Melaleuca trees for sustainable livelihoods in Gohong Village

Kahayan Hilir District, Central Kalimantan, Indonesia

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Preface

My name is Samantha de Fluiter, and the last six months I have been working on this bachelor thesis. I wrote this thesis report as final project of the study Forest- and Nature management at the University of Applied Sciences Van Hall Larenstein. This report is made in addition to the Melaleuca Honey Supply chain Project of SFP Social Forestry. I have immersed myself in the tropical peatlands of Central Kalimantan, Indonesia, and the potential of *Melaleuca cajuputi* and how this species can be implemented in a sustainable forest plantation design in peatland ecosystems.

During my study, I was interested in a lot of things, from frog species and flowers to the bigger picture we call ecosystems. The immensity of tropical ecosystems and the enormous biodiversity led me to choose the specialisation Tropical Forestry during my study. This project offered me the opportunity to dive into the peatland ecosystem and at the same time look into a species with high potential, on social, economic and environmental level. Doing research on paludiculture was a very interesting and informative experience.

I want to thank my supervisor Peter van der Meer for his help during the research and report writing. Peter taught me to think first, then ask. He was also helpful with helping in unforeseen situations, such as the cancelation of the fieldwork trip to Indonesia.

Next, I want to thank my commissioner of SFP, Jeroen Knol, for his guidance during the project. There wasn't a moment when he wasn't there to answer questions or to give me the confidence I needed to finish the report.

I also want to thank Jelle Linders for helping me the moment I lost confidence and got stuck. Our brainstorm session helped me to look forward and to let go the disappointment of changed plans such as the cancelation of the fieldwork trip and changing the methods.

At last, I want to thank my mom, my boyfriend and my friends for the support and distraction during my graduation phase and helping me focus on it when necessary.

I hope you enjoy reading!

Samantha de Fluiter

09-06-2023

Summary

Tropical peatlands cover around 45 million hectares of the world. Half of these peatlands are located in Indonesia, mostly on Kalimantan. Tropical peatlands are currently under threat due to land-use change, drainage and climate change. One of these locations under threat is Desa Gohong (Gohong village), Central Kalimantan, where peat fires caused deforestation and loss of various income sources for the community. This report focusses on the development of a sustainable Melaleuca focussed plantation design to improve the livelihoods in Gohong and restore degraded peatlands, in collaboration with SFP Social Forestry. The main research questions are “what is the current situation in Gohong Village?”, “What is the potential of Melaleuca cajuputi?” and “How can Melaleuca cajuputi be implemented so that it generates actual benefits and improves the livelihoods of Gohong Village?”. The methods consist of an extensive literature research and semi-structured interviews. Based on the results of the literature study and interviews, a forest plantation design is presented. The design comprises a sustainable approach with a primary focus on Melaleuca. It integrates both short- and long term income generating species, enhancing the community’s livelihoods in Gohong. By integrating dryland species as per the community demand and paludiculture species to safeguard the peatlands and prevent further degradation, the design effectively contributes to the preservation of peatland and the conservation of natural resources for long-term sustainability. By utilising various products derived from Melaleuca, notably honey, the design capitalises on the species’ full economic, social and environmental potential. In order to be able to realise the design, a follow-up research is recommended, including new interviews and water level research.

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1. Introduction

1.1 Tropical peatlands

Tropical peatlands cover around 45 million hectares (ha) of the world. Half of these peatlands are located in Indonesia, mostly on Kalimantan (Wageningen university & research, sd). These peatland soils are made from organic matter composed of decomposing tree trunk, leaves and roots. Natural peatlands serve as important carbon stores and hydrological buffers and provide habitats for various important and endangered species, including the Orang-utan (Graham, Giesen, & Page, 2016). Peatlands are the largest natural terrestrial carbon store and store more carbon than all other vegetation types in the world combined (IUCN, 2021).

One of the locations where peatlands are located is the Pulang Pisau Regency in Central Kalimantan, Indonesia. Pulang Pisau Regency is one of the thirteen regencies which comprise the Central Kalimantan Province on the island of Kalimantan. Peatlands cover more than 60% of the districts area and store a significant amount of carbon stock (Indonesian Green Growth Program, 2015). Desa Gohong (Gohong Village) is one of the 95 villages in the Pulang Pisau Regency (see figure 1). The Pulang Pisau Regency is located on two tropical peat domes, peatland in a characteristic dome shape and formed between two rivers or stream channels (thornton, Page, Green, Cook, & Wright). Gohong has an area of approximately 51.037 Ha and is crossed by the Kahayan River (Novitasari, Aprisiska, & Cristmastianto, 2018). The peatlands of Gohong are currently in poor condition and under threat due to land-use change, drainage and climate change (Roucoux, et al., 2017).

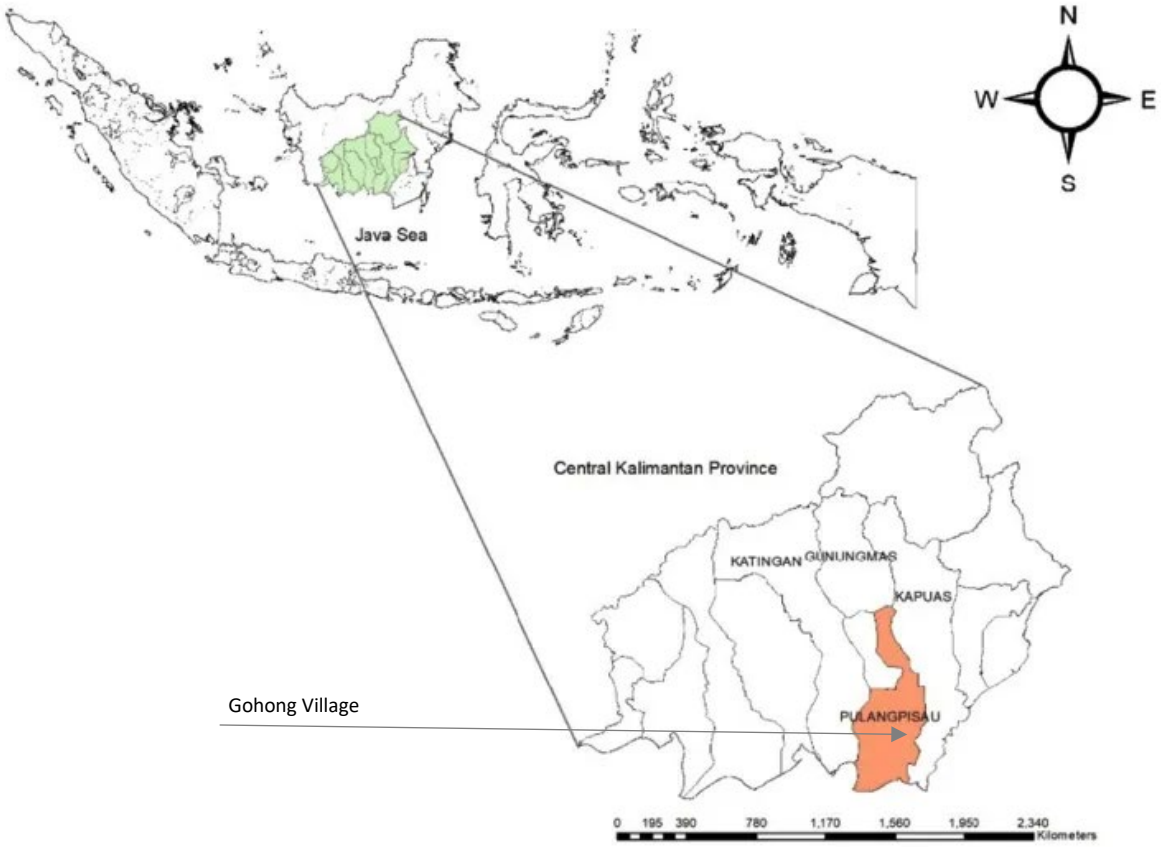

Figure 1: Location Gohong, located in Central Kalimantan, Indonesia (SFP, 2022).

1.2 General background

in 1996, the Indonesian government initiated the Mega Rice Project, a project to alleviate Indonesia's growing food shortage by constructing irrigation canals and removing trees for rice plantations on peatlands across Central Kalimantan (Rieley, 2007). Because of the nutrient peat soil, which is not usable for the kind of rice cultivation which was used, the Mega Rice Project turned out as a disaster and left behind a waste land of drained and degraded peat. In 2015, peat fires across Indonesia spewed an enormous amount of carbon into the atmosphere. Half a million people got sick from the smoke and haze (SFP, 2022). The affected area includes the Pulang Pisau Regency, where Gohong Village is located.

To help protect the forest and reducing deforestation and peat degradation, the Ministry of Environment and Forestry (MoEF) gave multiple villages including Gohong Village a permit for Village Forest (also called Hutan Desa, HD) in 2012. The Village Forest of Gohong is about 3155 Ha, which is mostly used for wood selling. Apart from the Village Forest, Gohong has a plantation of 10.207 Ha (Rubber, Sengon, oil palm and fruits), 600 Ha of paddy fields and 302 Ha of land to grow rice, cassava, corn and other products. Efforts to catch fish are mostly carried out by using ponds, sometimes in the river. Through the HD program, community institutions are responsible to help reducing deforestation and degradation rates in Central Kalimantan. At the same time, HD are expected to secure livelihoods (SFP, 2022). A livelihood is the way the someone earns money to pay for a living (food, place to live, clothes etc.). securing livelihoods is achieved with sustainability projects, executed by the government whilst working together with organisations and foundations such as SFP Social Forestry (SFP). SFP intends to provide communities such as in Gohong with legal access to utilise forest resources in a sustainable way in the form of projects. This includes aspects such as forest management, forest protection and improving social development. In social forestry projects, the needs of local communities come first. One of the current projects in development by SFP is the Melaleuca Honey Project: the development of a value chain for Melaleuca honey that needs to be sustainable and profitable (SFP, 2022). This project (and Melaleuca as income generating species) has potential in Gohong Village since the people of Gohong are already aware of the need for more sustainable management of their product resources. In addition, the government of the Pulang Pisau Regency has already begun revitalising the forestry sector by clarifying land tenure and is therefore cooperative.

Melaleuca honey is a monofloral honey produced by some tree species of the Melaleuca genus. Melaleuca is a genus of plants in the myrtle family Myrtaceae (see figure 2). Melaleuca species are shrubs and trees growing to 2-30m tall, depending on the species (Bionity, sd). Like other members of the family, Melaleuca sheds its bark and contains fragrant oils. Melaleuca is commonly known as paperbarks or tea-trees. Most Melaleucas are endemic to Australia with a few occurring also in Indonesia. *Melaleuca cajuputi* occurs in Indonesia. In Indonesia, naturally they are dispersed in lowland peat swamp forest. Melaleuca trees can grow in very moist and saline conditions and are exceptional resilient trees. They can withstand frequent flooding and acidic soils, but also brackish conditions. Melaleuca also survives small fires fairly well (Graham L. L., 2009). Melaleuca is considered a pioneer species, colonizing the new habitat created by disturbance such as fires (Giesen, 2015). It is a fast growing species and is therefore often found in disturbed areas and/or revegetated peatland. It is also a versatile species and has many other uses than piles and construction wood. Etheric oils can be derived from the leaves, its wood can also be used in the pulp-and- paper industries and the flowers produce honey and support beekeeping (Giesen, 2015). It is also proven that Melaleuca has positive health benefits such as wound healing properties (Rozaini, Zuki, Noordin, Norimah, & Nazrul Hakim, 2005), antioxidant and antimicrobial (Puvača, Čabarkapa, Bursić, Petrović, & Aćimović, 2018). At this moment, very few smallholder producers are involved in

the processing of Melaleuca or practice any form of sustainable management of the resource. But, because of all the environmental and economic values of the species, Melaleuca can be a supportive species to improve livelihoods in Gohong.

Figure 2: Flower of *Melaleuca Spp.* (Lotus Garden Botanicals, sd).

The honey of the Melaleuca tree (mainly from the migratory Asian Giant Bee, *Apis dorsata*) is collected by smallholder beekeepers (SFP). There is lots of market potential for Melaleuca, in the form of cajuput oil and Honey (Giesen & Sari, 2018). The Melaleuca of the Village Forest of Gohong is currently mostly being used for firewood and sawn timber and poles for fast income to support their households. Next to Melaleuca, species such as rubber (*Hevea brasiliensis*) rotan, rice and sengon are planted by the community for own consumption and for sale.

1.3 Problem description and definition

The conversion of peatlands for agricultural purposes, primarily driven by the Mega Rice Project, has resulted in severe deforestation and peatland degradation in areas like Gohong. The associated peat fires have not only harmed the health of half a million people due to smoke and haze but also led to significant loss of flora and fauna, impacting the local community's livelihoods due to loss of crops and income generating species. At this moment, SFP is creating a Melaleuca Honey supply chain to improve the livelihoods of Gohong and simultaneously reduce peat fires.

While Melaleuca shows promise for both environmental recovery and economic potential, the community is currently unaware of its benefits as Non Timber Forest Product (NTFP). Consequently, other species with better sell ratings for wood are favoured, and the potential for non-timber forest products from Melaleuca, such as honey and essential oils, remains untapped (Novitasari, Aprisiska, & Cristmastianto, 2018).

Currently, it is not clear which other factors prevent Melaleuca from being used for other income generating product other than construction- and firewood. That being the case, it is clear that for a sustainable way of processing Melaleuca more information regarding the demand of the people of Gohong and options for Melaleuca products is necessarily.

Additionally, to ensure both short- and long-term income generation, a diversified, sustainable plantation design that goes beyond the current focus of SFP on Melaleuca is needed. Thus, other species that can be combined with Melaleuca should be considered to improve the livelihoods of the people in Gohong. Income generating species with social, economic and environmental potential such as Melaleuca that fit the growing environment need to be found and a plan to improve the livelihoods need to be made in addition to the Melaleuca Honey supply chain of SFP. This includes paludiculture species, economically beneficial peat swamp adaptive species on wet or rewetted peatland, with near natural ground water levels.

1.4 Objectives and sustainability

The main objective is to develop a sustainable Melaleuca focussed forest plantation design to improve the livelihoods in Gohong: a sustainable forest plantation design with a combination of short- and long term income generating species, including *Melaleuca cajuputi*. The main objective can be subdivided into environmental and social/economic objectives:

Environmental objectives:

- A sustainable managed Melaleuca focussed forest plantation design in Gohong, resulting in reduction of peat fires and less smoke and haze.

Social/economic objectives:

- The development of a plantation design that includes options for short- and long-term revenues, to manage the Village Forest resources for long-term social, environmental and economic sustainability, all whilst meeting the demands of the people of Gohong.
- Introduce other *Melaleuca* tree uses then wood, such as NTFP's like Melaleuca honey and essential oils, to generate more income and therefore improve the livelihoods of the community of Gohong.

The goal of this project is to enhance the livelihoods of the residents of Gohong Village by implementing a design that incorporates Melaleuca. The project aims to contribute to the conservation of peatlands and preserve natural resources for long-term sustainability.

The commissioner can utilize this design in conjunction with SFP's Melaleuca supply chain project. By incorporating information on the benefits of Melaleuca in a plantation design, along with options for short-term and long-term species and a recommended design map, the lack of trust and knowledge of the community of Gohong regarding new land use practices can be alleviated. By selecting species that are well-suited to the environment and the community's needs, peatland degradation, peat fires and CO2 emissions can be reduced. This design supports the goals of the commissioning organisation by providing insights into the potential of Melaleuca and the possibility of creating a design that combines Melaleuca with other potential paludiculture species.

1.5 Research questions

The objective is addressed by answering the following three main questions:

"what is the current situation in Gohong?"

"What is the potential of Melaleuca?"

"How can Melaleuca be implemented so that it generates actual benefits and improves the livelihoods of Gohong?"

The following sub questions have been formulated to answer the main questions:

- What is the current social, economic and environmental situation in Gohong?
- Why is Melaleuca not yet being used according to its potential?
- What are the demands of the people of Gohong to support their livelihoods?
- What are the social, economic and environmental potentials of Melaleuca?
- Which other species then Melaleuca are suited to use in a Melaleuca focussed plantation design to improve the livelihoods of Gohong?
- What management activities are necessary for the Melaleuca focussed plantation design?
- What are the suspected costs and benefits of the Melaleuca focussed plantation design plan?

1.6 Project structure

The Melaleuca focussed forest plantation design consists of seven chapters (including the introduction). Chapter two consists of the methods, which explains how the design is formed. Chapter three focusses on the results: answering the research questions. Chapter four contains the program of requirements and vision of the design. Chapter 5 contains the plantation design, which consist of the species selection, a description of the selected species, management activities, expected costs and revenues and the visualisation of the design. Chapter 6 addresses the conclusion, whilst chapter 7 contains the discussion, recommendations and reflection on sustainability.

2. Methods

For a sustainable way of using Melaleuca in combination with other short- and long term income generating species, the development of a plantation forest design is needed. A plantation forest is a cultivated forest ecosystem set up by planting or seeding in the process of reforestation, where the planted trees are also used for economic and environmental purposes (Zhang, et al., 2019). Determining a plantation forest design is a fundamental strategy for supporting the effort of sustainable forest management (Sadono, Dewanto, & Wirabuana, 2021). For the project, a mix of qualitative and quantitative data is needed. Data is collected by literature research, GIS maps, Semi structured interviews and field research. Data of the interviews will be analysed by coding. A schematic overview of the methods is made (see figure 3).

2.1 Literature research

To answer the research questions quantitative data research is needed. Suitable species, information about Melaleuca and economic data such as costs and revenues are existing data and will be gathered by literature research. Literature source selection is done according to the following criteria:

1. Published/ written between 1990 – present
2. Using keywords: Peatland (in combination with Sustainable, Degradation, Restoration, Development, Management, Kalimantan, Indonesia), Melaleuca (in combination with Honey, Species, Peatland), Cajuputi, Peat swamps, Paludiculture, Peat (in combination with Crops, Management, Sustainable, Kalimantan, Indonesia).
3. Source – of – source exploration: exploration of bibliography of the source.

Literature is mostly obtained via documents made available by SFP, Greeni database, Research gate, Peter van der Meer and data made available by the ULM University in Banjarmasin, Kalimantan.

2.2 Interviews

Semi structured one-on-one interviews were conducted by an external acquaintance of Jeroen Knol (SFP social forestry). Interview questions were send to the external acquaintance, where after he/she interviewed the participants on location (Gohong). With semi-structured interviews, open and closed questions can be asked, such as: “what is your opinion regarding more Melaleuca trees planted?” and “How much yield comes from the rice that is currently planted per year?”. The interview answers were translated on the spot to English by the external acquaintance and then send to the report writer. Participants included farmers, rattan workers and other stakeholders. Both women and men were included. Interviews were no longer than one hour to maintain attention span. Interviews couldn’t be recorded due to lack of available materials and because there is was no permission.[1]

[1] The methods deviate from the Plan of approach due to cancelation of the fieldwork trip to Gohong. Methods are adapted to available possibilities.

2.3 Maps

Maps of the current situation (land use, conservation areas) will be derived from SFP social forestry. Data for the maps is obtained via PRIMS. Maps are then made in Arc GIS Maps by the organisation. The zonation map will be made by hand. Existing maps with boundaries of the village are adjusted in CANVA, printed out and the zonation will be drawn in the map by hand. The complete zonation map is then scanned and transferred to the computer.

2.4 Data analysis

All interviews were coded. Coding is the procedure of organizing and labelling qualitative data to identify relationships and themes between them (Medelyan, sd). Coding qualitative data such as semi-structured interviews provides transparency and enables you to find insights that are representative of the data. It also increases the validity of the data analysis by providing organisation and structure to the data. (Delve, sd). Coding interviews require a transcript. Therefore, the interviews are transcribed. Transcription was done by hand in Word. The type of transcription that was done is called intelligent transcription: transcribing every word, but exclude pauses and filler words and clean up the grammar (Delve, sd). The coding of qualitative research (such as the semi-structured interviews) can be done by means of inductive coding, deductive coding or a combination of both. Inductive coding is an approach where the codes are derived from the data. Deductive coding is an approach where you start with the development of a codebook with a set of codes, which can be based on the research questions or an existing theory. By using a combination of both, the researcher starts with a set of codes and comes up with new codes as an addition to the already existing codes (Delve, sd). For the coding of the semi-structured interviews, a combination of inductive and deductive coding was used.

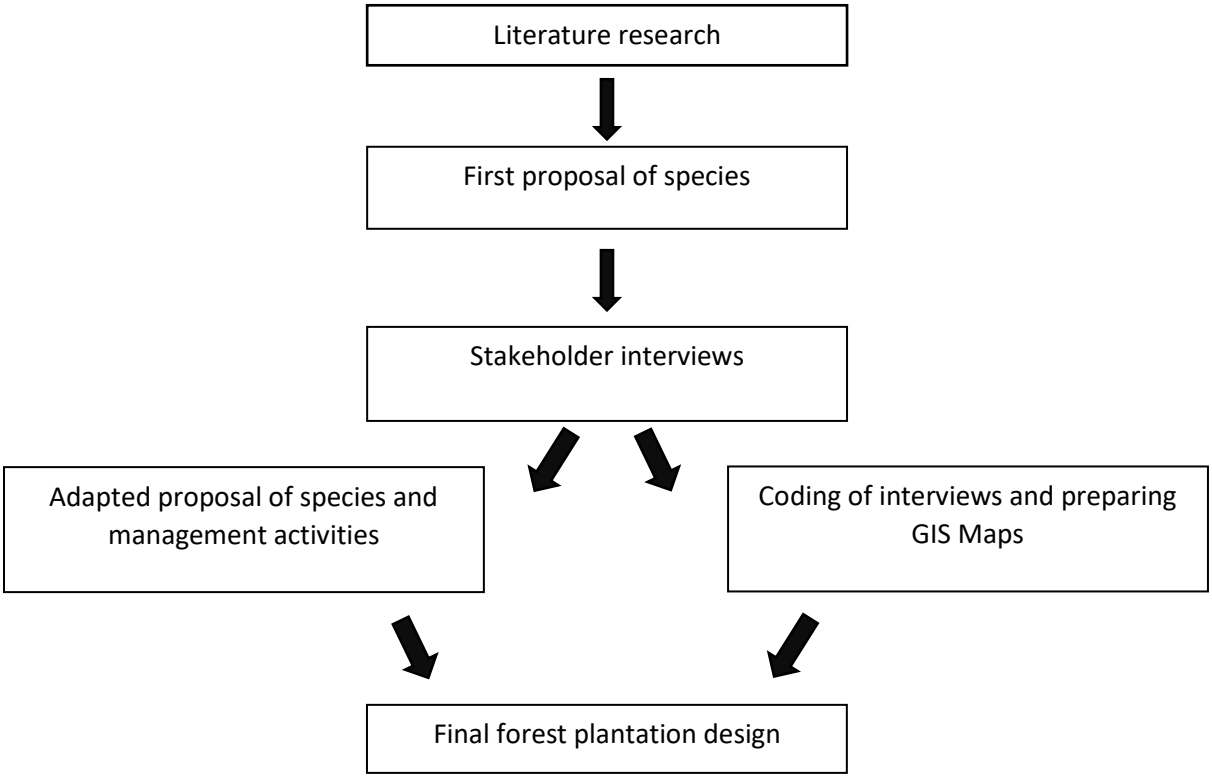

Figure 3: Schematic overview of methods.

3. Results

The results of the literature research and interviews are described in order of the sub questions (see 1.5). First, the current social, economic and environmental situation of Gohong are described. Then, the social, economic and environmental potential of Melaleuca are discussed.

3.1 Current social situation Gohong

The residential area of Gohong is divided into 7 Rukan Tetangga's (RT) (neighbourhoods). In 2017, the population of Gohong consisted of 1050 men and 1107 women. The most dominant ethnicity in Gohong is Dayak Ngaju (Novitasari, Aprisiska, & Cristmastianto, 2018). This is because the indigenous people of the village are ethnic Dayak Ngaju. There are also Balinese and Javanese ethnic groups living in Gohong. The major religions adopted by the people of Gohong are Islam and Christianity.

Livelihoods

The majority of the livelihoods are rubber farmer, plantation and agriculture, stock husbandry and fishery, rattan crafter and traders (Yanto, 2017). For land use the local wisdom (custom traditions) of the residents is still practiced. Local wisdom in the management of natural sources in peatland is used by the community of Gohong for agriculture and plantations, which are used for personal consumption and for external sale. Species such as rubber (*Hevea brasiliensis*) rotan, rice, sengon (*Paraserianthes falcataria*) and Melaleuca (*Melaleuca Spp.*) are planted by the community for own consumption and for sale. According to the respondents of the interviews (see appendix A), vegetables such as tomatoes, eggplants, green beans and lettuce are harvested for own consumption and for sale. Rotan and rice are also important income sources, according to the respondents.

Education

Education is well arranged in Gohong. there is a kindergarten, 2 Elementary schools and a Junior High School. The school enrolment rate (dividing the number of students of a particular age enrolled in these levels of education by the size of the population of that age.) is 92,01% (Novitasari, Aprisiska, & Cristmastianto, 2018). As can be seen in table 1, the higher the educational level, the lower the school enrolment rate.

Table 1:
School enrolment rates per educational level.

Participation rate	Type sex	SD / MI	JUNIOR HIGH SCHOOL / MTS	SENIOR HIGH SCHOOL / MA	College
School participation rate (APS)	Men	100	93,14	71.05	25.52
	Woman	98.26	90.03	49.38	27,21
	Mean	99.05	91.54	62.65	26,18

(Source: (Novitasari, Aprisiska, & Cristmastianto, 2018)

Gender roles

Gender is one of the considerations for determining roles in natural resources management, which is known as gender roles. Here, gender serves to identify differences between men and women in terms of social and cultural aspects, values, and behaviour. The gender roles of men and women can differ per community and has a significant effect on the community structure. Gender roles in a community can be productive roles, reproductive roles and community and political management roles (Marlina, Lautt, Usup, & Sunaryati, 2021). The productive role is the role of men and women to get income, for example working in household production or formal sector. Reproductive roles are related to childcare responsibilities, mostly by women. Community management roles include all activities in the community on a voluntary basis. The political management relates to the role at a formal political level (paid) which increases status or power. Mostly, this role is fulfilled by men.

Reproductive activities in the Kahayan Hilir district are still dominated by women based on community norms such as parenting, cooking and cleaning (Marlina, Lautt, Usup, & Sunaryati, 2021). There is still strong segregation in perceiving roles in the family (Marlina, Lautt, Usup, & Sunaryati, 2021). For example, domestic roles related to heavy work are perceived as masculine roles.

Gender roles are also affected by land use change, for example the impact of palm oil plantations. According to Bowman (2020), women are especially negatively impacted by palm oil development, because they have unequal access to land, resources and opportunities. because palm oil companies are able to acquire government permits to develop land, a shift in land claiming within communities was created: from local elders to state control. Because the state views women as dependents of their husbands, meaning often only the husband's name is on the land title, this has a direct consequence for women: women cannot reclaim land if their husband dies. This is one example on how land use change affects gender roles in communities in Indonesia nowadays.

Government

The formation of the government of Gohong is stipulated by the Regency. The structure of the village government includes the village head, village secretary and the head of affairs (administration, finance, development, governance and welfare). The village government carries out village household affairs, government affairs, development and community development and has the duty to operate according to the provincial and/ or district government. In 2016, Yanto L. Adam became the head of the village. The head of the village plays an active role in social and religious activity, as well as political activity. Yanto L. Adam is also the chairman of the Institution Manager Village Forest (LPHD). This institution has the aim to protect forest areas and sustainable forest communities in the village (Novitasari, Aprisiska, & Cristmastianto, 2018). The village secretary is tasked with assisting the Village head to prepare and carrying out the administrative management of the village and preparing reports on the implementation of the village government. The head of affairs carries out tasks related to their subject, such as governance, welfare or development.

BUMDes

An important organisation in Gohong is the BUMDes Hantantiring, formed in 2017 by the Gohong Village Government. In Indonesia, BUMDes (Badan Usaha Milik Desa) refers to Village-Owned Enterprises. These are business entities that are owned and managed by rural villages or local communities. BUMDes are established with the aim of improving the socio-economic conditions of the village and its residents (Novitasari, Aprisiska, & Cristmastianto, 2018).

BUMDes are pillars of economic activity in the village that serve as a social institution and commercial institution (Srirejeki, 2018). It also serves as a social purpose by providing financial transfers to the village treasury and it facilitates coaching and business companionships by the village community (Knol, 2023). BUMDes aims to improve the residents' standard of living and well-being. They can engage in various types of businesses and activities based on the specific needs and resources of the village. Some common examples include agricultural cooperatives, tourism ventures, handicraft production, microfinance services, and small-scale manufacturing.

The chairman of the BUMDes in Gohong is Mr. Suryadi. Business units of BUMDes Hantantiring in Gohong are tent renting, increasing marketing capacity and revitalizing wicker craft culture with Rattan crafts and Forest honey (Melaleuca). According to data obtained by SFP Social Forestry (J. Knol, personal communication, April 1, 2023), no one in the organisation has an entrepreneurial spirit yet and the organisation hasn't been able to make optimal use of local resources yet. The management is also not very cooperative and not able to prepare a business plan. Therefore, the organisation has a lot of improvement points.

3.2 Current economic situation Gohong

Gohong has its own village budget. At least 70% of the total village budget is used to fund the village administration, village community development, implementation of village development and village community empowerment. 30% of the total village budget is used to fund activities such as payment and health insurances for the village head and village officials, operational government and finance for the neighbourhoods (Novitasari, Aprisiska, & Cristmastianto, 2018).

Livelihood types

Income for people of Gohong comes from various types of livelihoods such as agriculture and non-agriculture. Below the most important types of livelihoods in Gohong, according to respondents.

Agriculture: This is the main livelihood of the people of Gohong. Farmers and farm labourers utilize 302 ha of land to grow rice, cassava, corn and other products, and 600 ha of paddy fields (see figure 4). Most agricultural products are used for daily needs. According to respondent 8, 9 and 10, most planted vegetables are green beans, tomatoes and eggplants. Rice is also mentioned as an important product to sell.

Plantation: Rubber, sengon, oil palm and fruits such as durian, cempedak, rambutan and mango are planted in plantations. The plantation land in Gohong is about 10.207 Ha. According to Novitasari, Aprisiska, & Cristmastianto (2018), the plantation sector can generate 400.000 IDR /week (in 2017). The marketing is done through middleman. According to respondent 1, rubber is an important income source for the family.

Fishery: Maintenance, cultivation and catching of fish in Gohong is carried out in rivers and ponds. Harvest of fish is carried out every six months. Sales are made directly to a middleman. Fishery products from the river can generate 100.000 IDR per catch. Fishery is done with the use of tampirai and nets. Tampirai is a traditional fishing tool, that looks like a basket that is put in the water.

Village forest: Income from the Village forest consists of income from wood (Melaleuca poles) and NTFP's (Non-Timber Forest Products) such as durian and rambutan.

Livestock: Livestock in Gohong consists of chicken and pigs.

Rattan crafting: The household industry in Gohong is mostly carried out by women. The main craft is woven rattan. Rattan is obtained from the garden or bought from sellers of raw materials. Men mostly do the hard work such as harvesting and transporting the Rattan. Women process the raw material of rattan into handicrafts such as bags, hats and baskets. The income of the craftsmen per week is uncertain, because it depends on the buyer's orders. It can be 200.000 – 300.000 IDR/week. According to respondent 10, first the income from rattan crafts were 5.000.000 IDR/month. Now it is only 2.900.000 IDR/month, due to less tourists (less sales). Other small industries in the village are people who become mechanics, sew handyman or stone craftsman. Other people become and employee of a private company.

Trading: trading provides groceries as well as supply and distribution of drinking water. Trading offers a result of around 1.000.000 IDR, net per month. Obstacles for traders is the rainy season. Most people that trade are rubber tappers. During heavy rain it is impossible to tap the rubber, so there is less to trade.

Service sector: the service sector of livelihoods in Gohong consists of people that become civil servants, midwives, teachers, bus drivers and consulting services. The salary for services depends on the type of service and class. For example, the salary of a civil servant is 2.890.500 IDR per month. Many people in the village have side jobs apart from their main livelihood.

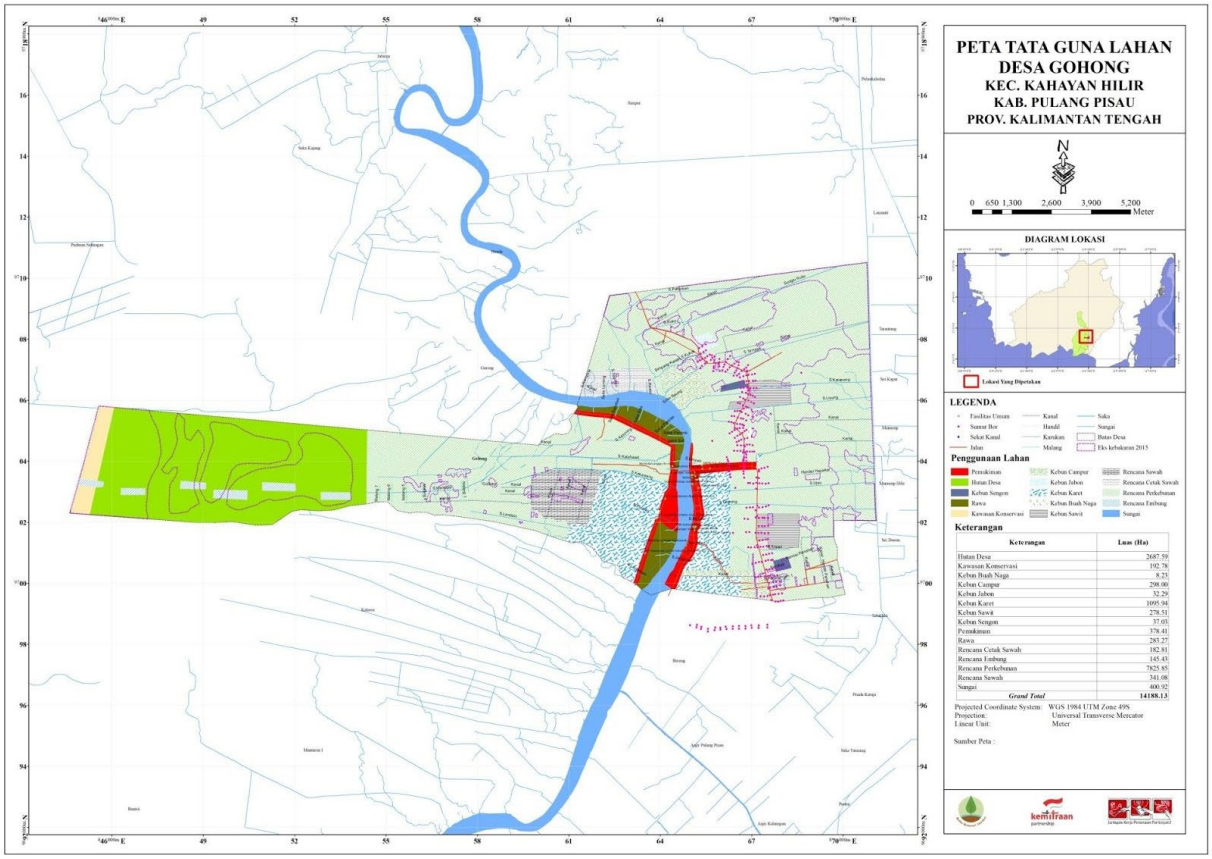

Figure 4: Land use map of Gohong, Central Kalimantan, Indonesia (Novitasari, Aprisiska, & Cristmastianto, 2018).

Average income

Based on the average income level of the Gohong community of the livelihood sectors, the average income per month is 1.000.000 IDR ((Novitasari, Aprisiska, & Cristmastianto, 2018). P71) If we look at the income of the respondents interviewed, we can see that income differs greatly between families in the village. The lowest income mentioned by a respondent was 1.800.000 IDR/month, whilst the highest income mentioned by a respondent was 8.776.000 IDR/month. However, the value of money fluctuates over time and is related to historic events, such as the COVID pandemic. 1.000.000 IDR could have had more value in 2018 then 1.800.000 has now (2023).

The average total profit of respondents from Long Beluah Village in North Kalimantan (agroforestry revenues and non-agroforestry revenues minus the costs) was 38.740.462 IDR/year (Putra, Rujehan, Sardjono, Matius, & Ahyauddin, 2021). This is a profit of 3.228.372 IDR/month. This average income/month is more than double the average income of the people of Gohong (except for outliers like the income mentioned above), meaning that the income level in Gohong is relatively low. Improvement in livelihoods is therefore important.

Income constrains

Several respondents mentioned constrains regarding income. The most important constrain mentioned was that income is not stable in the village. Too much rain means it is difficult to grow vegetables. Income from Rattan crafts is very dependent on the amount of tourists that visit the village. Another problem mentioned is health. Hospital costs are very expensive and can therefore have a great impact on the income of a family. The hospital is also more than an hour drive by motorcycle.

The average annual production in the village is also uncertain because it depends on the yield of the annual harvest, which depends on nature. The benefits of superior commodities (like rubber) for residents is that they fulfil their daily lives needs on short term. However, for plants with a long growth period like Sengon, a long term income is generated because it could only produce in 4-5 years. During the dry season, fires and pests negatively affect crops and other products.

Obstacles in the Maintenance, Processing and Marketing in Gohong are also present. The land of Gohong has a lot of potential and not all options have yet been explored even though there are many potential natural resources available. Another obstacle is the fluctuation of market prices. During the main harvest, prices of rice often drop drastically. The land clearing regulations about rice cultivation without burning the land also have impact, because they still haven't found new effective methods for planting rice without burning.

3.3 Current environmental situation Gohong

The current environmental situation of Gohong is related to the overall environmental situation of Central Kalimantan and the Pulang Pisau Regency. It is therefore important to first look at the current environmental situation of Central Kalimantan and the Pulang Pisau Regency, before looking at the situation in Gohong.

Central Kalimantan and Pulang Pisau Regency

Central Kalimantan is a province of Kalimantan, the Indonesian part of Borneo. It has a tropical rainforest climate, with an average rainfall of about 125 mm per month, which is 1500 mm per year precipitation. the temperature ranges from 21 – 36 degrees Celsius.

Pulang Pisau Regency is one of the thirteen regencies in the Central Kalimantan province. The Pulang Pisau Regency is divided into 2 regions, the highlands and lowlands. The northern part has a height of 50-100m above sea level, a hilly area. The southern part is lowlands consisting of beaches/coasts and swamps, with a high flood intensity. The Pulang Pisau Regency is located on two tropical peat domes, peatland in a characteristic dome shape and formed between two rivers or stream channels (thornton, Page, Green, Cook, & Wright). These peatlands cover more than 60% of the district area including peat swamp forests (Novitasari, Aprisiska, & Cristmastianto, 2018).

According to the peat distribution map from the Plantation and Forestry Office of Pulang Pisau Regency, Central Kalimantan Province, it can be seen that almost all sub-districts in Pulang Pisau have a thickness of 1 to 4 meters, including the peat ecosystem in Gohong Village. According to Pantau Gambut (2023), the criteria of peat depth is as follows: shallow peat 50–100 cm, medium peat 100–200 cm, deep peat 200–200 cm and very deep peat >300 cm. Therefore, the area consists of shallow, medium -, deep -, and very deep peat.

Peatlands in Gohong

The location of Gohong is a non-coastal lowland area with an altitude of 10-50 meters above sea level. The area of Gohong is mostly peat soil, with a few places consisting of mineral soil. The area of Gohong is ± 51.037 Ha. The area of peat land in Gohong is ± 60% of the total area of the village, which equivalents with 30.622 Ha (Novitasari, Aprisiska, & Cristmastianto, 2018). The peat depth in Gohong ranges from thin peat with a depth of 50 cm to deep peat with a thickness of over 300cm. While the Village forest area of 3155 hectares has a thick peat soil, all other types of land use have a peat soil or mineral soil (*see table 3)*.

Table 3:
Type Land/soil in Gohong Based on Land use type.

Type Space Mastery	Large Land	Type Land / Soil
Soil village treasury	2.0 Ha	Peat thin and mineral
Complex hall village/ village office	0.5 Ha	Peat thin and mineral
Soil grave (Muslim, Christian)	3.0 Ha	Peat thin and mineral
Community farming	600.0 Ha	Peat thin and mineral
Plantation	10,207.0 Ha	Peat thin and mineral
yard	7705.0 Ha	Peat thin and mineral
Forest Village	3155.0 Ha	Peat thick

Source : (Novitasari, Aprisiska, & Cristmastianto, 2018)

Peatland degradation

After 1967, human activities such as land clearing by burning land became a much higher threat to the existence of peatland and peat swamp forests. This also threatens the endemic fauna such as gibbons, black eagles and the Orang-Utan. Peat fires also caused the decline in many assets like rattan and sengon. The fires in 2015 (Mega Rice Project) were the biggest fires in the region. From 1987 to 2017 there was also a decline in use of rubber, rice and cempedak. The decrease in rice use was due to the ban on clearing land by burning. Land clearing by burning land caused an increased potential for fires and was therefore banned. The habit of people in clearing land by burning it existed because they assumed that by burning the land the soil fertility would increase. This was banned and therefore not possible anymore, so the cultivation of rice decreased. Decline in rubber was caused by fires and a drop of cempedak use was due to felling of trees for building materials (Novitasari, Aprisiska, & Cristmastianto, 2018).

The peatlands are currently still under threat due to land-use change, drainage and climate change (Roucoux, et al., 2017). A good example of the effect of land-use change on peatland is the conversion of peatlands to agriculture. To converse peatland to agricultural land, drainage is needed. drainage of peatland causes the peat body to undergo enhanced decay, compaction and oxidation (Moore et al, 2013, as cited in (Roucoux, et al., 2017). This way, peatland becomes vulnerable to increased droughts and fires associated with climate change.

Since the peat fires in 2015, the area of Gohong is still in the recovery stage. The community has re-planted rubber and Sengon. In 2016 and 2017, the Peat Restoration Agency built drilled wells in Gohong to restore the hydrology of the peatland. They also funded canal blocks, built by community groups. These measures were taken to increase the water holding capacity to prevent the peat from becoming dry and highly flammable. The area is also divided into conservation area, protected forest and production forest (see figure 5).

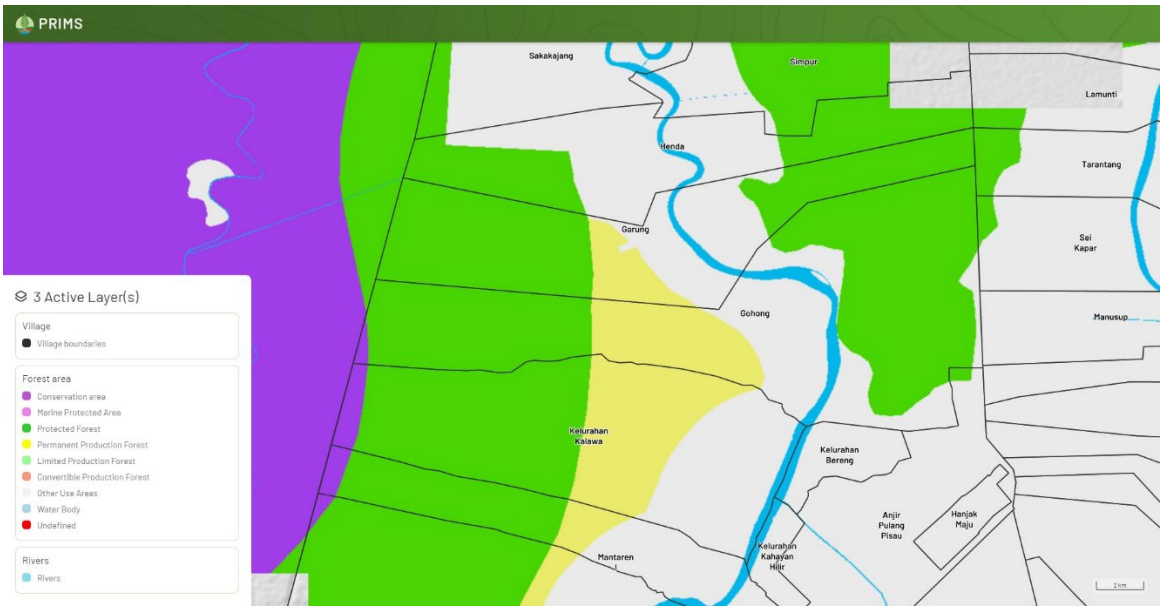

Figure 5: Forest areas in Kahayan Hilir district, Central Kalimantan, Indonesia (PRIMS).

The suitability of species depends on the land characteristics in the area such as soil type, peat depth and duration of flooding during the rainy season. The land characteristics in Gohong are highly influenced by the river. The land is also relatively fertile because of flood runoff. Close to the river, the land is generally mineral soil. further away from the riverbank, the land turns to peat. The further away from the riverbank, the thicker the peat is. The type of plants selected in agroforestry systems in Central Kalimantan is adjusted to the depth of peat (Rotinsulu, et al., 2022).

Paludiculture

Currently, most species that are cultivated on peatland in Indonesia are dryland species, such as rubber, durian and mango. These all require at least 40 cm or more drainage (Giesen, 2021). The cultivation of these species provide a steady income on peatland, but this will disappear when peat can no longer be drained by gravity and waterlogging becomes an issue. Therefore, it is more sustainable to select species that can thrive in wet peatland without drainage: paludiculture species. Paludiculture is defined as the cultivation of economically beneficial peat swamp adaptive species on wet or rewetted peatland, with near natural ground water levels. In Indonesia, there is a lot of misconception about the term paludiculture. It has been wrongly used to describe all forms of cultivation on peatland, including drained peatland agriculture, which involves dryland species as describe above (Giesen, 2021). True paludiculture has rarely been tried in Indonesia. Lack of paludiculture in Indonesia is caused by the fact that dryland species are trusted by local communities, there are not enough examples of paludiculture for farmers to copy and there is insufficient information about the paludiculture species. The potential for paludiculture in Indonesia is high, according to (Giesen, 2015). 81 NTFP species have a major economic use, according to (Giesen & Sari, 2018).

3.4 Economic potential of Melaleuca

Melaleuca is a versatile species and produces a number of highly desirable commercial products. There is lots of market potential for Melaleuca in the form of non-timber forest products (NTFP's) such as cajuput oil and Honey, but it can also be used in the pulp- and paper industry. The wood of Melaleuca has also excellent characteristics. Melaleuca can provide economic opportunities for the local community.

Essential oils

Etheric oils can be derived from the leaves of Melaleuca. These essential oils have medicinal characteristics and can be used as treatment of coughs and colds, asthma and is used as insect repellent. According to studies of Manurung (2015), cajuput oil production from Melaleuca spp. on degrade peatlands in Central Kalimantan has a significant potential. The market potential for cajuput oil is also high. In 2018, there was a big shortage of Melaleuca oil and honey production in Indonesia, compared to the demand (see table 4). The shortage was imported (Giesen & Sari, 2018). Thus, a market gap can be filled here by meeting the needs of the cajuput oil market.

Table 4:
Melaleuca cajuputi oil and honey demand and production in 2018.

	Internal Indonesian demand (ton/year)	**Produced (ton/year)**	**Shortage (ton/year)**
Oil	1500	450-500	1000 - 1050
Honey	7500	2000-4000	3500 - 5500

Source: (Giesen & Sari, 2018)

In Indonesian plantations Melaleuca trees are allowed to grow for 4 years after planting. At the first harvest, the trees are pruned 1m above the ground. After that, leaves can be harvested every 6-9 months. Essential oil from Melaleuca has a high potential income (see table 5) and is an attractive revenue to improve the livelihoods of people around the peatland. But, a lack of cajuput oil supply is related to the source of raw materials (Rimbawanto, Kartikawati, & Prastyono, 2022). The cajuput stands in Indonesia (Java and Maluku) are of low productivity, caused by low plant quality and a not optimal crop cultivation. To get an increase in production of Melaleuca essential oil, there need to be invested in plant quality and optimizing crop cultivation. The use of superior seeds by selection of superior individuals of plants will help increase stand productivity (Rimbawanto, Kartikawati, & Prastyono, 2022).

Table 5:
Melaleuca oil income potential.

Harvest (ton/ha/year)	**Amount of oil (kg)**	**Oil price (USD/kg)**	**Revenue (USD/year)**
7,5 ton	86,4 kg	16 USD	1382,40 USD

Source: (Widiana, Taufikurahman, Limin, & Manurung, 2015) *and* (Widiana, Taufikurahman, Limin, & Manurung, 2015)

Pulp- and paper industry

Melaleuca wood can also be used in the pulp- and paper industries. In 2016, the pulp and paper company Asia Pulp and Paper conducted trials with alternative species for *Acacia crassicarpa* in rewetted peat (Giesen & Sari, 2018). They planted four species of which *Melaleuca cajuputi* seemed the most promising species in terms of growth rate and pulping properties (APP, 2017, as cited in (Giesen & Sari, 2018).

But, large scale pulp plantations are associated with many cases of deforestation of peat swamp forest in South-East Asia. Peat swamp forests are cleared and drained for pulp plantations, which has important repercussions for hydrology and water management and local income. Alternatives are small scale crop systems with pulp and timber production. Melaleuca can hereby be used for the production of timber (poles) with the leftovers being used for pulp, in combination with for example Geronggang (*Cratoxylon arborescens*) for pulp production (van der Meer & Karyanto, 2013).

Wood

Gelam poles (Melaleuca spp.) are mostly used for construction. Thicker trunks are used for sawn timber and high quality fuel wood. Wood of gelam is durable under wet conditions. The wood of Melaleuca is hardwood. Once production systems have been established on peat, one needs to consider adopting a low impact means of harvesting gelam poles. Clear-felling of areas is to be avoided as this will lead to desiccation of peat, and subsequent subsidence and a much increased fire risk. This can be mitigated to some degree by planting mixed age stands and selectively felling older specimens, or by felling alternate rows or small blocks (<5x5m) (Giesen, 2015).

Figure 6: Pak Henri Sournantono from Gohong with gelam poles. Source: SFP Social Forestry.

Melaleuca Honey

Melaleuca honey is a monofloral honey, produced from *Melaleuca cajuputi*. Melaleuca flowers produce good quality honey and are favoured by honeybees. Melaleuca flowers abundantly all-year round and produces large amount of nectar, which makes it an ideal host species for bees. 5-6 litres of honey can be harvested per ha of honey per year (Giesen & Sari, 2018). The honey of the Melaleuca tree (mainly from the migratory Asian Giant Bee, Apis dorsata) is collected by smallholder beekeepers (SFP). Honey is collected during two major seasons, each nest being cropped 3-4 times per season the first harvest is done three weeks after the observed first arrival of the colony, followed by the next harvest after a two-week interval.

Production quantities

The amount of honey that a Melaleuca tree can produce varies widely and is dependent on factors such as size and age of the tree, the abundance of nectar and weather conditions. The yield per harvest per tree is about 4kg of honey per year (Giesen & Sari, 2018). Areas where Melaleuca can be managed sustainably on shallow peat, or on deep peat inside protected zones are highly compatible with honey production and this is an enterprise that can involve the local community with minimal time inputs (Applegate, Freeman, Tular, Sitadevi, & Jessup, 2021). There are 2 honey production systems: wild honey or honey from apiculture. Beekeeping has relatively low establishment costs (approximately 100 USD per hive and 60 USD per hive for annual maintenance) and requires only a small area of land to locate the hives with minimal manual inputs. 11-20 kg of honey can be produced per hive during a season (Jeroen Knol, personal communication). With an average price of 175.ooo IDR/kg of honey, the average income per household/season from Melaleuca honey can be as high as 3206,18 USD (see table 6). Melaleuca also has co-benefits for the honey industry as it flowers at different times throughout the year, enabling honey production through apiculture and collection of wild honey. Indonesia is a net importer of honey, so there is potential for locally produced honey (van der Meer, et al., 2021).

Table 6:
Average income from Melaleuca honey in Indonesia.

Harvest of honey (kg/hive/season)	Average amount of hives/ household	Price of Melaleuca honey (IDR/kg)	Price of Melaleuca honey (USD/kg)	Average income per household per season (USD)
15,5 kg	17,5	175.000 IDR	11,81 USD	3206,18 USD

Source: (Social Forestry Program , 2023) and (van der Meer, et al., 2021)

Rafter beekeeping as a sustainable harvest option

The giant honey bee (*Apis dorsata F*) is a single-comb open-nesting specie of honey bee, distributed in southern Asia. The colonies are very defensive and demonstrate seasonal migration. That's why domestication of this species is thought to be almost impossible (Guerin, 2019). However, in several locations in Southeast Asia, locals have used rafters in order to attract migrating giant honey bees. Rafters are tree-poles positioned at a slight angle and low to the ground, supported by two vertical poles, that are placed to mimic tree branches. It attracts the giant honey bee to build a nest underneath the pole. This traditional practice allows beekeepers to harvest two or three times from the same colony per season without harming the bees (WWF, 2019). The rafters also allow much safer honey harvesting, because they are placed near the ground. Therefore, risking the high climb up to the colony nesting far off the ground is not necessary anymore. Because the giant honey bee usually establishes its single-comb colony high up in tall trees, rafter beekeeping is particularly adapted to areas where the only suitable nesting sites for the bees are the rafters itself. For rafter beekeeping to be sustainable, a sense of ownership and clarity on land tenure must be present that is enforced by surrounding communities. Rafter honey can be sold at a high price due to its bee-friendly harvesting and because it is organic. Harvest can take place 20-30 days after the bees settled on the rafter, and a second harvest 1 month later. It is usually possible to harvest two or three times from 1 colony ((Guerin, 2019).

Honey production in Pulang Pisau region

Taruna, and Tumbang Nusa (Pulang Pisau) are already villages known as centers of natural honeybee production in Central Kalimantan (Hakim, et al., 2020). Here, harvesting of honey is only done once a year, in the rainy season from November to January. After the honey is harvested, most of the honey is sold directly without being processed, because the consumers are more trustful of the authenticity with direct sales. Only a small portion is filtered for personal purposes (Hakim, et al., 2020). Because of the high fluctuation in prices for NTFP's, a NTFP-only based income source is questionable for a sustainable livelihood. It is better to combine NTFP's with timber products or agricultural crops (fruits etc.).

3.5 Social potential of Melaleuca

Melaleuca has the potential to positively influence social aspect of livelihoods, such as health, income, and resource management:

Employment and income: The sustainable production of Melaleuca honey, oil and wood can provide a new source of income for the community. Melaleuca planting can provide employment and improve the welfare of the community around the forest by active participation of the community in future cajuput oil businesses for example. Therefore, it is a species suitable to be developed to create jobs and reduce poverty (Ermawati, Syaufina, & Hariyadi, 2021). By providing income from the different products of Melaleuca (in combination with other suitable species) livelihoods can be improved.

Health benefits: For many years Indonesian people are familiar with cajuput oil and use it to overcome mild health problems. It is proven that Melaleuca oil and honey have positive health benefits such as wound healing properties (Rozaini, Zuki, Noordin, Norimah, & Nazrul Hakim, 2005), antioxidant and antimicrobial (Puvača, Čabarkapa, Bursić, Petrović, & Aćimović, 2018). The consumption of Melaleuca honey and the use of its oils can therefore contribute to improving the health of the community.

Resource management: The sustainable management of Melaleuca is part of the management of the owned resources for long term sustainability. By sustainable management of the community, loss of resources can be prevented.

Community interest Melaleuca

According to the outcomes of the interviews, many respondents were not familiar with Melaleuca. Therefore, they were also not able to answer the question why Melaleuca is not yet used according to its potential. Lack of knowledge about the species was the most common reason for people not to use the species as an income opportunity. However, some respondents were familiar with Melaleuca used as furniture, building wood for houses and some were even familiar with the honey and its positive health effects. Respondent 10 said: ": I want to learn about the cajuputi tree, because there are many forests. Maybe we can sell the honey in the city (Palangkaraya)." Many respondents were open to an introduction of using Melaleuca to increase revenues in their village, even if they were not yet familiar with the species. Respondent 9 even mentioned: "I am too old, but I think the villagers should learn about the Melaleuca. Not many trees can grow here, but Melaleuca can." This shows that there is already an interest in the species. Respondent 11 mentioned that she "likes to learn about the honey because it is not a hard job" and "many people like honey and it is also healthy".

3.6 Environmental potential of Melaleuca

Apart from a plantation in Central Java, Melaleuca is known in Indonesia from natural stands only (Giesen, 2015). The natural stands are in disturbed coastal habitats and occur in shallow to moderately deep peatland. Melaleuca trees can grow in very moist and saline conditions and are exceptional resilient trees. They can withstand frequent flooding and acidic soils, but also brackish conditions. Melaleuca also survives small fires fairly well (Graham L. L., 2009). It is able to re-sprout from the base of the trunk after a fire and seeds can germinate after fires. Melaleuca is considered a pioneer species, colonizing the new habitat created by disturbance such as fires (Giesen, 2015). It is a fast growing species and is therefore often found in disturbed areas and/or revegetated peatland. These Melaleuca wetlands provide significant environmental ecosystems services, including protection of peat, soil and water resources, provisioning of habitats for flora and fauna and climate change mitigation by its capacity in storage of large carbon stock (Dang, Reid, & Kumar, 2023).

Peatlands are a significant source of greenhouse gas emissions, especially when they are drained or degraded. A sustainable Melaleuca focussed plantation design can help reduce emissions by promoting responsible land use and management activities. Melaleuca helps to rehabilitate degraded peatlands and if managed sustainably, it will also reduce peat fires resulting in less smoke and haze (UN-REDD programme, 2022). By promoting a melaleuca focussed plantation design, the restoration of degraded peatlands can be stimulated whiles also providing economic benefits for the community. A combination of timber and non-timber forest products from melaleuca helps to make the plantation design sustainable and helps to conserve the peatlands. Additionally, for sustainable livelihoods a combination of short- and long term income is needed. Thus, other species that can be combined with Melaleuca should be considered. The example from the Mekong Delta ((Giesen, 2015)) shows that multiple products can be derived from Melaleuca paludiculture stands. It is also possible to intercrop other species with rows of Melaleuca, as the species does not provide much shade and does not compete strongly for light (Giesen, 2015).

3.7 Discussion of results

On the basis of the literature research and interview, the results have been collected. These results form the basis of the plantation design. Due to a deviation from the original methods of the Plan of Approach, not all sub questions could be answered. To answer sub question “Why is Melaleuca not yet being used according to its potential?”, interviews were conducted. But, due to the fact that the interview was conducted by an external acquaintance in a short time span, the answers of the respondents were not as extensive as expected. Respondents were reluctant in providing information and opinions.

Other results show that the current social, economic and environmental situation in Gohong are not optimal and can use a lot of improvement. The potential of Melaleuca is high: Melaleuca has multiple uses like honey production and can provide a new source of income and employment in the village. Melaleuca also helps to rehabilitate degraded peatlands. Melaleuca can therefore be implemented to improve the social, economic and environmental situation of the community in Gohong. For a sustainable plantation design, a combination of short- and long term income is necessary. Therefore, Melaleuca can be combined with other potential species (both short- and long term) to improve the livelihoods. Because the community in Gohong relies not only on native peatland species but more on dryland species, a combination of both is preferred for the plantation design to meet the demands of the community. For a sustainable plantation design that helps the community to manage the village forest resources for long-term sustainability, sustainable management activities are needed.

4. Program of requirements and vision

With the results from the literature research and the interviews and in collaboration with the requirements of the commissioner the program of requirements has been drawn up. The program of requirements leads to a vision for the plantation forest design. With the program of requirements and the vision, a design for a plantation forest is made.

4.1 Program of requirements

The program of requirements consists of demands and wishes for the forest plantation design drawn up by the commissioner and other involved parties such as the community of Gohong. These include demands and wishes regarding the species selection, economic, social and environmental impact of the design but also the outlines of the design itself. The demands and wishes of the commissioner arise from the sub questions that the commissioner wants answered (see chapter 1.5) and include social, environmental, economic and overall demands and wishes. For the commissioner, it is also important that the design aligns to the project of SFP and therefore includes Melaleuca honey as income generating product. The demands and wishes of the community mostly arise from the need of a stable economic situation and improve livelihoods. The following requirements have been drawn up in collaboration with the commissioner:

Table 7:
Program of requirements for a sustainable forest plantation design for Gohong, Central Kalimantan, Indonesia.

Sub question	Requirement	Criteria
Demand of commissioner: environmental	Reduce negative impact on peatland of the management activities	Implementation of RIL
Demand of commissioner: Melaleuca	Include Melaleuca in the forest plantation design, including honey	At least 2 income sources from Melaleuca including honey
Demand of commissioner: environmental	The plan must successfully contribute to the rehabilitation of degraded peatlands	Use at least 3 paludiculture specie including Melaleuca
Demand of commissioner: social	The selected species and management activities must be in line with the skills and ability of the community to apply these	The design is adjusted to the ability and available skills of the community and includes a description of the management activities and selected species
Demand of commissioner: social	Gain trust of the community for the implementation of a design that includes paludiculture species and new Melaleuca products	Include a description of all positive properties of the selected species. conclusion contains all positive impacts of the design

Demand of commissioner: outlines	The design is made for the area of the village Gohong	The design is drawn up for the area of Gohong, including the village forest, river side and houses/gardens
Economic situation	Improve the current economic situation of the community	A combination of short- and long term income generating species
Demand of community: economic	To have a short term income source for subsistence use	At least two short term income generating species
Demand of community: social	Take into account the existing challenges in livelihoods	Increase knowledge and confidence by including a description of all selected species and management activities. Adjust recommendations by including further research and community engagement in the future
Additional species	Species selection dependent on if they are dryland or paludiculture species, dryland species are important for the community	Both dryland and paludiculture species are used for the design

4.2 Vision

Following extensive literature research, interviews and the establishment of a program of requirements, the forest plantation design envisions a sustainable approach with a primary focus on Melaleuca. This design combines both short- and long term income generating species, including Melaleuca. By integrating dryland species as per the community demand and paludiculture species to safeguard the peatlands and prevent further degradation, the design effectively contributes to the preservation of peatland and the conservation of natural resources for long-term sustainability. Simultaneously, it enhances the community's livelihoods in Gohong without disregarding their wishes. By utilising various products derived from Melaleuca, notably honey, the design capitalises on the species' full economic, social and environmental potential.

This multifaceted approach not only addresses the community's lack of trust in melaleuca but also introduces new sustainable revenue options, such as paludiculture species, creating a greater sense of confidence within the community while promoting their knowledge and understanding.

Furthermore, the design includes management recommendations and activities aimed at minimising negative impacts on the peatland ecosystem and to offer guidance on the recommended use of the selected species in the design.

Overall, the vision for the forest plantation design encompasses a community-based approach that leverages the unique qualities of melaleuca and other species. It emphasises sustainability, peatland preservation, resource conservation, community empowerment, and knowledge enhancement, while also providing practical management guidelines to mitigate negative environmental impacts.

5. Plantation design

Chapter 5 includes the species selection for the plantation design, a description of the selected species, management activities and expected costs and benefits.

5.1 Species selection

A combination of timber and non-timber forest products from melaleuca helps to make the plantation design sustainable and helps to conserve the peatlands. Additionally, for sustainable livelihoods a combination of short- and long term income is needed. Paludiculture species will be selected. As aforementioned, currently most of the species used in Gohong are dryland species. These species are trusted by the community. It is therefore important to also select an amount of these dryland species next to paludiculture species, to have the possibility to combine paludiculture species with dryland species already known by the community in the final design.

5.1.1 Species selection criteria

To determine the suitability of the species, criteria were determined based on a combination of interviews and literature research (see table 8). Factors such as climate, availability, and commercial potential are also included. The species are given a grade for each criteria. Grading is done with – and +, with a minimum of - - - and a maximum of + + +. The – refers to a negative effect on the criteria and + refers to a positive effect on the criteria. +/- is used when there is no clear positive or negative effect. For the total grading, the grading represents the following: - - - (-3), - - (-2), - (-1), +/- (0), + (1), + + (2), + + + (3).

Some criteria appeared to be more important for the community than others, according to the interviews. The importance of the criteria is given as high, medium or low (see table 8), and effects the grade given to each species as follows: high = x3, medium = x2, low = x1.

Table 8:
Selection criteria for species selection and importance per criteria.

No.	Factor	Criteria	Importance
1.	Weather tolerance	Plant must be able to survive floods during rainy season. Species is tolerant to different circumstances.	Medium
2.	Subsistence potential	The species can meet the subsistence needs of the family/ community.	High
3.	Maintenance and labour	Low to medium maintenance and labour input needed.	Medium

4.	Availability	The availability of seeds/seedlings of the species is medium to high.	Medium
5.	Commercial potential	The species is marketable and has a profitable product.	Medium
6.	Environmental impact	Minimal environmental impact. Does not disturb the peatlands.	High
8.	Site suitability	Plant is suitable for growing on the peatland in Gohong.	High

5.1.2 Selected species

Based on the literature research and interviews, a pre-selection of paludiculture species is done (see appendix B). Further selection is done based on the selection criteria (see table 8). Four paludiculture species have been selected for the forest plantation design. As can be seen in in table 9, Melaleuca has the highest rating. This is the result of the high tolerance of the species and the fact that Melaleuca is a species that helps to rehabilitate degraded peatlands. It has also multiple economic uses and high economic potential. Therefore, the species scores high on criteria such as “weather tolerance”, “Commercial potential” and “Environmental impact”. Sago, jelutung and purun are the next highest rated species. They do score lower than Melaleuca. Sago needs lots of maintenance and is labour but can be intercropped with eggplant because the Sago does not suppress eggplant growth and vice versa (Zuhro & Bintoro Djoefie, 2020). Jelutung scores lower in commercial potential because currently there are too few buyers to avoid price setting and not enough product supply to attract new traders into markets (Houweling , 2017). They do have potential to provide economic benefits to local communities and to minimize environmental degradation. Purun needs more maintenance, has less commercial potential and does not have the same positive environmental impact as Melaleuca (BRON). Purun is suitable for shallow to deep peat (van der Meer, et al., 2021), resulting in a high score on criteria “site suitability”. Commercial potential is low: it is a quick gain species used for handicrafts. Therefore, subsistence potential is high. Kangkong has a too limited market and rambutan needs regular fertilization and grows better on mineral soil then peatlands (Sakuntaladewi, et al., 2022). Therefore, they have the lowest rating in the species selection (see table 9).

Table 9:
Paludiculture species selection.

Criteria → / Species ↓	Weather tolerance	Subsistence potential	Maintenance and labour	Availability	Commercial potential	Environmental impact	Long term or short term income	Site suitability	Species selection rating
Melaleuca (*Melaleuca cajuputi*)	+ + +	+ +	+	+ +	+ + +	+ + +	Long term	+ + +	42
Sago *(Metroxylon sagu)*	+ + +	+ +	_ _	+ +	+ + +	+ +	Long term	+ +	30
Jelutung *(Dyera polyphylla)*	+ +	+ + +	+ +	+ +	+	+ +	Long term	+ + +	38
Purun *(Lepironia articulate)*	+ +	+ + +	+	+ +	+	+	Short term	+ + +	33
Kangkong *(Ipomoea aquatica)*	+	+ + +	+ +	+ +	_	+	Short term	+ +	26
Rambutan *(Nephelium lappaceum)*	+	+ +	+	+ +	+ +	+/-	Long term	+	21

Based on the literature research and interviews, a pre-selection of dryland species is done (see appendix C). Further selection is done based on the selection criteria (see table 8). Four dryland species are selected. As can be seen in table 10, Sengon has the highest rating. Sengon has a high economic potential, commonly planted for timber and fuelwood. It can easily adapt to various environmental conditions and is able to improve soil fertility. Therefore, the species scores highest in site suitability (see table 10). On shallow to moderate peat depth, sengon grows better, but it does need drainage (Nuroniah, Tata, Mawazin, Martini, & Dewi, 2021). Rotan, tomato and eggplant are the next best rated species. Tomato and eggplant have high subsistence potential, which has a high importance for the community. Tomato does not require lots of maintenance and labour but is less suitable for the site then sengon. Eggplant has the potential that it can be intercropped with sago. Both are already used by the community, mostly in their own gardens. Rotan has a high subsistence potential and is also already used by the community of Gohong, mostly for handicrafts. Rotan is labour intensive. All other dryland species had a significant lower score, mostly due to lack in site suitability, negative environmental impact and high labour intensity (see table 10).

Table 10:
Dryland species selection.

Criteria → / Species ↓	Weather tolerance	Subsistence potential	Maintenance and labour	Availability	Commercial potential	Environmental impact	Long term or short term income	Site suitability	Species selection
Sengon (*Paraserianthes falcataria*)	+ +	+ + +	_ _	+ +	+ +	_	Long term	+ +	20
Durian (*Durio zibethinus*)	_	+ +	_ _	+	+	+	Long term	_ _	1
Cempedak (*Artocarpus integer)*	_	+	+	+	+	_	Long term	+	7
Mango (*Mangifera indica L*)	+	+	_	+ +	+	_ _	Long term	_ _	-3
Cassava (*Manihot esculenta)*	_	+ +	_	+	_	_	Short term	_	-4
Tomato *(Solanum lycopersicum)*	+	+ + +	+ + +	+ +	+ +	+/-	Short term	_ _	19
Eggplant (*Solanum melongena)*	+	+ + +	_	+ +	_	+/-	Short term	_	8
Rubber (*Hevea brasilliensis)*	_ _	+ + +	_ _	+ +	+ +	+/-	Long term	_	6
Rotan *(Calamus rotang)*	+ +	+ + +	+	+ +	+ +	_	Short term	_	17
Green bean *(common bean)*	_	+ +	+	+	_	+/-	Short term	+/-	6
Rice (*Oryza sativa)*	_	+ +	_ _	_	+ +	_ _	Short term	+/-	-4

5.2 Management activities

For sustainable management of the Melaleuca focussed plantation plan, management activities are necessary. This includes proposed activities for sustainable production of wood, agriculture and NTFP's. A visualisation of the design is presented in the form of a zonation map.

5.2.2 Zonation of the forest plantation design

In figure 6, the proposed zonation map of the village is visualised. The map visualises the proposed locations for use of the selected species, both paludiculture and dryland species. the community forest is located on the left side of the map, adjacent to the conservation area. Here, Melaleuca and purun are intercropped, sago and eggplant are intercropped and rotan is harvested. Sengon is planted on the already existing sengon plantations in the north-east part of the village and two new plantation locations in the south-east (see figure 6) to increase production. Tomato plants are located mostly in the personal gardens located in the settlement next to the river. Jelutung stands are planted in area which currently comprises rubber plantation, to slowly replace the rubber plantation areas to swamp jelutung.

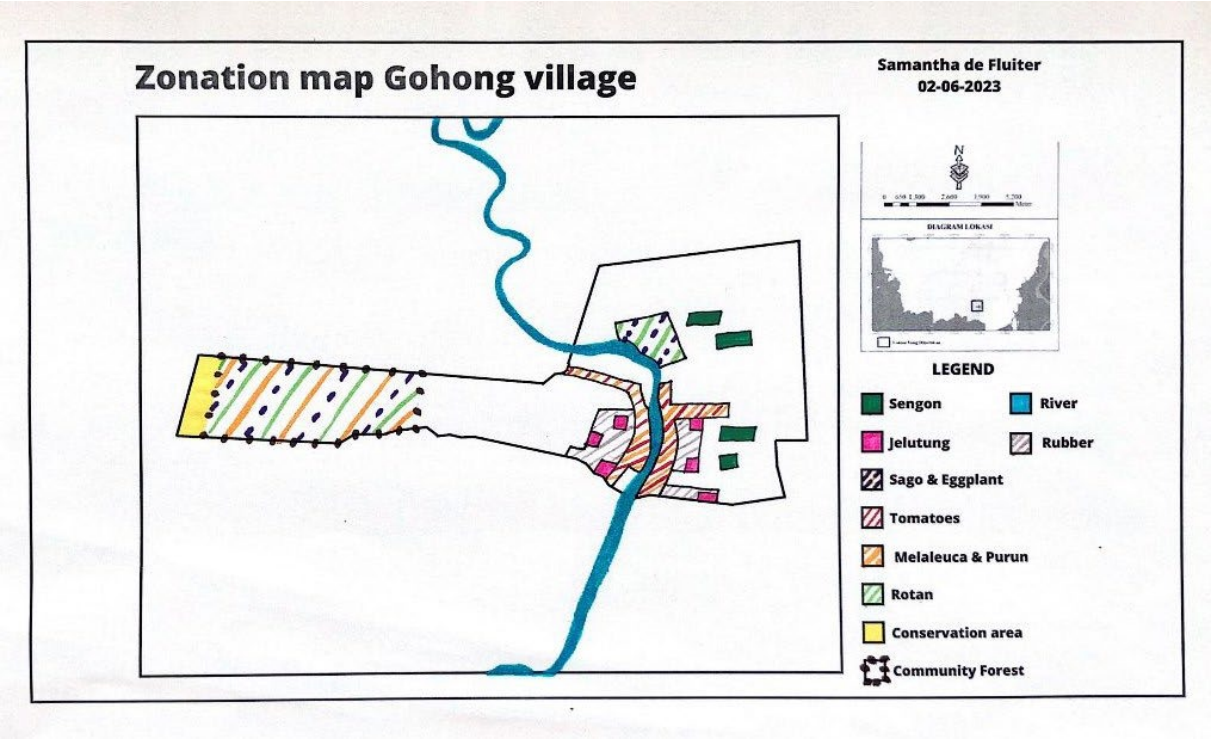

Figure 6: Zonation map Gohong, located in Central Kalimantan, Indonesia.

5.2.2 Sustainable production of wood

Sengon **(***Paraserianthes falcataria*) and Melaleuca (*Melaleuca cajuputi*) are selected species with potential for wood production. They both have different growth circumstances. That being the case, the species are discussed separately. Reduced impact logging recommendations are discussed and apply to all wood production species.

Sengon (*Paraserianthes falcataria*)

Sengon is a fast growing pioneer species, native to Indonesia. It grows often in secondary lowland rainforest and light montane forest. It is known for its ability to grow on poor soils but likes deep and well-drained, fertile soils. Sengon is commonly planted in Central Kalimantan for timber, pulpwood and fuelwood. Sengon is a long term species with an 8-10-year rotation age. On Java sengon is planted in mixed plantations with corn, cassava, pineapple and mango, variable on the number of trees per ha (Siregar U. J., Rachmi, Massijaya, Ishibadhi, & Ando, 2006). Most of the time, other crop cultivation mixed with sengon was done until the sengon reached 4 years of age, because most crops can't tolerate the shade of sengon trees. Sengon can easy adapt to various environmental conditions and is amble to improve environmental quality such as increasing soil fertility. On mineral soils, Sengon grows very fast. In deep peat soils, Sengon has a slower growth performance. On shallow to moderate peat depth, sengon grows better, but is does need drainage (Nuroniah, Tata, Mawazin, Martini, & Dewi, 2021). It is recommended to plant sengon on shallow to moderate peat. Sengon does need some drainage.

mr

Melaleuca (*Melaleuca cajuputi*)

Melaleuca can tolerate very moist and saline conditions and are exceptional resilient trees. They can withstand frequent flooding and acidic soils, but also brackish conditions. It is recommended not to harvest Melaleuca trees with a diameter <4cm, because these are too young. It is also recommended to not harvest Melaleuca trees with a diameter of >30cm, because these are an important source of seeds.

Reduced impact logging (RIL)

To ensure sustainable production and harvest of the wood producing species and to minimize environmental impacts, it is recommended to use reduced impact logging techniques (RIL). Reduced impact logging is the intensively planned and controlled implementation of timber harvesting operations to minimize the negative environmental impacts on the forest (ITTO, N.D.). RIL activities can be implemented for a reduction in damage of the remaining stand and the soil caused by felling or logging. Recommended RIL measures are:

- Planning: mapping the planned harvest.
- Mapping of roads and extraction routes for easy access to the forest for logging and extraction.
- Use appropriate felling techniques to minimize felling damage. For example, directional felling (steering the direction of the fall of the tree).
- Using logging residues or slash to reduce soil disturbance.
- Conducting a post-harvest assessment for feedback regarding logging activities and to evaluate the RIL measures implemented.

It is also recommended to plant mixed age stands of both Melaleuca and Sengon, to avoid clear-felling of areas, as this will lead to dehydration of the peatland and increased risk of fire.

5.2.3 Sustainable NTFP production and intercropping

Species selected for NTFP production and agriculture are discussed. Recommendations for intercropping and NTFP harvest are made.

Melaleuca (*Melaleuca cajuputi*) and Purun (*Lepironia articulata*)

Melaleuca has lots of market potential in the form non-timber forest products such as cajuput oil and Honey. Melaleuca flowers produce good quality honey. It is recommended to use rafters for the honey harvest (see chapter 4.1.3). This traditional practice allows beekeepers to harvest two or three times from the same colony per season without harming the bees (WWF, 2019). The rafters also allow much safer honey harvesting, because they are placed near the ground. Therefore, risking the high climb up to the colony nesting far off the ground is not necessary anymore. For rafter beekeeping to be sustainable, a sense of ownership and clarity on land tenure must be present that is enforced by surrounding communities. It is recommended to have community meetings to clarify land tenure.

Melaleuca can be intercropped with sedges such as purun (*Lepironia articulata)* to provide material for weaving (Giesen, 2015). Purun is a fast growing sedge species which grows naturally in peatlands. It is used for handicraft like bags and hats and plastic replacement straws. The species is suitable for shallow to deep peat (van der Meer, et al., 2021). Purun is a quick gain species (short-term). Quick gain species are species that produce quick results but have a lower unit value, although the overall market is good (van der Meer, et al., 2021). This means purun can provide the short term income that is needed for the community. It is a drought-resistant aquatic plant, which can be grown year-round and grows close to rivers and can tolerate flooded areas. It is therefore recommended to intercrop purun with melaleuca trees in parts that are seasonally flooded.

Sago (*Metroxylon sagu*) and eggplant (*Solanum melongena*)

Sago palm is a long-term paludiculture species with high economic and commercial potential. The first harvest is 9-10 years when cultivated on peat. The trunk is harvested for starch and leaves are used for weaving. Starch of the sago palm is used in cooking and as a thickener and can be stored for a long time (Ehara, Toyoda, & Johnson, 2018). It is a proven commercial species (has products of a known commercial value and are known to perform in peat (Giesen & Sari, 2018). To harvest the starch, the stem is felled shortly before flowering stage. The natural distribution of Sago covers wetland areas in Indonesia. The species has a high tolerance to harsh environmental conditions such as peatland. Sago can grow in neutral to highly acidic soils and mineral soils. The yield of sago is more than six times higher per year than rice paddy, cassava and maize (Boseren & Weterings, 2021). Peatlands do not have to be drained in order to grow sago. Because sago palms require at least 8 years before they can be harvested, this is a long-term species. According to a research by (Zuhro & Bintoro Djoefie (2020), sago can be intercropped with eggplant, because the sago did not suppress eggplant growth and vice versa. Hence, it is recommended to intercrop sago with eggplant (*Solanum melongena*). Here sago is used as a long term NTFP income source, whilst eggplant provides short term income for subsistence use. Eggplant, also called aubergine, is a perennial plant, grown for the

edible fruits. It required a warm climate and is native to South-East Asia**.** They grow best in sandy loam or loam soil that is high in organic matter (Boeckmann, 2023). The plant grows 40 – 150cm tall. Labour intensity for eggplant is low. As can be seen in figure 6, areas of intercropping of sago and eggplant are located in the village forest, where intercropping between Melaleuca and purun also takes place.

Jelutung (*Dyera polyphylla*)

Jelutung is a tree that produces rubber/latex and timber for pencils, matches, furniture. Fruits are used for mosquito repellent and torches. *Dyera poluphylla* is the swampland jelutung species, which grows naturally in peatland forests. The species can survive high water tables. The first harvest (tapping) is possible after 7 years or a BHD (breast height diameter) of 25cm. It is a long term income generating species. The plant is good in mixed systems. Jelutung can be planted with other tree crops such as rubber (Houweling , 2017). Jelutung does not have a high economic potential. There are too few buyers to avoid price setting and not enough product supply to attract new traders into markets. They do have potential to provide economic benefits to local communities and to minimize environmental degradation. Tapping techniques for Jelutung are already sufficient to avoid environmental damage. Jelutung does not require peat drainage and labour costs for jelutung are lower than rubber and rattan. Jelutung does not require logging, and is more sustainable then rubber. It is therefore recommended to slowly replace the rubber plantation areas to swamp jelutung. As can be seen in figure 6, small jelutung plantations are located in the previous rubber plantation locations.

Tomatoes *(Solanum lycopersicum*)

Tomato is one of the short term income generating species that is already used by the community of Gohong, mostly for subsistence use. Tomato is the fifth most important vegetable crop in Indonesia in cultivated areas, according to (Australian Centre for International Agricultural Research, 2013). Botanically a tomato is a fruit, however it is considered a culinary vegetable. Tomatoes are grown all year around, with a peak harvest period from May to October. It is a short term income species. It grows in well drained sites with a slightly acidic soil. The plant is native to tropical highlands. Tomatoes grow about 1-3 meters tall. Since tomato is already an important subsistence crop, is it recommended to continue the production of it.

Rotan (*Calamus rotang*)

The dryland species selection shows that rotan is species with high potential. Rotan is an annual rattan palm species that is native to Southeast Asia. It grows up to 10m tall and 200m wide. The fruits are edible, the red resin is used as dye, in painting and in medicine. The cane is used as weaving material. It is suitable for light, medium and heavy soils. It can stand a mildly acid, neutral and basic PH (Plants For A Future, sd). They grow best with their roots in the shade but the stems in the light. They require fairly moist soil conditions to grow good. Not a lot of care is needed when the seedlings are established, however weeding is needed occasionally until the plants are more than 2 meters tall (Tropical plants database, 2023). Labour intensity of Rotan is low. Rotan is mostly used for handicrafts as weaving material, like purun. Rotan is already an important short term crop for the community. It is therefore recommended to continue the production of it.

5.3 Costs and benefits

A brief overview of the costs and benefits of the forest plantation design and given recommendations is made. Since there is no data available to derive costs of small scale plantations of the species, the costs are displayed as activities that cost money.

Table 11.
Costs and benefits per forest plantation design activity.

Activity	Costs	Costs IDR/ha/year	Benefits
Sengon	Treatment of plant, planting investment	5.960.471 IDR	15.551.554 IDR/ha/year[1)]
Melaleuca honey	Labour, honey production facility, marketing, licenses, maintenance	Unknown	3206,18 USD/season/household[2)]
Melaleuca wood and purun intercropping	Labour, treatment, harvest	Unknown	Melaleuca wood: 2000-12000 IDR/stem (depending on Diameter and length)[3)] Purun: unknown
RIL	Execution and implementation	Unknown	Prevention of soil disturbance, peat conservation, biodiversity conservation
Sago palm and eggplant intercropping	Labour, harvest, treatment of plant	Unknown	Sago: 400 USD/ha/year (extensive harvest)[4)] Eggplant: Unknown
Jelutung	Labour, harvest, treatment of plant	Unknown	3600 USD/year[5)]
Tomato	Seeds, labour, treatment of plant, harvest	9.415.812 IDR/ha/year	46.606.477 IDR/ha/year[6)]
Rotan (handicrafts)	Labour (intensive), Harvest, treatment of plant	Unknown	2.900.000 – 5.000.000 IDR/month[7)]

[1)]**Sengon:** Production costs and benefits of Sengon are based on data available from (Siregar & Rachmi, 2007): economic analysis of sengon in a community forest plantation, in East Java.
[2)]**Melaleuca honey:** See chapter 3.4 for Melaleuca honey production.
[3)]**Melaleuca wood:** Income from wood stems of Melaleuca based on data from (Arifin, Hamidah, & Arifin, 2014).
[4)]**Sago palm:** (Setyarso, et al., 2014)**.**
[5)]**Jelutung:** (Setyarso, et al., 2014)**.**
[6)]**Tomato:** Production costs of tomato are based on the data available from (small scale tomato production of farmers in Southeast Sulawesi).
[7)]**Rotan:** Interviews (see appendix A).

6. Conclusion

Based on the extensive literature research, interviews and the establishment of the Melaleuca focussed plantation design, a number of conclusions can be made. The conclusion follows up the research questions:

“What is the current situation in Gohong?”

“What is the potential of Melaleuca?”

“How can Melaleuca be implemented so that it generates actual benefits and improves the livelihoods of Gohong?”

Examining the current situation in Gohong reveals an insecure balance between the village's dependency on its natural resources and the threat those resources face due to changing land use, drainage, and climate change. This balance is particularly strained by the peatland degradation resulting from human activities such as land clearing. Peat fires, a consequence of this degradation, have led to a significant decline in the village's assets, making it difficult for the community to generate consistent income. The current income sources (agriculture, fishery, village forest and rattan crafting) are subject to the unpredictability of climate, tourist activity and healthcare costs. However, there have been significant efforts to improve the community’s living standards, such as the establishment of BUMDes, a village owned enterprise. Therefore, the community is willing to adapt and improve their situation.

While cultivation of dryland species planted by the community provide steady income and are trusted by the community, it can be concluded that it is necessary to use paludiculture species if we want to safeguard the peatlands and prevent further degradation. Research indicates that currently a lack of knowledge regarding paludiculture and in particular about Melaleuca is present in the community of Gohong. Most people want to learn more about the species, but are reluctant because of lack of confidence and knowledge.

Melaleuca is one of the paludiculture species with high economic, social and environmental potential. Melaleuca offers several highly desirable commercial products: cajuput oil, wood, pulp and paper and especially honey. These could provide sustainable income sources for the community. Melaleuca honey, in particular, has significant income potential, with a potential average income of 3206,18 USD per household per season. It has relatively low establishment costs, and in combination with rafter beekeeping, the honey can be harvested safe and sustainable. Additionally, the cultivation of Melaleuca could stimulate local employment by encouraging the community’s active participation in future honey businesses.

Moreover, Melaleuca can withstand adverse conditions like flooding and acidic soils, making it exceptionally resilient. Importantly, its cultivation could contribute to the rehabilitation of the degraded peatlands, promoting responsible land use and helping restore the balance between the community's livelihood and its environment. This is particularly vital given that the village's livelihood depends on the health of its local ecosystem.

The research also suggests that sustainable development in Gohong would necessitate a different approach, integrating both dryland and paludiculture species for a balanced and sustainable ecosystem. Moreover, a balance between short- and long term income generating species would provide the community with a more reliable income stream. For instance, Melaleuca could provide

long-term income through the sale of honey, while short-term income could be obtained through the cultivation of crops or other species preferred by the community. This way, the design also contributes to the preservation of peatland and the conservation of natural resources and at the same time enhances the community's livelihoods without disregarding their wishes. To ensure sustainable use of the species and minimise negative impact on the peatland ecosystem RIL activities are implemented.

Still, one significant obstacle could be identified in the research: the lack of knowledge and confidence within the community about Melaleuca and paludiculture in general. Most community members are open to learning more about these subjects, but their reluctance stems from a lack of understanding. This highlights the need for effective community education and engagement activities to build trust and confidence in these new livelihood opportunities.

7. Discussion and recommendations

An overall discussion of the methods and results is given and recommendations for follow-up research are presented.

7.1 Discussion

Following extensive literature research and interviews, the results have been collected. Despite the fact that most research questions have been answered, the results showed that more research still needs to be done in order to create the most suitable forest plantation design. One of the constraints of the design is related to the methods. Due to the cancelation of the fieldwork trip to Gohong, no field research is done at location. Therefore, there was no sufficient information available about the current structure of the community forest and current abiotic situation of the location. No research has been done on water levels in Gohong and preferable water levels of the species that are selected. There was also no information available about costs and benefits of the selected species.

Besides, the interviews had to be carried out by an acquaintance of the commissioner, which led to a number of biases. First, there was no opportunity to get to know the respondents and to build trust before starting interviews. As a result, respondents where shy and reluctant in giving information. The willingness to participate in the interviews was low. Second, the interviewer changed the questions during the translation, which resulted in loss of the intention of the question and getting different answers than expected. The interviewer also translated the respondents' answers on the spot, so an English version of the answers were the only interview results given. Since a main part of the design includes the demand and wishes of the community, the interviews were an important source of information. Due to the biases, and the lack of trust of the respondents to give information, the sub questions "Why is Melaleuca not yet being used according to its potential?" and "What are the demands of the people of Gohong to support their livelihoods?" could not be fully answered.

Although the design comprises a subsistencial amount of information regarding Melaleuca and paludiculture species, there is still a lack of information on especially paludiculture species in peatland. Since 2015, more literature research has been done, but real pilots have not yet been executed. It Is therefore difficult to provide proof that paludiculture species give enough income possibilities to improve the livelihoods of the community, which is needed to gain the trust of the people in Gohong to apply this design. It makes the design innovative, but also makes follow-up research and pilots necessary. There is already interest within the community for sustainable management and peatland rehabilitation programs, but more trust and knowledge to change from dryland to paludiculture is desirable.

7.2 Recommendations

In order to be able to realise the design, the next step is to present the outcome of this report to the community of Gohong. This allows the design to be improved and information gaps to be filled. Due to the fact that information was lacking in the report, new interviews and focus groups are recommended to adjust the plan to the wishes and demands of the community. It is recommended to first create a relationship with the respondents to build trust between the interviewer and respondent. That way, people are more willingly to answer difficult questions and to provide sensitive information. Afterwards, a 2.0 version of the design can be presented and implemented. For a 2.0 version of the design, it is recommended to include water level research, as this has not been included in this report but is an important factor for species selection and site suitability.

7.3 Reflection on sustainability

The design comprises a sustainable approach with a primary focus on Melaleuca. It integrates both short- and long term income generating species, enhancing the community's livelihoods in Gohong. By integrating dryland species as per the community demand and paludiculture species to safeguard the peatlands and prevent further degradation, the design effectively contributes to the preservation of peatland and the conservation of natural resources for long-term sustainability, which is in line with the vision of the design. By utilising various products derived from Melaleuca, notably honey, the design capitalises on the species' full economic, social and environmental potential. Since the design also introduces new sustainable revenue options and paludiculture species, it can be a great addition to the Melaleuca Honey Supply Chain project of SFP social forestry, combining the goals of the project of SPF with recommendations for long-term sustainability of the livelihoods of Gohong.

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Appendix A

Structural coding of interviews

Step 1: Topics and research questions

- Melaleuca
- Which agricultural species are currently used for revenues and own consumption by the community of Gohong?
- What types ways to generate income are used by the Gohong community?
- Current problems encountered by the community

Step 2: Creating codes

- Melaleuca
- Species used
- Livelihoods
- Community problems

Step 3: Coding sections

Interview 1: (male) (BUMDes organisation)
Personal questions:
IV: What is your home situation? With who do you live?
Respondent 1: 5 children.
IV: What is your age?
Respondent 1: 43.
IV: What are your daily tasks on a typical workday?
Respondent 1: Farmer (agriculture) and admin for BUMDes. Wife is working in Rattan.
IV: What species are currently planted/harvested during the year?
Respondent 1: Vegetables.
IV: Which products do you sell for revenues?
Respondent 1: Rubber. Money brought every month together is 6.500.000.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 1: Money. Very hard because everything is expensive. Peat fires.
IV: Are you familiar with Melaleuca and its potential?
Respondent 1: Yes.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 1: Don't know.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 1: Good.
BUMDes questions:
IV: What are the most important revenues for the village? (which crops, wood, other products?) livelihood activities?
Respondent 1: Rattan, rubber, fruits, other agriculture.
IV: The goal of BUMDes is to improve the economy of the village and opening up business opportunities. is sustainability an important factor to include in these business opportunities?
Respondent 1: No.
IV: What do you think of introducing more Melaleuca products such as honey and essential oils to increase the revenues for Gohong Village?

Respondent 1: Yes, because many Melaleuca trees.

Interview 2: (male)
IV: What is your home situation? With who do you live?
Respondent 2: 4 children.
IV: What is your age?
Respondent 2: 33.
IV: What are your daily tasks on a typical workday?
Respondent 2: Farmer.
IV: What species are currently planted/harvested during the year?
Respondent 2: Rice.
IV: Which products do you sell for revenues?
Respondent 2: Rice.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 2: Income not enough.
IV: Are you familiar with Melaleuca and its potential?
Respondent 2: Yes.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 2: Never tried.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 2: Yes.

Interview 3: (male)
IV: What is your home situation? With who do you live?
Respondent 3: 2 children.
IV: What is your age?
Respondent 3: 26.
IV: What are your daily tasks on a typical workday?
Respondent 3: Rattan worker.
IV: What species are currently planted/harvested during the year?
Respondent 3: Rattan.
IV: Which products do you sell for revenues?
Respondent 3: Rattan.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 3: Income not enough.
IV: Are you familiar with Melaleuca and its potential?
Respondent 3: No.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 3: NO ANSWER.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 3: Yes.

Interview 4: (male)
IV: What is your home situation? With who do you live?
Respondent 4: 3 children.
IV: What is your age?
Respondent 4: 31.
IV: What are your daily tasks on a typical workday?

Respondent 4: Farmer and work for BUMDes.
IV: What species are currently planted/harvested during the year?
Respondent 4: Oil palm.
IV: Which products do you sell for revenues?
Respondent 4: Palm oil.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 4: Money and Health.
IV: Are you familiar with Melaleuca and its potential?
Respondent 4: Yes.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 4: Don't know.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 4: Don't know.

Interview 5: (male)
IV: What is your home situation? With who do you live?
Respondent 5: 3 children.
IV: What is your age?
Respondent 5: 38.
IV: What are your daily tasks on a typical workday?
Respondent 5: Farmer.
IV: What species are currently planted/harvested during the year?
Respondent 5: Rice and vegetables.
IV: Which products do you sell for revenues?
Respondent 5: Rice and vegetables.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 5: NO ANSWER.
IV: Are you familiar with Melaleuca and its potential?
Respondent 5: No.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 5: A few people using.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 5: Depends.

Interview 6: (male)
IV: What is your home situation? With who do you live?
Respondent 6: 2 children.
IV: What is your age?
Respondent 6: 48.
IV: What are your daily tasks on a typical workday?
Respondent 6: Farmer.
IV: What species are currently planted/harvested during the year?
Respondent 6: Many species.
IV: Which products do you sell for revenues?
Respondent 6: Vegetables and fruit.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 6: Health.
IV: Are you familiar with Melaleuca and its potential?
Respondent 6: No.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 6: NO ANSWER.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?

Respondent 6: Yes.

Interview 7: (female)
IV: What is your home situation? With who do you live?
Respondent 7: 3 children.
IV: What is your age?
Respondent 7: 30.
IV: What are your daily tasks on a typical workday?
Respondent 7: Rattan worker.
IV: What species are currently planted/harvested during the year?
Respondent 7: Rattan.
IV: Which products do you sell for revenues?
Respondent 7: NO ANSWER
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 7: Money.
IV: Are you familiar with Melaleuca and its potential?
Respondent 7: No.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 7: NO ANSWER.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 7: NO ANSWER.

Interview 8: (female)
IV: What is your home situation? With who do you live?
Respondent 8: 2 children.
IV: What is your age?
Respondent 8: 31.
IV: What are your daily tasks on a typical workday?
Respondent 8: Teacher in the afternoon and rubber tapper early in the morning.
IV: What species are currently planted/harvested during the year?
Respondent 8: In my family many people grow vegetables such as tomatoes, eggplants and green beans.
IV: Which products do you sell for revenues?
Respondent 8: I don't sell vegetables, but my family sell all vegetables.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 8: Every month I have salary of IDR 4.276.000 from my teaching and about IDR 1.000.000 from rubber. My husband brings home about IDR 3.500.000. Our situation is much better than other people.
IV: Are you familiar with Melaleuca and its potential?
Respondent 8: My husband works as a carpenter in Palangkaraya and sometimes brings some Melaleuca wood for our house. I heard that the honey is very healthy.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 8: People use Cajuputi.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 8: I love my teaching job.

Interview 9: (male)
IV: What is your home situation? With who do you live?
Respondent 9: Only my wife.
IV: What is your age?
Respondent 9: 68.
IV: What are your daily tasks on a typical workday?
Respondent 9: I used to work as contractor, but now just some simple farming like chicken and vegetables.
IV: What species are currently planted/harvested during the year?
Respondent 9: Just lettuce and green beans.
IV: Which products do you sell for revenues?
Respondent 9: Eggs, chicken, vegetables and my wife sells cakes. Our money is IDR 1.800.000.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 9: If you don't have a stable job, things are very tough here. My two sons work in Jakarta and they bring money for us. If you become sick it's very expensive to go to hospital.
IV: Are you familiar with Melaleuca and its potential?
Respondent 9: I think Melaleuca very good species because many forests in this area.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 9: Some people use Melaleuca, but not many people know about the honey.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 9: I am too old, but I think the villagers should learn about the Melaleuca. Not many trees can grow here, but Melaleuca can.

Interview 10: (female)
IV: What is your home situation? With who do you live?
Respondent 10: 3 children.
IV: What is your age?
Respondent 10: 29.
IV: What are your daily tasks on a typical workday?
Respondent 10: Agriculture and rattan weaver.
IV: What species are currently planted/harvested during the year?
Respondent 10: Green beans, tomatoes and eggplants.
IV: Which products do you sell for revenues?
Respondent 10: Rattan bags and bracelets to handicraft centre and twice a week vegetables at night market.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 10: Income is not stable because if too much rain it's difficult to grow vegetables. For the rattan products we need more tourists who buy the goods. Last time more tourists came to visit Gohong, nowadays they hardly come. Last time my money is nearly IDR 5.000.000 now only IDR 2.900.000. My husband works in Palangkaraya.
IV: Are you familiar with Melaleuca and its potential?
Respondent 10: Yes, I use minyak cajuputi as medicine for headache and mosquito bites. The medicine is made locally. The tree has also honey.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 10: People use the tree for wood for their house.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 10: I want to learn about the cajuputi tree, because many forests. Maybe can sell the honey in the city (Palangkaraya).

Interview 11: (female)
IV: What is your home situation? With who do you live?
Respondent 11: Husband, children and mother.

IV: What is your age?
Respondent 11: 44.
IV: What are your daily tasks on a typical workday?
Respondent 11: Last time I worked as farmer and tourist guide, but now I need to look after my mother. My husband works as a bus driver and my children are 16 and 14.
IV: What species are currently planted/harvested during the year?
Respondent 11: NO ANSWER.
IV: Which products do you sell for revenues?
Respondent 11: NO ANSWER.
IV: What problems are you facing within your tasks? Lack of time, or climate issues?
Respondent 11: The hospital is more than hour drive by motorcycle.
IV: Are you familiar with Melaleuca and its potential?
Respondent 11: I don't know this tree, but sounds interesting.
IV: Why is Melaleuca currently not used as a crop to increase revenues?
Respondent 11: Maybe the government should promote.
IV: Are you open to an introduction of using Melaleuca to increase revenues in your village?
Respondent 11: I like to learn about the honey because is not a hard job. Many people like honey and it is also healthy.

Appendix B

Paludiculture species selection based on literature research

Based on the literature research, the following paludiculture species are selected:

Sago (*Metroxylon sagu*): Sago palm is a long-term paludiculture species with high economic and commercial potential. first harvest is 9-10 years when cultivated on peat. Trunk is harvested for starch; leaves are used for weaving. The starch is used in cooking and as a thickener and can be stored for a long time (Ehara, Toyoda, & Johnson, 2018). It is a proven commercial species (has products of a known commercial value and are known to perform in peat (Giesen & Sari, 2018). To harvest the starch, the stem is felled shortly before flowering stage. It is propagated by man by collecting and replanting young suckers rather than by seed. The natural distribution if Sago covers wetland areas in Indonesia. It has a high tolerance to harsh environmental conditions such as peatland. It can grow in neutral to highly acidic soils and mineral soils. Yield of Sago is more than six times higher per year than rice paddy, cassava and maize. (Boseren & Weterings, 2021). Peatlands do not have to be drained in order to grow Sago. Because Sago palms require at least 8 years before they can be harvested, this is a long-term species. According to a research by Zuhro & Bintoro Djoefie (2020), Sago can be intercropped with eggplant, because the Sago did not suppress eggplant growth and vice versa. Food processing is labour intensive.

Jelutung (*Dyera polyphylla*): Jelutung is a tree that produces rubber/latex and timber for pencils, matches, furniture. Fruits are used for mosquito repellent and torches. Dyera poluphylla is the swampland jelutung species, which grows naturally in peatland forests. The species can survive high water tables. The first harvest (tapping) is possible after 7 years or a BHD (breast height diameter) of 25cm. The plant is good in mixed systems. Jelutung can be planted with other tree crops such as rubber and coffee (Houweling , 2017). Jelutung does not have a high economic potential, because there are too few buyers to avoid price setting and not enough product supply to attract new traders into markets. They do have potential to provide economic benefits to local communities and to minimize environmental degradation. Tapping techniques for jelutung are already sufficient to avoid environmental damage. Jelutung does not require peat drainage. Labour costs for jelutung are lower than rubber and rattan.

Purun (*Lepironia articulata)*: Purun is a long grass-like plant, which grows naturally in peatlands. It is used for handicraft like bags and hats and plastic replacement straws. It is a fast growing sedge species that grows close to rivers and tidal swamps. The species is suitable for shallow to deep peat (van der Meer, et al., 2021). Purun is a quick gain species (short-term). Quick gain species are species that produce quick results but have a lower unit value, although the overall market is good (van der Meer, et al., 2021). It is a drought-resistant aquatic plant, which can be grown year-round.

Kangkong (*Ipomoea aquatica*): Kangkong, also called water spinach, is a vegetable that can be harvested year-round. Next harvest is normally after 4-5 weeks. It is a quick gain species and can be intercropped with rice. It can be grown under undrained conditions. Water spinach seeds are easy to obtain, and the maintaining and harvesting of the species is easy, according to (Uda, Hein, & Adventa, 2020`) . Water spinach has only a limited market, and is therefore not recommended as a commercial crop, but only as a subsistence crop for the community.

Rambutan (*Nephelium lappaceum*): Rambutan is cultivated in Southeast Asia and native to Indonesia and humid tropical lowlands. The trees occur in different types of primary and secondary forest. Mean annual rainfall is preferred to be 2000-3000mm. It prefers clay loam soil but can grow in a wide range of soils but not water logged soils (world agroforestry database, 2018). Fruits that look like lychee but with a hairy outside. It grows up to 10-20m tall/ it likes deep soils that contain lots of organic matter. The rambutan tree fruits twice a year (World Crops Database, sd). Well-drained sandy loam soil with organic matter is most suitable soil for rambutan. It is sensitive to water logging. Rambutan produces fruits twice a year (June and December in Southeast Asia). An average tree may produce 5000-6000 fruits per year. They decay fast so fruits need to be sold immediately (Karunakaran & Tripathi, 2013). In a study about peatland restoration and livelihood improvement in Central Kalimantan (Sakuntaladewi, et al., 2022), they found that Rambutan was grown by more than 75% of the respondents and was therefore considered as important species for their livelihoods. Also, according to the respondent's experience of the above study, rambutan trees need regular fertilization or they will not bear fruits. Because rambutan grows better on mineral soil, one of the options was to make peat mounds with a hole in the middle that is filled with a small quantity of mineral soil and manure or mineral fertilizer. This technique is effective but also expensive if mineral soil is bought from outside the village (Sakuntaladewi, et al., 2022). It is an annual crop.

Appendix C

Dryland species selection based on literature research

The following dryland species are selected:

Sengon (*Paraserianthes falcataria)*: Sengon is a fast growing pioneer species, native to Indonesia. it grows often in secondary lowland rainforest and light montane forest, on a wide range of soils, alkaline or acid. It is known for its ability to grow on poor soils but likes deep and well-drained, fertile soils. Sengon is commonly planted in Central Kalimantan for timber, pulpwood and fuelwood. Sengon is a long term species with an 8-10 year rotation age. On Java sengon is planted in mixed plantations with corn, cassava, pineapple and mango, variable on the number of trees per ha (Siregar U. J., Rachmi, Massijaya, Ishibadhi, & Ando, 2006). Most of the time, other crop cultivation mixed with sengon was done until the sengon reached 4 years of age, because most crops can't tolerate the shade of sengon trees. Sengon can easy adapt to various environmental conditions and is amble to improve environmental quality such as increasing soil fertility. On mineral soils, Sengon grows very fast. In peat soils, Sengon has a slower growth performance. The growth is influenced by peat depth and results in poor performance. On shallow to moderate peat depth, sengon grows better, but is does need drainage (Nuroniah, Tata, Mawazin, Martini, & Dewi, 2021).

Durian (*Durio zibethinus*): Durian is an edible fruit of several tree species belonging to the Durio genus. 9 of the durio species produce edible fruit. *Durio zibethinus*, native to Borneo and Sumatra, is the only available species in the international market. Other durio species are sold in their local regions. The ripe fruits are also eaten by many animals, and therefore it is an important part of local ecosystems (Encyclopaedia Britannica, 2023). The height is between 20-50m. the trunk diameter can grow 120cm up to 200cm. the fruits weight between 2 and 5 kg, sometimes more. Durian seeds are dispersed by frugivorous animals such as primates. Currently, primates such as the Orang-Utan are endangered and this can influence the natural distribution of Durian. The tree is adapted to high amounts of precipitation (annual rainfall>2000m/year) and it requires moisture from rivers or ponds to grow. PH needed is 5-6,5, but peat soil PH is lower. It does not bear fruits until 7 years of age. Germination is quick so the seeds need to be purchased from fresh fruit. A young tree can produce 10-40 fruits in the 1st year, 100 in the 6th year and 200 in the 10th year of production. Networks are placed to capture the fruits, because due to the weight of the fruits it is dangerous to go near a tree of durians when they drop (botanical-online, 2022). Sensitive to standing water, so sloping situations are best. Rich, deep, sandy clay or clay loam. Durian is used on shallow peat in Central Kalimantan (Rotinsulu, et al., 2022). It is an annual crop. Young durian plants need shade for the first few years, so it is common to plant them under a fast growing perennial plant.

Cempedak (*Artocarpus integer*): Cempedak is a fruit similar to jackfruit. It is native to Southeast Asia. It is a fast growing tree with a dense crown. It can grow 10-24m tall. The diameter is up to 60cm. The fruit is edible. It is a plant of lowland humid tropics. It prefers a mean annual rainfall of 2200-3500mm but can also grow with 1250-4500mm. It needs a deep, well-drained fertile soil. the PH range that is prefers is 4,5-6, which is higher than peat soils. It can survive periodic flooding. It gets fruits after 3-6 years (Tropical Plants Database, 2023). It can tolerate shade in early life (world agroforestry database, 2018). Cempedak is one of the fruit species that grow well on deep peatlands (Rotinsulu, et al., 2022). Cempedak is an ecological tolerant species with potential for paludiculture in peatland (Pratiwi & Yuwati, 2022). Cempedak is an annual crop.

Mango (*Mangifera indica L*): Mango is a large evergreen fruit tree, up to a height of 15-30m. They grow in tropical lowland and subtropical areas. It needs a dry weather season of 3 months to set fruit. It doesn't seem to suffer from occasional flooding. It gives a lot of shade because of its thick crown. Mean annual rainfall is preferred to be 300-2500mm (World Agroforestry Database). It grows best in well-drained sandy loam soil; it does not grow well in heavy wet soils. Optimal PH is 5.5 – 7.5. Mango is pollinated by flies, hoverflies and bees. High rainfall will result in poor pollination (World Crops Database, sd). Because mango grows better on mineral soil, one of the options was to make peat mounds with a hole in the middle that is filled with a small quantity of mineral soil and manure or mineral fertilizer. This technique is effective but also expensive if mineral soil is bought from outside the village (Sakuntaladewi, et al., 2022). Mango needs excellent drainage and deep soil for the extensive root system. Mango is also an important honey plant secreting large quantities of nectar. young mango is often inter-planted with other fruits and vegetables. Mango leaves improve the soil fertility when used as mulch (world agroforestry database, 2018). It is annual harvested so it gives medium-term income.

Cassava (*Manihot esculenta*): Cassava is a perennial crop (lives more than two years. Grow back automatically after harvest.) but cultivated as annual. It has cyanide in it, so to safely eat the cassava, the skin should be generously peeled off and the tubers must be well cooked (Encyclopaedia Britannica, sd). Because of their perishability, most roots are for own consumption. Cassava prefers annual rainfall of 1000 or more. The best soils for cassava are well-drained soil that are not less than 30cm shallow. It does not thrive well in waterlogged soils. If waterlogged, soil mounds can be made (see mango). Minimal management skills are needed, but care should be taken to avoid spread of diseases (weed control). It can be intercropped with other crops such as maize (corn) (Hauser, et al., 2014).

Rice (*Oryza sativa)*: Rice is the seed of the grass species Oryza sativa. As described in (Novitasari, Aprisiska, & Cristmastianto, 2018), in Gohong the land is cleared for rice in December, with planting done in January. Harvest is done in April. High fluctuating in prices of seeds are a problem for rice cultivation. Currently the rice is grown on thin peat soil and mineral soil in Gohong. There are a lot of rice varieties: local varieties that grow on mineral soil and swamp rice varieties. Rice cultivation still requires drainage. A lot of weeding is needed for rice. Manual weeding is labour intensive.

Green beans *(Phaseolus vulgaris)*: Green beans are young unripe fruits of the common bean (*phaseolus vulgaris*), also known as string beans. It is an annual plant. It grows best in soil with an acidic to neutral PH (5.5-7), in a well-drained soil. They are easy to grow, enrich the soil and are a nutritious addition to the diet. To high temperatures (>30 Celsius) a not good for green beans. It is the most cultivated legume in the tropics. they are very susceptible to excessive water, but recent findings (Susilawati & Lakitan, 2019) indicated that it could tolerate shallow water table at 15cm below soil surface or lower.

Tomatoes *(Solanum lycopersicum*): Tomato is the fifth most important vegetable crop in Indonesia in cultivated areas, according to (Australian Centre for International Agricultural Research, 2013). Botanically a tomato is a fruit, however it is considered a culinary vegetable. Tomatoes are grown all year around, with a peak harvest period from May to October. It is a cash crop. It grows in well drained sites with a slightly acidic soil. The plant is native to tropical highlands. Tomatoes grow about 1-3 meters tall. Tomato is a perennial plant but often grown as an annual.

Eggplant (*Solanum melongena*): Eggplant, also called aubergine, is a perennial plant, grown for the edible fruits. It required a warm climate and is native to Southeast Asia**.** they grow best in sandy loam or loam soil that is high in organic matter (Boeckmann, 2023). The plant grows 40 – 150cm tall.

Labour intensity is low. Eggplant prefers a soil with a PH of 5.5-6.5. rainfall requirements vary from 1000-1500 annually.

Rubber (*Hevea brasilliensis)*: Rubber tree is a tropical tree, cultivated on plantations. The latex is harvested with taps. Rubber is planted in rows and forestry plants grow naturally between rubber. The experience of living on peatlands teaches them that thick peat is not suitable for growing crops (Rotinsulu, et al., 2022). They usually plant thick peat with forestry plants that are endemic to the peat ecosystem that tolerant to soil acidity. Fruit plants are usually planted on peat of medium depth. Medium peat is also used for planting rubber. It is a quick growing tree. Rubber cultivation is a labour intensive job and requires skilled manpower. As described in (Novitasari, Aprisiska, & Cristmastianto, 2018), every month the rubber plants in Gohong can be tapped four times a week.

Rotan (*Calamus rotang*) also called rattan: Rotan is a rattan palm species that is native to Southeast Asia. It grows up to 10m tall and 200m wide. The fruits are edible, the red resin is used as dye, in painting and in medicine. The rattan cane is used as weaving material. It is suitable for light, medium and heavy soils. It can stand a mildly acid, neutral and basic PH (Plants For A Future, sd). They grow best with their roots in the shade but the stems in the light. They require fairly moist soil conditions to grow good. Not a lot of care is needed when the seedlings are established, however weeding is needed occasionally until the plants are more than 2 meters tall (Tropical plants database, 2023). Labour intensity is low.