous planting ensures uninterrupted supply as oil palms grow less fruit the older they get. Some of the oil palms were becoming increasingly old, so he started growing new ones to have oil palms ready to harvest once the ones that were too old were removed. This process ensures an overlap in production and allows him to cut down the oil palms that stop growing fruit as they are too old. Occasionally, we also spot other tree species on the plantation. He explains that there is no particular reason why other tree species are there; they just happen to grow there, and he can’t be bothered to remove them.

Walking close to the oil palms, we see many dead palm leaves on the ground and sandbags on the trail leading through the plantations. While the dead palm leaves do not have any purpose, Ismail explains that the sandbags are there because the paths are hard to maintain due to soil erosion. We asked him if he thought the soil erosion he had noticed also affected the oil palm, and he simply answered no. Subsequently, he points out that a river borders the plantation, which is why he has a direct water supply on this plantation. We ask him what he thinks about spraying pesticides near the river and whether this is problematic. He explains that he is not worried about using the pesticides so close to the river because he sees where he sprays the pesticides on the palm trees, so he can ensure that no pesticides end up in the river and the quality of the soil, the plantation, and the water in the river remains the same.

When we are almost out of the plantation, Ismail starts talking about the process of beginning oil palm production. Initially, they learned about cultivating oil palms because a woman from another village who had already begun cultivating them married a villager from Kepayang. When she moved to Kepayang to live with her husband's family, she told the villagers about the oil palm production that had already started in her old village.

Ismail explains to us that the previous land was covered in forest, and with the help of one employer and his family members, they cut down the whole area within two weeks, only using chainsaws. He mentions that some of the trees they cut down were used for timber, whereby he points out that he used the timber only for personal purposes, such as building his house and not to sell. When we are almost out of the plantation and back on the road from which we came, we tell Ismail to imagine that he is standing in front of the area after all the forest has been cleared and ask him, "Do you remember what you were thinking and feeling?". He remembers feeling very excited about growing the plantation. Ismail further explains that after cutting down the trees, it took two more weeks to plant all the oil palm seedlings with the help of friends, families, and some employees. During this process, nothing unexpected happened as he learned what to expect from other villagers in Kepayang who had already started cultivating oil palm.

We leave the old oil palm plantation and cross a gravel road to enter the new one. We have to help each other climb up a little hill and onto the plantation because of all the slippery mud caused by the last few days of heavy rain. Ismail leads the way through the plantation, and while he tells us about the oil palms gesturing with one hand, the other is holding the third cigarette he has smoked since we got here. When one cigarette is finished, he throws it away on the plantation, one time actually hitting an oil palm tree as he gets rid of the bud. It is much greener than the old plantation, and many weeds and wild edible vegetation grow on the ground. The oil palms are much shorter here, and they have just been harvested for the first time. We start to make our way up through the plantation and ask Ismall why there are many more weeds here than on the other plantation. He explains that they have not yet sprayed with pesticides because of all the rain, but once the rainy season stops, he will use the pesticides to remove everything.

While we walk further up the plantation, we notice several empty pesticide bottles and other trash lying around on the ground. He picks one of the empty pesticide bottles up and fills it with water, explaining that they use the pesticide bottles as water containers once they are empty. "Recycle," he says while laughing softly. He puts the water container down as we continue walking. We notice that the number of different tree species on this plantation is higher than on the other. Ismail mentions that he intentionally grows fruit trees on this plantation as the hilly area provides better soil, even though most of the trees we see are oil palm. In addition to the oil palm, he also grows durian, chai, banana, jackfruit, cassava and fern. He explains that the maintenance of the plantation is more challenging on the hilly ground, and he mentions that whatever he harvests from the fruit trees is just for self-consumption. He also points out a medicinal plant and picks some leaves but throws them away soon after. However, he carries the ripe jackfruit he spots later on the ground to the car and brings it home. As we finish touring the second plantation, he mentions that he owns more land currently covered by forest, but he plans to turn it into a third oil palm plantation to generate more income.

Appendix 11: Map of Transect Walk (Google Earth, 2024)

Green pins indicate major land use changes related to cultivation.

Appendix 12: Synopsis

Synopsis

(CIFOR Photo/Nanang Sujana via Forests News, 2017)

Land Use Transition in Kepayang

Bridging Perceptions and Physical Environmental Change

Annabelle Yifei Chen Wu
Jasmine Vorburger
Juni Victoria Moe Moltubak
Katrine Bruun Piester
Magnus Winther Damkaer Jensen

Word count: 2.496

Introduction

Global demand for palm oil has increased exponentially in recent decades, supplying everything from food producers to biofuel industries across the globe (UNDP, 2020). Due to Malaysia's favorable climatic conditions (Uning et al., 2020), it has become the second-largest palm oil producer in the world, as seen below in figure 1. Nearly 26% of the world's total palm oil production is centered in Malaysia (Malaysian Palm Oil Council, 2024), hosting about 90% of the world's oil palm trees (UNDP, 2023).

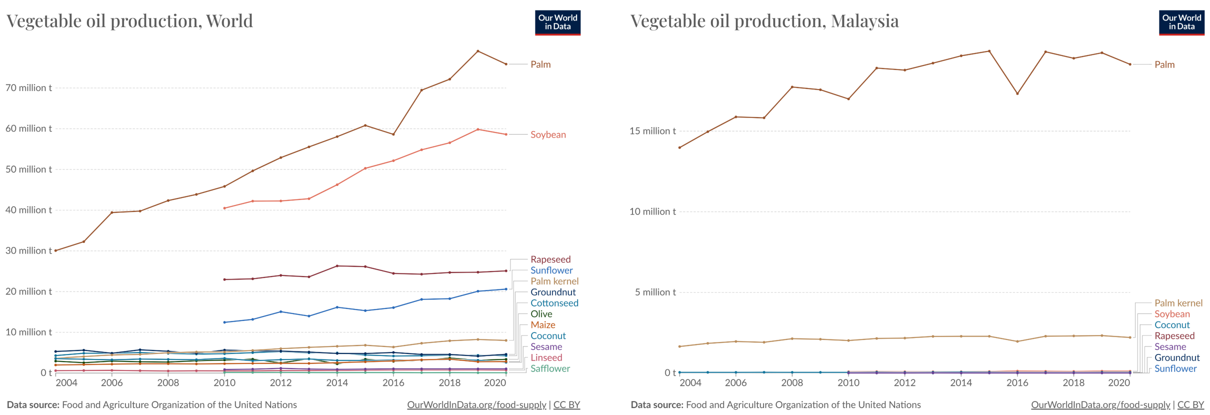

Figure 1: (Our World in Data, 2021)

Millions of Malaysians rely on oil palm cultivation for their livelihood (Unilever, 2022), and the industry has become an essential part of Southeast Asian socio-economic development. However, oil palm cultivation fosters deforestation and subsequent harmful effects on biodiversity (Uning et al., 2020). More than 99% of Malaysia's deforestation was between 1988 and 2012 caused by the expansion of oil palm plantations (Shevade & Loboda, 2019) - a fact that should be carefully considered in regard to the industry's positive effects on Malaysia's socio-economic development.

In Sarawak, on the island of Borneo in Eastern Malaysia, lies Kepayang, an area in the Gedong district consisting of four small villages. Some of the world's most biodiverse forests surround the hills of Kepayang, which, combined with the area's fertile soil, has created the foundation for varied and fruitful livelihood opportunities (UNDP, 2023). Although Kepayang is relatively populous with its 147 households, the villages are increasingly experiencing out-migration to the larger cities, primarily due to improved road infrastructure and financial motivations. These migration patterns create a lack of available workforce, which, along with the global financial drivers illustrated above, is among the reasons why Sarawak has seen a significant change in land use practices in recent years. The area has gradually moved away from traditional rice cultivation towards widespread oil palm cultivation (Cramb & Sujang, 2013).

While numerous studies have looked at the effects of land use transitions on the physical environment in general, few have looked at these dynamics in the Sarawak region specifically (Mertz et al., 2013). Previous studies in Malaysia have established that transitioning to monocultures and cash crop cultivation rather than traditional crop practices can harm biodiversity (Hughes, 2017), while other studies have shown how unsustainable land use and land cover changes can negatively impact local livelihoods and natural resource governance (Munthali et al., 2019), or at best generate mixed results and opinions in local communities (Ismail et al., 2023). It is the goal of this research to establish the main physical changes to the natural environment that have occurred as a result of Kepayang's land use transition and compare this to the local community's perception of the land use changes in their area. This will contribute to the larger body of work that currently exists on the socio-ecological effects of land use transitions, and the numerous works that compare perceived and actual environmental changes (Bruun et al., 2016). We hope this study will provide a stepping stone into further interdisciplinary research on the socio-economic and environmental sustainability of oil palm cultivation.

Research Question and Objectives

We wish to investigate how land use transitions influence the physical and lived realities of the rural community in Kepayang by deploying social science methods to explore local perceptions of natural environmental change and natural science methods to measure physical environmental changes. We argue that it is of key importance to consider both social and ecological variables in tandem if one wishes to understand how societies navigate change. Omitting one aspect in favor of the other might not only lead to incomplete conclusions but also unsustainable notions of governance and development (Andrachuk & Armitage, 2015). With this in mind, we will analyze Kepayang's land use transition through a comparative approach that juxtaposes the communities' perceptions of environmental changes with observable changes in land cover and biodiversity. We focus on observable changes, because these are directly perceptible by the communities, thus allowing a comparison between physical and perceived changes in the environment. This has led to the following research question:

How do local perceptions compare to physical environmental changes of the transition to oil palm cultivation in Kepayang, Malaysia?

In order to answer this guiding question, we pose four sub-questions emphasizing an interdisciplinary approach:

1. Physical environmental changes
    a. How has land cover changed?
    b. What is the state of biodiversity across different land-uses?

2. Perceptions of change
    a. How does the local community of Kepayang describe changes to their surrounding natural environment?
    b. From which sources of knowledge do these definitions derive?

Methodology

Analytical Framework

Andrachuk & Armitage (2015) highlight the importance of considering the interplay of changes in both social and ecological systems, rather than conceptualizing the changes in these spheres in separate subsystems. Thus, we are taking a comparative approach in analyzing land use change, whereby our analysis of local perceptions through social science methodology will be juxtaposed against observable environmental changes, obtained through natural science methodology. Through the integration of these techniques, we are able to analyze how lived experiences are valued compared to what we are able to observe from an external standpoint, either reinforcing or challenging existing ideas (Bruun et. al, 2016). According to Andrachuk & Armitage, transformations in the ecological domain may manifest in a change in landscape patterns and alterations in biodiversity. Simultaneously, the changes in the social domain may include a shift in norms and values (Andrachuk & Armitage 2015). Following this, ecological changes of the land use transition will be explored as land cover and biodiversity, and social changes through the concept of perception, facilitating interdisciplinary data collection and complementary analysis through both natural and social science methods (Krishnan, 2009).

The Societal Relations to Nature Framework (SRN) is employed as an analytical framework in order to operationalize the concept of perception. This framework explores people's relationship with nature by revealing underlying factors of human-nature entanglements (Berghöfer et al., 2022). It Investigates the diversity of perspectives and values within critical issues and conflict situations while acknowledging spatio-temporal disparities, such as historical contexts and geographical differences. In our case study, we analyze the transition to oil palm cultivation and its consequent impacts on the natural environment as the central conflict. Through this framework, we take departure in the dimension of *knowledgescapes*, defined as "the lens through which people perceive and understand their natural environment" (ibid.). Because the analysis of knowledgescapes involves examining the distinction between concrete experience-based knowledge and abstract principles and concepts, perception will be explored firstly through descriptions of the natural environment and its changes, referring to what is known, and secondly through knowledge acquisition, referring to how something is known. The *natural environment* is here defined through the "global and endangered nature perspective" (ibid.). Often associated with indigenous communities, it represents the natural environment as a space that is embedded into daily lives through material and immaterial interactions with nature and dependencies on local resources. In specifying the area of study, the natural environment will refer to land on which people live, land that is cultivated, and the land that surrounds Kepayang, which will be defined in collaboration with the local community.

Applied Methods and Sampling

Sub-question 1 - How has land cover changed?

To understand the local perception of the transition to oil palm cultivation compared to the environmental changes, it's necessary to investigate the characteristics of the area's land cover, both current and previous. In order to answer this sub-question, two indicators are applied: *Forest cover loss* and *oil palm production*. These indicators will be investigated through remote sensing and in-situ verification. Remote sensing is applied to examine the large-scale changes that have occurred over the last 20 years, from 2004 to 2024. This will be conducted using the feature 'historical images' in Google Earth as it allows us to visually interpret the current and previous landscape. The vegetation cover might 'hide' specific land-use systems due to similar spectral reflections as well as the potential of agroforestry (Lillesand et al. 2015). Therefore, in-situ verification will be applied to compare the accuracy of the remote sensing of the current land cover to accommodate potential limitations. In-situ verification is a method to verify and assess the quality of large-scale data, in our case satellite images. It focuses on the primary indicators of previous established classification, and is therefore a tool to enhance the precision of data as well as generate generalizable knowledge, as it is highly accurate and reflects the actual conditions of a system (Apostolova et al. 2018)

Sub-question 2 - What is the state of biodiversity across different land-uses?

In order to answer sub-question 2, qualitative biodiversity assessments will be employed to investigate the indicator of vegetation biodiversity, focused on the number of *plant species in 4 predefined* *ecological habitats* - old forest, oil palm, rice fields, other (rubber, pepper, new forests, etc.). These four habitats will be investigated through the use of the Shannon Diversity Index which incorporates the richness and evenness of species (Hill et al., 2005). This project focuses on the above-ground flora (herbaceous, herbaceous perennials and perennials) across the different land use practices in our study area. The vegetation biodiversity within the forest will be used as our baseline to evaluate changes that have occurred, especially in the transition from forest to oil palm plantations. In practice, we conduct assessments of each ecological habitat enabling us to compare the biodiversity. We will do a systematic sample placing our quadrants in the center of the habitat, to enhance the representativeness of each assessment; this is, however, not logistically possible in the forest. Quadrants do not have specified definitions of optimal size, and due to the variation of ecological habitats, it's challenging to apply a one-size-fits-all solution (ibid.). The quadrant size will be determined in-situ based on judgment and logistically plausible assessments in the forest, and will afterwards be scaled to the other habitats.

> Sub-question 3 - How does the local community of Kepayang define changes to their surrounding natural environment?

In order to answer this sub-question, two indicators guide the data collection process. First, we aim to investigate the *categorization of the natural environment across time*, using the 4 predefined habitats, by employing participatory mapping and questionnaires. Community mapping is a qualitative, participatory rural appraisal (PRA) method used in ethnographic studies that will be incorporated into focus groups. It involves the participants collectively mapping out the physical spaces they live, work, and spend time in and their relationship to these areas, bringing clarity to lived experiences on the ground. (Mikkelsen, 2005). To highlight potential environmental changes, we will ask the participants to draw maps for both 2004 and 2024. Participants will be selected from the semi-structured interviews who seem particularly knowledgeable and eager to share more about their experiences in regard to perceived environmental changes. We will form 2 focus groups with 5 participants each, comprised of different ages, genders, and occupations. Ranking, another PRA method, will be used in conjunction with the mapping exercise. This method provides further insight into the local community's priorities and values, which would offer a deeper look into their perceptions of spatial change (Mikkelsen, 2005). By viewing the natural environment of Kepayang through this perspective, we further contribute to our goal of data triangulation and reduce investigator bias. Insights into the communities' description of changes to the natural environment will be further accumulated through questionnaires (see sub-question 4).

Our second indicator is *narratives of experienced environmental changes*. Hereby, we aim to conduct semi-structured interviews, participant observation, and transect walks. Participant observation is a qualitative method through which we immerse ourselves in the lifeworlds of the Kepayang community. By exercising and observing activities of day-to-day life, this method provides insights that move beyond what people are able to articulate about themselves (Dewalt & Dewalt, 2011). We will explore what characterizes everyday interactions with the natural environment through observing land use practices, assuming how people interact with their natural environment is rooted in their perceptions of it (ibid.). In practice, the observations will be carried out over two days and individuals will be selected through snowballing, following predetermined criteria as best as possible. These criteria are as follows; various age groups, different scales of oil palm cultivation, and gender diversity.
Moreover, we will conduct transect walks, a qualitative method that involves systematically walking along a predetermined path, observing and documenting socio-ecological characteristics. Walk-along interviews will provide understanding of the communities' perception of their natural environment, and the dynamics that come into play in light of perceived environmental changes stemming from the transition to palm oil plantations (Mikkelsen, 2005). Participant observation and the transect walk will

define the beginning of the field research, building a foundational understanding of Kepayang and its inhabitants. This process enhances subsequent data collection as the gained insights point towards important aspects for further investigation. Following this initial immersion into the lifeworld of the communities in Kepayang, semi-structured interviews (see sub-question 4) will be conducted to gain a deeper understanding of experienced environmental changes.

Sub-question 4. - From which sources of knowledge do these descriptions derive?

In order to answer this sub-question, semi-structured interviews and a questionnaire will be employed as primary methods to explore two indicators. The first indicator is the *primary sources of knowledge acquisition* amongst the community of Kepayang, investigating where the descriptions of changes to the natural environment originate from. This will be explored through a questionnaire, where sources of knowledge are operationalized as the following categories: life experience, cultural customs and traditions, authorities, scientific knowledge, and other sources. The questionnaire will further provide background information to get a systematic grasp of the key attributes and demographic information of the sample (Spradley, 1980). The indicator will also be included in the semi-structured interviews, elaborating on what sources of knowledge the community draws from. In practice, we aim to conduct surveys with 40 heads of households as representatives of the social unit. Participants will be selected through simple random sampling (Rea & Parker, 2014).

The second indicator, *how knowledge is shared amongst the community*, will be studied through semi-structured interviews, focusing on exploring the flows of knowledge. Questions will delve into how knowledge about the natural environment is established, circulated, and prioritized. In practice, we aim to conduct 10 to 15 semi-structured interviews. Interviews will be recorded on dictaphones and later transcribed, whereby interviewees are assigned pseudonyms. Interviewees will be selected through purposive sampling, based on preliminary observations and insights from both participant observation and questionnaire (Brinkmann, 2014).

In order to generate a basis for comparison between the two data sources, we aim to keep the topics of the questions posed in the interviews as similar as possible to those of the questionnaire. However, the interviews will naturally go more in-depth, be more exploratory, and most likely generate unexpected data that the questionnaire will not be able to reflect. The use of both quantitative and qualitative data will therefore serve as a point of triangulation in the data analysis process of local sources of knowledge (Thurmond, 2001).

Time Schedule

A preliminary time schedule of the fieldwork can be found below in figure 2.

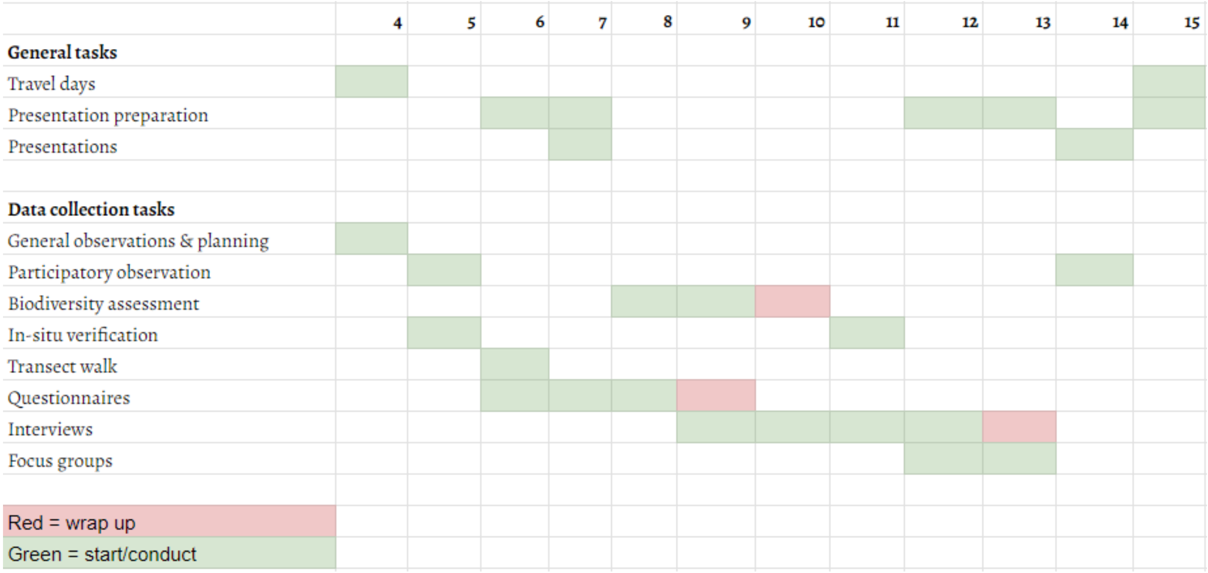

Figure 2: Preliminary fieldwork schedule

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Appendices

A. Data Matrix

Research question: How do local perceptions of the transition to oil palm cultivation compare to physical environmental changes in Kepayang, Malaysia?			
Sub-questions	**Indicators**	**Data collection method**	**Data analysis method**
1. How has land cover changed?	Forest cover loss (visual change in years, from 2000 - 2024)	Remote sensing, GE In situ-verification	Visual interpretation of satellite images
	Oil palm cultivation (visual change in years, from 2000 - 2024)	Remote sensing, GE In-situ verification	Visual interpretation of satellite images
2. What is the state of biodiversity across different land uses?	Plant species in 4 predefined ecological habitats: Old forest Oil palm Rice fields Other (rubber, pepper, new forests, etc.)	Qualitative biodiversity assessment	Shannon-Wiener Species Diversity Index
3. How does the local community of Kepayang describe changes to their surrounding natural environment?	Categorization of natural environment across time (using the 4 predefined habitats)	Participatory mapping Questionnaire	Content analysis Statistical analysis
	Narratives of experienced environmental changes	Semi-structured interview Participant observation Transect walk	Content analysis Content analysis Content analysis
4. From which sources of knowledge do these descriptions derive?	Primary sources of knowledge acquisition categorized as: Life experience Cultural customs and traditions Authorities Scientific knowledge Other	Questionnaire Semi-structured interview	Statistical analysis Content analysis
	How knowledge is shared amongst the community	Semi-structured interview	Content analysis

B. Questionnaire

Consent information

Background information

1. Village
   (1) Kepayang Berangan
   (2) Kepayang Setia Raja
   (3) Kepayang Lama
   (4) Kepayang String

2. Name

   ____

3. Gender
   (1) Female
   (2) Male
   (3) Other (what?)

4. Age

   ____

5. Number of household members (How many members does your household have?)

   ____

6. Position in the household
   (1) Head of the household
   (2) Other (what?)

7. Highest educational level
   (1) No formal education
   (2) Primary school (7-12)
   (3) Secondary school (13-17)
   (4) Tertiary education (bachelor's and more)
   (5) Trade or skilled education (carpenter etc.)
   (6) Others (craft)

8. Primary occupation
   (1) Oil palm cultivation
   (2) Rice cultivation
   (3) Cultivation of other crops (what?)
   (4) Hunting / fishing
   (5) Collection of forest products
   (6) Wage labor (employed by someone)
   (7) Own business (self-employed)
   (8) Other (what?)

Income & Land use change

9. What are the two main sources of income for your household?
   (1) Agricultural
      (a) Crops
      (b) Livestock
      (c) Fishing
      (d) Other (what?)
   (2) Wage Labor
      (a) Manufacturing
      (b) Service
      (c) Other (what?)
   (3) Remittances
   (4) Other (what?)

10. Do you have land that you consider as yours?
   (1) Yes
   (2) No

11. How do you use your land? (choose multiple)
   (1) Agriculture
      (a) Oil palm
      (b) Rubber
      (c) Pepper
      (d) Rice
      (e) Other (what?)
   (2) Livestock
   (3) Leasing
   (4) Logging/Forestry
   (5) Hunting/fishing
   (6) Mining
   (7) Property
   (8) Other (what?)

12. Are your current livelihood practices different from what they were around 20 years ago (2004)?
   (1) Yes
   (2) No

13. If yes, what were your previous practices?
   (1) Agriculture
      (a) Oil palm
      (b) Rubber
      (c) Pepper
      (d) Rice
      (e) Other (what?)
   (2) Livestock
   (3) Leasing
   (4) Logging/Forestry

(5) Hunting/Fishing
(6) Mining
(7) Property
(8) Other (what?)

14. Why did your land use practices change?

____

15. If yes, how many years ago did you begin to change your practices?
(1) 2020 - 2024
(2) 2015 - 2019
(3) 2010 - 2014
(4) 2005 - 2009
(5) 2000 - 2004
(6) Before 2000
(7) Don't recall

<u>Categorization of changes to the natural environment across time</u>

16. To what extent have these specific areas increased or decreased?

Old forest	-5 -4 -3 -2 -1 0 1 2 3 4 5
Oil palm cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Rice cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Other	-5 -4 -3 -2 -1 0 1 2 3 4 5

17. To what extent has your access to (specific area) increased or decreased?

Old forest	-5 -4 -3 -2 -1 0 1 2 3 4 5
Oil palm cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Rice cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Other	-5 -4 -3 -2 -1 0 1 2 3 4 5

18. To what extent has the amount of plants available in (specific area) increased or decreased?

Old forest	-5 -4 -3 -2 -1 0 1 2 3 4 5
Oil palm cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Rice cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Other	-5 -4 -3 -2 -1 0 1 2 3 4 5

19. To what extent has the diversity of plants in (specific area) increased or decreased?

Old forest	-5 -4 -3 -2 -1 0 1 2 3 4 5

Oil palm cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Rice cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Other	-5 -4 -3 -2 -1 0 1 2 3 4 5

20. Have these changes in land use of (specific area) been positive or negative to you?

Old forest	-5 -4 -3 -2 -1 0 1 2 3 4 5
Oil palm cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Rice cultivation	-5 -4 -3 -2 -1 0 1 2 3 4 5
Other	-5 -4 -3 -2 -1 0 1 2 3 4 5

Primary sources of knowledge acquisition

21. Where do you learn about the natural environment around you? (choose all that apply)

    (1) Life experience (observing)
    (2) Cultural customs and traditions (local knowledge / narratives)
    (3) Authorities (local government / companies)
    (4) Scientific knowledge
    (5) Other sources

22. Please rank the following sources of knowledge from most important to least important:
    Life experience (observing), Cultural customs and traditions (local knowledge / narratives), Authorities (local government / companies), Scientific knowledge, Other sources

Potential closing questions

- Is there anyone you would recommend us to go and talk to?
- Are there any important topics in the community you feel we have not talked about?
- Do you have any questions for us?
- Is there anything you would like to clarify/elaborate on that you feel like you have not had the opportunity to clarify/elaborate on so far in this questionnaire?

C. Semi-structured interview guide

We are 5 students from the University of Copenhagen in Denmark. We are here to conduct a field study as part of a university course on land use transitions. We are interested in learning about how the natural environment has changed around the area of the Kepayang villages.

- ★ Consent form questions

Introduction

1. Can you please tell us a little bit about yourself (name, age, background, village, role in village, role within household)?

2. What do you do for a living?
   a. Is this your current primary income for your household?
   b. Do you own land?
   c. How important is land to you?
      i. Are you dependent on the land?
      ii. Are the natural environment of any importance to you, besides economic benefits?

Narratives of experienced environmental changes

3. How would you describe the natural environment in and surrounding this village?

4. Has the way you have used land changed within the past twenty years?
   a. What was the transition?
   b. What were the primary reasons behind this transition?

5. How do you see the surrounding land of Kepayang mostly being used for?
   a. Out of these activities, which have seen the most significant increase within the past twenty years?
   b. Out of these activities, which have seen the most significant decrease within the past twenty years?
   c. Out of these activities, which have the most significant impacts on the environment, such as plant and animal biodiversity?

6. Have you experienced environmental changes in the surrounding…
   a. Forest
      i. If yes, what do you think caused this?
      ii. What do you think about the changes?
   b. Rice cultivation
      i. If yes, what do you think caused this?
      ii. What do you think about the changes?
   c. Oil palm cultivation
      i. If yes, what do you think caused this?
      ii. What do you think about the changes?
   d. Other areas of the nature
      i. If yes, what do you think caused this?
      ii. What do you think about the changes?

Primary sources of knowledge acquisition

7. If you see something new occur or disappear in your natural environment, who do you consult / where would you seek information in order to learn more about this?
    a. Has this always been like this? If not, what has caused you to change?

8. Who do you believe has the most credible knowledge of changes in this natural environment?
    a. Do you have access to this source?

9. Do you feel like you share the same understanding/knowledge about changes in your surrounding natural environment as other members of your community?
    a. Are there differences in knowledge between generations?

How knowledge is shared amongst the community

10. Can you describe how information about the natural environment and its changes typically are shared in the community?
    a. Has this changed?
    b. Do you think this will change in the future?
    c. Who usually gives advice in your community about the natural environment/changes/land use?
    d. How does the structure of the community leadership (elders or heads) influence the way information is shared within the community?

11. Is the natural environment a topic of conversation in everyday interactions?

12. What are the biggest challenges faced by the community in sharing knowledge?
    a. How are these solved?

13. What happens if your understanding of the natural environment is in conflict with someone else's understanding of the same topic?

14. Do members of your community interact with nearby communities to exchange knowledge?

Closing questions

- Is there anything you would like to share with us that we have not talked about?
- Do you have any questions about your participation in this research project?

Thank you for your time!

D. Conducting the participatory mapping

Drawing of the maps

1. Map 1 - 2024: Please draw a map of your community and the natural environment surrounding it as of today. (using 1 color, black)
    a. Mark the predefined areas of old forest, oil palm cultivation, rice cultivation and other areas on the map, using different colors for each category.
2. Map 2 - 2004: Please draw another map of your community and the natural environment surrounding it as of 2004. (using 1 color, black)
    a. Mark the predefined areas of old forest, oil palm cultivation, rice cultivation and other areas on the map, using the same colors for each category as with map 1.

Discussion of the maps

3. How would you describe the predominant uses of the surrounding land of Kepayang?
    a. Spatially, how would you categorize these activities into areas in/around Kepayang? Identify 5 most important areas of change
4. Are there any specific changes in your natural environment that you would like to discuss? (marking these areas with post-its)
5. How has the introduction of oil palm cultivation affected/changed the natural environment in your community? Please draw or describe any changes you've observed
6. If you could change any areas in the natural environment surrounding your community, which ones would you change?

Ranking exercise

7. First round: Marking the 5 most important areas of change with smileys (choice of all)
8. Second round: Ranking the 5 most important areas of change with smileys (choice of one)

Closing discussion

9. How do you envision the future of the physical spaces in your community, considering any environmental changes or developments that may occur?
10. Is there anything you want to elaborate on before we end the discussion?