



Faculty of Resource Science and Technology

**Paddy Farmers' Awareness, and Perception Towards Agroforestry
Practice and The Effect of Different Agricultural Practices on Selected
Soil Properties in Siburan Sarawak**

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Paddy Farmers' Awareness, and Perception Towards Agroforestry Practice
and The Effect of Different Agricultural Practices on Selected Soil Properties
in Siburan Sarawak

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

Agriculture is essential for the survival of humanity, but unsustainable practices threaten its long-term viability. Rice is an important crop as it is a staple food and the main source of income and livelihood, especially for rural communities in Malaysia. Intensive farming activities such as tillage, residue burning and the use of agrochemicals can lead to soil erosion and degradation. Sustainable practices such as intercropping, agroforestry and home gardening are known to improve soil health and reduce environmental impact. Agroforestry has gained popularity due to its ability to counteract the effects of climate change by increasing the resilience of agriculture but also combat food insecurity and land degradation. Therefore, it is crucial to introduce agroforestry practices to farmers to diversify their income sources and help them adapt to climate change. The aim of this study was to determine the awareness and perception of rice farmers in Siburan, Sarawak towards agroforestry. Moreover, different agricultural practices have different effects on soil properties, so this study also aimed to determine the selected physicochemical properties of soil under different agricultural practices. Data for the first two objectives were collected through questionnaire-based interviews in Kampung Skuduk and Kampung Chupak. 43 responses were obtained, and the data were analysed statistically to interpret farmers' responses. For the third objective, soil samples from three sites with different agriculture practices were collected and analysed. The samples were then analysed for various soil fertility indicators. The results show that farmers' knowledge of agroforestry practices was limited, especially among non-agroforestry practitioners. There are no significant income differences between agroforestry practitioners and non-agroforestry practitioners as agroforestry is practised on a small scale and for domestic use as there are no commercial market opportunities for the products. Awareness raising and information dissemination

activities are important as lack of awareness hinders the implementation of agroforestry. Furthermore, the respondents have a positive attitude towards agroforestry practices. They expected awareness-raising activities and workshops on agroforestry, which shows that they are willing to learn more about these practices. 80% of respondents who do not practice agroforestry are interested in practicing agroforestry if there are no obstacles. This positive attitude indicates that farmers in the study area are ready and willing to practice agroforestry. Among the land-use systems, agrisilviculture recorded the highest overall soil fertility, as indicated by its superior Soil Fertility Index (SFI) and Soil Evaluation Factor (SEF). This system maintained favourable conditions across multiple soil fertility indicators, including higher organic matter content, better moisture retention, and lower compaction. The soil pH under agrisilviculture was also optimal, contributing to a more balanced soil environment. In contrast, home gardens showed signs of acidification, which corresponded with reduced levels of essential nutrients, ultimately lowering their SEF values. These results emphasise the need to understand how different agricultural practices soil properties and provide practical insights to improve soil management strategies in Siburan, Sarawak.

Keywords: Agroforestry, awareness, knowledge, perception, soil properties

Kesedaran, dan Persepsi Petani Padi Terhadap Amalan Agroforestry dan Kesan Terhadap Amalan Pertanian Berbeza ke atas Tanah Terpilih di Siburan Sarawak

ABSTRAK

Pertanian penting untuk kelangsungan hidup manusia, namun amalan yang tidak lestari mengancam daya tahannya dalam jangka panjang. Padi ialah tanaman utama yang berperanan sebagai makanan ruji dan sumber pendapatan utama, terutamanya bagi komuniti luar bandar di Malaysia. Aktiviti pertanian intensif seperti pembajakan, pembakaran sisa tanaman dan penggunaan agrokimia boleh menyebabkan hakisan serta kemerosotan tanah. Amalan lestari seperti tanaman selingan, agroforestri dan taman rumah diketahui berpotensi meningkatkan kesuburan tanah dan mengurangkan impak alam sekitar. Agroforestri semakin mendapat perhatian kerana kemampuannya untuk mengurangkan kesan perubahan iklim dengan meningkatkan daya tahan pertanian, di samping mengatasi masalah ketidakcukupan makanan dan kemerosotan tanah. Oleh itu, adalah penting untuk memperkenalkan amalan agroforestri kepada petani bagi mempelbagaikan sumber pendapatan mereka dan membantu mereka menyesuaikan diri dengan perubahan iklim. Kajian ini bertujuan untuk menentukan tahap kesedaran dan persepsi petani padi di Siburan, Sarawak terhadap agroforestri. Selain itu, memandangkan pelbagai amalan pertanian memberi kesan yang berbeza terhadap sifat tanah, kajian ini juga bertujuan untuk menentukan sifat fizikokimia tanah yang terpilih di bawah pelbagai amalan pertanian. Data bagi dua objektif pertama dikumpul melalui temu bual berasaskan soal selidik yang dijalankan di Kampung Skuduk dan Kampung Chupak. Sebanyak 43 respons telah diperolehi dan dianalisis secara statistik untuk mentafsir maklum balas petani. Bagi objektif ketiga, sampel tanah dari tiga tapak yang mengamalkan amalan pertanian berbeza telah dikumpul dan dianalisis. Sampel tersebut dianalisis berdasarkan pelbagai penunjuk kesuburan tanah. Hasil kajian menunjukkan bahawa pengetahuan petani

mengenai agroforestri adalah terhad, terutamanya dalam kalangan mereka yang tidak mengamalkan agroforestri. Tiada perbezaan pendapatan yang signifikan antara petani yang mengamalkan agroforestri dan yang tidak, kerana agroforestri diamalkan secara kecil-kecilan dan hanya untuk kegunaan domestik disebabkan ketiadaan peluang pasaran komersial bagi hasil tanaman tersebut. Aktiviti pemerksaan kesedaran dan penyebaran maklumat adalah penting kerana kekurangan kesedaran menjadi penghalang utama kepada pelaksanaan agroforestri. Tambahan pula, responden menunjukkan sikap yang positif terhadap amalan agroforestri. Mereka menyatakan harapan untuk diadakan aktiviti kesedaran dan bengkel berkaitan agroforestri, menunjukkan bahawa mereka bersedia untuk belajar lebih lanjut tentang amalan ini. Sebanyak 80% daripada responden yang tidak mengamalkan agroforestri berminat untuk mengamalkannya sekiranya tiada halangan. Sikap positif ini menunjukkan bahawa petani di kawasan kajian bersedia dan berminat untuk mengamalkan agroforestri. Akhir sekali, tanah di sistem agrisilvikultur mencatatkan indeks kesuburan tanah (SFI) dan faktor penilaian tanah (SEF) yang tertinggi. Ini disebabkan oleh kandungan bahan organik, karbon organik dan kelembapan tanah yang tinggi serta ketumpatan pukal tanah yang rendah. Selain itu, pH tanah di bawah agrisilvikultur adalah pada tahap optimum (6.65), menunjukkan bahawa agrisilvikultur cenderung untuk mengekalkan keseimbangan tanah yang lebih stabil. Keasidan tanah di taman rumah menyebabkan kejatuhan dalam kandungan kation dan anion tanah seperti ammonium (NH_4^+), fosfat (PO_4^{3-}), kalium (K^+), natrium (Na^+), magnesium (Mg^{2+}) dan kalsium (Ca^{2+}), yang seterusnya menurunkan SEF. Hasil kajian ini menekankan keperluan untuk memahami bagaimana amalan pertanian yang berbeza mempengaruhi sifat tanah serta menyediakan panduan praktikal bagi meningkatkan strategi pengurusan tanah di Siburan, Sarawak.

Kata kunci: Agroforestri, kesedaran, pengetahuan, persepsi, sifat tanah

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LIST OF ABBREVIATIONS

BNF	Biological nitrogen fixation
BD	Bulk density
CGS	Centre for Graduate Studies
UNIMAS	Universiti Malaysia Sarawak
GDP	Gross domestic product
GHG	Greenhouse gas
MC	Moisture content
MOA	Ministry of Agriculture
NAP 2.0	National Agriculture and Food Policy
NAP3	3rd Malaysian National Agriculture Plan
RM	Ringgit Malaysia
SEF	Soil evaluation factor
SFI	Soil fertility index
SOC	Soil organic carbon
SOM	Soil organic matter
SSR	Self-sufficiency rate
WM	Weighted mean

CHAPTER 1

INTRODUCTION

1.1 Study background

The agricultural sector is one of the most important sectors, as it plays an important role in economic development and employment. In 2023, the agricultural sector contributed 7.8% to Malaysia's gross domestic product (GDP) (Siddharta, 2024). In addition, the agricultural sector also plays an important role in poverty alleviation as most low-income people in Malaysia are engaged in agriculture (34% of the total number of low-income people) (Saari et al., 2013). Rice is one of the most important crops in the Malaysian agricultural sector as rice is the staple food for most of the population (Firdaus et al., 2020). A Malaysian consumes 80kg of rice per person, which costs an average of RM44/month per household (Che et al., 2019). Paddy cultivation is the main source of income and livelihood especially for rural communities in Malaysia, where 40% of farmers are entirely dependent on rice cultivation (Firdaus et al., 2020). However, the rice production has decreased by 4.7%, from 2.28 million tonnes in 2022 to 2.18 million tonnes in 2023 (The Star Online, 2024). According to Agriculture and Food Security Ministry, the reduction was accredited to various internal and external factors that affected the country's padi and rice productivity.

Besides, both lowland and paddy are highly dependent on climate, as most of the world's paddy production is grown in regions where the temperature is already close to the optimum for rice cultivation (Fahad et al. 2018). An increase in temperature could reduce rice yields by up to 40 %, as heat stress impairs the ability of rice flowers to pollinate (Fahad et al. 2018).

Furthermore, the study by Shamsudin et al (2014) has shown that climate change affects the net revenue from paddy cultivation in Malaysia. In general, climate change has an impact on agricultural, economic, social and environmental sustainability (Arora, 2019). This is because climate change has altered the unpredictability of climatic factors such as temperature, rainfall, soil moisture, floods, drought and other natural disasters (Tang, 2019). If this situation is prolonged and uncontrollable, the future generation will face a severe food and economic crisis. Therefore, it is important to find ways to mitigate climate change. According to Brown et al. (2018), agroforestry has gained popularity as a land use strategy to mitigate climate change and offers additional environmental, economic and social benefits. Agroforestry is the practice of integrating trees into agricultural systems and their management to increase the yield, profitability, diversity and sustainability of ecosystems (Wangpakapattanawong et al., 2017). Agroforestry has numerous economic and environmental benefits that can help farmers adapt to rapidly changing weather patterns and mitigate climate change (Bogale and Bekele 2023). Agroforestry helps to reduce carbon dioxide concentration in the atmosphere through carbon sequestration by removing carbon from the atmosphere and depositing it in the soil (Rizvi et al., 2019).

Agroforestry offers other benefits, including regulation of nutrient cycling (Sileshi et al., 2020), habitat for biodiversity (Jose, 2012), erosion control (Jafari et al., 2022), flood control (Quandt et al., 2017), cultural benefits (Falkowski & Diemont, 2021) and contribution to food security and income (Duffy et al. 2021). To introduce and properly manage agroforestry, it is therefore important to understand the agroforestry systems that can help mitigate climate change. For example, farmers in Vietnam, Indonesia, the Philippines, Myanmar, Laos and Thailand who practise agroforestry in their paddy have been able to counteract the effects of climate change such as flooding and drought

(Wangpakapattanawong et al., 2017). In Vietnam, farmers use fish to control aphids when cultivating rice fields, while in the Philippines, coconuts are planted along the rice fields to stabilise the soil (Wangpakapattanawong et al., 2017).

In Malaysia, agroforestry was included as one of the strategic action plans in the 3rd National Agricultural Plan of Malaysia (NAP3) to increase farmers' income (MOA, 1999). The rural communities were not aware that they were practising agroforestry because they lacked the knowledge and understanding about agroforestry (Musa et al., 2019). Local communities in Merotai Besar, Tawau, were able to generate income and reduce poverty after applying agroforestry (Musa et al., 2019). Agroforestry in Malaysia has also attracted the attention of the private sector as they started to introduce agroforestry in oil palm plantations and forest plantations (Jeyanny et al., 2022). However, research on agroforestry in Malaysia is limited due to the lack of attention from the government (Keat, 2018). To fully comprehend the potential of agroforestry across Malaysia—as a means for enhancing farmer incomes, improving soil health, and mitigating deforestation—the federal government would need to pair strategic policy direction with robust infrastructural, financial, and research support.

1.2 Problem statement

Kampung Skuduk and Kampung Chupak are the main paddy growing areas in Sarawak with an area of about 200 hectares where paddy is grown twice a year (Kassim, 2014). Although agroforestry remains part of Sarawak's strategic resource planning since NAP3, its current implementation is largely small-scale, and project driven. More broadly, the state's policy trajectory now prioritizes technology-led agriculture, food security, and circular economic frameworks. There is potential to weave agroforestry into these emerging agendas, especially in forest rehabilitation zones, livelihood programmes, and sustainable biomass use, but comprehensive agroforestry policy remains underdeveloped at the state level. There is no agroforestry activities were documented in the paddy fields in Kampung Skuduk and Kampung Chupak. This may be attributed to the informal nature of agroforestry practices in areas such as Siburan, which are not formally recorded in academic literature. Furthermore, small-scale farmers often do not explicitly identify or classify their land-use systems as agroforestry, leading to underrepresentation in documented studies. It is important to provide farmers with information on agroforestry practices because agroforestry can help them adapt to the climate change crisis. However, before knowledge on agroforestry is disseminated, it is important to determine the level of awareness, knowledge and perception of farmers to ensure successful implementation of agroforestry.

Therefore, it is crucial to measure the level of awareness of agroforestry among farmers, especially rice farmers in Kampung Skuduk and Kampung Chupak, to determine the extent of their knowledge and awareness of agroforestry practices. It is also important to study soil properties under different practice in the study area because different agricultural practices may contribute differently to soil properties. According to Yasin et al. (2019), the application of agroforestry practices has been shown to lead to a steady increase in carbon

sequestration, which unintentionally contributes to mitigating the effects of climate change. Therefore, it is crucial to determine soil properties and carbon sequestration in the study area. Together, these two areas of focus address the social and environmental aspects of agroforestry adoption. By understanding both farmers' readiness and the effect of agroforestry on soil, we can better inform sustainable farming strategies in Sarawak. These data also important for future research on agroforestry and the implementation of agroforestry in Kg. Chupak and Kg. Skuduk.

1.3 Objectives

This study highlighted the following objectives:

- i. Identifying the paddy farmers' knowledge and awareness on agroforestry practices in Kg. Chupak and Kg. Skuduk.
- ii. Determining the paddy farmers' perception on agroforestry practices in Kg. Chupak and Kg. Skuduk.
- iii. Investigating the selected soil physicochemical properties under different agricultural practices in Kg. Chupak and Kg. Skuduk.

1.4 Structure of thesis

This thesis was divided into five main chapters. For chapters 3 to 5, we have formulated research questions based on the study objectives, which guide the data collection and analysis. Chapter 3 examines the level of knowledge of rice farmers in Kampung Skuduk and Kampung Chupak, Siburan, Sarawak, in relation to agroforestry practices and their benefits. This chapter is based on the following research questions:

- i. What is the level of knowledge of rice farmers in Kampung Skuduk and Kampung Chupak, Siburan, Sarawak, in relation to agroforestry practices?
- ii. What benefits of agroforestry practices do rice farmers in Kampung Skuduk and Kampung Chupak, Siburan, Sarawak, perceive?

Chapter 4 examines farmers' perceptions and attitudes towards agroforestry practices. The primary research question explored in this chapter is:

- i. What are farmers' perceptions and attitudes towards agroforestry practices?

Understanding farmers' perceptions and attitudes is critical prior to the adoption of agroforestry, as their acceptance and willingness to adopt these practices will influence successful implementation. Chapter 5 assesses the impact of different agricultural practices on selected soil properties in Siburan, Sarawak. This chapter addresses the research question:

- i. What are the impacts of different sustainable agricultural practices on selected soil properties in Siburan, Sarawak?

By analysing these impacts, this chapter provides insights into the relationship between agricultural practices and soil health, contributing to the broader discussion on sustainable land management.

CHAPTER 2

LITERATURE REVIEW

2.1 Agricultural sector in Malaysia

The agricultural sector plays an important role in economic development, employment and food security. In 2023, the agricultural sector contributed 7.8% to Malaysia's gross domestic product (GDP), which is higher than the previous year (6.6%) (Siddharta, 2024). The growth of the agricultural sector contributes more to poverty reduction than any other sector (Entezari et al., 2021). According to Saari et al. (2013), the agricultural sector plays a crucial role in reducing poverty as most low-income households in Malaysia are engaged in agriculture (Saari et al., 2013). In the National Agriculture and Food Policy 2021-2030 (NAP 2.0), Malaysia has committed to strengthen the agricultural sector and has allocated RM6.42 billion in the 2025 budget for the Ministry of Agriculture and Food Security, with sustainable agricultural practices being one of the key initiatives proposed (Bernama, 2024).

The production of the crop sub-sector excluding paddy increased by 1.9% 2023, reaching 4.09 million tonnes compared to 4.01 million tonnes in 2022 and the production of the livestock sub-sector increased by 4.6% to 2.87 million tonnes in 2023 compared to 2.74 million tonnes in 2022 (Ministry of Agriculture and Food Security, 2024). In contrast, the fisheries sector's production decreased by 5.5% in 2023, with total landings of 1.79 million metric tonnes compared to 1.89 million metric tonnes in 2022 (Ministry of Agriculture and Food Security, 2024).

2.2 Rice industry in Malaysia

Rice is one of the most important crops in Malaysia, as rice is the staple food for most of the population (Firdaus et al., 2020). Rice cultivation is the main source of income and livelihood especially for rural communities in Malaysia, where 40% of farmers are entirely dependent on rice cultivation (Firdaus et al., 2020). The Deputy Minister of Agriculture and Food Security, Datuk Chan Foong Hin, stated that the country is targeting a rice SSR of 75% by 2025 and 80% by 2030 (Tan et al., 2023). However, the Ministry of Agriculture and Food Security stated that the self-sufficiency rate (SSR) for Malaysia's rice supply is 56.2% and 76.7 kg per capita consumption (PCC) per year (Paddy Industry Development Division, Ministry of Agriculture and Food Security and Ministry of Agriculture, 2024). Rice production fell by 4.7% from a production of 2.28 million tonnes in 2022 to 2.18 million tonnes in 2023 (Ministry of Agriculture and Food Security, 2024).

According to the statements Sarawak government officials, Sarawak's rice production currently meets only approximately 32% of its own domestic demand, meaning the state must import the remaining 68% to satisfy consumption needs (Wong, 2024). Minister of Agriculture and Regional Development Dato Sri Dr Stephen Rundi Utom said that the decline in rice production was due to the lack of agricultural infrastructure, high production costs, ageing farmers and competition for land from other crops (Tawie, 2023). He also mentioned that agricultural development in the state is focussed on commodity crops, especially oil palm, rather than food crops. In 2012, about 130,000 ha of land in Sarawak was under rice cultivation, but by 2021, the area decreased 3,000 ha (Ali, 2022).

This declining trend in paddy productivity is primarily due to some problems such as pests and diseases in paddy crops as well as unfavourable weather conditions such as floods and droughts (Dorairaj & Govender, 2023). For instance, the total area paddy

cultivation in Malaysia has decreased from 700 thousand hectares in 2018 to 647.9 thousand hectares in 2021 (Statista Research Department 2021). Furthermore, this trend is caused by the conversion of paddy cultivation areas to other crops such as pineapple, oil palm or rubber and the lack of interest of the younger generation in paddy cultivation as they prefer to work in the city (Ali, 2022). If this trend continues, Sarawak will have to rely on imported rice and face food security issues in the future. In 2021, Sarawak imported 145,468 tonnes of rice worth RM387 million (Cheng, 2022). However, the Sarawak government is pressing ahead with large-scale rice cultivation initiatives, supported by an allocation of RM1 billion for farm infrastructure, including advanced drainage and irrigation systems (Wong, 2024).

2.3 The impact of agricultural activities

Despite the importance of the agricultural sector, there are several challenges that threaten the ability of agriculture to meet human needs now and in the future, including climate change, biodiversity loss, land degradation and pollution of water resources. (Begum et al. 2020; Karp et al. 2012; Naseem et al. 2020; Zia et al., 2013). The agricultural sector is strongly affected by climate change due to the changing unpredictability of climate factors such as temperature, precipitation, soil moisture, floods, drought and other natural disasters (Tang, 2019). The needs of agriculture, especially the yield, area under cultivation and value of the crop, are changing due to climate change and ultimately affect the sustainability of agriculture (Alam et al., 2011). However, agriculture is one of the sources of greenhouse gas (GHG) emissions, accounting for more than 11% of total anthropogenic emissions (Maraseni, & Qu, 2016).

Intensive cultivation in practice lead to soil erosion, soil pollution and soil degradation through tillage, the use of agrochemicals and deforestation (Moldavan et al.,

2024). According to Nunes et al. (2020), intensively tilled soils are more susceptible to soil compaction compared to non-tilled soils due to the oxidation of SOM and soil erosion combined with the cumulative loading effect of the tillage equipment used. Intensive tillage also promotes soil degradation by increasing subsoil compaction, topsoil depletion and surface crusting, will water and wind erosion (Karlen & Rice, 2015). In addition, clearing land for agricultural purposes and leaving the soil for long periods of time also leads to soil erosion (Ahmed & Boon, 2023).

According to Coulibaly et al. (2021) and Yusof et al. (2022), agriculture is one of the main causes of soil erosion, which leads to various environmental complications, including runoff and sediment pollution, reduction in water storage capacity, flooding due to the reduction in the capacity of river channels, and loss of recreational and commercial value. In addition, the use of chemical fertilizer such as N and P fertilizers in will to excess nutrients in the soil and leaching of nutrients into the water system (Abbasi et al. 2013; Kumar & Yaashikaa, 2019). In addition, the use of pesticides in agriculture can kill beneficial insects, pollute water bodies and affect human and animal health (Abbasi et al., 2013). Measures must be taken to reduce the impact of agriculture on the environment and to ensure the sustainability of agriculture.

2.4 Sustainable agriculture to mitigate the impact of agricultural activities

Sustainable agriculture has gained attention because it can reduce the negative impact of the agricultural sector on the environment while improving production (Sharma et al. 2024; Siebrecht 2020; Xu et al., 2024). Sustainable agriculture can be defined as a management strategy that helps farmers choose farming practices that enable sustainable production and profit while minimising environmental impacts, minimising waste and

conserving resources (Trigo et al. 2021; Velten et al., 2015). In addition, the adoption of sustainable agriculture can help conserve resources, improve soil fertility and protect ecosystems (Jawad et al. 2017; Pigford et al. 2018; Sharma et al. 2024).

Sustainable agriculture is also beneficial for economic and social development. Studies have shown that farmers who use sustainable agricultural practises such as intercropping achieve higher yields and profits (Ghimire et al. 201; Latatia et al., 2016). Intercropping also helps to suppress weeds, reduce pest or disease infestation and reduce the risk of droughts (Chazovachii, 2012; Fanadzo, 2012; Kuwornu and Owusu, 2012). Furthermore, sustainable practices such as agroforestry improved soil health and the soil ecosystem and significantly reduced soil erosion (Muchane et al. 2020; Pinho et al., 2012). In addition, Zada et al. (2022) found that agroforestry has a positive impact on livelihoods and economic development, as farmers who adopt agroforestry earn 6% more income. The study by Akter et al. (2022) also showed that agroforestry systems improve farmers' livelihoods by improving their access to food, timber, fodder and firewood. In addition, agroforestry systems also play a role in mitigating climate change by reducing greenhouse gas emissions and sequestering atmospheric carbon and storing it as a carbon stock in the soil (Getnet et al. 2023; Yasin et al., 2024).

2.5 Intercropping practices

Intercropping is one of the sustainable agriculture practices of growing two or more crops simultaneously on the same field, has been widely recognized for its ecological and economic benefits. This practice efficiently utilizes space, water, and nutrients (Xu et al., 2020). Intercropping can also improve soil fertility and structure, suppress weeds, and reduce pest and disease incidence due to increased biodiversity (Brooker et al., 2015; Verret et al.,

2017; Darayanto et al., 2020). According to Maitra et al. (2021), intercropping could help to control soil erosion as it prevents the rain striking the soil surface directly, improves water infiltration and reduces runoff. A study by Chai et al. (2013) reported that a maize-pea intercropping system increased the water use efficiency by 95% compared to monocropping of pea only. Cereal-legume intercropping enhances the nutrient utilization efficiency because legumes can alter the soil pH which create microenvironment that enhances the nutrient availability for cereals (Goyal and Habtewold, 2023). Prolonged use of legumes in intercropping systems also enhance the soil organic matter (Kebede, 2021) which can improve the soil physical, chemical, and biological properties of and enhance the nutrient availability (Paramesh et al., 2023). A study by Buakong et al. (2024) in Thailand reveal that mixed-rubber systems reduced physiological stress in rubber and improved microclimate variables. In Malaysia, alley-cropping trials in oil palm estates such as those incorporating black pepper or cacao, enhanced vegetation diversity, helped regulate extreme microclimatic conditions, and increased arthropod biodiversity compared to monocultures, demonstrating ecological co-benefits without compromising palm yields (Ashraf et al., 2018).

2.6 Agroforestry system

According to Brown et al. (2018), agroforestry has gained popularity as a land use strategy to mitigate climate change and provide additional environmental, economic and social benefits. The agroforestry system is proposed to address food security issues as it increases the productivity of the agricultural ecosystem and mitigates the effects of climate change through increased carbon sequestration (Branca et al., 2013). In general, agroforestry can be defined as a land use system that combines trees and crops or livestock on the same land unit, either temporally or spatially (Bishaw et al., 2022). Agroforestry practices provide

several benefits to farmers and the landscape, such as forests and watershed protection (Maponya et al., 2022). Nair et al. (2008) mentioned that agroforestry not only provides environmental services such as soil conservation, carbon storage, biodiversity conservation and water quality improvement, but also alleviates poverty, ensures food security and controls land degradation.

2.7 Agroforestry effects on soil

Agroforestry is widely recognised for its potential to improve soil quality (Dollinger & Jose, 2018). Agroforestry also enables efficient utilisation of resources such as nutrients, light and water, provides great structural diversity and supports nutrient cycling (Nair et al., 2008). The diverse vegetation of agroforestry practices continuous process of decomposition and will increase organic matter and nutrients in the soil (Dollinger & Jose, 2018). In a study by Prakash et al. (2017), it was found that agricultural land under agroforestry in India has higher soil organic phosphorus and SOC content, but lower inorganic phosphorus content compared to other conventional land uses.

In addition, agroforestry systems also provide tree canopies that reduce evaporation and transpiration from the soil and plants, water use efficiency and provides optimal soil moisture (Kaur et al., 2023). This study has proven that agroforestry systems can help improve soil productivity and restore degraded land. It is also hypothesised that agroforestry could play an important role in mitigating climate change as it sequesters more atmospheric carbon in plant parts and soils than conventional agriculture (Verchot et al., 2007). Agroforestry systems have a higher potential to sequester atmospheric carbon dioxide (CO²) than soil organic matter (Ghale et al., 2022). The extensive root system that grows deep into the mineral soil in agroforestry systems help to increase carbon sequestration and store soil

organic carbon in deeper soil horizons (Canadell et al. 1996; Lorenz and Lal 2005; Rasse et al. 2005). Agroforestry also improves carbon sequestration as tree roots have the potential to extract nutrients below the root zone of plants and promote tree and plant growth by increasing nitrogen supply, which could contribute to an increase in soil organic carbon (Lorenz & Lal, 2014).

2.7.1 Agroforestry mitigating climate change through carbon sequestration.

Agroforestry is one of the ways to reduce the concentration of carbon dioxide in the atmosphere through carbon sequestration. Carbon sequestration is a process in which carbon is removed from the atmosphere and deposited in soil. Albrecht and Kandji (2003) conducted an analysis of carbon stocks in different parts of the world to show that a significant amount of carbon could be removed from the atmosphere over a 50-year period if agroforestry were practiced worldwide. It is believed that agroforestry could play an important role in mitigating climate change because it sequesters more atmospheric carbon in plant parts and soils than conventional agriculture (Verchot et al., 2007). Agroforestry systems have a higher potential to sequester atmospheric carbon dioxide (CO₂) as soil organic (Ghale et al., 2022). The extensive root system that grows deep into mineral soil in agroforestry system helps to increase the carbon sequestration and stock soil organic carbon in deeper soil horizons (Canadell et al. 1996; Lorenz and Lal 2005; Rasse et al. 2005). Besides, trees have a greater potential for carbon sequestration than plant and pasture species due to the trees have ability to stabilize soil organic carbon in deeper mineral soil horizons (Jobbágy and Jackson 2000). Root-derived carbon from trees is four times more stable as soil organic carbon than an equivalent amount of aboveground litter carbon (Jackson et al. 2017; Prescott 2010). Agroforestry also improved carbon sequestration because the tree roots have the potential to

recover nutrients below the plant root zone and enhance tree and plant growth by increasing nitrogen supply, which could help increase soil organic carbon (Lorenz & Lal, 2014).

2.8 Soil Fertility Index (SFI) and Soil Evaluation Factor (SEF)

The Soil Fertility Index (SFI) and the Soil Evaluation Factor (SEF) are two key indicators commonly used to assess soil quality and productivity. The SFI is a weighted composite of several soil chemical properties, including pH, organic matter content, nutrient availability and cation exchange capacity (Naumann et al., 2019). Higher SFI values indicate better soil health and greater potential to support plant growth. In contrast, the SEF represents a more comprehensive soil quality index that incorporates both chemical and physical attributes such as soil moisture, bulk density, texture, porosity and, in some cases, biological indicators. It was specifically developed to assess the suitability of soil for specific land uses or cropping systems (Kumar et al., 2012; Wani et al., 2017).

In contrast to SFI, which mainly focuses on nutrient-related parameters, SEF provides a more comprehensive assessment by integrating structural and moisture-related characteristics that directly affect crop development. Research by Zhao et al. (2020) and Bera et al. (2017) has shown that conservation practices such as agroforestry or reduced tillage can improve SEF scores by improving soil structure and water retention. Comparative assessments have shown that soils managed under agrisilviculture systems generally have higher SFI and SEF values than soils managed under monoculture or intensive agriculture. These improvements are often attributed to increased organic matter, lower bulk density and better water retention in the soil (Sudomo et al., 2023; Emi Roslinda et al., 2023). Thus, the

combined application of SFI and SEF offers a more holistic assessment of soil health, providing valuable insights for the development of sustainable land management strategies.

2.9 Agroforestry in Malaysia

In Malaysia, the development of agroforestry is moving towards commercial agroforestry. Musa et al (2018) reported that Malaysia has adopted agroforestry practices by integrating plantation crops with woody species. Furthermore, agroforestry was identified as one of the strategic action plans in the 3rd Malaysian National Agriculture Plan (NAP3) due to its benefits. Many private sectors in Malaysia practise agroforestry through the integration of forest and plantation, intercropping of tropical fruit trees, livestock and beekeeping (Vijayanathan et al., 2022). Despite the above-mentioned integrations and practices, agroforestry in Malaysia is still under-researched (Keat et al., 2018). Noor et al. (2012) emphasised that local agroforestry research received little attention due to the government's focus on industry and the automotive sector, resulting in slow progress. Therefore, a comprehensive study on knowledge, awareness and challenges of agroforestry needs to be conducted to raise awareness on agroforestry in Malaysia. This will help to ensure a stable and successful adaptation of agroforestry in Malaysia.

2.10 Awareness and perception towards agroforestry system

The first step in the decision-making process when introducing new practices, such as how to apply them and what results will be achieved in terms of products, yields, potential environmental benefits, risks and costs (Rogers et al., 2019). This knowledge then forms the basis for the perceptions and attitudes that person develops towards the practice (Meijer et

al., 2014). Knowledge refers to the information and understanding of agroforestry, while perception refers to the farmer's view based on their needs and experiences, such that both knowledge and perception determine their attitude towards it (Meijer et al., 2014). In Borneo, Malaysia, agroforestry has long been practiced by rural communities, but most farmers are unaware of it (Azmy et al., 2013). Agroforestry practices are largely practised by rural communities with low levels of education, making it difficult to recognise the limitations to the practise (Musa et al., 2019), and sometimes it is difficult for them to market their products that can earn them a side income. To date, there is a lack of specific studies in Sarawak examining farmers' awareness and perceptions of agroforestry practices. Therefore, the present study serves to address this gap and contribute to the understanding of agroforestry adoption at the local level.

CHAPTER 3

PADDY FARMER'S AWARENESS AND PERCEPTION OF AGROFORESTRY PRACTICES IN SIBURAN, SARAWAK

Preamble:

This chapter was published in Urban Agriculture & Regional Food Systems (Mathew, J., Echoh, D. U.A., & Ibrahim, M. H. (2025). Paddy farmers' awareness and knowledge of agroforestry practices in Siburan, Sarawak. Urban Agriculture & Regional Food Systems, 10, e70011. <https://doi.org/10.1002/uar2.70011>) and in Borneo Journal of Resource Science and Technology (Mathew, J. A., Jamali, M. H. B., Sitthan, V. K., Tagang, R. R., & Ibrahim, M. H. (2024). Farmers' perception towards agroforestry practices in Siburan. Borneo Journal of Resource Science and Technology, 14(2), 210–216. <https://doi.org/10.33736/bjrst.6954.2024>) at the time of submission of this thesis. This work was mainly conducted by me; however, all co-authors contributed significantly to original idea generation, experimental design, data interpretation and manuscript editing.

3.1 Introduction

Rice is one of the most important crops in Malaysia, as rice is the staple food for most of the population (Firdaus et al., 2020). Malaysians consume 80 kg of rice per person annually, which costs an average of RM 44/month per household (Hua et al., 2024). This amount equates to approximately 14.45% of an individual's daily caloric intake, based on the caloric content of rice (approximately 130 calories per 100 grams of cooked rice) and average dietary patterns in Malaysia. Rice cultivation is the main source of income and

livelihood especially for rural communities in Malaysia, where 40% of farmers are entirely dependent on rice cultivation (Firdaus et al., 2020).

Globally, climate change has affected agricultural, economic, social and environmental sustainability (Ulises et al., 2022). The increasing volatility of climate variables such as temperature fluctuations, changes in precipitation patterns, soil moisture variability, floods, droughts, and other natural calamities directly undermines the sustainability of agricultural systems on economic, social, and environmental fronts (Tang, 2019). Rice production is highly dependent on climate, as most of the world's rice production is grown in regions where the temperature is already close to the optimum for rice production (Fahad et al., 2018). An increase in temperature could reduce rice yields by up to 40 %, as heat stress impairs the ability of rice flowers to pollinate (Fahad et al., 2018). An increase of 1% in temperature is expected to cause a 3.44% decrease in rice yield during the current season, with a minor residual impact leading to an additional 0.03% yield decrease in the following season due to ongoing heat stress on the crop system.

Farmers in Vietnam, Indonesia, the Philippines, Myanmar, Laos and Thailand who practice agroforestry in their rice fields have been able to counteract the effects of climate change such as flooding and drought (Wangpakapattanawong et al., 2017). In the Philippines, coconuts are planted along rice fields to stabilize the soil (Figure 3.1) (Wangpakapattanawong et al., 2017). Agroforestry can be defined as a land-use system that combines trees and crops or livestock on the same land unit, either temporally or spatially (Atangana et al., 2014; Köthke et al., 2022). A study by Santos et al. (2019) found that agroforestry systems provide up to 45-65 % benefits for biodiversity and ecosystem services. These ecological advantages fortify the environment and translate into tangible social and economic gains for farmers, providing increased profitability and sustainability. The

potential of agroforestry to deliver financial benefits is undeniable, as it improves soil quality, enhances crop yields, and diversifies income sources (Castle et al., 2022).



Figure 3.1: Trees in rice-production landscape, the Philippines (Source: Wangpakapattanawong et al., 2017)

Agroforestry has numerous economic and environmental benefits that can help farmers adapt to rapidly changing weather patterns and combat climate change (Bogale & Bekele, 2023). In addition, when properly managed, agroforestry also makes a significant contribution to food access and income (Duffy et al., 2021). In Malaysia, agroforestry is not a new issue as it is one of the sectors that contribute to socio-economic development, especially for rural communities. Agroforestry was identified in Malaysia's 3rd National Agricultural Plan (NAP3) as one of the strategic action plans to achieve higher profit margins and increase farm incomes (MOA, 1999). Little research has been conducted on agroforestry in Malaysia (Keat et al., 2018). Noor et al. (2012) emphasized that local agroforestry research

received little attention as the government focused on industry and the automotive sector, resulting in slow progress.

However, despite its proven success, agroforestry activities have yet to be documented in the paddy fields in Kampung Skuduk and Kampung Chupak. These villages are successful pilot projects for wet rice cultivation in Sarawak (Kong, 2014), and rice cultivation is one of the most important economic activities in Siburan. Farmers who only grow rice on their farms are considered more vulnerable to climate and market shocks (Wangpakapattanawong et al., 2017). This is because monocropping increases exposure to risks such as floods and droughts. Trees, by contrast, offer greater resilience against these extreme weather events, providing a buffer that rice alone cannot. Farmers who integrate tree crops can maintain food production and income even when rice yields face challenges. Therefore, it is important to provide farmers in Kg. Skuduk and Kg. Chupak with opportunities to diversify their sources of income and thus help them adapt to the climate change crisis.

However, before introducing agroforestry to farmers, it is crucial to determine their attitudes towards agroforestry practices to ensure the successful implementation of agroforestry. This is because the first step in the decision-making process when adopting new practices depends on their knowledge of the practice, e.g. how to apply it and what results it brings in terms of products, yields, potential environmental benefits, risks and costs (Rogers et al., 2019). This knowledge then forms the basis for a person's perceptions and attitudes towards the practice (Meijer et al., 2014). Knowledge refers to the information and understanding about agroforestry, while perception refers to the farmer's view based on their needs and experiences. Both knowledge and perception determine the farmer's attitude toward agroforestry (Meijer et al., 2014). Few studies conducted in Bangladesh and Malaysia

indicate that most farmers have a positive attitude toward agroforestry, especially middle-aged farmers who prefer to adopt agroforestry techniques (Islam et al., 2021; Sheikh et al., 2021). Therefore, this study aimed to determine awareness and perceptions toward agroforestry practices.

3.2 Methodology

3.2.1 Study area

This study was conducted in Kampung Skuduk and Kampung Chupak, located in the Siburan district, about 32 kilometers (about 19.88 miles) from Kuching, the capital of Sarawak. The geographical coordinates of the study area are 1.3619° north latitude and 110.4045° east longitude, with an elevation 56 metres above sea level (Figure 3.2). Kg. Skuduk and Kg. Chupak is one of the wet paddy cultivation areas in Sarawak where rice is cultivated twice a year (Musa et al., 2021) and a successful pilot project for wet paddy cultivation (iM Sarawak ‘Wet Paddy Cultivation Program’) (Kong, 2014). The most important economic activity for the local population in Kg. Skuduk and Kg. Chupak is rice cultivation, according to the Siburan agricultural officer (personal communication). According to Jabatan Pertanian Daerah Siburan (Siburan District Department of Agriculture), there are about 89 rice farmers registered for 2023, most of whom are majority Bidayuh ethnic group and Christian.

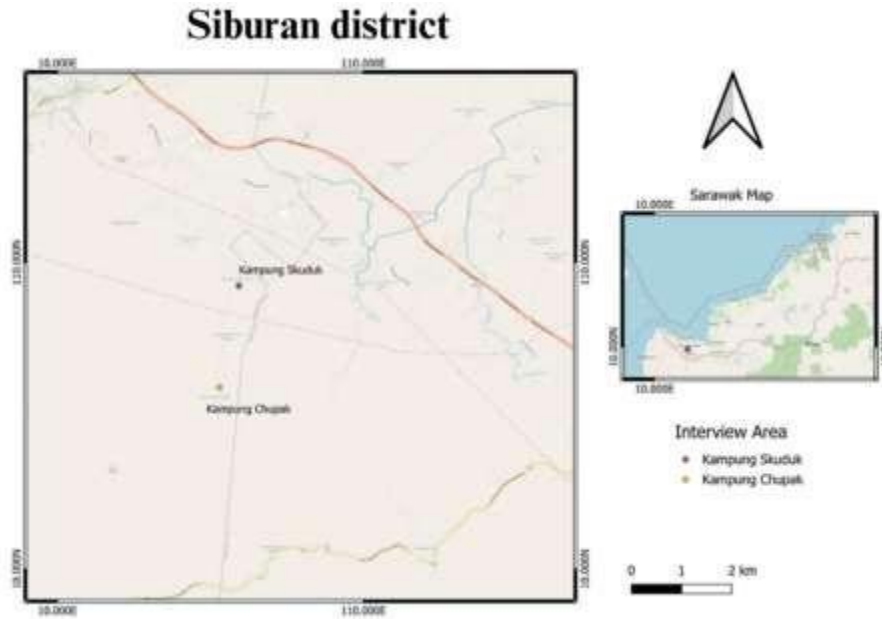


Figure 3.2: The location of study area, Kampung Skuduk and Kampung Chupak

3.2.2 Data collection

Data were collected through a formal questionnaire survey and interviews with registered rice farmers in Siburan. To ensure the representativeness of sample in this study, the Jabatan Pertanian Daerah Siburan (Siburan District Department of Agriculture) assisted to identify a diverse group of respondents. Participants for this study were selected using purposive sampling to ensure the inclusion of individuals actively engaged in rice farming. This approach allowed us to focus on participants who could provide detailed insights into the practices, challenges, and knowledge associated with rice farming in the region. This approach was also chosen to ensure that the data collected would reflect the experiences, perceptions, and practices of farmers who are currently involved in agricultural activities and thus have relevant knowledge about agroforestry practices. However, the samples might

over-represent more active or accessible farmers, and that results may not generalize to all paddy farmers especially the non-registered farmers.

Efforts were also made to balance educational levels within the sample by including participants with varying degrees of formal education. However, we acknowledge that the sample reflects the broader demographic trends of rice farmers in the region, where the majority tend to be older individuals. This age distribution aligns with regional statistics indicating that younger generations are less involved in traditional farming practices. The questionnaire contained open-ended questions that sought respondents' opinions and closed-ended questions that included a menu of response options. The 5-point Likert scale was used to assess respondents' knowledge, awareness and perception. The scales used in this study are (1 = very aware, 2 = aware, 3 = not sure, 4 = not aware, 5 = not aware at all) for knowledge and awareness.

The questionnaires consisted of seven sections: i) General socio-demographic information of the respondents; ii) General information on rice cultivation; iii) Respondents' perception of rice cultivation; iv) Awareness and knowledge on agroforestry practices; v) Respondents' awareness on the benefits of agroforestry; vi) Respondents' perception on agroforestry practices; and vii) The challenges in adopting agroforestry practices. For this study, we categorized agroforestry practices to include both tree-based systems and annual crop intercropping systems. This inclusive categorization reflects the diverse agroecological strategies adopted by farmers in the study area. Farmers practicing tree-based agroforestry (e.g., rubber, fruit trees, or oil palm with rice) and non-tree-based intercropping (e.g., rice intercropped with maize or vegetables) were analysed under the broader agroforestry framework. This approach allows us to capture the spectrum of agroecological practices and better understand their socio-economic and environmental implications. The decision to stop

conducting interviews was guided by the principle of data saturation. Data saturation occurs when no new themes, patterns, or significant insights emerge from additional interviews, indicating that further data collection is unlikely to contribute substantially to the research findings. The study involved 83 paddy farmers. The qualitative component comprised 43 in-depth interviews. Thematic saturation was reached at interview 43. Descriptive summaries of respondent characteristics use the full sample ($n = 83$). Qualitative findings refer to the interviewed subsample ($n = 43$). After the interview, the paddy field of the respondent agroforestry practitioners was visited to verify the information provided by the agroforestry practitioners and to determine the type of agroforestry practiced.

3.2.3 Data analysis

The data obtained from the interview and the questionnaires were analyzed using the Statistical Package for the Social Sciences (SPSS). An unpaired t-test was used to compare the data and find a significant difference between respondents practicing agroforestry and respondents not practicing agroforestry. Chi-square test of independence was used to determine the significant difference between agroforestry practitioners and non-agroforestry practitioners. Since farmers in the study area practice agroforestry on a small scale, agroforestry practitioners in this study are rice farmers who grow other crops near their rice field and non-agroforestry practitioners are farmers who grow only rice in the field. The data for the Likert scale on knowledge and awareness were analyzed according to the method of Alonazi et al. (2019). The weighted means were calculated for the Likert scales, from Strongly Agree=1 to Strongly Disagree=5, (Table 3.1) to determine the trend of the composite score (Alonazi et al., 2019). The weighted averages are calculated using the

formula; Weighted mean = $\Sigma(w)x/\Sigma(w)$. where, $\bar{x}$ = the mean value of the set of given data. w = corresponding weight for each observation.

Table 3.1: Weighted means for 5-point Likert scale adapted from Alonazi et al. (2019)

Weighted mean	Result
1 - 1.79	Strongly agree
1.8 - 2.59	Agree
2.60 - 3.39	Neutral
3.40 - 4.19	Disagree
4.20 – 5	Strongly disagree

3.3 Results

3.3.1 Socio-demographic patterns of respondents in the study area

Table 3.2 shows the socio-demographic data of the paddy farmers who participated in this study. Of the 89 registered farmers, 43 responses were obtained, and the analysis revealed that 42% of respondents actively engaged in agroforestry, while 58% did not (Figure 3.3).

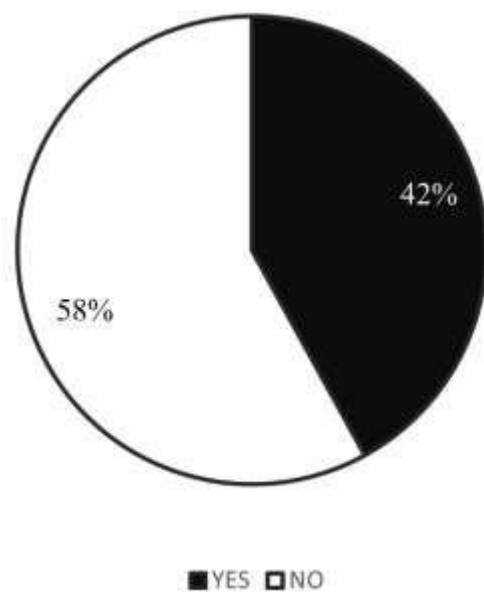


Figure 3.3: Respondents practising agroforestry and not practising agroforestry

Gender distribution among the surveyed group indicates a predominance of male farmers (63%), with females constituting 37%. Most of the respondents were older than 65 years old (49%), and most of them were married (91%). Most of the farmers in Kampung Skuduk and Kampung Chupak belong to the older generation, so most of them have been cultivating paddy for more than 21 years (74%). As most of the respondents belonged to the Bidayuh ethnic group (77%), many of them practised the Christian faith (98%). Most of the respondents (72%) have formal education, i.e. they have completed primary or high school, and only 1% of the respondents have higher education. Meanwhile, 26% of respondents have no formal education. More than half of the respondents primarily engaged in rice farming as their main occupation (84%), and most of them (84%) have a monthly income of less than RM1300.

Table 3.2: Sociodemographic of respondents in Kampung Skuduk and Kampung Chupak, Siburan, Sarawak.

Variables	No. of Respondents (%)
1. Gender	
Female	16 (37%)
Male	27 (63%)
2. Age	
35 – 44	1 (2%)
45 – 54	10 (23%)
55 – 64	11 (26%)
≥ 65	21 (49%)
3. Marital status	
Single	1 (2%)
Married	39 (91%)
Divorce/Widow	3 (7%)
4. Race	
Iban	4 (9%)
Bidayuh	33 (77%)
Cina	4 (9%)
Orang Ulu	1(2%)
Others	1(2%)
5. Religions	
Christian	42 (98%)
Islam	1 (2%)

Table 3.2 continued

6. Education	
No Formal Education	11 (26%)
Formal education	31 (72%)
Higher education	1 (2%)
7. Paddy cultivation	
status	36 (84%)
Full Time	
Part Time	7 (16%)
8. Income	
Less than RM 1300	36(84%)
RM 1300 – RM 1400	5 (12%)
RM 1401 – RM 1700	1 (2%)
More than RM 1701	1 (2%)
9. Experience	
5 – 10 years	6 (14%)
11 – 20 years	5 (12%)
≥ 21 Years	32 (74%)

3.3.2 The types of agroforestry practices practised by the agroforestry practitioners in the study areas

During the field visit, we found that most respondents engaged in two distinct practices: annual crop intercropping and agroforestry. Annual crop intercropping included combinations such as rice with maize (*Zea mays*) (Figure 3.4a) and rice with vegetables (Figure 3.4b). Agroforestry practices, which involve the integration of trees with crops or livestock, included examples such as the cultivation of palm oil opposite rice paddies (Figure 3.4 c) and rubber intercropped with local fruit trees such as rose apples (*Syzygium jambos*) or pineapples (*Ananas comosus*) and livestock (Figure 3.4d).



Figure 3.4: Examples of agricultural practices observed in Kampung Skuduk and Kampung Chupak, including intercropping systems (e.g., maize-paddy [a] and vegetables-paddy [b] combinations) and agroforestry systems (e.g., palm oil cultivation adjacent to rice paddy [c]) and with local fruit trees such as rose apples (*Syzygium jambos*) or pineapples (*Ananas comosus*) and livestock[d]

3.3.3 Agroforestry practitioners and non-agroforestry practitioners in the study area

Most agroforestry practitioners were self-taught in their knowledge of agroforestry practices, followed by influences or teaching from the older generation and finally from friends, authorities and the media (Figure 3.5).

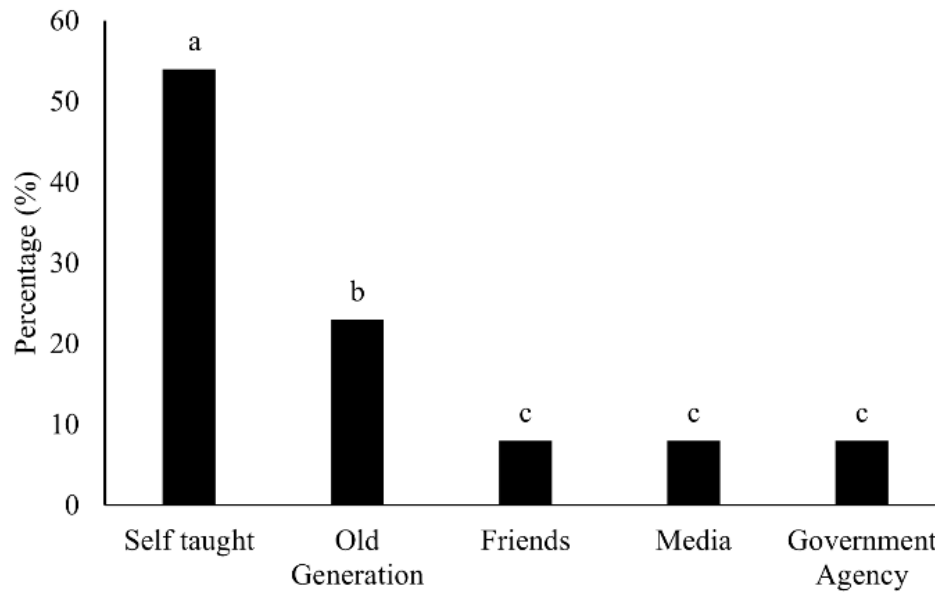


Figure 3.5: The source of agroforestry influences among the agroforestry practitioners in the study area. **Note: Means with the same letter are not significantly different.*

The duration of agroforestry practice among respondents was categorized into three groups: "since started paddy cultivation" (more than 10 years), "lately" (0 to 2 years), and "a few years after paddy cultivation" (3 to 9 years). The majority (70%) reported practicing agroforestry since starting paddy cultivation. This was significantly higher than the 40% who began agroforestry lately and the 20% who adopted it a few years after starting paddy cultivation (Figure 3.6).

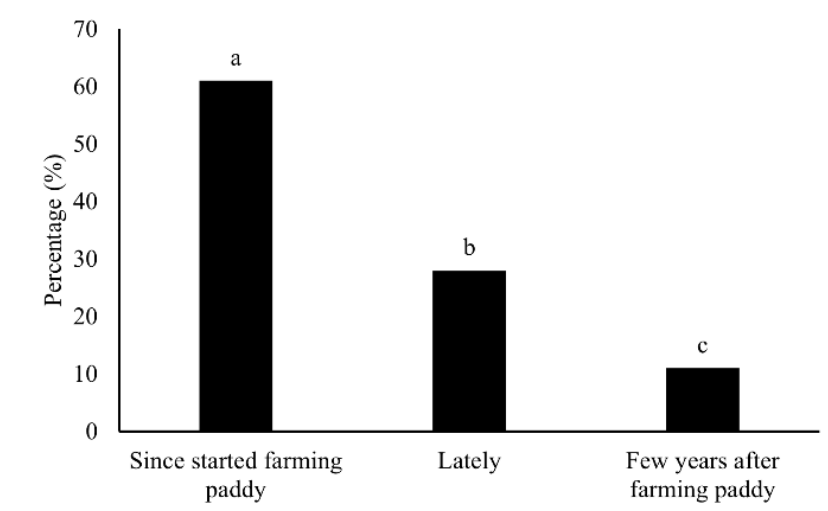


Figure 3.6: Duration of agroforestry practice among respondents categorized by years of experience (since paddy cultivation $\approx$ more than 10 years, lately $\approx$ 0 to 2 years, few year $\approx$ 3 to 9 years). **Note: Means with the same letter are not significantly different.*

More than half of the agroforestry practitioners practice agroforestry for consumption or to produce additional food for the family (60%), only a few practices agroforestry for additional income (32%) and the rest practice agroforestry because there is available land or area for cultivation (8%). Some respondents reported practicing agroforestry primarily because they had available land, which they utilized to plant additional crops or trees. This suggests a land-use optimization strategy rather than a direct focus on consumption or profit. However, these practices may also reflect traditional forms of land management, such as shifting cultivation or maintaining biodiversity on unused land. Land access factors such as lack of land or space and unsuitable land for cultivation are one of the main reasons given by respondents for not practicing agroforestry (47%) (Figure 3.7). The next most common reason for not practicing agroforestry is the lack of time, cost and labour to simultaneously manage the paddy field and other integrated crops or livestock (Figure 3.7). Some of the non-agroforestry practitioners (13%) expressed concerns that

integrating other crops or trees into their paddy fields could attract pests, potentially impacting their rice yields.

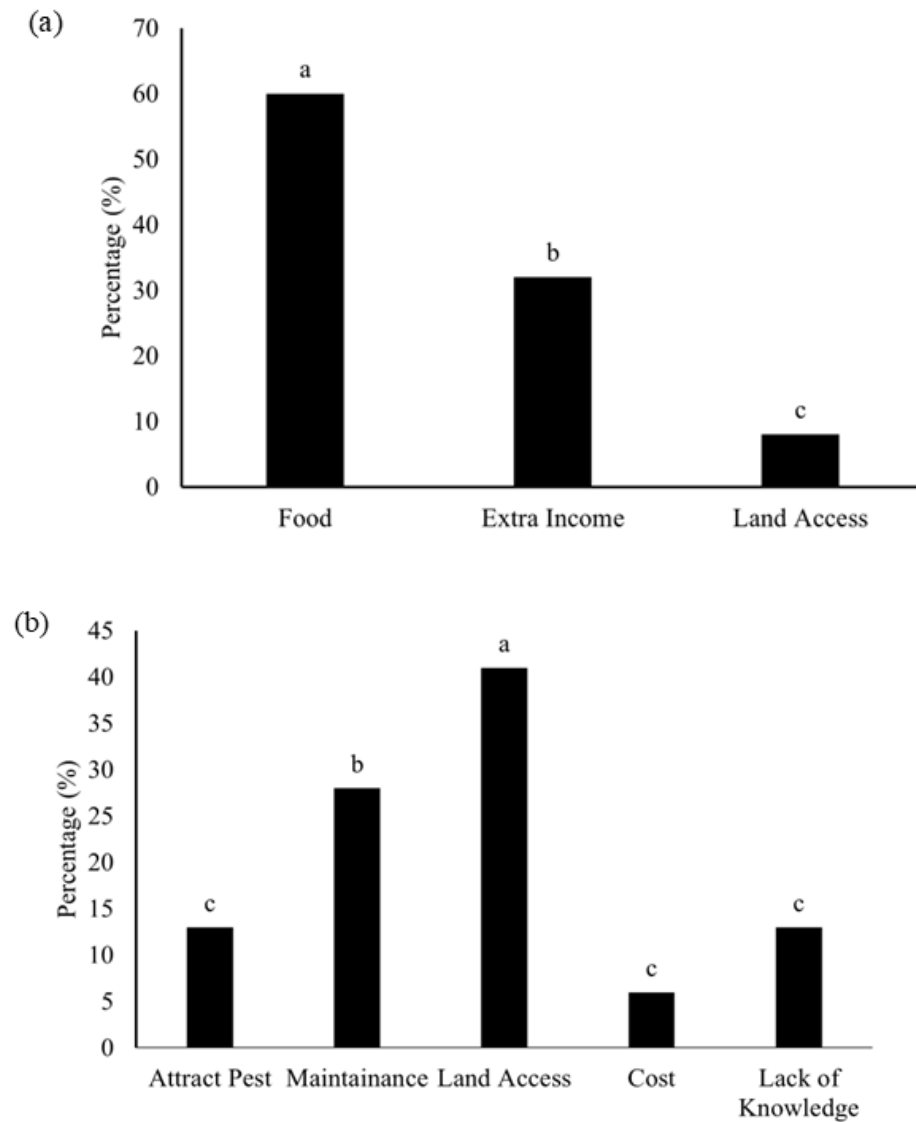


Figure 3.7: a) The reasons agroforestry practitioners practicing agroforestry practices; b) The reasons non-agroforestry practitioners did not practice agroforestry practices. **Note: Means with the same letter are not significantly different.*

Additionally, 80% of non-agroforestry practitioners indicated interest in adopting agroforestry if specific barriers, such as financial constraints, labour requirements, policy restrictions, or market access challenges, were addressed (Figure 3.8). These concerns

highlight the perceived challenges associated with agroforestry practices, including potential increases in land and labour requirements, as well as fears of pest attraction.

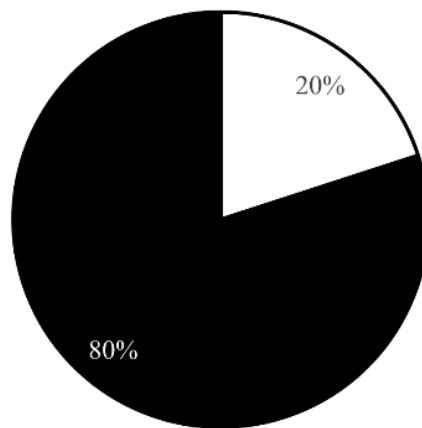


Figure 3.8: Interest in practicing agroforestry among non-practitioners, contingent upon the removal of key obstacles, including financial constraints, labor requirements, policy restrictions, and market access challenges.

3.3.4 Awareness and knowledge about agroforestry practices and their benefits among agroforestry practitioners in the study area

Table 3.3 show that agroforestry practitioners were significantly more likely to have heard of the term 'agroforestry' compared to non-practitioners. Specifically, 61% of agroforestry practitioners reported familiarity with the term, while only 24% of non-practitioners had heard of it. This significant difference underscores the critical role that awareness and exposure play in the adoption of agroforestry practices. However, it is worth noting that even among agroforestry practitioners, 39% had never encountered the term, suggesting that some farmers may be practicing agroforestry without a formal understanding of the concept. Based on the weighted mean (WM) of the Likert scale, non-agroforestry practitioners demonstrated measurably less knowledge about agroforestry compared to agroforestry practitioners and were had less awareness of its benefits (Table 3.4).

Table 3.3: The respondents that heard of “*Agroforestry*” term and the respondents that never heard of “*Agroforestry*” term and their adaptation of agroforestry practices. An unpaired t-test was used to determine the significant difference between the respondents that heard the “*Agroforestry*” term and the respondents that never heard of “*Agroforestry*” on their adaptation of agroforestry practices. **Note: Significant level is at $p < 0.05$, the significant value was bold.*

Description	Respondents	t-value	p-value
Heard of agroforestry (<i>Agroforestry practitioners</i>)	11 (61%)	-6.12	0.0036
Heard of agroforestry (<i>non-agroforestry practitioners</i>)	6 (24%)		
Heard of agroforestry (<i>Agroforestry practitioners</i>)	11 (61%)	4.90	0.008
Never heard of agroforestry (<i>Agroforestry practitioners</i>)	7 (39%)		
Heard of agroforestry (<i>Agroforestry practitioners</i>)	11 (61%)	9.80	0.0006
Never heard of agroforestry (<i>non-agroforestry practitioners</i>)	19 (76%)		

Table 3.4: Knowledge and perception towards agroforestry practices among agroforestry practitioners and non-agroforestry practitioners. Weighted means for the Likert Scale were calculated, and the weighted mean tendency was determined.

Statements	Agroforestry practitioners		Non-agroforestry practitioners	
	Weighted mean	Interpretation	Weighted mean	Interpretation
Knowledge on agroforestry practices	2.33	Good knowledge	3.88	Lack of knowledge
Awareness on the benefits of agroforestry practices	2.39	Aware	3.64	Not aware

However, when examining specific benefits of agroforestry, no significant differences were observed between practitioners and non-practitioners in many areas, except

for knowledge about pest reduction benefits ($X^2 = 6.344$, $p = 0.012$). This indicates that while non-practitioners perceive themselves as having less knowledge, there is overlap in understanding some specific benefits among both groups (Table 3.5). Respondents identified several key benefits of agroforestry practices, including improved soil fertility (61% of agroforestry practitioners), reduced pest infestations (67%), and enhanced food security (83%). These benefits were recognized by both agroforestry practitioners and non-practitioners, though practitioners reported higher levels of awareness and understanding. These findings underscore the potential for agroforestry to address critical challenges in rice farming systems, particularly those related to climate resilience and sustainable agricultural practices. Both agroforestry practitioners and non-agroforestry practitioners strongly agree that agroforestry should be practiced and would recommend it to others. This finding is surprising given the lower knowledge levels reported among non-agroforestry practitioners (Table 3.5). It suggests that positive perceptions of agroforestry may stem from general awareness or perceived social desirability rather than detailed understanding of its practices and benefits

Table 3.5: Agroforestry practitioners and non-agroforestry practitioners' awareness on the benefits of agroforestry practices. A chi-square test of independence was used to determine the significant difference in awareness on agroforestry practices among agroforestry practitioners and non-agroforestry practitioners. **Note: the significant value was bold.*

Benefits of agroforestry practices	Awareness	Agroforestry Practitioners	Non-agroforestry Practitioners	Chi-square value	p-value
Increase the yield.	Yes	67%	52%	0.925	0.336
	No	33%	48%		
Improve the soil fertility	Yes	61%	36%	2.652	0.103
	No	39%	64%		

Table 3.5 continued

Reduce the pest attack	Yes	67%	28%	6.344	0.012
	No	33%	72%		
Provide/increase job opportunity	Yes	56%	44%	0.559	0.455
	No	44%	56%		
Improve food security	Yes	83%	68%	1.292	0.256
	No	17%	32%		
Reduce the impact of climate change	Yes	67%	64%	0.033	0.856
	No	33%	36%		
Reduce soil erosion risk	Yes	83%	64%	1.944	0.163
	No	17%	36%		

3.3.5 Perception and attitudes towards agroforestry practice

Most respondents indicated a solid inclination to recommend agroforestry practices to their friends or acquaintances (WM = 1.60). They strongly agreed that agroforestry should be practised in agriculture (WM = 1.51), as shown in Table 3.6. The respondents also anticipated increased awareness programs, and skill-development workshops focused on agroforestry practices (WM = 1.40 for both).

Table 3.6: Farmers' perception on agroforestry practices. Weighted means for the Likert Scale were calculated, and the weighted mean tendency was determined (Refer Table 1).

Descriptions	Weighted mean	Result
Recommending agroforestry practice to acquaintances	1.60	Very likely to recommend
Agroforestry practice must be practised in agriculture	1.51	Strongly agree
Workshop skills on agroforestry practices must be organized	1.40	Very Anticipating
More awareness activity on agroforestry must be organized	1.40	Very Anticipating

The results of this study show that the respondents have a positive perception and attitude towards agroforestry practices after being informed about the benefits of agroforestry. Moreover, 80% of the respondents who do not practice agroforestry were interested in practising agroforestry if there were no obstacles.

3.3.6 Challenges and benefit adoption of agroforestry among agroforestry practitioners and non-agroforestry practitioners in the study area

The results show access to land, such as lack of land or space and unsuitable land for cultivation, is one of the main reasons respondents did not practice agroforestry. The common reason for not practicing agroforestry is the need for more time, cost, and labour to manage the paddy field and other integrated crops or livestock. Besides, the limited market opportunities to sell their produce are also one of the challenges in adopting agroforestry, which the respondents raised during the discussion. Some non-agroforestry practitioners

expressed concerns that integrating other crops or trees into their paddy fields could attract pests, potentially impacting their rice yields.

3.4 Discussion

3.4.1 Socio-demographic patterns of respondents in study area and adoption of agroforestry practice

The respondents' socio-demographics play a crucial role in determining their perceptions and attitudes towards adopting or rejecting new ideas (Phondani et al., 2020). Various studies have shown that socioeconomic characteristics significantly influence adoption behaviour in relation to new practices. Various studies have shown that socioeconomic characteristics significantly influence adoption behaviour in relation to new practices. The level of education of farmers is said to have a positive impact on the adoption of agroforestry as a climate change adaptation strategy, as well- educated farmers can adapt to the latest technologies (Kebede et al., 2015). Abdulazeez et al. (2014) also reported that education influences the adoption of agroforestry.

The study by Obeng and Weber (2014) in Ghana showed that age, education level, gender and monthly income had an influence on the adoption of agroforestry practices. Education plays a crucial role in shaping respondents' perceptions and attitudes toward agroforestry because it enables farmers to comprehend the knowledge associated with this practice. This understanding is the foundation for individuals' perceptions and attitudes about agroforestry (Meijer et al., 2014). Given that most respondents in this study have formal education, they may find it easier to understand and adopt agroforestry if provided with the proper information.

A study by Tangonyire and Akuriba (2020) in the Talensi District in the Upper East Region of Ghana found that access to land, gender dynamics and financing are the socio-economic factors influencing agroforestry adaptation in the study area. Furthermore, Sabastian et al. (2014) found that access to land is positively correlated with the adoption of agroforestry in Gunung Kidul, Indonesia. Tangonyire and Akuriba (2020) suggest that younger farmers are more willing to adopt agroforestry practices because they see the long-term benefits of trees as an investment in the future and are not affected by the general perception that agroforestry is capital intensive but brings long-term returns. Furthermore, Mukundente et al. (2020) reported that age, marital status, gender and income range are not associated with the adoption of agroforestry practices. However, most of the rice farmers in Kg. Skuduk and Kg. Chupak belongs to the older generation. This might be the reason of the low adoption of agroforestry practice among the respondents.

Many studies have shown that agroforestry makes a significant contribution to income. For example, Rahman et al. (2016) in West Java, Indonesia, concluded that farmers who use agroforestry as an alternative cropping strategy can increase their average agricultural income. Farmers who practice agroforestry also have greater income potential because their land productivity increases (Johar, 2021). However, as shown in Table 3.2, most of the respondents (84%) have an income lower than RM 1300 monthly, which is below the poverty line. This is because most agroforestry practitioners engage in agroforestry consumption at home, so agroforestry does not contribute significantly to income generation. During the field visit, it was observed that agroforestry is not practiced on a large scale due to lack of market opportunities.

Respondents stated that it is difficult for them to sell the harvest, even for their rice. In a study by Saliu et al. (2015) in the North Central Zone of Nigeria, it was found that lack

of market opportunities for agroforestry products are the factors leading to farmers not continuing with agroforestry. The economic potential of agroforestry lies in its ability to diversify farm income through products such as fruits, timber, and fodder while reducing reliance on external inputs. However, our findings indicate that this potential remains underutilized due to limited market opportunities. Respondents reported challenges in accessing markets for agroforestry products, which often discourages adoption. Developing strong, localized markets and improving supply chain infrastructure are critical to ensuring the economic viability of agroforestry systems in the study area.

Similarly, the lack of market opportunities for agroforestry products is one of the barriers to the introduction of the agroforestry system in the Czech Republic (Krčmářová et al., 2021). Therefore, the authorities should take the initiative and support farmers in marketing their products. This would enable farmers to participate in agroforestry on a larger scale to improve their socio-economic situation and quality of life. Farmer participation in agroforestry practices could help solve current food supply and demand problems (Banyal et al., 2015).

3.4.2 The awareness and knowledge on agroforestry practices and their benefits among the agroforestry practitioner and non-agroforestry practitioners in the study area

A study by Musa et al. (2019) in Tawau found that rural communities are not aware of the term "agroforestry" even though they practice agroforestry in their daily lives. Our study found that agroforestry practitioners were significantly more likely to have heard the term 'agroforestry' compared to non-practitioners (Table 3.3). While familiarity with the term is associated with adoption, this finding alone is not particularly meaningful without understanding the context of how practitioners gained this knowledge. For instance, exposure to training, extension programs, or community demonstrations may play a more critical role in fostering adoption. The lack of familiarity with the term among non-practitioners highlights the need for targeted awareness and capacity-building initiatives that not only introduce the concept of agroforestry but also provide practical knowledge about its implementation and benefits.

Agroforestry practitioners have a better knowledge of agroforestry practices and are more aware of the benefits of agroforestry than non-agroforestry practitioners (Table 3.4). Surprisingly, when asked about the benefits of agroforestry, there is no significant difference between agroforestry practitioners and non-agroforestry practitioners in terms of knowledge of most of the benefits, except for reducing pest infestation. Farmers' concerns about the challenges of agroforestry, such as its potential to attract pests, are valid and supported by some research (e.g., Aristizábal et al. (2016) and Beilhe et al. (2020)). They found in coffee systems, they found that a *higher percentage of shade favors CBB infestation*, though overall regulation depends on landscape and management. While well-designed agroforestry systems can promote natural pest control and reduce infestations, inadequate implementation may result in unintended consequences, such as increased pest activity. Additionally,

agroforestry often demands additional labor and land resources, which can act as barriers for smallholder farmers.

Addressing these concerns through targeted education and practical support, including demonstrations of effective agroforestry systems, may help mitigate apprehension and promote adoption. The impact of agroforestry on pest pressures is highly context-dependent and varies across systems. While research often shows that agroforestry can promote natural pest control through increased biodiversity, certain systems may also experience pest challenges depending on the crops and management practices involved. In our survey, 67% of agroforestry practitioners reported no increase in pest issues associated with their practices. However, some non-agroforestry practitioners expressed concerns that agroforestry could attract pests, potentially affecting their paddy yields. These concerns highlight the need for targeted education and demonstration programs to address misconceptions and provide evidence-based information about agroforestry's pest management potential in specific contexts.

Although the knowledge of agroforestry practices among agroforestry practitioners is better than that of non-agroforestry practitioners, their knowledge of agroforestry is not sufficient as most of them are self-taught. Although there is a significant difference between agroforestry and non-agroforestry practitioners in their knowledge about the benefits of agroforestry, almost half of agroforestry practitioners did not know about the benefits of this practice. The main sources of agroforestry influence among agroforestry practitioners are self-taught, followed by the influence of the older generation. Some agroforestry practitioners in this study may not fully implement agroforestry systems as described in scientific literature, but this does not necessarily indicate a lack of effective knowledge. For many, their practices are rooted in traditional knowledge passed down through generations,

reflecting a deep understanding of local conditions and sustainable land-use strategies. While this knowledge may not always align with formal education or scientific frameworks, it provides sufficient, locally relevant insights to drive adoption in the study area. Future research should examine how traditional knowledge interacts with formal education to shape agroforestry practices and identify ways to integrate these knowledge systems to enhance outcomes. These points are confirmed by Musa et al. (2020) who further reported that poor dissemination of information on agroforestry systems and lack of awareness among communities in Tambunan Sabah lead to their inability to fully implement the agroforestry system despite knowing the benefits of the agroforestry system.

Our study shows that friends, government agencies and the media have the least influence on agroforestry practitioners. To understand the low adoption of agroforestry practices, we examined regional initiatives aimed at promoting agroforestry. Preliminary investigations indicate limited awareness campaigns and formal programs in the study area. While national programs supporting agroforestry exist, such as the Agroforestry Development and Biodiversity Conservation Program under the Ministry of Agriculture and Food Security, their reach and implementation in this region appear minimal. This program emphasizes integrating tree planting with agricultural systems to enhance biodiversity and improve farm productivity but has limited direct engagement with smallholder farmers in remote areas like Siburan. This gap underscores the need for tailored, localized initiatives to address specific barriers and leverage the region's traditional knowledge systems. This also indicates that few educational activities on agroforestry have been carried out. Interaction with different information providers, where the combination of different providers enriches farmers' knowledge because the different sources provide them with different perspectives (Martini et al., 2016). Therefore, it is important to conduct awareness-raising activities with

communities to share knowledge and information about agroforestry. Awareness-raising activities are important to increase knowledge about agroforestry practices. To ensure the success of awareness-raising activities, the age group and education level of the communities must be considered.

3.4.3 Farmers' perceptions towards agroforestry practices

After learning about the benefits of agroforestry, most respondents expressed a desire to recommend these practices to their acquaintances. They believe that agroforestry should be adopted in the agriculture sector, as they recognise its potential to improve land productivity and quality of life. These findings indicate that they are likely to recommend agroforestry to others and have a higher tendency to apply agroforestry in the future. Furthermore, their anticipation of awareness activities and workshops indicates a willingness to learn about agroforestry practices. This positive attitude demonstrates that the farmers in the study area are willing and ready to adopt agroforestry, provided there are no significant obstacles. This finding is further supported by the fact that the majority (80%) of respondents not currently practising agroforestry expressed interest in doing so. Such positive attitudes towards agricultural innovations increased the likelihood of adoption, whereas negative attitudes typically lower adoption probabilities (Meijer et al., 2014).

3.4.4 Challenges of adopting agroforestry among the agroforestry practitioner and non-agroforestry practitioners in the study area

Access to land remains a major obstacle to the introduction of agroforestry. Most of respondents cited the lack of available or suitable land for cultivation as the main reason for not practicing agroforestry (Figure 3.5b). This result emphasizes the structural challenges

that many farmers face in accessing adequate resources to diversify their farming systems. Limited space and unsuitable land directly hinder the feasibility of integrating agroforestry practices, especially in regions where the land is overexploited or degraded. Study by Kennedy et al. (2024) reported that land access is significantly influenced the likelihood of agroforestry adoption.

The second most frequently cited obstacle is the lack of time, financial resources and labour required to manage paddy fields, and the additional crops or livestock associated with agroforestry (Figure 3.5b). This illustrates the complexity of maintaining such integrated systems, as they require a significant amount of physical labour and economic investment (Ibrahim & Nabage, 2023). The dual management of paddy fields and agroforestry components often exceeds the capacity of smallholder farmers who already suffer from resource constraints. Mwase et al. (2015) stated high initial costs required for the establishment of agroforestry practices can demotivate the farmers to adopt agroforestry.

Interestingly, 13% of respondents expressed concerns about the potential environmental disadvantages of agroforestry, particularly the risk of attracting pests to their paddy fields. This indicates a perceived trade-off between diversification and the stability of their primary crop yields. Farmers' concerns about the challenges of agroforestry, such as its potential to attract pests, are valid and supported by some research (e.g., Altieri & Nicholls, 2004). While well-designed agroforestry systems can promote natural pest control and reduce infestations, inadequate implementation may result in unintended consequences, such as increased pest activity. Additionally, agroforestry often demands additional labor and land resources, which can act as barriers for smallholder farmers.

These concerns may stem a lack of knowledge about pest control strategies in agroforestry systems or previous negative experiences, emphasizing the need for targeted

education and support to address such fears. Tranchina et al. (2024) highlighted that the availability or quality of knowledge or experience on technical and agronomic matters, or knowledge diffusion necessary to implement or maintain agroforestry systems are the most encountered obstacles in agroforestry adoption. Meijer et al. (2014) also reported that the role of knowledge is one of the challenges applying the evidence to agroforestry development programs. A study by Musa et al. (2020) reported that poor dissemination of information on agroforestry systems and lack of awareness among communities in Tambunan Sabah lead to their inability to fully implement the agroforestry system despite knowing the benefits of the agroforestry system.

3.4.5 Management implication of the study

Previous studies reported that the decision to adopt agroforestry is influenced by socio-demographic factors such as age group, education level, etc. However, the results of this study show that the socio-demographic factors do not influence the adoption of agroforestry in the study area. Many studies have shown that agroforestry contributes to farmers' income (Desmiwati et al., 2021; Muthuri et al., 2023; Sudomo et al., 2023) but in this study agroforestry does not contribute to farmers' income because the products are grown only on a small scale for household consumption. Although 42% of the respondents practice agroforestry, they may not fully understand the concept as most of them are self-taught and the influence of government agencies and media is very low.

Therefore, it is important to disseminate more information about agroforestry and raise awareness, especially among non-agroforestry practitioners. Respondents have gained a positive attitude towards agroforestry, which increases their willingness to adopt agroforestry and share relevant information about agroforestry with other farmers - a crucial

step for these farmers to adopt this practice. The results of this study can serve as a guide for the authority to plan steps to improve the knowledge and relevance of the agroforestry sector and the implementation of agroforestry.

The authorities should assign officials with expertise in agroforestry or provide agroforestry extension services in the study area to enhance the agroforestry knowledge of farmers and facilitate their understanding of the concept of agroforestry. Since most of the farmers in the study area are elderly, it might be more difficult for them to learn and understand the practice only through theory or seminar. Therefore, the authorities should organize a training program or workshop that facilitates learning through practical demonstration. This includes the design and establishment of agroforestry demonstration plots on farmers' land and in farmers' conditions managed by agroforestry practitioners. In addition, subsidies or incentives such as the provision of land and planting materials could help encourage farmers to adopt agroforestry practices. However, before implementing agroforestry programs with farmers, it is important to determine their level of knowledge to ensure the effectiveness of information dissemination and awareness-raising activities.

Although the role of knowledge, perceptions and attitudes in the adoption of agroforestry has been documented, challenges remain in applying the evidence to agroforestry development programs (Meijer et al., 2014). Therefore, it is important that we conduct further research on farmers' knowledge, awareness and perceptions of agroforestry to understand their behavior and decision-making factors. Only then can we ensure successful planning of agroforestry interventions for rice farmers that will help them improve their quality of life and sustain their livelihoods while protecting the environment.

3.5 Conclusion

To summarize, most of the non-agroforestry practitioners are interested in practicing agroforestry if there are no obstacles and most of both agroforestry practitioners and non-agroforestry practitioners would like to recommend agroforestry to their acquaintances. The data obtained shows that the non-agroforestry practitioners have a lack of knowledge compared to the agroforestry practitioners and are not aware of the benefits of agroforestry practice. Although agroforestry practitioners have good knowledge of agroforestry practice, they may not have adequate knowledge of the practice as most of them are self-taught. This is evidenced by the finding that some agroforestry practitioners have never heard the term “agroforestry”. The significant difference between agroforestry practitioners and non-agroforestry practitioners in terms of awareness of the term 'agroforestry' shows that farmers who have been exposed to or heard about agroforestry are more inclined to practice or adopt agroforestry. The farmers in Kampung Chupak and Kampung Skuduk have a positive attitude towards agroforestry. They express a desire for awareness activities and skills workshops related to agroforestry, indicating their willingness to learn more about this sustainable practice. This positive attitude suggests that farmers in the study area are ready and willing to practise agroforestry if there are no obstacles. A positive attitude towards agricultural innovation will increase the likelihood of adoption. However, despite positive attitudes, recall that many farmers noted challenges such as land access and maintenance. This suggests that while attitudes are positive, practical barriers still need to be addressed to increase the adoption. Therefore, the government and the private sector should collaborate to disseminate knowledge and information about agroforestry to the community, as a lack of understanding can hinder the adoption of agroforestry. This study provides new insights into agroforestry practices within the specific context of Kampung Skuduk and Kampung

Chupak, Siburan, Sarawak. It uniquely focuses on understanding how traditional knowledge and formal education influence farmers' awareness, knowledge, and adoption of agroforestry. By examining the perceived benefits and barriers to agroforestry practices, such as financial constraints and market access challenges, this research offers actionable recommendations tailored to the local context. These findings contribute to the limited body of research on agroforestry in rural Sarawak and provide practical implications for policy and program development.

CHAPTER 4

SELECTED SOIL PROPERTIES UNDER DIFFERENT AGRICULTURE PRACTICES IN SIBURAN, SARAWAK

4.1 Introduction

The agricultural sector is one of the most important sectors, as it plays an important role in economic development and employment. In 2023, the agricultural sector contributed 7.8% to Malaysia's gross domestic product (GDP) (Siddharta, 2024). In addition, the agricultural sector also plays an important role in poverty alleviation as most low-income people in Malaysia are engaged in agriculture (34% of the total number of low-income people) (Saari et al., 2013). The agricultural sector also plays a strategic role in ensuring food security. The National Agriculture and Food Policy 2021-2030 (NAP 2.0) prioritises strengthening the agricultural sector, such as enabling modernisation through smart agriculture and promoting research, development, commercialisation and innovation, strengthening the value chain of agri-food products for the domestic and international market, developing talent and skilled labour, emphasising sustainable practices and facilitating the business ecosystem, including land use, finance, infrastructure, investment and governance, are the key measures (Malaysia Ministry of Agriculture and Food Security, 2024).

Although agriculture is vital to human existence, there are many issues that threaten the ability of agriculture to meet human needs now and in the future, including climate change, biodiversity loss and pollution of water resources. (Begum et al., 2020; Karp et al. 2012; Naseem et al., 2020; Zia et al., 2013). Soil degradation is one of the biggest problems caused by agriculture. Soil degradation is a long-term loss or decrease in soil productivity over time due to human activities or natural factors (Müller et al., 2023). In Malaysia, there

are various types of land degradation, including forest land degradation, soil erosion, salinisation, soil fertility declines and waterlogging (Ahmed & Boon, 2023). Shifting cultivation is one of the possible causes of soil degradation in Malaysia, especially in Sarawak (Ahmed & Boon, 2023). Soil erosion is caused by poor practices such as removal of vegetation cover, inappropriate ploughing and large fields with no boundary to slow down water movement (Alam, 2014). According to Sofo et al (2020), intensive agricultural activities can lead to soil erosion and degradation due to tillage, burning of residues and agrochemicals. The use of conventional tillage has an impact not only on the physical and chemical properties of the soil, but also on the biodiversity below and above ground (Domínguez et al., 2010). This will production and the sustainability of the agricultural sector, as agriculture is highly dependent on the soil.

Various agricultural practices have a significant impact on soil properties and the sustainability of crop production (Reilly et al., 2023). Intercropping, agroforestry and home gardening are among the best-known sustainable practices soil health and reduce environmental impact. In intercropping, several plant species are grown simultaneously in one field to maximise resource use and reduce dependence on chemical inputs such as fertilisers and pesticides (Weih et al., 2022). Agroforestry, on the other hand, combines trees with crops and livestock to promote better soil utilisation and improve soil fertility and water retention (Fahad et al., 2022). Home gardening, which often combines perennial crops, fruit trees and small livestock, plays an important role in improving soil organic matter and biodiversity (Wolle et al., 2021). Each of these practices the physical and chemical properties of the soil in different ways and provides numerous benefits such as increased organic matter, improved water retention and reduced soil compaction (Kaur et al., 2023; Pandey et al., 2024). However, improper management can lead to problems such as acidification,

nutrient imbalances and lower crop yields (Zhang et al., 2016). Understanding the impact of these practices on soil properties is critical to promoting sustainable agriculture and ensuring long-term food security

In Malaysia and Southeast Asia, intercropping, agroforestry and home gardening are practised in different regions depending on local conditions and needs. In Malaysia, intercropping is commonly practised in areas such as Cameron Highlands for vegetable production where crops such as cabbage, lettuce and beans are grown together to optimise land use and reduce soil erosion (Weih et al., 2022). Agroforestry is widespread in Sarawak and Sabah, where farmers combine crops such as pepper, rubber and fruit trees with forest species, contributing to better soil health and biodiversity (Fahad et al., 2022). In Java, Indonesia, practicing agroforestry helps conserve soil and restore degraded land (Mohamad Siarudin et al., 2021). In rural Malaysia, particularly in Kelantan and Terengganu, home gardening is widespread, where families grow vegetables, fruits and herbs for daily needs, reducing dependence on market produce (Wolle et al., 2021). These practices not only adapt to the local environment, but also support sustainable livelihoods and the long-term

Intercropping, agroforestry and home gardening combine traditional knowledge with innovative approaches to ensure long-term food production while protecting the environment. By adopting these practices, farmers can improve soil health, reduce pollution and increase resilience to climate change, benefiting both current and future generations. Malaysia has allocated RM6.42 billion for the Ministry of Agriculture and Food Security in Budget 2025, with sustainable agricultural practices being one of the key initiatives proposed (Bernama, 2024). Despite this focus, the impacts of various sustainable agricultural practices on soil properties in specific local contexts remain poorly understood. Understanding these impacts is crucial as soil health has a direct influence on crop productivity, environmental

sustainability and local livelihoods. This study seeks to answer the research question: What are the impacts of different sustainable agricultural practices on selected soil properties in Siburan, Sarawak? Therefore, the aim of this study is to determine how these practices affect specific soil properties in Siburan to provide practical insights for improving soil management strategies in the region.

4.2 Methodology

4.2.1 Study sites

This study in the district of Siburan, approximately 32 kilometres (19.88 miles) from Kuching City, the capital of Sarawak, Malaysia. The geographical coordinates of the study area are 1.3619° north latitude and 110.4045° east longitude, with an elevation 56 metres above sea level. According to *Malaysian Meteorological Department* (2024), the dry season in Sarawak occurs in June or July and much of monsoon season is in December to March. Generally, the rainfall distribution in Sarawak is around 2500 – 4000mm annually with the highest rain in February (*Malaysian Meteorological Department*, 2024). The weather conditions and tropical soil characteristics of this region provide a suitable environment for various agricultural practices. Three different sites were selected for this study, each representing a specific sustainable agricultural practice. At each site, three plots measuring 20 m × 20 m were established for soil sampling and analysis.

Site 1 (N 01°15.4446' E 110 °26.0234) represents intercropping, where cucumbers (*Cucumis sativus*) were grown with long beans (*Vigna unguiculata*) in alternating rows to optimise soil use and reduce pest infestation (Figure 4.1a). Site 2 (N 01°15.5989' E 110 °25.8408) was identified as an agrisilviculture system combining crops and tree species such as rubber (*Hevea brasiliensis*), durian (*Durio zibethinus*), and various vegetables (Figure

4.1b). Site 3 (N 01°14.3844' E 110 °25.9977) was a home garden in a backyard where rubber trees were planted together with pineapple (*Ananas comosus*) and small livestock, including chickens and geese (Figure 4.1c). These sites were selected based on interviews with local farmers and observed practices that each site reflects the key characteristics of the farming system in question. This detailed classification allows for a better understanding of how each practice affects the soil were analysed and compared in the subsequent sections of this study.



Figure 4.1: Different types of agricultural practices a) Intercropping practice, b) Agrisilviculture practice, c) Home Garden practice

4.2.2 Sample collection and preparation

Soil samples were taken at three depths: 0–20 cm (surface layer), 20–40 cm (subsurface layer) and 40–60 cm (deep layer) for a more comprehensive analysis of soil properties in different horizons. Soil samples were collected using a soil auger and a core sampler to ensure consistency and accuracy. The systematic sampling method was used, with samples taken at regular intervals within each 20 m × 20 m plot to minimise sampling bias.

At each depth, several subsamples were taken from different points within the plot to represent the overall soil condition.

The subsamples from the same depth were thoroughly mixed in a clean plastic container to create a composite sample for each depth. This process was repeated for all three depths at each site. The composite samples were then air-dried in a well-ventilated laboratory, taking care not to expose them to direct sunlight so as not to alter the chemical properties of the soil. After drying, the samples were crushed with pestle and mortar and carefully crushed to break up lumps. Large impurities such as stones, plant roots and other organic residues were removed manually. Finally, the samples were sieved through a 2 mm mesh sieve to obtain a uniform size of soil sample suitable for laboratory analysis.

These prepared soil samples were then stored in labelled, airtight plastic bags to preserve their integrity and transported to the laboratory for further analysis, including determination of, pH, total acidity and exchangeable aluminium and hydrogen ions. This systematic approach ensures that the samples accurately represent the soil profile and provide reliable data for assessing the impact of different agricultural practices on soil properties.

4.2.3 Soil bulk density, moisture content, organic matter and organic carbon determination

The bulk density of the samples was determined using the method described by Tan (2005), the core sample method. The soil samples were oven-dried at 105 °C for 24 hours and the oven-dried mass of the soil was divided by the volume of the soil (Equation 4.1).

$$\text{Soil bulk density}(gcm^{-3}) = \frac{\text{Weight of oven dry soil}}{\text{Volume of soil}} \quad \text{Equation 4.1}$$

The moisture content of the soil was determined using the gravimetric method or oven drying technique where the difference in the weight before and after drying representing the amount of water present (Dutta, 2015; Kashyap & Kumar, 2021; Ungar et al., 1992). The soil sample were dried in an oven at 105 °C until constant weight and calculated using equation 4.2.

$$\text{Soil moisture content (\%)} = \frac{\text{Weight of water loss}}{\text{Weight of oven dried soil}} \quad \text{Equation 4.2}$$

The organic matter content of the soil was based on the gravimetric weight change associated with the high-temperature oxidation of organic matter. The difference in mass before and after ignition was calculated and the SOM was calculated using equation 4.3. According to Sikora and Stott (2015), approximately 58% of organic matter is composed of carbon. Therefore, we can estimate the percentage of SOM using the SOC% with the conversion factor 1.72 (derived from 100/58) and calculate the total organic carbon using Equation 4.4.

$$OM = \frac{\text{Weight before ignition} - \text{weight after ignition}}{\text{Weight before ignition}} \times 100\% \quad \text{Equation 4.3}$$

$$\text{Organic carbon} = \text{Organic matter} \times 1.72 \quad \text{Equation 4.4}$$

4.2.4 Soil pH in water and potassium chloride (KCl) suspension, total acidity and exchangeable Al and H determination

The pH value of the soil was determined in potassium chloride (KCl) and water in a ratio (1:2.5) according to the method of Tan (2005). The total acidity and the concentrations

of exchangeable aluminium (Al) and hydrogen (H) will 1 M potassium chloride (KCl) and then will 0.01 M sodium hydroxide (NaOH) and 0.01 M hydrochloric acid (HCl). The concentrations of total acid, exchangeable Al and H are calculated using the formulae described by Rowell (1993/2014) as follows:

$$\text{Total acidity (mgkg}^{-1}\text{)} = 0.2 \times \frac{\text{Vol. of NaOH used (ml)} \times 10}{\text{soil sample (g)}} \quad \text{Equation 4.5}$$

$$\text{Exchangeable Al (mgkg}^{-1}\text{)} = 0.2 \times \frac{\text{Vol. of HCl used (ml)} \times 10}{\text{soil sample (g)}}$$

$$\text{Exchangeable H (mgkg}^{-1}\text{)} = \text{Total acidity} - \text{Exchangeable Al}$$

4.2.5 Cations exchangeable capacity (K⁺, Na⁺, Mg²⁺, Ca²⁺) and ammonium (NH₄⁺), nitrate (NO₃⁻) and phosphate (PO₄³⁻) determination

The cations were extracted using the ammonium shaking method as outlined (Page, 1982). The concentration of the exchangeable potassium (K⁺), sodium (Na⁺), calcium (Ca²⁺) and magnesium (Mg²⁺) were determined using Absorption Spectrophotometer (AAS) (iCE 300, Thermo Fisher Scientific®, NSW, Australia). The available ammonium, nitrate and phosphate under different agriculture practices were determined using Nutrient Analysis Photometer (HI83325).

4.2.6 Soil fertility index (SFI) and soil evaluation factors (SEF)

The Soil Fertility Index (SFI; Equation 4.6) and Soil Evaluation Factor (SEF; Equation 4.7) were calculated following the formulae by Moran et al. (2000) and Lu et al. (2002), respectively:

$$SFI = pH + \text{organic matter (\%)} + \text{available P (mg kg}^{-1}\text{)} + \text{Exch. K (ceq kg}^{-1}\text{)} + \text{Exch. Ca (ceq kg}^{-1}\text{)} + \text{Exch. Mg (ceq kg}^{-1}\text{)} - \text{Exch. Al (ceq kg}^{-1}\text{)}$$

Equation 4.6

$$SEF = [\text{Exch. K (ceq kg}^{-1}\text{)} + \text{Exch. Ca (ceq kg}^{-1}\text{)} + \text{Exch. Mg (ceq kg}^{-1}\text{)} - \log (1 + \text{Exch. Al (ceq kg}^{-1}\text{)})] \times \text{Organic matter (\%)}$$

Equation 4.7

4.2.7 Data analysis

The data were analysed using Statistical Analysis Software Version 9.2 (SAS, 9.2). Before the main analysis was performed, the data were checked for normality and homogeneity of variance to fulfil the assumptions of the parametric tests. The Shapiro-Wilk test was used to assess the normality of the data distribution, while the Levene test was used to assess the homogeneity of variances between groups. Post-hoc comparisons were performed using Tukey's Honestly Significant Difference (HSD) test to determine which groups showed significant differences. The significance level was set at $p < 0.05$ for all statistical tests. This robust statistical approach ensures the reliability of the results and enables a comprehensive comparison of soil properties between the intercropping, agrisilviculture and home gardening systems. The results of these analyses are presented in the following sections. The effects of the different practices on soil moisture content, bulk density, organic matter, organic carbon, pH, total acidity and exchangeable aluminium and hydrogen ions are highlighted.

4.3 Results

4.3.1 Soil properties under different agriculture practices

The soil in the home garden (57.89%) has the highest moisture content, followed by agrisilviculture (47.84%) and finally intercropping (25.60%). All three locations differ significantly in terms of moisture content. Regarding the bulk density of the soil, the soil under intercropping practice (1.09 g cm^{-3}) is significantly higher than in agrisilviculture farming (0.67 g cm^{-3}) and home garden (0.58 g cm^{-3}). As shown in Table 4.1, the soil in intercropping had the highest organic matter and organic carbon content, 8.38% and 4.86% respectively. However, there is no significant difference in the organic matter and organic carbon content of the soil compared to the soil in the home garden. The soil under practice is significantly lower in terms of organic matter and practice and home garden.

Table 4.1: Soil properties under different agriculture practices. Values are expressed as mean $\pm$ standard error, and significances between the practice's differences (5% significance or $p < 0.05$) are conducted by Tukey's test after one-way ANOVA. Mean with different letters within the same row are significantly different ($p < 0.05$).

Variables	Practice		
	Intercrop	Agri-silviculture	Home garden
Soil moisture (%)	25.60 ± 0.52^c	47.84 ± 0.40^b	57.89 ± 0.67^a
Bulk density (gcm^{-3})	1.09 ± 0.09^a	0.67 ± 0.10^b	0.58 ± 0.16^b
Organic matter (%)	5.72 ± 0.78^b	8.38 ± 0.65^a	8.16 ± 0.03^a
Organic carbon (%)	3.32 ± 0.45^b	4.86 ± 0.38^a	4.74 ± 0.02^a

4.3.2 Soil pH in water and KCl suspension under different agriculture practices

Figure 4.2 shows that the soil at 0-20 cm under agrisilviculture crops has the highest soil pH, with a pH of 6.65, which is significantly higher than that of a home garden, but not significantly higher than that of intercropping crops. At 20-40 cm, however, there is no significant difference in soil pH between the two sites. At 40-60 cm, on the other hand, the soil under the home garden with a pH value of 5.88 is significantly lower than the intercropping crop and agrisilviculture farming.

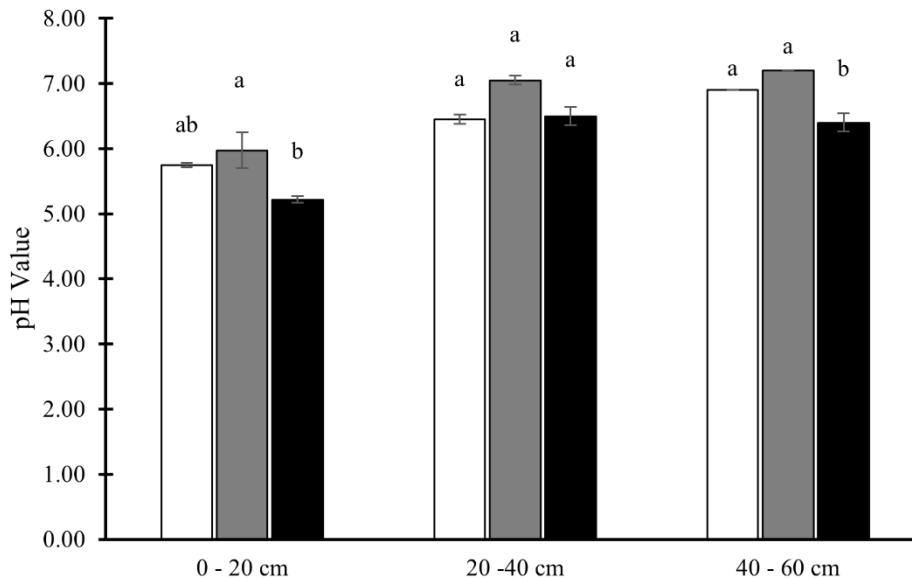


Figure 4.2: Soil pH in water suspension under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The pH values were compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

As for the pH of the soil in the KCl suspension, soil pH under intercropping at 0 -20 cm is significantly higher, followed by agrisilviculture. At the depth of 20 – 40 cm and 40 – 60 cm, soil under home garden practice is significantly lower compared to the other practices.

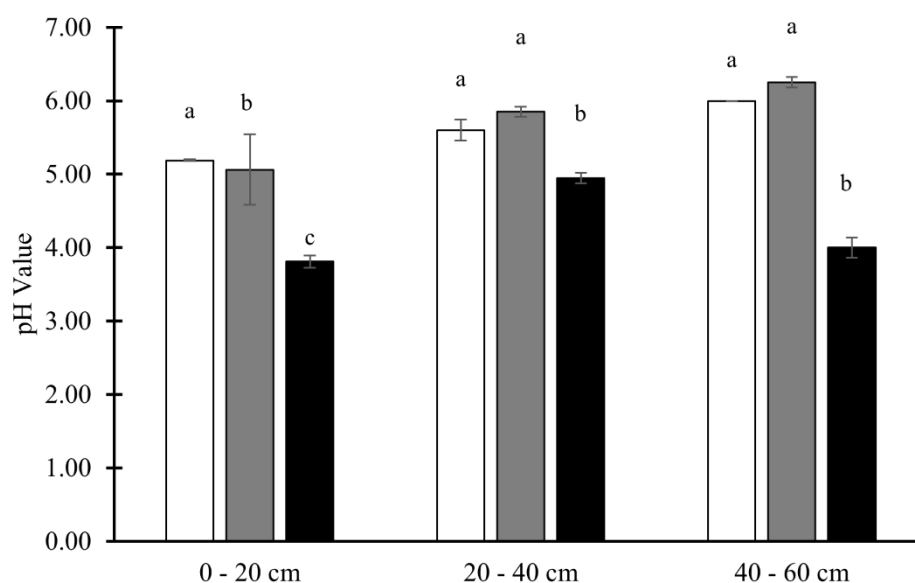


Figure 4.3: Soil pH in KCl suspension under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The pH values were compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

4.3.3 Total acidity, exchangeable Al^{3+} and H^+ under different practices

At all depths, the acidity of the soil in the home garden is significantly higher than in intercropping and practices (Figure 4.4).

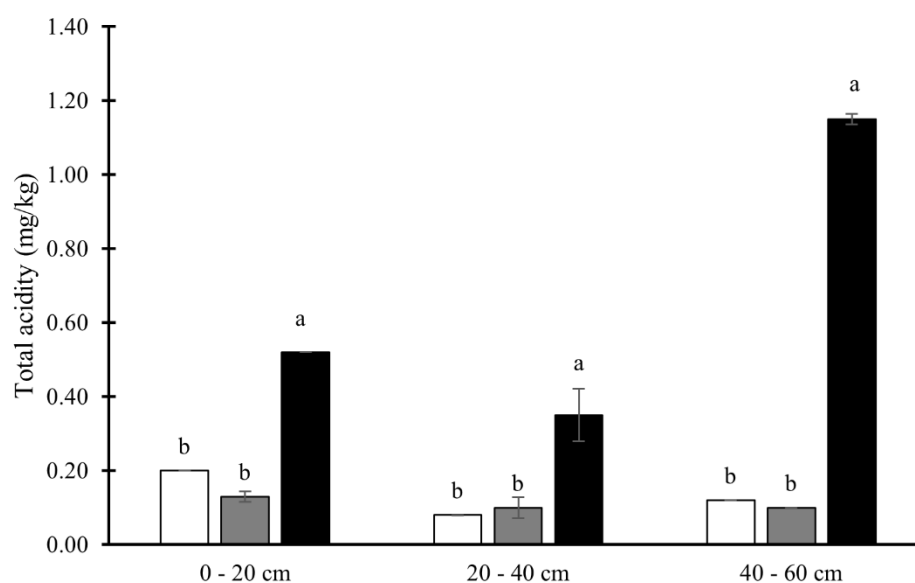


Figure 4.4: The soil acidity under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The total acidity was compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

In terms of exchangeable aluminium ion (Al^{3+}) content, the soil under the home garden practice is significantly higher at 0-20 cm (0.65 mg/kg) and 40-60 cm (0.24 mg/kg) than under the other practises (Figure 4.5). However, at 20-40 cm, there is no significant difference among the practice in terms of exchangeable Al^{3+} .

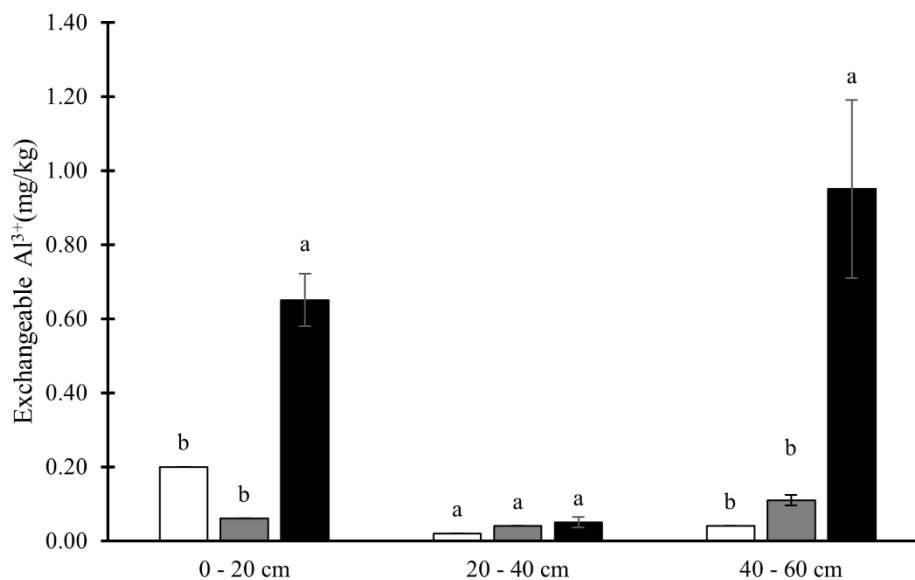


Figure 4.5: Exchangeable aluminium ion (Al^{3+}) under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The exchangeable Al^{3+} was compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

Soil exchangeable hydrogen ions (H^+) in the home garden are significantly higher at depths 0-20 cm (0.45 mg/kg) and 40-60 cm (0.38 mg/kg) than in the intercropping and agrisilviculture practices (Figure 4.6). At 20-40 cm, there is no significant difference in exchangeable H^+ for all practices.

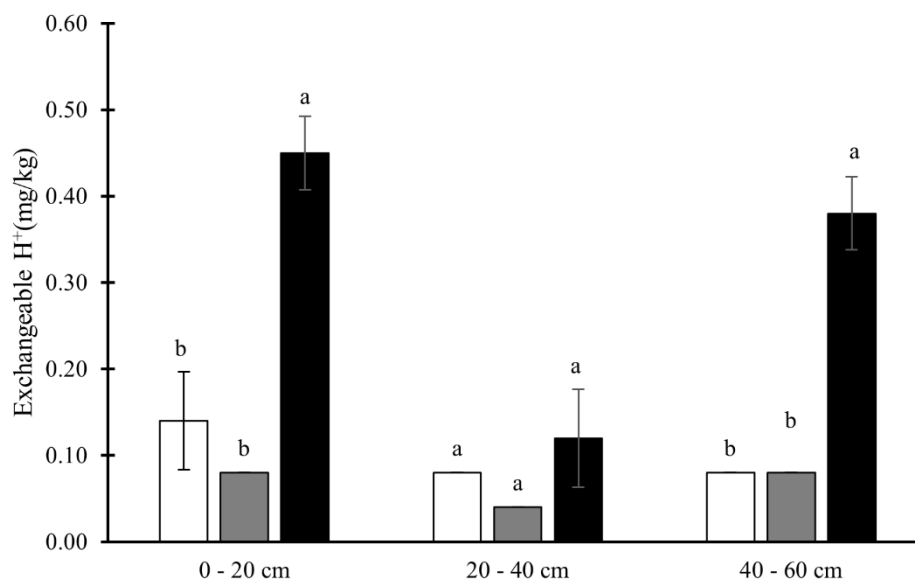


Figure 4.6: Exchangeable hydrogen ion (H^+) under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The exchangeable H^+ was compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

4.3.4 Available ammonium, nitrate and phosphate under different agriculture practices

As can be seen from Table 4.2, the ammonium content in the soil is highest in intercropping (7.3 ppm) compared to agrisilviculture and home gardens. However, there is no significant difference in ammonium ions between all three sites. At 36.7 ppm, the nitrate practice is significantly higher than agrisilviculture and home gardens. For phosphate, practice is significantly lower than the other practices 1.0 ppm. The home garden practice the highest value (6.0 ppm), but not significantly more than agrisilviculture (2.0 ppm).

Table 4.2: Ammonium (NH_4^+), nitrate (NO_3^-), phosphate (PO_4^{3-}) under different agriculture practices (depth 0 – 20cm). Values are expressed as mean $\pm$ standard error, and significances between the practice's differences ($p < 0.05$) are conducted by Tukey's test after one-way ANOVA. Mean with different letters within the same row are significantly different ($p < 0.05$).

Variables	Agriculture practices		
	Intercrop	Agri silviculture	Home garden
NH_4^+ (ppm)	7.3 ± 0.09^a	6.5 ± 0.11^a	6.8 ± 0.03^a
NO_3^- (ppm)	36.7 ± 0.59^a	11.0 ± 0.89^b	14.7 ± 0.57^b
PO_4^{3-} (ppm)	1.0 ± 0.14^b	2.0 ± 0.16^{ab}	6.0 ± 0.31^a

4.3.5 Cations (K^+ , Na^+ , Mg^{2+} , Ca^{2+}) concentration at different depths under different agricultural practices

At 0 - 20 cm, the exchangeable potassium ion (K^+) in the soil under agrisilviculture is significantly higher than in the other practice, followed by the soil under intercropping practice and finally the soil under home garden practice with the lowest exchangeable K^+ . At depths 20 – 40 cm and 40 – 60 cm, the exchangeable K^+ content is significantly higher in intercropping and agrisilviculture than in home gardening (Figure 4.7).

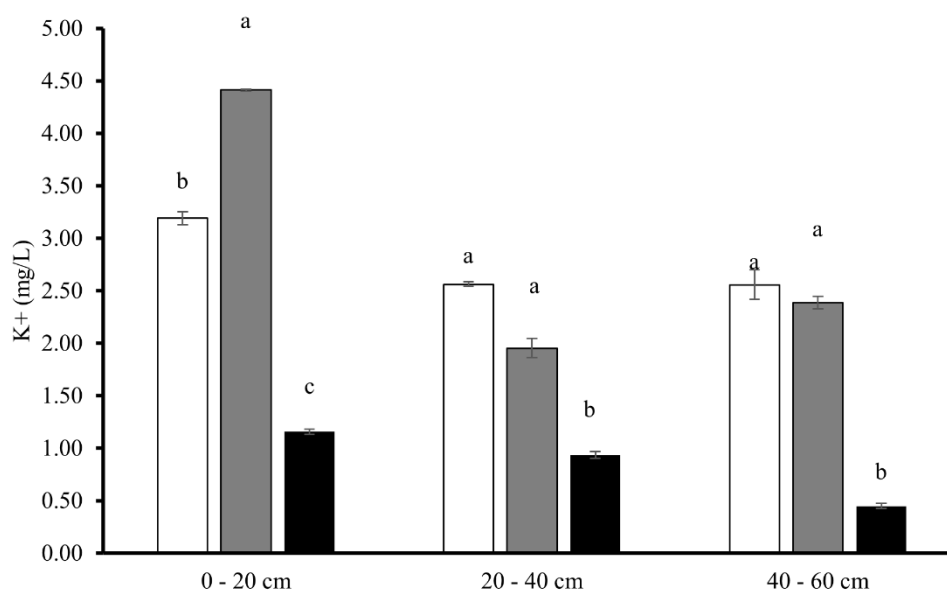


Figure 4.7: Exchangeable potassium ion (K^+) under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The exchangeable K^+ was compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

At a depth of 0 - 20 cm, the content of exchangeable sodium ions (Na^+) is significantly higher in agrisilviculture than in home gardens, but not significantly higher than in intercropping (Figure 4.8). At depths 20 – 40 cm and 40 – 60 cm, the exchangeable Na^+ is significantly lower than in the home garden.

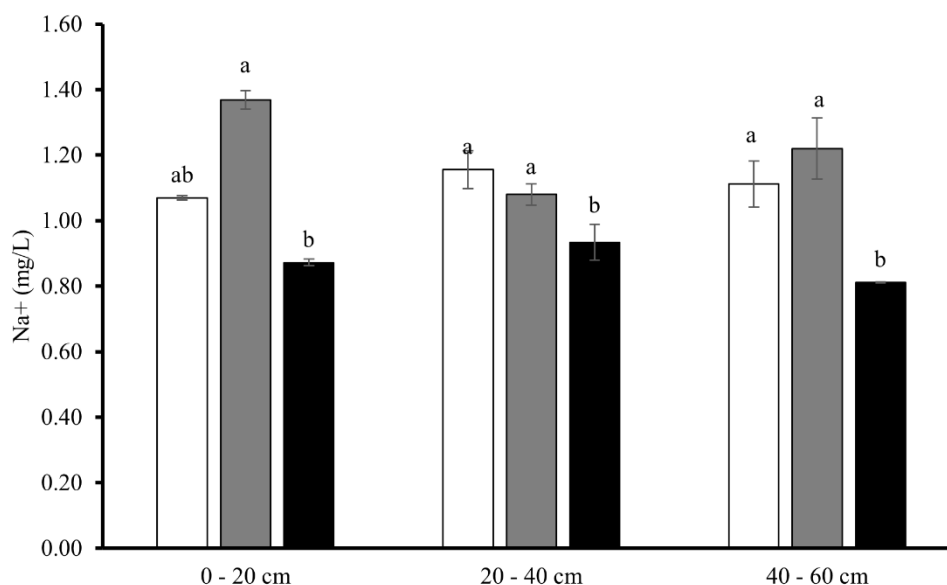


Figure 4.8: Exchangeable sodium ion (Na^+) under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden) at different depths. The exchangeable Na^+ was compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

As far as the magnesium ion (Mg^{2+}) content is concerned, the soil under agrisilviculture is significantly higher than that under home gardens, but not significantly higher than that under intercropping at 0 - 20 cm (Figure 4.9). At 20 - 40 cm, the soil under agrisilviculture has the highest exchangeable Mg^{2+} , followed by intercropping practice and the home garden with the lowest exchangeable Mg^{2+} . At 40 - 60 cm, however, the exchangeable Mg^{2+} in the soil under intercropping and agrisilviculture significantly higher than in the home garden.

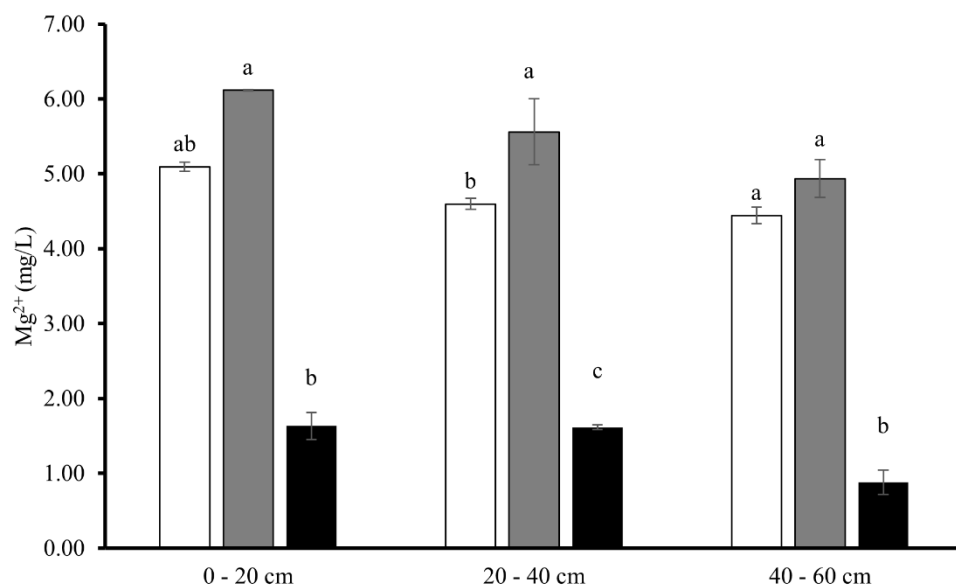


Figure 4.9: Exchangeable magnesium ion (Mg^{2+}) under different agriculture practices (White: intercropping; Grey: agrisilviculture; Black: home garden at different depths. The exchangeable Mg^{2+} was compared between different agriculture practices for each depth. The mean with different letters is significantly different ($p < 0.05$)

At depths 0 – 20 cm and 40 – 60 cm, the exchangeable calcium ions (Ca^{2+}) are significantly higher than in the home garden (Figure 4.10). Meanwhile, at 20 - 40 the soil under intercropping practice has the highest exchangeable Ca^{2+} followed by agrisilviculture and finally home garden with the lowest exchangeable Ca^{2+} .

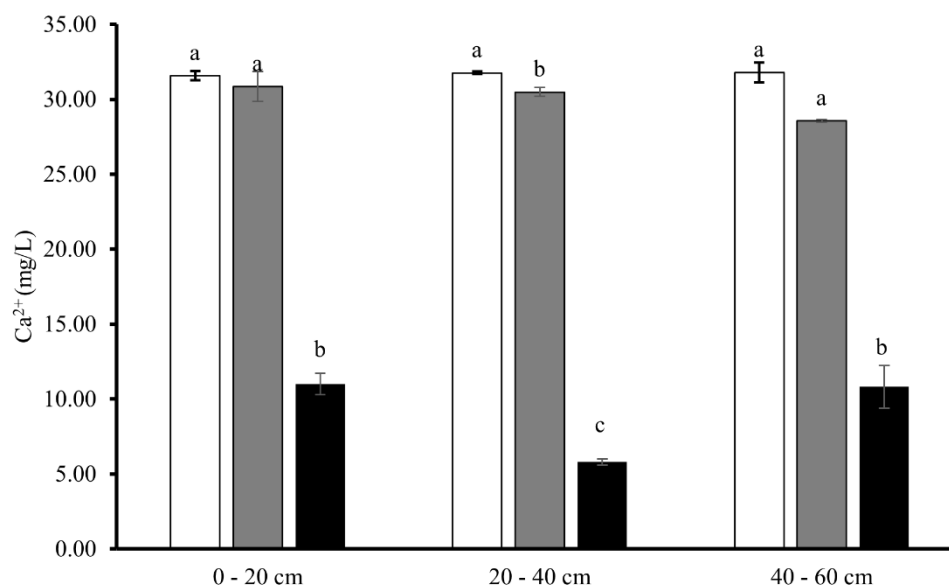


Figure 4.10: Exchangeable calcium ion (Ca^{2+}) under different agriculture practices at different depths. The exchangeable Ca^{2+} was compared between different agriculture practices for each depth. The mean with different letters is significantly different depths ($p < 0.05$)

4.3.6 Soil fertility index (SFI) and soil evaluation factor (SEF) under different agricultural practices

The results obtained show that the soil under agrisilviculture exhibits the highest (17.92) soil fertility index (SFI) followed by the soil under home garden (14.87) and lastly the soil under intercropping (12.50). As shown in Table 4.3, agrisilviculture exhibit the highest (5.02) soil evaluation factor followed by intercropping (4.86) and home garden with the lowest soil evaluation factor (3.67).

Table 4.3: Soil fertility index (SFI) and Soil evaluation factor (SEF) under different agriculture practices. Values are expressed as mean $\pm$ standard error, and significances between the practice's differences (5% significance or $p < 0.05$) are conducted by Tukey's test after one-way ANOVA. Mean with different letters within the same row are significantly different ($p < 0.05$).

Variables	Practice		
	Intercrop	Agri-silviculture	Home garden
Soil fertility index (SFI)	12.50 ± 0.02^c	17.92 ± 0.33^a	14.87 ± 0.16^b
Soil evaluation factor (SEF)	4.86 ± 0^b	5.02 ± 0^a	3.67 ± 0^c

4.4 Discussion

4.4.1 Soil physical properties under different agricultural practices

Based on the results, the significant differences in soil moisture content could be due to a better vegetation cover and the accumulation of organic matter (agroforestry; home gardens and agrisilviculture) tend to retain more moisture than systems with less soil cover, such as intercropping. Agroforestry systems (home gardens and agrisilviculture) often contain a mixture of plants, trees and shrubs that form a canopy, reduce evaporation and retain soil water better, resulting in higher moisture content. The trees provide shade and maintain soil moisture by reducing soil evaporation (Lin, 2010). Agroforestry systems also provide tree canopies that reduce evaporation and transpiration from the soil and plants, will efficiency and ensuring optimal soil moisture (Kaur et al., 2023).

The results also show that the soil under the agroforestry system (home garden and agrisilviculture) contains more organic matter and carbon. The high accumulation of organic matter in agroforestry systems could be due to the leaf litter and plant debris from trees and

the diverse vegetation, the minimal disturbance of the soil that allows natural accumulation and decomposition of organic matter, and the higher microbial activity that supports nutrient cycling and improves soil fertility (Pandey et al., 2024). The diverse vegetation of the agroforestry system also ensures a continuous process of decomposition of organic matter in the soil (Dollinger & Jose, 2018). The increase in organic matter input will enrich the organic carbon in the soil, which could improve nutrient availability and soil fertility, which would have a positive impact on soil health (Dollinger & Jose, 2018).

A high proportion of organic matter in the agroforestry system then led to a low bulk density, as the result of our study shows, in which the bulk density in the agroforestry system (home garden and agrisilviculture farming) is significantly lower than the bulk density in intercropping. This is consistent with the results of the studies conducted in Yemen by Aldeen et al. (2013), who found that an increase in organic matter led to a decrease in the bulk density of the soil. The study by Athira et al. (2019) reported that bulk density has a negative relationship with soil organic matter, with bulk density being lower when soil organic matter is higher. Pandey et al. (2024) also mentioned that agroforestry systems can improve soil physical properties by reducing soil bulk density and compaction. This suggests that the agroforestry system appears to maintain soil structure, create favourable conditions for root development and possibly help maintain crop productivity (Chavez et al., 2024; Fahad et al., 2022; Kaur et al., 2023). High soil bulk density is usually associated with soil compaction, which leads to reduced pore space for air and water and can negatively affect root development and overall plant productivity (Shaheb et al., 2021; Watson & Kelsey, 2006).

4.4.2 Soil pH in water and KCl suspension under different agriculture practices

Soil pH is a critical factor in soil health, nutrient availability and microbial activity. Our results, presented in Figure 1 and Figure 2, show that soil pH varies at different soil depths in the different agricultural systems, the agroforestry system (agrisilviculture and home garden) and intercropping. At depths 1 and 3, the home garden practice the lowest soil pH, but at 20-40 cm depth there is no significant difference between the practices. In the KCl suspension, the pH values provide further information about the acidity of the soil and the exchangeable hydrogen/aluminium content. There is no significant difference in soil pH between the sites at 0-20 cm and 40-60 cm, suggesting that the buffering capacity of the soil in these layers is relatively stable between the different systems. However, at 40-60 cm, the soil of the home garden has the lowest pH, which is significantly lower than that of agrisilviculture and intercropping.

The lower pH value in the home garden could be due to the high content of organic material in the home garden. According to Porter et al. (1980), organic matter lowers the pH of the soil through the release of hydrogen associated with the nitrification process. A high accumulation of organic material from tree or shrub litter and root biomass in home gardens likely contributes to soil acidification (Wolle et al., 2021). Although the soil in agrisilviculture has a high proportion of organic matter, the pH value of the soil in agriculture is significantly higher than in home gardens. This could be due to the good buffering capacity and lower acidity of the soil. The presence of trees in agrisilviculture farming may contribute to deeper root activity, which supports nutrient cycling and pH regulation. According to Jiang et al. (2018), soils with a high organic matter content have a better acid buffering capacity due to their contribution to cation exchange capacity. Dvořáčková et al. (2022) also discussed that organic matter stabilises the buffering capacity of soil and regulates soil pH.

The contradiction between soil pH in home gardens and in agriculture could be due to the fact that different soil management practices buffering capacity of the soil. This is consistent with the study by Zhang et al. (2016), who reported that different soil management practises lead to differences in soil buffering capacity. In addition, domestic wastewater in the home garden system could also contribute to acidification. Urbaniak et al. (2017) reported that sewage sludge could inhibit microbial activity and organic matter decomposition, which could reduce the buffering capacity of the soil. Bai et al. (2016) found that the application of sewage sludge to the soil would lower the pH of the soil.

Our results suggest that agrisilviculture tends to maintain a more balanced soil pH, especially in the topsoil, whereas home garden soils are more susceptible to acidification, especially in deeper layers. Although in many cases the pH of intercropping does not differ significantly, it lies between the extremes observed in home gardens and agrisilviculture. Proper soil management, including organic matter management, controlled fertilisation and liming, is essential for maintaining an optimal soil pH for sustainable crop production.

4.4.3 Soil Acidity, Exchangeable Aluminium (Al^{3+}), and Exchangeable Hydrogen (H^+) in Different Agricultural Practices

The acidity of the soil plays a decisive role in the availability of nutrients, plant growth and microbial activity. The results of Figures 3, 4 and 5 show that soil acidity and the concentration of exchangeable aluminium (Al^{3+}) and hydrogen (H^+) vary significantly with different agricultural practices (home garden, intercropping and agrisilviculture farming) and soil depths. At a depth of 0-20 cm and 40-60 cm, the soils in the home garden practices significantly higher acidity than the soils in intercropping and agrisilviculture farming. This could be due to the greater decomposition of organic matter, which leads to

the release of organic acids and sewage sludge for domestic use. Alghobar (2014) found that the soil irrigated with wastewater has a lower pH and the exchangeable cations are increased. This also agrees with the study by Mojiri et al. (2011) who reported that wastewater can lower soil pH and increase exchangeable cations. This suggests that the home garden may be susceptible to acidification. At 20-40 cm depth, there is no significant difference in soil acidity, suggesting that the middle soil layer is better buffered against acidification.

Acidification in the domestic garden system could also lead to high levels of exchangeable Al^{3+} and exchangeable H^+ . At depths 1 and 3, the soil in the home garden contains significantly more exchangeable Al^{3+} and exchangeable H^+ than in the other systems. This is an important indicator of strong acidification of the soil, as the solubility of aluminium increases under more acidic conditions. This could also be due to the continuous decomposition of organic matter releasing H^+ into the soil, as well as the loss of basic cations (Ca^{2+} , Mg^{2+} , K^+) through leaching and the regular cultivation of plants, which can accelerate acidification in the home garden system. In practise, the soil has the highest exchangeable Al^{3+} values at 20-40 cm, significantly higher than in the other systems. This suggests that aluminium mobilisation occurs at this depth in intercropping systems, possibly due to nutrient leaching from upper layers or differences in root activity. These trends suggest that home gardens are more susceptible to acidification, while agricultural cropping systems promote better soil buffering capacity. Although intercropping is generally moderately acidic, it shows signs of Al^{3+} accumulation at 20-40 cm depth, which requires close monitoring.

A high content of exchangeable Al^{3+} has a variety of toxic effects on plants. It will plant roots as it can inhibit root growth and elongation (Kochian et al., 2015; Ur Rahman et al., 2024) Aluminium also leads to imbalances in the uptake and acquisition of various

mineral elements, such as Ca, Mg and P (Silva et al., 2012). In acidic soils, the toxicity of aluminium (Al) is an important factor in reducing crop yields (Kochian et al., 2015). High concentrations of exchangeable Al^{3+} and exchangeable H^+ would replace the base cations (e.g. Na^+ , K^+ , Mg^{2+} , Ca^{2+}), which will the available nutrient uptake by the plant (Owusu et al., 2024). Soil aluminium ions can be influenced by various soil physiochemical factors, including pH, organic matter content, cation exchange capacity, soil structural classes and interactions between target elements. However, according to Ur Rahman et al. (2024), soil pH is the most important determinant of Al availability as it influences its various forms, and precipitation will to the accumulation and transport of Al in the soil. Therefore, effective soil management practices, including liming, organic amendments and conservation techniques, are essential for maintaining soil fertility and ensuring sustainable agricultural productivity.

4.4.4 Available ammonium, nitrate, and phosphate under different agriculture practices

The data presented in Table 3 show that there is no significant difference in soil ammonium concentration between all sites, but the intercropped soil has the highest ammonium concentration (7.3 ppm) compared to agrisilviculture and home garden systems. At the same time, the nitrate concentration in intercropping is significantly higher (36.7 ppm) agrisilviculture and home practices. This indicates that the nitrification process is higher in intercropping, which promotes the conversion of ammonium to nitrate. Furthermore, this could be due to the presence of legumes (long beans) in the intercropping system, which can fix nitrogen. Legumes enhance nitrogen fixation in the soil via the process of biological

nitrogen fixation (BNF), which is a symbiotic relationship with bacteria called rhizobia (Singh et al., 2023)

In contrast to phosphate availability, intercropping has a significantly lower phosphate concentration (1.0 ppm) than agrisilviculture and home gardens. Conversely, home gardens have the highest phosphate content (6.0 ppm), although this does not differ significantly from agrisilviculture (2.0 ppm). The higher phosphate content in home gardens could be due to the supply of organic matter such as compost or manure, less plant competition or limited phosphorus uptake by certain species. According to Melese et al. (2015), organic matter can improve the availability of phosphorus through the solubilisation of bound P by soil microorganisms. In addition, organic matter forms a protective shell by coating sesquioxides and thus reducing P adsorption, so that more P is released and available for plant uptake (Nthejane et al., 2021).

4.4.5 Cations (K^+ , Na^+ , Mg^{2+} , Ca^{2+}) concentration under different agricultural practices

The data show that the soil in the home garden practice the lowest potassium concentration (K^+) compared to the other two practices. In contrast, agrisilviculture the highest concentration of exchangeable potassium (K^+) at a depth of 0 – 20 cm, but at a depth of 20 – 40 cm and 40 – 60 cm it is not significantly higher than intercropping. This could indicate that the combination of trees and crops in agrisilviculture K^+ storage in the soil, possibly through the contribution of organic matter and reduced leaching. In terms of magnesium (Mg^{2+}) and calcium (Ca^{2+}), agrisilviculture consistently have the highest concentrations. On the other hand, home garden practice consistently has the lowest concentrations of magnesium (Mg^{2+}) and calcium (Ca^{2+}).

Plant residues are rich in K, therefore the K storage in the topsoil increases with the organic matter content in the soil (Bel et al. 2020; Wu et al., 2021). According to Bader et al. (2021), organic matter in the soil will potassium release and reduces potassium fixation in the soil. Furthermore, increasing biological activities will the availability of potassium in the soil and one way to improve biological activities in the soil is to add organic matter (Purbajanti et al. 2019; Taiwo et al., 2018). McAlister and Rott (2019) also found that higher soil organic matter increases the cation exchange capacity and the potassium available in the soil. The lower levels of potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}) in the home garden could be due to the lower soil pH, as acidic conditions can lower available potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}). Legesse et al (2017) found that soil acidification will manganese and aluminium toxicity to plants and deficiencies in nutrients such as K. In addition, a higher soil pH can help to increase the availability of potassium, as Han et al. (2019) have shown that liming improves K availability in the soil. Han et. al (2019) also found that liming indirectly influences K uptake by plants through its effects on exchangeable Ca^{2+} and Mg^{2+} .

4.4.6 Soil fertility index (SFI) and soil evaluation factor (SEF) under different agricultural practices

The results show that the soil agrisilviculture has the highest soil fertility index (SFI) and the highest soil evaluation factor (SEF), while the soil in intercropping has the lowest SFI and the soil in home gardens has the lowest SEF. The high SFI and SEF agrisilviculture be due to the high organic matter content and the low bulk density of the soil. This is due to the fact that organic matter content will soil structure, water holding capacity and nutrient availability, while bulk density is lower (Javed et al., 2022). This condition allowed for better

rooting, aeration and water infiltration, which improved nutrient uptake by plants. In addition, the organic matter content contributed to soil fertility as it improved nutrient retention and microbial activity in the soil. Yadav et al. (2023) also mentioned that organic matter increases soil fertility because it serves as a source of nutrients such as phosphorus (P), nitrogen (N) and sulphur (S) (Duong et al. 2013; Yadav et al., 2023). In addition, the data from our study show that agrisilviculture high content of soil cations and anions such as ammonium (NH_4^+), phosphate (PO_4^{3-}), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}). According to Yang et al. (2024), an increase in cations such as K^+ , Ca^{2+} and Mg^{2+} in the will soil fertility.

4.4.7 Implication of Different Agriculture Practices on Soil Management Practices

The results of this study provide crucial insights into sustainable soil management practices for different agricultural systems in Siburan. Agrisilviculture farming and home gardening showed the most positive effects on soil health, especially in terms of organic matter, moisture content and reduced bulk density, emphasising their potential as a sustainable option for smallholder farmers. However, the higher soil acidity and increased levels of exchangeable aluminium and hydrogen ions in the home gardens suggest that targeted soil management practices such as liming and organic amendments are needed to maintain soil pH and fertility. In intercropping systems, improved organic matter management and the use of mulch or cover crops could help to reduce bulk density and better retain moisture in the soil.

These findings emphasise the importance of promoting sustainable practices through farmer education and policy support to encourage the adoption of agrisilviculture farming and home gardening while addressing site-specific soil management issues. Integrating these

practices into local agricultural policies can contribute to long-term soil fertility and sustainable agricultural productivity in the region. The higher organic carbon under agrisilviculture indicates greater carbon sequestration potential in that system, aligning with the idea that tree-integrated farming can store more carbon in soil (Yasin et al., 2019).

4.5 Conclusion

The results of our study show that, among sustainable agricultural practices, agrisilviculture farming has the most positive effects on the soil compared to home gardening and intercropping. The soils in agrisilviculture farming and home gardening have a high content of organic matter, organic carbon and moisture. This indicates that home gardening and agrisilviculture practices are more favourable for soil health. Although intercropping is a sustainable practice, it may require soil conservation strategies to prevent moisture loss, compaction and organic matter depletion. However, home garden soil is more acidic and has higher acidity, exchangeable aluminium and hydrogen ions than the other practices.

Acidification in the home garden results in lower soil cations and anions such as ammonium (NH_4^+), phosphate (PO_4^{3-}), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}). Meanwhile, agrisilviculture practice has high content of soil cations and anions such as ammonium (NH_4^+), phosphate (PO_4^{3-}), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}). In addition, the soil under agrisilviculture practice has the highest soil fertility index (SFI) and soil evaluation factor (SEF), while the soil in intercropping has the lowest SFI and the soil in home gardens has the lowest SEF. Therefore, proper soil management, including organic matter management, controlled fertilisation and liming, is crucial for maintaining optimal soil pH levels for sustainable crop production. Although sustainable practices have a positive impact on soil properties, they can also have

a negative impact on the soil if it is not managed properly. It is therefore important that authorities spread awareness and knowledge about sustainable agriculture in communities.

While this study provides valuable insights into the effects of different land-use practices on soil properties, several limitations should be acknowledged. First, the soil measurements were based on a single-time sampling and do not capture temporal changes. Continuous or long-term monitoring would be beneficial to confirm and strengthen the observed trends over time. Second, the results are based on specific sites namely, one home garden, one intercropping plot, and one agrisilviculture plot which may limit the generalizability of the findings. Soil characteristics can vary significantly between locations due to differences in management practices, climate, and soil types. As such, caution should be exercised when extrapolating these results to broader regions. Recognizing these limitations highlights the need for further studies across diverse sites and over extended periods to validate and expand upon the findings presented here.

CHAPTER 5

SYNTHESIS AND GENERAL DISCUSSION

5.1 Introduction

This work investigated the awareness, knowledge and perception of rice farmers on agroforestry practice and the impact of different agricultural practices on selected soil properties in Siburan Sarawak. This study aimed to achieve three objectives including determining the knowledge and awareness of rice farmers on agroforestry practices in Kg. Chupak and Kg. Skuduk, to determine the paddy farmers on agroforestry practices in Kg. Chupak and Kg. Skuduk and determine the selected physicochemical properties of soil under different agricultural practices in Kg. Chupak and Kg. Skuduk.

This first objective focuses on rice cultivation in Malaysia, where climate change has negatively impacted rice production, which is an important livelihood for rural communities. The research aims to assess rice farmers' awareness and knowledge of agroforestry, a method that integrates trees and crops to improve the resilience of agriculture to climate change. Data for the first and second objectives of the study were obtained through questionnaire-based interviews in Kampung Skuduk and Kampung Chupak. Statistical tests were used to analyze and compare the data. Farmers' knowledge of agroforestry practices was limited, especially among non-agroforestry practitioners. The third objective was achieved through field and laboratory analyses. The field study to determine the physicochemical properties of the soil and nutrient deposition was conducted by establishing 20 m x 20 m plots and taking the soil samples from the selected study sites. The soil samples were taken from three sites representing intercropping, agrisilviculture and home gardening at a

depth of 0–20 cm, 20–40 cm and 40–60 cm. The samples were analysed for moisture content, bulk density, pH, organic matter, organic carbon, total acidity and exchangeable aluminium and hydrogen ions.

5.2 Summary of results

The results in Chapter 3 have shown that although agroforestry can help farmers adapt to climate change, many are unaware of its benefits. There is no significant difference in income between agroforestry practitioners and non-agroforestry practitioners as agroforestry is practised on a small scale and for household consumption as there are no commercial opportunities for the products. Governmental or non-governmental organisations should organise education activities on agroforestry to disseminate information on these practices appropriate to the education level and age group of the target farmers. Awareness raising and information dissemination activities are important as lack of awareness hinders the implementation of agroforestry, e.g. through awareness campaigns and training programmes on agroforestry.

The results in Chapter 4 show that the respondents have a positive attitude towards agroforestry practices. They also expected awareness-raising activities and workshops on agroforestry, indicating that they are willing to learn more about these practices. Eighty per cent of respondents who do not practice agroforestry are interested in practicing agroforestry if there are no obstacles. This positive attitude indicates that farmers in the study area are ready and willing to practice agroforestry if there are no obstacles, because a positive attitude towards an agricultural innovation will increase the likelihood of adoption.

Finally, the results in Chapter 5 show that the moisture content of the soil in home gardens (57.89%) is significantly higher than in agrisilviculture (47.84%) and intercropping (25.60%). Organic matter content was also highest in-home gardens (8.38%), while soil acidity and exchangeable aluminium content were significantly higher in-home garden soils compared to other practices. Acidification in home gardens resulted in lower soil cations and anions such as ammonium (NH_4^+), phosphate (PO_4^{3-}), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}), leading to lower SEF.

5.3 Synthesis of main findings and implications

The main findings show that although some farmers practice agroforestry, most are only small-scale and self-taught, which limits their effectiveness. The study suggests that targeted education programmes are needed to improve farmers' understanding and implementation of agroforestry. This can help them to better cope with the challenges of climate change and ensure more sustainable and productive farming practices. Furthermore, the results in Chapter 4 have shown that respondents have a positive attitude towards agroforestry practices. This indicates that farmers in the study area are willing to practice agroforestry if there are no obstacles, as a positive attitude towards an agricultural innovation will the likelihood of adoption. Finally, our results in Chapter 5 showed that the soils under agroforestry (agrisilviculture) had the highest soil fertility index (SFI) and soil evaluation factor (SEF). This is due to the fact that soils under agrisilviculture have a high organic matter content, organic carbon, soil moisture and low bulk density. In addition, the pH of the soil under agrisilviculture optimal (6.65), indicating that agrisilviculture tends to maintain a more balanced soil.

The findings of this study reveal a meaningful connection between the observed soil properties and the level of farmers' awareness and understanding of agroforestry practices. Soils under agroforestry, particularly agrisilviculture systems, exhibited higher soil fertility indices (SFI) and soil evaluation factors (SEF), which are attributed to better soil structure, higher organic matter, and more favorable pH levels. However, despite these clear soil health benefits, many farmers practicing agroforestry do so on a small scale and with limited formal knowledge, often relying on self-taught methods. This gap suggests that while agroforestry has a measurable positive impact on soil quality, the lack of structured knowledge and awareness among farmers limits the optimization and scaling of these benefits. Therefore, increased education and training in agroforestry could not only improve implementation practices but also enhance soil health outcomes, creating a reinforcing cycle between informed practice and improved land productivity. This correlation underlines the need for integrated approaches that address both technical knowledge and environmental outcomes in promoting sustainable agriculture.

In conclusion, this study highlights the potential of agroforestry, particularly agrisilviculture, as a sustainable land-use practice that enhances soil fertility and supports more resilient agricultural systems. While several farmers in the study area are already practicing agroforestry, their efforts are often small-scale and largely self-initiated, limiting the full benefits that could be achieved. The findings underscore the importance of providing structured education and support programs to improve farmers' knowledge and capacity to implement agroforestry effectively. Encouragingly, the positive attitudes expressed by respondents suggest a strong willingness to adopt such practices if barriers are removed. Moreover, the superior soil quality indicators observed under agroforestry systems affirm its ecological value, particularly in mitigating the effects of land degradation and climate

change. These insights should inform future policy and extension strategies aimed at promoting widespread adoption of agroforestry for sustainable rural development.

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APPENDICES

APPENDIX A: Journal Publications

1. Mathew, J., Ugih, D., & Ibrahim, M. H. (2025). Paddy farmers' awareness and knowledge of agroforestry practices in Siburan, Sarawak. *Urban Agriculture & Regional Food Systems*, 10(1). <https://doi.org/10.1002/uar2.70011>
2. Mathew, J., JAMALI, M. H., VANISHRI KALY SITTHAN, ROMIA RONA TAGANG, & IBRAHIM, M. H. (2024). Farmers' Perception Towards Agroforestry Practices in Siburan. *Borneo Journal of Resource Science and Technology*, 14(2), 210–216. <https://doi.org/10.33736/bjrst.6954.2024>

APPENDIX B: Questionnaire survey



UNIVERSITI MALAYSIA SARAWAK

Borang Soal Selidik: Kajian Kesedaran Pesawah Padi Terhadap Amalan Agropertanian

Makluman kepada responden:

- ❖ Soal selidik ini bertujuan mendapatkan maklumat tentang kesedaran pesawah padi terhadap amalan agropertanian dan pandangan pesawah padi tentang sektor penanaman padi.
- ❖ Soal selidik ini terbahagi kepada 7 bahagian. Responden dikehendaki menjawab semua bahagian.
- ❖ Segala maklumat yang diperolehi melalui kaji selidik ini adalah sulit.
- ❖ **Arahan:** Responden dikehendaki mengisi maklumat yang diperlukan pada ruangan yang disediakan atau menandakan (X) pada ruangan yang disediakan

APA ITU AGROPERTANIAN?

- ❖ Agropertanian ditakrifkan sebagai gabungan pokok (seperti getah, sawit dll) dan tanaman (sayuran berdaun dan berbuah) atau haiwan (ruminan; lembu kambing dll atau bukan ruminan; Ayam, khinzir dll) dan ikan yang boleh dicantum pada satu unit tanah yang sama.
- ❖ **Atau** agropertanian bermaksud amalan menanam pelbagai jenis tanaman seperti tanaman jenis "pokok", buah-buahan, sayur-sayuran serta ternakan seperti haiwan dan ikan.
- ❖ Agropertanian sangat baik kepada petani kerana dapat memaksimumkan landskap sekeliling seperti **penggunaan ciri hutan**, kawasan pertanian dan perikanan dalam satu masa.
- ❖ Agropertanian juga mengurangkan kemiskinan kerana amalan ini meningkatkan pendapatan dan sumber makanan hasil daripada kepelbagaian tanaman diusahakan di kawasan padi.

MAKLUMAT AM

Enumerator:

Tarikh :

Lokasi :

BAHAGIAN A. MAKLUMAT RESPONDEN

1. Nama	:	No. Telefon:	
2. Kampung	:	☐ Chupak	☐ Plaman Payang ☐ Skuduk
3. Umur	:	☐ 18 – 27 ☐ 28 – 37	☐ 38 – 47 ☐ 48 – 57 ☐ Melebihi 58 tahun
4. Jantina	:	☐ Lelaki	☐ Perempuan
5. Status Perkahwinan	:	☐ Bujang ☐ Berkahwin	☐ Berceraai ☐ Duda / Janda
6. Bangsa	:	☐ Iban ☐ Bidayuh ☐ Cina	☐ Orang Ulu ☐ Lain-lain (<i>Sila nyatakan</i>):
7. Agama	:	☐ Islam ☐ Kristian ☐ Hindu	☐ Buddha ☐ Lain-lain (<i>Sila nyatakan</i>):
8. Kelayakan Pendidikan	:	☐ Tiada Pendidikan Formal ☐ UPSR ☐ SRP / PMR	☐ SPM ☐ Diploma/STPM ☐ Ijazah ☐ Lain – lain
9. Apakah faktor anda menanam padi?		☐ Sebagai pendapatan utama ☐ Sebagai pendapatan sampingan ☐ Mengekalkan budaya menanam padi	☐ Hobi ☐ Untuk mempertahankan tanah ☐ Supaya baka benih padi tidak pupus
10. Status sebagai Pesawah Padi	:	☐ Sepenuh masa	☐ Sambilan (<i>Sila jawab soalan 10</i>)
11. Pekerjaan utama	:	☐ Sektor Kerajaan ☐ Sektor Swasta ☐ Bekerja Sendiri	☐ Penternak ☐ Lain-lain (<i>Sila nyatakan</i>):

Anggaran Pendapatan Bulanan	:	☐ $\leq$ RM1300 ☐ RM1301 – RM1400	☐ RM1401 – RM1700 ☐ $\geq$ RM1701
Anggaran pendapatan sampingan	:	☐ $\leq$ RM1300 ☐ RM1301 – RM1400	☐ RM1401 – RM1700 ☐ $\geq$ RM1701
Pengalaman Menanam Padi	:	☐ $\leq$ 4 Tahun ☐ 5 – 10 Tahun	☐ 11 – 20 Tahun ☐ $\geq$ 21 Tahun

BAHAGIAN B. MAKLUMAT AM PENANAMAN PADI

- Apakah jenis baka padi yang anda tanam?
☐ Baka tradisional ☐ Baka moden
- Adakah anda menanam padi baka tradisional? Jika ya, sila nyatakan jenis baka dan sebab anda menanam baka tersebut?

- Adakah anda menanam padi baka moden? Jika ya, sila nyatakan jenis baka dan sebab anda menanam padi tersebut.

- Adakah anda masih mengamalkan amalan penanaman padi tradisional seperti mengamalkan pantang larang? Kalau ya, kenapa?
☐ Ya ☐ Tidak

5. Adakah anda mengamalkan amalan pertanian moden sepenuhnya? Nyatakan sebab.

☐ Ya ☐ Tidak

Sebab:

6. Adakah anda pernah berhenti menanam padi? Nyatakan sebab.

☐ Ya ☐ Tidak

Sebab:

7. Adakah anda berhasrat untuk mengajak rakan atau sanak saudara menanam padi?
Nyatakan sebab.

☐ Ya ☐ Tidak

BAHAGIAN C. PANDANGAN TERHADAP SEKTOR PENANAMAN PADI

Pada soalan **5 dan 6** sila tandakan pada kotak mengikut skala di bawah;

- ☐ **1 - SANGAT BERSETUJU**
- ☐ **2 - BERSETUJU**
- ☐ **3 - TIDAK PASTI**
- ☐ **4 - TIDAK BERSETUJU**
- ☐ **5 - SANGAT TIDAK BERSETUJU**

1. Adakah hasil tuaian padi digunakan untuk kegunaan isi rumah? Jika tidak, sila jawab soalan seterusnya.

☐ Ya ☐ Tidak

2. Adakah anda menjual hasil padi?

☐ Ya ☐ Tidak

3. Adakah anda menjual lebihan hasil padi? Nyatakan sebab.

☐ Ya

☐ Tidak

Sebab:

4. Adakah hasil tuaian padi dalam masa 3 tahun kebelakangan meningkat atau menurun?

☐ Meningkat

☐ Menurun

☐ Tiada perubahan

5. Adakah anda akan meneruskan aktiviti penanaman padi dalam masa lima 5 tahun akan datang? Nyatakan sebab kepada jawapan anda.

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

6. Adakah aktiviti penanaman padi menguntungkan?

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

7. Apakah faktor yang mempengaruhi hasil tuaian padi?

8. Apakah masalah yang dihadapi oleh pesawah padi pada masa kini? Sila nyatakan.

BAHAGIAN D: KESEDARAN DAN PENGETAHUAN TERHADAP AMALAN AGROPERHUTANAN

Arahan: Sila tandakan (X) pada ruangan berkenaan.

Pada soalan **3 dan 4** sila tandakan pada kotak mengikut skala di bawah;

☐ **1 - SANGAT MAKLUM**

☐ **2 - MAKLUM**

☐ **3 - TIDAK PASTI**

☐ **4 - TIDAK MAKLUM**

☐ 5 - SANGAT TIDAK MAKLUM

1. Adakah anda menanam tanaman lain selain padi di sekitar bendang? (penanaman sayur, pokok buah, menternak ikan dan lain-lain). Jika ya, sila nyatakan.

☐ Ya

☐ Tidak

-
2. Adakah anda pernah mendengar mengenai amalan agroperhutanan?

☐ Ya

☐ Tidak

3. Sejauh manakah anda mengetahui amalan agroperhutanan?

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

4. Adakah anda sedar mengenai kebaikan amalan agroperhutanan?

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

Soalan 5 – 7 hanya perlu dijawab sekiranya responden menjawab 'Ya' pada soalan 1

5. Sejak bilakah anda mula mengamalkan amalan agroperhutanan?

☐ Sejak mula
menanam
padi

☐ Beberapa tahun
selepas
menanam padi

☐ Kebelakangan
ini

6. Siapakah yang mempengaruhi anda untuk mengamalkan amalan agroperhutanan?

☐ Diri sendiri
☐ Orang tua
☐ Rakan
☐ Media

☐ Agensi Kerajaan
☐ Agensi Swasta

7. Kenapakah anda mengamalkan amalan agroperhutanan?

Soalan ini hanya perlu dijawab sekiranya responden menjawab 'Tidak' pada soalan 1

8. Nyatakan sebab anda tidak mengamalkan amalan agroperhutanan.

- | | |
|---|---|
| ☐ Tidak tahu mengenai amalan ini | ☐ Tiada masa |
| ☐ Tanah tidak mencukupi | ☐ Kekurangan tenaga buruh |
| ☐ Tiada modal | ☐ Lain-lain (<i>sila nyatakan</i>) |
-

9. Sekiranya tiada halangan, adakah anda akan mengamalkan amalan agroperhutanan?

- ☐ Ya ☐ Tidak

BAHAGIAN E: KESAN-KESAN AMALAN AGROPERHUTANAN

Arahan: **Bahagian ini hanya perlu diisi sekiranya responden menjawab 'Ya' pada soalan 1 di Bahagian D sahaja.** Sila tandakan (X) pada kotak yang disediakan

1. Adakah hasil tuaian padi anda meningkat selepas mengamalkan amalan agroperhutanan **forestry?**

- ☐ Ya ☐ Tidak ☐ Mungkin

2. Adakah hasil tuaian tanaman sampingan anda meningkat selepas mengamalkan amalan agro **forestry?**

- ☐ Ya ☐ Tidak ☐ Mungkin

3. Adakah serangga perosak di sawah padi menurun selepas anda mengamalkan amalan agroperhutanan?

- ☐ Ya ☐ Tidak ☐ Mungkin

4. Adakah amalan agroperhutanan meningkatkan kesuburan tanah di kawasan sawah padi anda?

- ☐ Ya ☐ Tidak ☐ Mungkin

5. Adakah pendapatan anda meningkat selepas mengamalkan amalan agroperhutanan?

- ☐ Ya ☐ Tidak ☐ Mungkin

6. Adakah sumber makanan lebih mencukupi selepas mengamalkan amalan agroperhutana?²
- ☐ Ya ☐ Tidak ☐ Mungkin
7. Adakah jumlah binatang di kawasan padi meningkat selepas mengamalkan amalan agroperhutanan?
- ☐ Ya ☐ Tidak ☐ Mungkin

BAHAGIAN F: PANDANGAN TERHADAP AMALAN AGROPERHUTANAN

Arahan: Sila tandakan pada kotak yang disediakan berdasarkan skala di bawah.

- ☐ **1 - SANGAT BERSETUJU**
☐ **2 - BERSETUJU**
☐ **3 - TIDAK PASTI**
☐ **4 - TIDAK BERSETUJU**
☐ **5 - SANGAT TIDAK BERSETUJU**

1. Amalan agroperhutanan mendatangkan manfaat dari segi ekonomi, sosial dan alam sekitar.
- ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
2. Saya akan mencadangkan amalan agroperhutanan kepada rakan atau sanak saudara.
- ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
3. Amalan agroperhutanan dapat meningkatkan pertumbuhan sektor pertanian dan agrikultur.
- ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
4. Amalan agroperhutanan harus diamalkan dalam sektor pertanian dan agrikultur,
- ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Kerajaan patut mengadakan lebih banyak aktiviti kesedaran mengenai amalan agroperhutanan kepada masyarakat.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. Kerajaan patut memberikan sokong serta bengkel kemahiran berkenaan amalan agroperhutanan.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

BAHAGIAN G: CABARAN MENGAMALKAN AMALAN AGROPERHUTANAN

Arahan: Sila isi jawapan pada ruangan yang disediakan.

1. Sekiranya anda ingin mengamalkan amalan agroperhutanan, apakah cabaran atau kekangan yang mungkin menghalang anda daripada mengamalkan amalan ini.