PLANT COMPOSITION AND ARRANGEMENT OF AGROFORESTRY SYSTEMS IN OIL PALM SMALLHOLDINGS AT KLUANG, JOHOR

BY

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ABSTRACT

Malaysia is known as the largest exporter and second largest producer of world palm oil market. Despite such contributions, a huge amount of forest land has been supplanted by oil palm cultivation. This activity is considered as a major driver of deforestation, which contributes to three-quarters of tropical deforestation globally. The critique of this field reveals agroforestry systems as an option to overcome the issues brought up by a monoculture system of oil palm cultivation. This inquiry is directed to study plant composition and arrangement for agroforestry systems in oil palm smallholdings. To this end, three objectives formulated which are: (i) to investigate agroforestry systems as sustainable agriculture practices in oil palm smallholdings, (ii) to explore plant composition and arrangement of agroforestry systems for a sustainable oil palm smallholdings, and (iii) to recommend sustainable plant composition and arrangement of agroforestry systems that can be implemented in oil palm smallholdings. Data were gathered using a qualitative approach involving 10 oil palm smallholdings at Kluang, Johor. Three methods of data collection were adopted, which consists of non-participant observation, semi-structured interview, and document analysis. The collected data were analyzed using thematic analysis that were triangulated to provide systematic, efficient, and accurate data analysis. The findings suggested that there are 50 plant species and 3 types of arrangement suitable to be implemented in oil palm smallholdings. The plant species are in the ranged of perennial crops, annual crops, leguminous cover crops, and grasses. Meanwhile, the arrangement involves triangular, double avenue, and boundary planting systems. Further analysis traced that these plant species and arrangement can be categorized into two main categories which are: (i) sustainable plant composition and arrangement, and (ii) unsustainable into sustainable plant composition and arrangement. The study concluded that the transformation of the monoculture system with low sustainability towards more sustainable farming practices of agroforestry systems can be achieved through five considerations. It is subjected to the oil palm crops as the main component, maturity of oil palm crops, market values and demand, belowground and aboveground interaction, and horizontal and vertical diversification of plant composition and arrangement.

ملخص البحث

تعرف ماليزيا بأنها أكبر دولة مصدرة لزيت النخيل وثاني أكبر دولة منتجة له في السوق العالمي، وقد جعلت هذه الإسهامات قدراً كبيراً من أراضي الغابات الماليزية يتحول إلى زراعة زيت النخيل، ويعد هذا النشاط عاملاً رئيساً في القضاء على هذه الغابات، مما يسهم في محو ثلاثة أرباع الغابات المداري على مستوى العالم. وإنَّ الانتقاد الموجه إلى هذا النشاط يكشف أن نظم الزراعة المختلطة بالغابات تعتبر خياراً للتغلب على المسائل التي أثيرت من لدن النظام الأحادي المتبع في زراعة زيت النخيل. إن هذا الاستفسار موجَّه لدراسة تكوين النبات وترتيب نظم الزراعة المختلطة بالغابات في الحيازات الصغيرة لزيت النخيل. زلتحقيق هذه الغاية تمت صياغة ثلاثة أهداف، وهي: أولاً: التحقق من نظم الزراعة المختلطة بالغابات، مثل: ممارسة الزراعة المستدامة لأصحاب الحيازات الصغيرة من مزارع زيت النخيل، ثانياً: استكشاف تكوين النبات وترتيب نظم الزراعة المختلطة بالغابات من أجل استدامة الحيازات الصغيرة لزيت النخيل، ثالثاً: التوصية بتكوين الزراعة الميتدامة وترتيب نظم الزراع المختلطة بالغابات التي يمكن تنفيذها في الحيازات الصغيرة لزيت النخيل. وقد تمَّ جمع البيانات باستخدام المنهج النوعي، حيث اشتمل على عشرة من الحيازات الصغيرة لزيت النخيل في: كلوانج بولاية جوهور، وتمَّ اعتماد ثلاثة أساليب لجمع البيانات اشتملت على الملاحظة لغير المشاركين، والمقابلات شبه المقيدة، والتحليل الوثائقي. وقد تمَّ تحليل البيانات التي تمَّ جمعها باستخدام التحليل الموضوعي؛ حيث تمَّ تثليثها للتأكد من تحليل البيانات بشكل منهجي وفعَّال ودقيق. وتشير النتائج إلى أنَّ هناك خمسين نوعاً من النباتات وثلاثة أنواع من الترتيبات المناسبة يمكن تطبيقها على أصحاب الحيازات الصغيرة لزيت النخيل. إن تلك الأنواع النباتية تتمثل في: المحاصيل المعمرة، والمحاصيل السنوية، وغطاء المحاصيل البقولية، والأعشاب. وفي الوقت نفسه فإنَّ الترتيب الثلاثي ينطوي على: السبل المزدوجة، وأنظمة زراعة الحواف. وبإجراء مزيد من التحليل يتبيَّن لنا أنَّ هذه الأنواع النباتية وتلك الترتيبات الإجرائية يمكن تقسيمها غلى فئتين رئيستين، وهما: (أ) تكوينات النظم النباتية المستدامة، و (ب) تكوينات النظم النباتية غير المستدامة. وقد خلصت الدراسة إلى أنَّ التحوُّل في نظام الزراعة الأحادية مع الاستدامة المنخفضة من أجل تحقيق ممارسة زراعة أكثر استدامة لنظم الزراعة المختلطة بالغابات يمكن أن يتحقق من خلال خمسة اعتبارات، تتمثل في: أن تكون خاضعة لمحاصيل زيت النخيل باعتباره العنصر الرئيس، واشتراط نضج محاصيل زيت النخيل، والقيمة السوقية والطلب، والتفاعل بين سطح التربة وقمة الأشجار، وأخيراً التنويع الأفقي والرأسي في زراعة النباتات وتركيبها.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Built Environment.

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Supervisor

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF ABBREVIATIONS

BPK	Bantuan Penyelenggaraan Kebun
COP	Codes of Practice
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
FRIM	Forest Research Institute Malaysia
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
MPIC	Ministry of Plantation Industries and Commodities
MPOB	Malaysian Palm Oil Board
NAP3	Third National Agricultural Policy
PKNS	Selangor State Development Corporation
QDA	Qualitative Data Analysis
RISDA	Rubber Industry Smallholder Development Authority
RSPO	Roundtable Sustainable Palm Oil
SALCRA	Sarawak Land Consolidation and Rehabilitation Authority
TBSPK	Tanam Baru Sawit Pekebun Kecil
TSSPK	Tanam Semula Sawit Pekebun Kecil
TUNAS	Tunjuk Ajar dan Nasihat Sawit

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

Sustainable development is becoming a dominant criterion in guiding current development in the planning stage. The concept of sustainable development is closely related to the humanity as a human has the ability to create and improve the development to become sustainable during the planning stage (United Nations Documents, n.d.). In order to protect the incorruption of the global environmental and developmental system at the local, national, and international levels (Malaysian Productivity Corporation, 2010), this concept has slowly been adapted by many developing countries such as Malaysia, Indonesia, Brazil, Papua New Guinea, and Zimbabwe (American Mathematical Society, 2014).

Among one of the most vital sectors that needs to be developed in a sustainable way is the agricultural sector. It is reported that food sufficiency, environmental stewardship, and socioeconomic viability and equity are the major paradigms of sustainable agriculture development (Smit and Smithers, 1993; Hansen, 1996; Smith and McDonald, 1998; Devendra, 2011). Sustainable agriculture is a multi-dimensional concept considering the environmental or ecological, social, and economic dimensions (Smit and Smithers, 1993; Smith and McDonald, 1998; Sydorovych and Wossink, 2008; Devendra, 2011; Suryanto and Susila Putra, 2012).

Environmental aspects focus on the plant development, including plant growth and its management, which are affected by the agronomic study of soil, water, and crops (Smit and Smithers, 1993). From an economic perspective, the importance of sustainable agriculture is seen in its sufficient economic returns as an enterprise at the farm level, and a vital economic sector at the regional and national levels. The sector contributes a large amount in the national gross domestic product (GDP) (Smith and McDonald, 1998; Dahlan Ismail, 2009). Finally, the social dimension suggests that agriculture as the primary supplier for food, fibre, and shelter, which simultaneously provide basic societal needs for human population and boost the quality of life of the surrounding community (Smit and Smithers, 1993; Kassie and Zikhali, 2009). The interaction of these dimensions is known as the principles of sustainability.

On the other hand, agroforestry systems are the approach in sustainable agriculture practices that consider the principles of sustainability. It is defined as a dynamic and harmonious solution of natural resources management with the efforts to integrate trees and animals in farming system (Suryanto and Susila Putra, 2012). The purpose is to increase environmental, social, and economic benefits for both agriculture and forestry sectors. In addition, agroforestry systems are also known as a practice of growing crops, trees, and animals in the same unit of agricultural land by holding the principles of sustainability (Nair, 2011). These imply that the systems have been accepted as an approach in sustainable agriculture practices. It becomes dynamic systems in which the joint application of agricultural crops, plant, and animal species is able to improve the effectiveness of natural resource usage, increase job opportunities and income, as well as an increase pragmatic production system (Devendra, 2011).

In details, this study examines the implementation of agroforestry systems as sustainable agriculture practices in oil palm cultivation, especially among smallholdings. The study concerns about how the plant composition and arrangement of agroforestry systems provide positive and neutral benefits to oil palm growers and the surroundings. As such, agroforestry interaction between oil palm crops and other plant species are studied as sustainable agriculture practices by concentrating on its environmental and rural quality, sustainable composition and arrangement, as well as factors that contributed to the agricultural sustainability of the systems in oil palm smallholdings. Thus, the study explores and discusses the plant composition and arrangement that has a potential to be integrated in oil palm smallholdings based on its suitability and sustainability.

Accordingly, this chapter presents the introduction of the study, which consists of ten sections. Section 1.0 introduces the research while Section 1.1 explains the research background, as well as the gap of the research. Problem statements are presented in Section 1.2. Sections 1.3, 1.4, and 1.5 review the questions, aim, and objectives of the research, respectively. Next, Sections 1.6 and 1.7 clarify the significance and scopes of the research, respectively. Section 1.8 outlines the research methodology and followed by Section 1.9 which explains the organization of the research. Finally, the summary is presented in Section 1.10.

1.1 RESEARCH BACKGROUND

Agroforestry systems are an attempt to overcome the negative effects of the oil palm monoculture development in the agriculture sector. The systems are seen as a sustainable form of land use options which have the capability to improve the productivity and well-being of rural community (Faridah Ahmad, 2001; Ahmad Fauzi and Huda Farhana, 2006; Nurul Ain et al., 2011). Most importantly, the systems enable oil palm farmers to maximize the utilization of agricultural land in a sustainable way. Therefore, for this research, agroforestry systems refer to various types of farming practices concerning the composition and arrangement of the components that involve in these systems. The systems must be systematically planned and designed in order to be adopted as a mechanism in planning good agricultural practices (GAP) (Faridah Ahmad, 2001; Ahmad Fauzi and Huda Farhana, 2006; Dahlan Ismail, 2009; Devendra, 2011).

Generally, the evolution of agroforestry systems has been started in Europe, America, Africa, and Asia through shifting cultivation, intercropping, and mixed farming practices (Conklin, 1957; Nair, 1993; Zeleza, 1993). The systems were first implemented in Malaysia through *taungya* method or intercropping in 1950 (Ahmad Fauzi and Huda Farhana, 2006). It involved a combination of agricultural and forestry components of agricultural crops, plant, and livestock species. As the knowledge has been developed, these farming practices were improved by considering the environmental, social, and economic aspects thus known as agroforestry systems. Nowadays, the systems recognized as a new name of old agricultural practices that improved and acknowledged as sustainable agriculture practices (Nair, 1993).

In details, Table 1.0 describes the chronological studies of agroforestry systems as sustainable agriculture practices around the world. The table suggests that the composition and arrangement of agroforestry components are linked to each other in generating sustainable agriculture practices. The concern of the study shows that the systems involve proper organization of land use management, planting design and planning, and technical skills of the farmers. As a result, agricultural land which is systematically planned and designed with proper management, selection of composition and arrangement of agroforestry components, and information on agroforestry systems gives consistent positive and neutral impacts towards the environment, social, and economic aspects.

Table 1.0
Chronological studies on agroforestry systems around the world

Year	Author	Concern of study
1996	Haselwandter and Bowen	Selection of tree species used in agroforestry, especially silvopastoral systems which influence the performance of soil fertility through the existence of fungus.
1998	Olson	Interrelation between landscape, farm structure, and crop production of agroforestry systems in order to provide balance needs of food, wood, and cash crop production.
1999	Balandier and Dupraz	Influence of component arrangement in tree height growth, diameter growth, tree death, and injury.
2001	Faridah Ahmad	Agroforestry systems as one of the sustainable agriculture practices that consider its sustainability, correct designs, and techniques of the combination between main crops and other crops.
2005	Thakur et al.	Selection and management of suitable agroforestry systems on agricultural fields and sloppy land in order to diversify and increase land productivity.
2006	Ahmad Fauzi and Huda Farhana	Recommendation on the most sufficient composition and arrangement based on economic feasibility.
2007	Thakur, Dutt, and Singh	Evaluation and development of suitable composition and arrangement of medicinal and aromatic herbs with timber tree species for diversification of land use option.
2010	Parwada et al.	Levels and factors that affect the adoption of agroforestry systems between trained and untrained farmers.
2011	Nurul Ain et al.	The sustainability on the composition and arrangement of the agroforestry components is examined through the development of diameter at breast height of the main crops.
2012	Suryanto and Susila Putra	Management of agroforestry systems in order to increase the application of the systems.

Since the study is concentrating on the implementation of agroforestry systems within oil palm cultivation in the Malaysian context, Table 1.1 further summarizes the benefits of the systems based on the environment, social, and economic aspects. Based on the concern of the study, it shows that oil palm crops in Malaysia tend to be integrated with livestock of cattle instead of goat, buffalo, and chicken. The integration that known as a silvopastoral sub-system is largely integrated within oil palm crops due to the decreased availability of arable land, as well as rapid demand for animal protein production include meat and dairy product (Dahlan Ismail, 2009; Devendra, 2011).

In contrast, studies that analyzed the integration between oil palm crops and other plant species or known as agrisilviculture sub-system are only slightly developed and undervalued its potential, especially towards the environment. As mentioned by Devendra (2011), the initial focus of sustainable agriculture is on environmental aspects. However, it has expanded into broader socioeconomic and political aspects rather than environmental aspects. As the knowledge on sustainability has been spreading in all sectors, it is important to draw attention on the environment, social, and economic benefits of agroforestry systems especially with the integration of oil palm crops and other plant species. Remarkably, the benefits on the environmental aspects are simultaneously giving positive and neutral impact on socioeconomic aspects.

Accordingly, the table further summarizes that studies on the composition of agroforestry components in oil palm cultivation are given attention by many researchers in the early 2000 to present due to its benefits of the environment, social, and economic aspects. However, the earlier studies are mostly focused on the socioeconomic benefits such as increase yield production, additional income for the farmers, and decline cost of weeding and herbicides instead of environmental benefits. Then, in the early 2010, studies on environmental benefits has been spreading among the researcher, especially governmental sector include Malaysian Palm Oil Board (MPOB), Sabah Forestry Department, and Forest Research Institute Malaysia (FRIM). Consideration on three aspects of environment, social, and economic benefits was further developed in the current studies.

Table 1.1
Studies on the benefits of agroforestry systems in oil palm cultivation in Malaysia

Year	Author	Concern of study	Benefit	
2000	Rosli Awaludin	Agrosilvopastoral sub-system: Oil palm – cattle (portable electric fence)	Save cost of weed control and reduce labor required for maintenance works	**Social & economic**
2003	Rosli Awaludin and Shariffhuddin	Agrosilvopastoral sub-system: Oil palm – cattle	Save cost for weed control, reduce labor required for maintenance works and increase cattle production for food supply	
2005	Lee et al.	Agrisilviculture sub-system: Oil palm – laran (*Neolamarckia cadamba*) Oil palm – binuang (*Octomeles sumatrana*)	Supply good quality logs for the timber industry with a very high price for per unit of biomass and the species are less labor-intensive that can reduce the reliance on foreign labor	
2006	Ahmad Fauzi and Huda Farhana	Agrisilviculture sub-system: Oil palm – banana (*Musa* spp.) Oil palm – sentang (*Azadirachta excelsa*)	Increase production cost and gross income	
2008	Ahmed Azhar et al.	Agrisilviculture sub-system: Oil palm – sentang (*Azadirachta excelsa*) Oil palm – teak (*Tectona grandis*)	Increase smallholder farmers' income	
2008	Tapsir Serin et al.	Agrosilvopastoral sub-system: Oil palm – cattle	Improvement of productivity and efficiency of beef cattle production through farmers' skill and land use management	
2009	Norkaspi Khasim et al.	Agrisilviculture sub-system: Oil palm – tongkat Ali (*Eurycoma longifolia*)	Increase in land productivity and generate additional income, especially during the immature phase	
2009	Ayob and Hj Kabul	Agrosilvopastoral sub-system: Oil palm – cattle	Save cost of weeding, labor required, and labor cost	
2011	Chia	Agrisilviculture sub-system: Monoculture: Teak only Agroforestry: Oil palm – teak (*Tectona grandis*)	Survival of teak is higher in the agroforestry systems than a monoculture plantation	**Environmental**
2012	Hasnol Othman, Farawahida, and Zulkifli Hashim	Agrisilviculture sub-system: Oil palm – *Mucuna bracteata*	Improve soil fertility, palm growth, and lower immaturity phase	
2014	Dahlan Ismail and Kamal Hisyam	Agrosilvopastoral sub-system: Oil palm – cattle	Increase family income and standard of living, improve crops and cattle production through centralization of cooperative marketing and management system, and improve the soil fertility via decomposition of dung and urine from cattle	**Environmental, social, & economic**

1.2 PROBLEM STATEMENTS

Based on the evaluation of the study by many researchers, it can be concluded that there are three main issues that are applicable: (i) global environmental impact of monoculture oil palm cultivation, (ii) limited knowledge, technical skill, and moral support for smallholder farmers, and (iii) insufficient information on agroforestry systems. The following sub-sections present the statements of problem that are relevant in this study. Table 1.2 shows related issues occurred in the oil palm cultivation and agroforestry systems among smallholder farmers throughout the world.

Table 1.2
Studies on the related issues range from oil palm cultivation, smallholder farmers, and agroforestry systems

Author	Concern of study
Rodriguez, Sultan, and Hilliker, 2004	Poor management of animal waste.
Faridah Ahmad, 2001; Rodriguez, Sultan, and Hilliker, 2004; Merem, 2005; Amekawa, 2010; Grain, 2006	Massive consumption of chemical fertilizer and agrochemical products.
Kassie and Zikhali, 2009; Devendra, 2011	Poverty of rural population among smallholder farmers.
Devendra, 2011	Inadequate food sources due to high human population.
Parwada et al., 2010; Suryanto and Susila Putra, 2012	Low level of awareness in the implementation of agroforestry systems.
Grain, 2006; Fitzherbert et al., 2008; Laurance et al., 2010	Monoculture plantation due to rapid demand in oil palm-based product leads to deforestation, loss of biodiversity, and climate change.

1.2.1 Global Environmental Impact of Monoculture Oil Palm Cultivation

Oil palm cultivation has become one of the fastest growing monoculture plantations in the tropics not only in Africa, but also in Asia-Pacific, Latin America, and the Caribbean. The increase in global demand for food and fuel is driving rapid expansion of oil palm monoculture plantation (Grain, 2006; Laurance et al., 2010). In 2050, agriculture sector needs to feed approximately 9 billion people, which requires 70 to

100% growth in food production (Wollenberg et al., 2011). In Malaysia, the current annual oil palm cultivation of 10.1% (Devendra, 2011) increased from 1.8 million hectares to 4.8 million hectares in 1960 to 2005 (Fitzherbert et al., 2008), and the latest planted area is more than 5 million hectares in December 2013 (MPOB, 2014). The rapid expansion of oil palm cultivation creates negative impact on the environmental aspect.

The environmental impacts of oil palm cultivation receive a lot of attention among the environmentalist rather than social and economic impacts. It has been documented as a cause of significant and often irreversible damage to the natural environment. Large areas of forest have been replaced by oil palm cultivation in Southeast Asia (Fitzherbert et al., 2008), Southern Thailand (Aratrakorn, Thunhikorn, and Donald, 2006), and Papua New Guinea (Buchanan et al., 2008). Thus, oil palm cultivation is seen as a major driver of deforestation, which contributes three-quarter of tropical deforestation globally (Grain, 2006; Fitzherbert et al., 2008; Laurance et al., 2010; Wollenberg et al., 2011). The statement is supported by Lian and Wilcove (2008), as 55 to 59% of oil palm expansions in Malaysia between 1990 and 2005 involved natural forest area.

Due to the conversion of forest area into oil palm cultivation, it has threatened the natural flora and fauna by causing habitat fragmentation. Forest areas in Malaysia are known as among the forest areas that are habituated by various species of terrestrial habitat (Fitzherbert et al., 2008; Sheil et al., 2009). In contrast, the environmental condition of oil palm cultivation only supports fewer species of flora and fauna in which it is greatly impoverished compared to the forest area (Grain, 2006; Fitzherbert et al., 2008). The structural character of oil palm crops is less complex than natural forests due to its lower canopy, uniform tree structure, sparse undergrowth, absence of stratification, and routinely cleared and planted within 25 to 30 years (Fitzherbert et al., 2008). Therefore, it causes extinction of a number of flora and fauna include wildlife, exotic and endangered species (Aratrakorn, Thunhikorn, and Donald, 2006; Sheil et al., 2009). The number of these species is rapidly decreasing in quantity and quality. Thus, environmental campaigners claimed that in 15 years, 98% of the rainforests in Malaysia will be gone unless drastic action is taken to find ways of producing sustainable oil palm cultivation (Fitzherbert et al., 2008).

1.2.2 Limited Knowledge, Technical Skill, and Moral Support for Smallholder Farmers

The norm of small scale farms throughout Asia involves poor small farmers and rural communities that lived in the gloom of poverty and hunger (Asy Syura and Tsan, 2008; Devendra, 2011). It has been reported that 50% of 4 billion poor rural people depending largely on the crops and livestock production in order to sustain their basic quality of life (Dahlan Ismail, 2009; Kassie and Zikhali, 2009; Devendra, 2011). Furthermore, it has been reported that the average income of Indonesian smallholder oil palm farmers was seven times higher than subsistence farmers (Wong, 2001), but vice versa to Malaysian smallholder farmers (Faridah Ahmad, 2001). As overall, Malaysian and Indonesian smallholder farmers contribute 35 to 40% of the whole oil palm production (Vermeulen and Goad, 2006). Based on the situation, Malaysian smallholder farmers need to have initiatives to gain proper technical skill to become skilled and trained farmers. These efforts have further improved their land use management in terms of appropriate planning and design of farming practices, suitable selection of composition and arrangement of agroforestry components, and produce continues self-sufficiency products.

Other than that, the price of oil palm commodities which increases and declines inconsistently gives a negative impact towards oil palm farmers in both stakeholder and smallholdings. In order to mitigate the impact, the Malaysian Ministry of Plantation Industries and Commodities (MPIC) has introduced B10 programs, which are specifically set up for stakeholder sector. The program estimated that 1 million tons of crude palm oil will be used a year in biodiesel production even though the country faced the decline of palm oil prices (Lee, 2012). Since there are programs developed for stakeholder sector, the effort for smallholdings is also developed, but only focusing on the contributions and financial assistance. For example, the allocation of RM297 million and RM7,000 per hectare was given to smallholder farmers by the Malaysian MPIC and the Rubber Industry Smallholders Development Authority (RISDA) (Utusan Borneo, 2011; Sinar Harian, 2012). However, without giving and exposing appropriate knowledge and institutional support to the smallholder farmers, they are unable to perform good and sustainable agriculture practices in terms of farming techniques and strategies.

1.2.3 Insufficient Information on Agroforestry Systems

The overdependence on oil palm products has made the smallholder farmers to consume huge quantities of chemical fertilizers and agrochemicals (pesticides, insecticides, herbicides, and fungicides) although they are practicing agroforestry systems. This is to ensure consistency and profitability of yield production (Wong, 2001; Faridah Ahmad, 2001; Rodriguez, Sultan, and Hilliker, 2004; Asy Syura and Tsan, 2008; Kassie and Zikhali, 2009). However, the utilization of chemical fertilizer and agrochemical is bad for human health and the environment, although it is considered as a modern agricultural practice (Faridah Ahmad, 2001; Rodriguez, Sultan, and Hilliker, 2004; Kassie and Zikhali, 2009). It also reduces soil fertility, degrade soil, lead to biodiversity loss, and pollute water bodies, even though it assures high output production for the short-term period (Wong, 2001; Merem, 2005; Grain, 2006; Kassie and Zikhali, 2009).

Insufficient information and knowledge on agroforestry systems are causing smallholder farmers to apply chemical fertilizers and agrochemicals to their agricultural land extensively. Instead of using chemical fertilizers, agroforestry systems are the sources for organic fertilizers through the decomposition of waste from crops, green manure from plant, and dung and urine from livestock (Asy Syura and Tsan, 2008). As such, the application is not only concentrating on the chemical fertilizer and agrochemical products, but also incorporates biological and organic fertilizers.

For example, the decomposition of empty fruit bunches, animal droppings, green manures, and legumes as organic fertilizers give environmental benefits of maintaining and improving agricultural soil through its nutrient recycling (Faridah Ahmad, 2001; Asy Syura and Tsan, 2008; Fitzherbert et al., 2008; Dahlan Ismail, 2009; Parwada et al., 2010; Amekawa, 2010). Other than that, the application of organic fertilizers also improves workers' safety, as well as provided healthy food to the consumers in the social side benefits (Asy Syura and Tsan, 2008). Therefore, it is necessary for farmers to access the knowledge and skills of agroforestry systems in enhancing the rural and environmental quality among smallholder farmers and the surrounding area.

To conclude, the problem statements raised in this study derived from the negative impacts of monoculture oil palm cultivation that continuously claimed as unsustainable oil palm production. The issues can be defeated starting from the small scale of oil palm cultivation through the application of agroforestry systems. However, limited knowledge, technical skills, and moral support of the appropriate planning and design of farming practices may cause the systems hardly accepted among the smallholder farmers. Due to the inconsistently of oil palm price, it is hard for the full time smallholder farmers to survive in this industry. Thus, it is needed for them to gain more knowledge and skills in order to be able to produce self-sufficiency products rather than solely rely on the oil palm production. As the agroforestry systems have been practiced among the smallholder farmers, the benefits of environmental and socioeconomic aspects should be fully beneficial for them. Yet, some of them are not being familiar with the benefits due to insufficient information gained regarding the systems.

1.3 RESEARCH QUESTIONS

The following questions are developed accordingly based on the statement of problems and objectives discussed earlier:

i. Key research question:

   How is the plant composition and space arrangement of agroforestry systems in oil palm cultivation of smallholdings can be seen as sustainable agriculture practices?

ii. Sub-research questions:

   a. How agroforestry systems contribute to the agricultural sustainability in oil palm smallholdings?

b. How to integrate oil palm crops and other plant species in terms of its composition and arrangement?
c. What is the most sustainable plant composition and arrangement to be implemented in oil palm smallholdings?

1.4 RESEARCH AIM

The aim of the research is to study plant composition and arrangement for agroforestry systems as sustainable agriculture practices in oil palm cultivation of smallholdings.

1.5 RESEARCH OBJECTIVES

To achieve the aim, the following research objectives are formulated:

i. To investigate agroforestry systems as sustainable agriculture practices in oil palm smallholdings.
ii. To explore plant composition and arrangement of agroforestry systems for a sustaianble oil palm smallholdings.
iii. To recommend sustainable plant composition and arrangement of agroforestry systems that can be implemented in oil palm smallholdings.

1.6 SIGNIFICANCE OF THE RESEARCH

Recently, with the increasing concern for sustainable oil palm production, the significance of agroforestry systems has increased. As a result, a monoculture system for oil palm cultivation, formerly known as the most important agricultural activity that contributes to the main agricultural sector of GDP (Kushairi, Azman Ismail, and Esnan, 2009) has changed into more diverse as oil palm farming practices of agroforestry systems, especially among smallholdings (Devendra, 2011). This tendency towards commercialization of agricultural sustainability was supported by various kinds of subsidy schemes provided by the Department of Agriculture since 2001. Among those were Program Tanam Semula Sawit Pekebun Kecil (TSSPK), Bantuan Penyelenggaraan Kebun (BPK), and Skim Tanam Baru Sawit Pekebun Kecil (TBSPK) Tahun 2012 (MPIC, 2014). Thus, this study may support the above scheme through the potential and suitability of agroforestry systems as sustainable agriculture practices to be implemented in oil palm cultivation among smallholder farmers.

Field study investigation using a qualitative approach was conducted by focusing on the identification of the suitable plant composition and arrangement to be implemented in oil palm smallholdings. It shows that plant composition of cash and cover crops identified as suitable species to be integrated within the area of oil palm crops. Meanwhile, plant arrangement can be done either through triangular, double avenue, or boundary planting system. A better spatial arrangement of agroforestry systems that make full use of plant composition by maximizing land use utilization influences the functional aspects of the agroforestry components. It could give positive and neutral environmental, social, and economic impacts. An exploration of farmers' knowledge, understanding, and awareness of the agroforestry systems is necessary before the systems can be successfully implemented in oil palm cultivation as a dynamic, harmonious, creative, and sustainable approach in the agriculture sector (Wong, 2001; Suryanto and Susila Putra, 2012). Thus, the findings lead to the formulation of model on favorable and sustainable agroforestry systems, especially in the agrisilviculture sub-system, which consider the composition and arrangement between oil palm crops and other plant species, but focusing on oil palm crops as the central crop production. It helps an organization and improving from unsustainable into sustainable oil palm production in Malaysia.

1.7 SCOPE OF THE STUDY

The scope of study is limited to the study of oil palm smallholdings that practices agroforestry systems located in the Paloh Township in Kluang district, Johor. The smallholdings are managed by registered smallholder farmers of the MPOB and monitored by the Tunjuk Ajar dan Nasihat Sawit (TUNAS) officer of MPOB. An oil palm cultivation project under MPOB was chosen as the site study due to its establishment as the main governmental agency for the promotion and development of the oil palm industry in Malaysia that consider the implementation of sustainable agriculture practices. A positive effort towards sustainable agriculture approach can be seen from its initiatives consideration on Roundtable Sustainable Palm Oil (RSPO), Codes of Practice (COP), and Good Agricultural Practices (GAP). As such, the implementation of agroforestry systems in oil palm cultivation may shed light to the knowledge, understanding, and awareness on the significance of the systems in the Malaysian agriculture sector.

In terms of parameters to be measured in this study, it involves three considerations which are the implementation of agroforestry systems in oil palm cultivation, plant composition and arrangement practiced in oil palm smallholdings, and benefits of agroforestry systems to smallholder farmers as can be referred in detail in Section 3.1 (Table 3.0). Each consideration involves different parameters in different scope which will be linked together as sustainable agriculture practices through the application of agroforestry systems.

1.8 OUTLINE OF RESEARCH METHODOLOGY

The study identifies the knowledge, understanding, and awareness of smallholder farmers on the agroforestry systems as sustainable agriculture practices, as well as the suitability of its implementation in oil palm cultivation especially smallholdings. There are five stages in the research methodology, which include:

1.8.1 Stage 1: Preliminary Study

The first stage is an overview of the research topic through identification of the problem statements, research questions, aim, and research objectives. This stage consists of the development of a research framework by introducing the research topic, as well as confirming the area of study that is involved in the research topic.

1.8.2 Stage 2: Literature Review

This stage gathers information through constructivism alternative knowledge claims on evolution, definitions, and the development of agroforestry systems by focusing on the plant composition of the agrisilviculture sub-system and the arrangement of agroforestry components (triangular, double avenue, and boundary planting systems), which are closely related to the principle of sustainability. The study also involves the identification of landscape planning and design for agricultural systems, both in vertical and horizontal diversification as well as the area and shape of the agricultural land. The reviews are further extended on the benefits of agroforestry systems as sustainable agriculture practices in terms of the environment, social, and economic aspects. Other keywords that are studied include the current practices of oil palm cultivation in Malaysia especially smallholdings. An analysis on the agroforestry systems and oil palm cultivation indicate suitable plant composition and arrangement to be integrated with oil palm crops. Both composition and arrangement through agroforestry systems are able to overcome the issues occurred by rapid expansion of oil palm cultivation, including: (i) global impact of monoculture system, (ii) limited knowledge, technical skill, and moral support for smallholder farmers, as well as (iii) insufficient information on agroforestry systems.

1.8.3 Stage 3: Research Methodology

The reviews in Stage 3 allow the researcher to identify the applicable method to collect primary data for the research. It involves a qualitative approach using non-participant observation, semi-structured interview, and document analysis as methods of data collection. Meanwhile, site study is chosen as the strategy of inquiry. In constructing the method, target population, sampling size, and types of information need to be collected, which have been analyzed during Stage 2, are considered as significant. The observation checklist and interview questionnaires are formulated parallel with the research questions, aim, and research objectives.

1.8.4 Stage 4: Data Collection and Analysis

This exploratory research uses qualitative approach. In brief, the research employs site study as the strategy of inquiry with three methods of data collection. The data for the site study are collected from oil palm smallholdings that practiced agroforestry systems in Kluang, Johor. Next, the data are analyzed using ATLAS.ti, which is qualitative data analysis (QDA) software through the application of thematic analysis. The data are themed into two main themes, which consist of Theme A (oil palm cultivation and sustainable agriculture) and Theme B (agroforestry systems in oil palm smallholdings).

1.8.5 Stage 5: Findings, Conclusion, and Recommendation

The findings on the suitability and sustainable plant composition and arrangement to be integrated in oil palm cultivation smallholdings are documented in the following themes:

i. Preliminary results on the level of knowledge, understanding, and awareness of the implementation of agroforestry systems in oil palm smallholdings by the experts and the local smallholder farmers of oil palm cultivation.
ii. Beneficial aspects of agroforestry systems toward smallholder farmers in terms of the environment, as well as its simultaneous positive and neutral impacts on socioeconomic aspects.
iii. Plant composition and arrangement of agroforestry systems that suit to be implemented in oil palm smallholdings and contribute to the agricultural sustainability of the systems.
iv. Implications and recommendations for future research in this area.

1.9 ORGANIZATION OF THE RESEARCH

The study is organized into six chapters as illustrated and summarized in Figure 1.0.

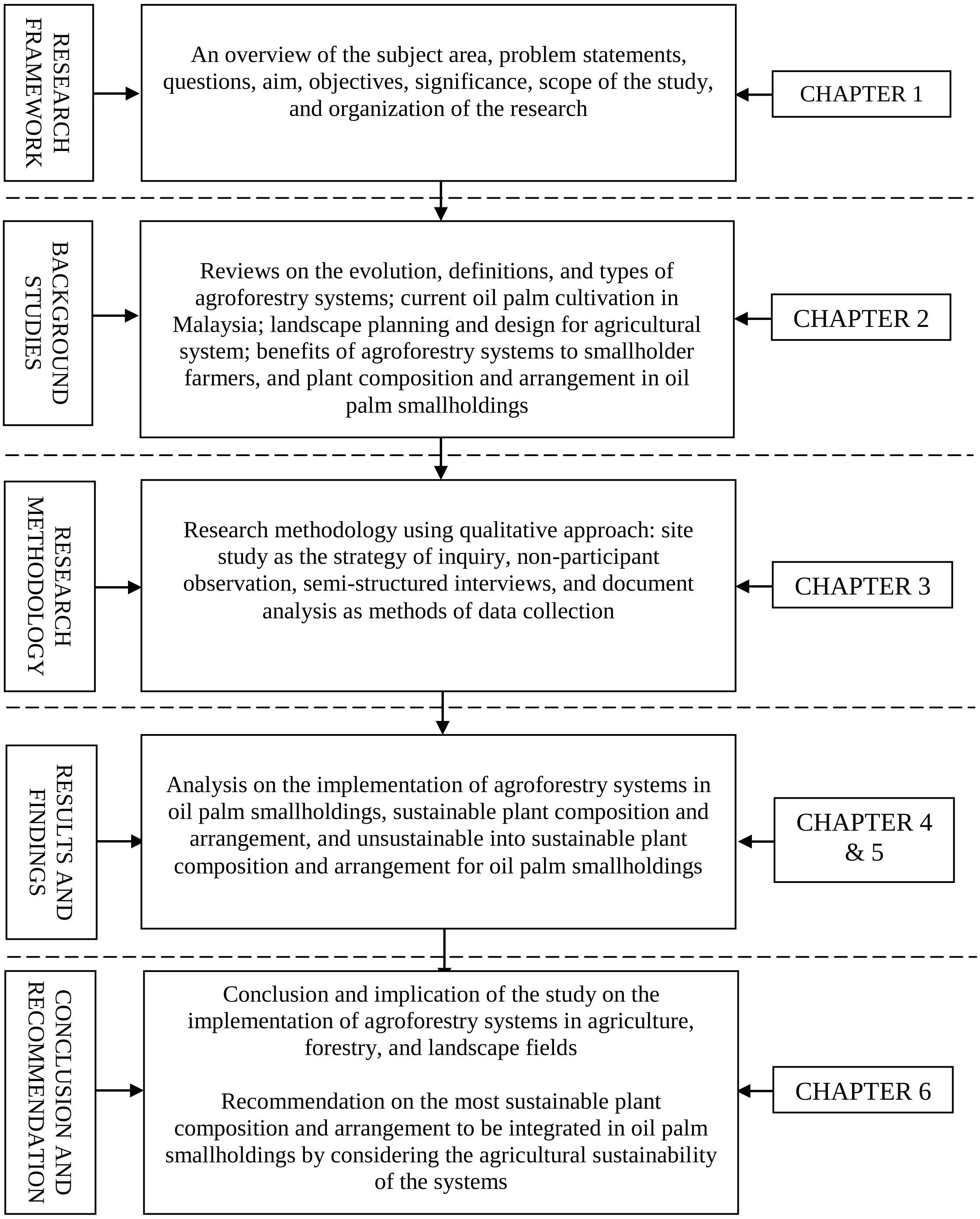


Figure 1.0: Summary of the organization of the study

1.10 SUMMARY

This chapter has briefly introduced the subject of discussion, which are agroforestry systems and its importance in sustainable agriculture practices. The study is developed in response to the needs of sustainable oil palm production due to its negative impacts of extensive agricultural land expansion from natural forest into oil palm cultivation. For this matter, the study has been started by outlining the issues, questions, aim, and objectives, followed by the scope of study, significance, and the specific methodology adopted for this research. Next, Chapter 2 will discuss and explain the background studies that are related to the topic of the research.

CHAPTER TWO

AGROFORESTRY SYSTEMS AND OIL PALM CULTIVATION

2.0 INTRODUCTION

This chapter is divided into seven sections. The chapter discusses the structural and functional basis of agroforestry systems that influence plant composition and arrangement of oil palm smallholdings. Section 2.1 reviews the evolution and development of agroforestry systems in different continents. Next, the definition and concept of agroforestry systems are discussed in Section 2.2. Section 2.3 presents the current oil palm cultivation in Malaysia and the selection of smallholdings as scope of study. The landscape planning and design that is involved in the agricultural system for agroforestry are further examined in Section 2.4. Section 2.5 further examines studies on the implementation of agroforestry systems in oil palm smallholdings. Later, Section 2.6 explains agroforestry systems as sustainable agriculture practices in terms of its environment and socioeconomic benefits. Lastly, the summary of the chapter is presented in Section 2.7.

2.1 AGROFORESTRY EVOLUTION AND DEVELOPMENT

This section explains the evolution and development of agroforestry systems around the world. The study considers four continental bases encompasses of Europe, America, Africa, and Asia.

2.1.1 Europe

History stated that agroforestry was first practiced in Europe. It was started when farmers cleared degraded forest, burned slash, cultivated for crops, and planted trees (Nair, 1993). This practice of slash-and-burn-farming is also known as swiddening or shifting cultivation (Lanly, 1985; Nair, 1993) or *jhum* cultivation system (Hasanuzzaman, 2009). In the late 1970s, the practice of shifting cultivation has been improved. The improvement was made by integrating trees and livestock in one unit of agricultural land. In addition, the manure of the livestock was used to fertile agricultural land (Smith, 2010). Figures 2.0 shows the experimental experiences conducted by International Forest Fire News in 2004 to study new and different arguments on slash-and-burn-farming in reconstructing shifting cultivation practices.

a) b) c)

Figure 2.0: a) An area of forest were slashed and burned to prepare the agricultural land, b) Cleared agricultural land was free from weeds and ready to be planted with selected agricultural crops (wheat), and c) Wheat was grown in dense stand and less free from weeds, but the surrounding ground area was covered with weeds
Source: International Forest Fire News (2004)

2.1.2 America

Agroforestry is known as a mixed farming system in America. Farmers in tropical America simulated forest ecosystem to be implemented in their agricultural land (Nair, 1993). The farmers would cultivate their agriculture land through the imitation of forest condition by planting different layer of vertical stratification. For example, in North America, a farmer would mix various types of trees, shrubs, and cover crop species for food, medicine, building, and craft material purposes, as well as for organic fertilizer (Bainbridge, 1994). The system was further developed with the addition of livestock production involving cattle, buffalo, sheep, and goat meat and dairy products (Blackburn, 1998). Each species has a different structure, which provides habitat for various ecosystems, including flora and fauna rather than focusing on agriculture products (Figure 2.1).

a) b) c)

Figure 2.1: a) Wheat, sorghum, and soybean were mixed in the walnut tree plantation that commonly integrated during the first 10 to 12 years of walnut planting, b) Coffee mixed within the coral trees and salmwood that imitate the forest structure, c) Citrus and plantain banana was mixed as main components in an agricultural land for food production purposes
Source: Nair (1993)

2.1.3 Africa

The application of mixed farming system is also practiced in Africa. Unlike America, farmers in Central Africa had grown their crops under a cover of scattered trees (Zeleza, 1993). Rather than concentrate on food production, the integration also has environmental values especially on soil improvement. For example, they cultivated sorghum, bananas, yams, maize, and sweet potatoes under forest trees in order to maximize the utilization of land in terms of soil and environment enhancement

(Figure 2.2). The practice of mixed farming that applied could naturally maintain soil erosion, fertility, moisture, and nutrient of the agricultural land.

a) b) c)

Figure 2.2: a) Maize integrated with white lead tree in a single row to improve the soil fertility of the agricultural land, b) Sorghum cultivated under the apple-ring acacia tree to maximize the utilization of land, c) Napier grass and maize mixed within the area of lead tree in a contour as an effective way for soil erosion
Source: Nair (1993)

2.1.4 Asia

In a study conducted by Conklin (1957), the author reported that the history of agroforestry in Asia also started through shifting cultivation. This practice was applied by Hanunoo community in the Philippines for growing rice, maize, bananas, yams, and sweet potatoes. Similar to farmers in Europe, each Hanunoo family cleared half hectares of forest area to be planted with agricultural crops (Figure 2.3). However, certain types of forest trees are spared for protective purposes include for fire breaker and windbreaker. In the interim, another study showed that *taungya* method or intercropping system was practiced in Myanmar as early as 1856 and Malaysia in 1950 (Ahmad Fauzi and Huda Farhana, 2006; Hasanuzzaman, 2009). The intercropping system integrates forest species and short-term crops temporarily. For example, the farmers of teak (*Tectona grandis*) plantations integrate annual crops between the rows of teak trees and cultivate the yields for daily use (Figure 2.4).

a) b) c)

Figure 2.3: a) Forest trees were cleared manually with a knife and axe, b) The area was then burned with fire for the preparation before planting the agricultural crops, c) Rice, maize, bananas, yams, and sweet potatoes cultivated for food sources purposes
Source: Conklin (1957)

a) b)

Figure 2.4: a) Rice cultivated during the first year of teak plantation, b) The rows between teaks plantations still cultivated with rice temporarily as the area receiving enough sunlight
Source: Nair (1989)

The exploratory review of agroforestry systems in other countries reveals that the application of shifting cultivation, intercropping, and mixed farming systems are referred as the common term used to explain the integration in agriculture sector. The systems become a starting point to the evolution and development of agroforestry systems throughout the world. It has been applied in four continents with different applications and agriculture techniques as shown in Table 2.0. The techniques are developed into more sustainable techniques than the early farming practices. Two different techniques can be found in Asia as it is a tropical region which creates more favorable climatic conditions than temperate region.

To summarize, as there are many different terms used previously for agroforestry systems, the terms are useful in defining the definition of agroforestry in sustainable agriculture scale for this study. The terms that are used by farmers throughout the world may differ depending on the continents, countries, and planting techniques. Thus, the term that is used in this study to explain the integration is agroforestry systems. The term comes from the combination of the words “agriculture and forestry”. The components of agriculture consist of trees and animal species, while forestry focuses on the forest trees, either timber or non-timber forest tree species. The approach of this system is further discussed in Section 2.2.

Table 2.0
Early history of agroforestry systems in four continents

Continent	Term	Description	Example
Europe	Shifting cultivation / swiddening / *jhum* cultivation	Cleared all forest areas needed for agricultural land area	Farmers integrate trees and livestock in the same unit of agricultural land in which the manure of the livestock was used as organic fertilizer
America	Mixed farming	Imitate forest conditions and ecosystems in their agricultural land area through vertical stratification	Farmers mixed various types of trees, shrubs, and cover crop species for food, medicine, building, and craft purposes
Africa	Mixed farming	Crops grown under scattered trees	Farmers integrated bananas, yams, maize, and sweet potatoes under forest trees, which helps maintain soil fertility, moisture, and nutrient naturally
Asia	Shifting cultivation	Spared certain types of forest tree species for protective function	Hanunoo community in the Philippines planted rice, maize, bananas, yams, and sweet potatoes under forest trees
	Intercropping / *taungya* method	Short-term crops integrated in the rows between main crops of the agricultural land temporarily for daily use	Farmers of teak plantation integrated short-term crops on the land between the rows of teak trees

2.2 AGROFORESTRY SYSTEMS

This section introduces the operational definition, components, and sub-system of the agroforestry systems. Based on the continental evolution and development review made in the earlier section, it can be summarized that agroforestry systems are developed through shifting cultivation, intercropping, and mixed farming systems. Thus, agroforestry systems are commonly known as a new system of old agriculture practices which involve agriculture and forestry sectors. A detailed study on the relationship between agriculture and forestry was carried out by Nair (1993). The study represents the interface between agriculture and forestry practices through maximum land utilization. The combination of agriculture and forestry practices by considering the special conditions and constraint is creating the practices as agroforestry systems as shown in Figure 2.5.

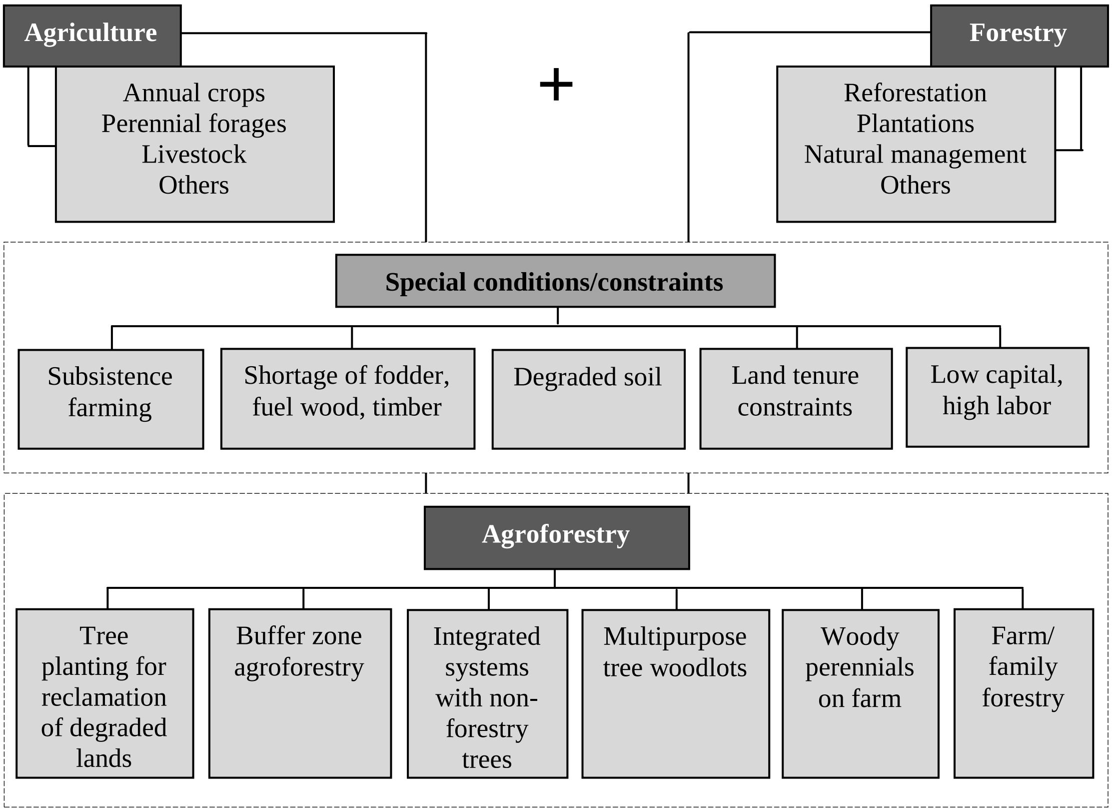


Figure 2.5: Agroforestry systems developed as an integration of agriculture and forestry in response to the needs and conditions of tropical developing countries
Sources: Nair (1993)

2.2.1 Definition of Agroforestry Systems

The main focus of agroforestry systems in the earlier 1980 until 2000 is to increase land productivity through maximum utilization of land. Since 2000 onwards, the focus has been improved to produce multiple outputs by concerning the sustainability aspects of environment, social, and economic. Table 2.1 shows the evolution in the definition of agroforestry systems by various scholars from 1984 until 2011.

The definition of agroforestry systems is developed parallel with the needs of developing countries with regard to sustainability aspect. The significance of agroforestry systems is viewed in three aspects, namely the environment, social, and economic (Smit and Smithers, 1993; Smith and McDonald, 1998; Maxey, 2006; Kassie and Zikhali, 2009). The overlap between these three aspects is in line with what has been mentioned by the International Trade Centre (2012), where sustainable agriculture is a "productive, competitive, and efficient way to produce agricultural products, while at the same time protecting and improving the natural environment and social or economic conditions of local communities". Therefore, referring to various definitions of agroforestry systems and considering the sustainable agricultural aspects, the operational definition of agroforestry systems applied in this research is "the integration of agricultural crops and plant and/or animals in the same unit of land management in the form of spatial arrangements that produce two or more outputs which contribute positive, neutral, or negative impacts on the environment, social, and economic".

Table 2.1
Definition and concern of study in agroforestry systems

Year	Author	Definition	Concern of study	
1984	Nair	A land-use and technology system where plant species (trees and cover crops) integrate with agricultural crops and/or livestock through spatial arrangement or temporal sequence. Both ecological and economic aspects interact with each other.	Integration between plant, crop, and animal in a systematic arrangement that considers the environment and economic interaction.	**Environment & economic**
1991	Petry	A land-use system which involves the interaction between trees, crops, and/or animals in the same unit or agricultural land that produce multiple outputs without threatening natural resource base.	Integration between plant, crop, and animal to produce multiple outputs that considers environmental aspects.	
2001	Faridah Ahmad	A combination of forest species into existing animal husbandry and agricultural land.	Integration of plant and animal that benefits each other.	**Environment, social & economic**
2005	Merem	An approach that maximizes the utilization of agricultural land to increase productivity in sustainable ways for profit and food safety and security.	Diversification of outputs in the same unit of agricultural land through sustainability.	
2006	Ahmad Fauzi and Huda Farhana	A combination of woody plants, non-woody plants, and animals with the implementation of land use technologies for productivity, sustainability, and equity.	Integration of plant and animal to achieve positive impacts towards the environment, economic, and social aspects.	
2007	World Agroforestry Centre	The integration of trees in agricultural landscapes to diversify and sustain the production for social, economic, and environmental benefits.	Integration between plant, crop, and animal as part of the natural landscape to increase revenue in sustainable ways.	
2008	Kusters et al.	A practice of integrating trees into agricultural land that is able to generate income, contribute to development, as well as conserve the environment.	Integration of plant and crop to provide better sustainable development.	
2011	Nair	A practice of growing trees, crops, and animals in the same unit of agricultural land to increase farm productivity by holding the principles of sustainability.	Integration of plant, crop, and animal for productivity through sustainable practices.	

2.2.2 Component of Agroforestry Systems

Referring to the operational definition of agroforestry systems, there are three components identified which are agricultural crop, plant, and animal species. It shows that the components in agroforestry systems represent the combination of both agriculture and forestry components. The detail explanation of each component is described as follows:

2.2.2.1 Agricultural Crop

Agricultural crops are plant species which are cultivated and managed for the economic and physical purposes (Hasanuzzaman, 2009). Most of the crops are commodity crops that contribute to the national GDP include oil palm, timber, rubber, cocoa, pepper, and tobacco (Nik Fuad Mohd Kamil, 2005). According to Tuah (2013), oil palm is the key commodity crops in Malaysia. As such, the focus of the study is on the Malaysian commodity crops, which are oil palm crops since it shares the highest GDP in January to June 2013 with 2.3% of 3.7% (MPIC, 2014c). Oil palm crops are chosen as the scope of research due to its contribution which has made Malaysia as the largest exporter of the world palm oil market and the second largest producers of palm oil (Kushairi, Azman Ismail, and Esnan, 2009). More importantly, oil palm crops are maintained as the main components for these agroforestry systems by following its planting strategies without decreasing the crop density.

2.2.2.2 Plant

The plant consist of various types of trees, shrubs, and cover crop species. Nair (1993) in his research explained that trees and cover crops are the elements that must be considered in agricultural land for each type of sub-system in agroforestry. Most of the plant species that are planted in agroforestry systems are for cash crops and cover crops purposes. Cash crops can be defined as crops that are produced for commercial value rather than being used by the grower (Poulton et al., 2001). Meanwhile, cover crops are planted to maintain the soil, water, pest, and biodiversity of the agroecosystem in agricultural land (Antichi et al., 2008). Accordingly, both cash and cover crop species will be considered in this study in determining the suitable species to be integrated in oil palm cultivation. A detailed study of both species will be explained in Section 2.5 on the implementation of agroforestry systems in oil palm smallholdings.

2.2.2.3 Animal

Animal species in agroforestry systems, mostly involve the integration of livestock. It can be divided into ruminants, non-ruminants, fishes, and bees. Ruminants refer to mammals that digest plant-based food in four stomach compartment, but non-ruminants only have one digestive system where foods are processed into required nutrients (Naminse, n.d.). There are two categories of ruminants, which are large ruminants (buffaloes, cattle) and small ruminants (sheep, goat) (Ahmad Salihin et al., 1998; Ludena, 2010), whereas, the example for non-ruminants include chicken, turkeys, ducks, and geese (Ludena, 2010).

In agroforestry systems, the integration with ruminants is more preferred than non-ruminants due to the high market demand for milk, dairy, and meat production. It has encouraged for the integration of these livestock into agroforestry systems (Ayob and Hj Kabul, 2009). Furthermore, the availability of undergrowth plants has made ruminants as the most suitable livestock for agroforestry systems. Other animal species, including fishes and bees are rarely practiced in oil palm cultivation due to the unsuitable surrounding and low market demand. However, the consideration on the integration of animal within the area of oil palm cultivation will not be covered in this study. Yet, indirect involvement of animal as one of the agroforestry components will be discussed briefly.

2.2.3 Sub-system in Agroforestry Systems

The integration of different agroforestry components produces different sub-systems. Each of the sub-system has a different composition and arrangement. Several studies have revealed that there are seven sub-systems in agroforestry systems involving agrosilvicultural, agrisilvicultural, agrihorticulture, agrihortisilviculture, silvopastoral, silvipastoral, and agrosilvopastoral as shown in Table 2.2. Different terms are used to explain the similar integration of the agroforestry components, but the systems hold similar principles of sustainability which is environment, social, and economic. The sub-systems of agrosilvicultural, agrisilvicultural, agrihorticulture, and agrihortisilviculture consist of similar composition and arrangement of agricultural crop and plant species. Other sub-systems of silvopastoral and silvipastoral also consist of similar composition and arrangement of plant and livestock. Meanwhile, agrosilvopastoral involves the integration of agricultural crops, plant, and livestock. It shows that different terms are used by different authors to explain similar sub-system.

Table 2.2
Sub-system in agroforestry systems according to different authors

Sub-system	Author			
	(Hasanuzzaman, n.d.)	(Petry, 1991)	(Nair, 1993)	(Thakur et al., 2005)
Agrosilvicultural	Agricultural land is used for the agriculture crops and forest tree production.	Integration of trees and agricultural crops.	-	-
Agrisilvicultural	-	-	Integration of crops (shrubs, vines, tree crops) and trees.	Integration of timber tree species, agricultural crops and high-value cash crops for productive purposes.
Agrihorticulture	-	-	-	Integration of various tree species that produce fruits.
Agrihortisilviculture	-	-	-	Integration of crops, fruit trees, and forest trees in one unit of agricultural land.
Silvopastoral	Land is managed for forest tree production and rearing of domestic animal.	-	Integration of trees and pasture and/or animals.	-
Silvipastoral	-	Deliberate integration of trees and livestock animal.	-	Integration of multipurpose tree species and grasses on sloppy land to enhance land productivity, as well as provide multiple outputs.
Agrosilvopastoral	Agricultural land is used for the agricultural crops and forest tree production, as well as rearing of domestic animal.	Temporary integration of trees, crops and livestock.	Integration of trees, crops and pasture or animals.	-

For this study, the terms that are used for the sub-systems in agroforestry can be categorized into four, which are agrisilviculture, silviagriculture, silvopastoral, and agrosilvopastoral sub-systems as shown in Table 2.3. However, this study focuses only on the integration of agricultural crops and plant species, namely agrisilviculture sub-system, where the dominant component is an agricultural crop of oil palm crops.

Table 2.3
Sub-system in agroforestry systems

Sub-system	Agroforestry components	Description	Status
Agrisilviculture	Agricultural crop and plant	Integration of agricultural crop and plant species in the same unit of agricultural land which focuses on the agricultural crop production.	Studied
Silviagriculture	Plant and agricultural crop	Integration of plant and agricultural crop species in the same unit of agricultural land which focuses on the plant production.	Not studied
Silvopastoral	Agricultural crop and animal or plant and animal *animal only cover for ruminant and non-ruminant species	Integration of agricultural crop or plant and ruminant or non-ruminant species in the same unit of agricultural land which focuses on both output productions.	
Agrosilvopastoral	Agrosilvofishery Agricultural crop, plant, and animal *animal only cover fish species	Integration of agricultural crops, plant, and fish species in the same unit of agricultural land which focuses on all components production.	
	Apiculture Agricultural crop, plant, and animal *animal only cover bee species	Integration of agricultural crops, plant, and bee species in the same unit of agricultural land which focuses on all components production.	

2.3 OIL PALM CULTIVATION IN MALAYSIA

This section investigates current practices and operation categories of oil palm industry in Malaysia. Currently, oil palm cultivation is rapidly expanding since there are 15 million hectares lands for oil palm cultivation area across the world (Lian and Wilcove, 2008; Fitzherbert et al., 2008; United Nations Environmental Programme, 2011). Oil palm cultivation has spread within the tropical country, and 85% of the world's palm oil outputs are from the Southeast Asian countries include Malaysia

(United Nations Environmental Programme, 2011). Malaysian palm oil industry plays an important role in the growth of the country's agricultural sector. In 2008, the industry contributed RM40 billion or 7.5% of the Malaysian GDP, and 30% of it was contributed by oil palm crops (Kushairi, Azman Ismail, and Esnan, 2009). This has made Malaysia as the second largest producers of palm oil with an output of 17,734 million tons (41.1%) in 2008.

2.3.1 Current Practices of Oil Palm Cultivation

In Malaysia, MPOB is the premier government agency that managed the Malaysian oil palm industry. The agency has the responsibilities in: (i) implementing the agricultural policy for oil palm development, (ii) conduct and promotes research and market in oil palm related industry, (iii) regulates and register liaison to oil palm growers, and (iv) plan and implement programs for human resources development of the oil palm growers especially among smallholder farmers (MPOB, 2014a). Other than that, the MPIC is the ministry that managed overall agricultural industries and commodities in Malaysia include MPOB. Thus, most of the current data on oil palm cultivation are referred to the statistic provided by the official portal of MPOB and MPIC.

The latest data by the MPOB (2014b) in December 2013 shows that the total areas for oil palm cultivation in Malaysia is 5,229,739 hectares (Table 2.4). Sabah leads the distribution of oil palm cultivation in Malaysia as a whole and East Malaysia in particular, which produces 28.21% of the overall oil palm production. Meanwhile, Peninsular Malaysia is monopolized by Johor with 13.97% of the Malaysian oil palm cultivation. Sabah (1,475,108 hectares) is also the largest state with oil palm crops, followed by Sarawak (1,160,898 hectares), Johor (730,694 hectares), Pahang (710,195 hectares), and Perak (384,594 hectares) as at December 2013.

Table 2.4
Oil palm area by states in December 2013 (hectares)

State	Mature	%	Immature	%	Total	%
Johor	639,946	87.58	90,748	12.42	730,694	13.97
Kedah	77,843	91.38	7,339	8.62	85,182	1.63
Kelantan	94,320	67.35	45,715	32.65	140,035	2.68
Malacca	49,635	94.18	3,069	5.82	52,704	1.01
Negeri Sembilan	142,452	83.77	27,596	16.23	170,048	3.25
Pahang	609,962	85.89	100,233	14.11	710,195	13.58
Perak	344,271	89.52	40,323	10.48	384,594	7.35
Perlis	190	68.35	88	31.65	278	0.01
Penang	13,163	97.65	317	2.35	13,480	0.26
Selangor	125,122	91.33	11,881	8.67	137,003	2.62
Terengganu	137,289	80.99	32,231	19.01	169,520	3.24
Peninsular Malaysia	2,234,193	86.14	359,540	13.86	2,593,733	49.60
Sabah	1,330,039	90.17	145,069	9.83	1,475,108	28.21
Sarawak	961,857	82.85	199,041	17.15	1,160,898	22.20
Sabah & Sarawak	2,291,896	86.95	344,110	13.05	2,636,006	50.40
Malaysia	**4,526,089**	**86.55**	**703,650**	**13.45**	**5,229,739**	**100.00**

Source: MPOB (2014b)

2.3.2 Operation Category of Oil Palm Cultivation

Referring to the overall oil palm cultivation report by MPIC (2014b), Malaysian oil palm agriculture sector is categorized into six agencies, namely private estates, Federal Land Development Authority (FELDA), Federal Land Consolidation and Rehabilitation Authority (FELCRA), Rubber Industry Smallholder Development Authority (RISDA), other government or state agencies, and smallholdings. In contrast, according to Kushairi, Azman Ismail, and Esnan (2009), there are only three categories of operation in Malaysian oil palm cultivation. It involves private estate, government and state agencies, and smallholdings. The other agencies of FELDA, FELCRA, and RISDA are categorized as government and state agencies due to its supervision which are managed by government agencies.

A report by the MPIC (2014b) on the distribution of oil palm planted area by state and sector in 2013 shows that 3,181,509 hectares of the area are undertaken by private estates, 720,549 hectares by smallholder, 707,723 hectares by FELDA, 308,519 hectares by state agency, 171,428 hectares by FELCRA, and 77,553 hectares by RISDA respectively as shown in Table 2.5. As overall, the total oil palm cultivation for government and state agencies is 1,265,223 hectares. The cultivation is still monopolized by private estate and followed by government and state agencies and also smallholdings.

Table 2.5
Distribution of oil palm planted area by state and sector in January - June 2013 (hectares)

State	Smallholder	Government and state agency				Private estate
		FELDA	FELCRA	RISDA	State agency	
Johor	190,570	131,266	22,295	4,237	39,859	335,003
Kedah	22,036	717	1,061	893	2,451	57,284
Kelantan	3,867	35,371	2,676	1,180	19,106	74,154
Malacca	10,118	2,460	2,519	1,293	-	36,805
Negeri Sembilan	21,038	41,179	7,745	9,721	341	88,449
Pahang	39,613	300,876	32,788	23,327	62,010	247,486
Perak	96,866	24,355	30,421	17,871	19,315	195,557
Perlis	58	94	127	-	-	-
Penang	8,575	-	472	-	-	4,446
Selangor	41,543	7,523	3,683	290	1,438	81,852
Terengganu	9,674	42,675	21,422	18,740	10,726	68,974
Peninsular Malaysia	443,958	586,516	125,209	77,553	155,244	1,190,010
Sabah	189,181	113,587	15,760	-	76,768	1,067,128
Sarawak	87,410	7,620	30,459	-	76,507	924,371
Malaysia	720,549	707,723	171,428	77,553	308,519	3,181,509

Source: MPIC (2014b)

2.3.2.1 Private Estate

Private estate for oil palm cultivation is defined as an individual or organization who has an interest in oil palm cultivation in large scale and able to take risks in any consequences of oil palm cultivation (Department of Standards Malaysia, 2013). According to the second largest market research organization in the United Kingdom, Ipsos MORI (2009), private estate is the central part of an organization's efficiency, in which it plays vital roles as supporters, funder, associate, and mediator of any development. It is proved based on the total hectares of oil palm cultivation owned by private estate as shown in Table 2.5. Accordingly, private estate in Sabah has the largest total oil palm cultivation for East Malaysian and Johor in Peninsular Malaysia with 1,067,128 and 335,003 hectares, respectively. Sime Darby Berhad is ranked as the largest local oil palm private estate and followed by Kuala Lumpur Kepong Berhad and IOI Corporation Berhad (Malaysian Rating Corporation Berhad, 2012).

2.3.2.2 Government and State Agency

Government and state agency for oil palm cultivation also known as supported or organized smallholdings. Supported smallholding is the oil palm farm with a total land area of less than 10 hectares (Department of Standards Malaysia, 2013). The smallholdings that owned by the farmers are tied with governmental and state agencies, including FELDA, FELCRA, and RISDA. These agencies are responsible to supervise, organize, and manage the supported smallholding in improving the quality and quantity of the oil palm crop production. Sarawak Land Consolidation and Rehabilitation Authority (SALCRA) in Sarawak and Selangor State Development Corporation (PKNS) in Selangor are among the other agencies for oil palm state management. Based on the data in Table 2.5, it shows that FELDA has the highest total land area planted with oil palm crops for government and state agency category with 707,723 hectares. In the interim, only 77,553 hectares planted with oil palm cultivation under the management of RISDA. This is because the concentration of the agency is more of a rubber plantation rather than oil palm cultivation.

2.3.2.3 Smallholding

In this scope of study, smallholdings refers to independent or individual smallholder farmers who owned oil palm cultivation less than 10 and not more than 40 hectares (Department of Standards Malaysia, 2013). Oil palm cultivation in Johor recognized as the highest smallholdings in Malaysia with total area of 190,570 hectares as shown in Table 2.5. In this category, smallholdings are registered to and managed by MPOB. Registered smallholder farmers have a chance to apply for licenses from MPOB through the application of GAP. The availability of licenses is the recognition by MPOB to the smallholder farmers as sustainable oil palm producer. Other than that, registered smallholder farmers have the right to apply subsidy scheme by MPOB including TSSPK, BPK, and TBSPK (MPIC, 2014a). Furthermore, they have the ability to employ workers to carry out daily work on their farm. This group is also certified as individual smallholder farmers, in which they have the right to sell their yield production individually to oil palm harvesters.

2.4 AGRICULTURAL LANDSCAPE PLANNING AND DESIGN

Diversification of agroforestry components with multi-dimensional concept on the principles of sustainability has led to the realization that agricultural sustainability is based on the enhancement of landscape planning and design of an agricultural system. This is because the agricultural sustainability can be determined through the interaction of the components. It involves the interaction between individuals within a species, between species themselves, and between communities, landscape, and ecosystems (Lambeck, 1999). In this study, attention was mainly directed by the interaction between species (oil palm crop and plant) and community (smallholder farmers) in agricultural landscape scale. The agroforestry interactions are further, creating good agroforestry planning and design by fulfilling the criteria of productivity, sustainability, and adoptability. As a whole, the agricultural landscape planning and design for the development of agricultural sustainability in agroforestry systems involve vertical and horizontal diversification and area and shape of the agricultural land.

2.4.1 Vertical and Horizontal Diversification

Vertical diversification refers to the structural stratification to species number in agricultural systems. In the interim, horizontal diversification provides an area for habitat that can be occupied by diverse flora and fauna. In the agroforestry guides wrote by Wilkinson and Elevitch (2000), they traced that the main components of agricultural crops can be integrated with forestry, orchard, or other plant species as secondary components. For example, in a case study conducted in Iowa by Straight (2011a), a couple of farmers planted more than 50 plant species on their agricultural land. They had an interest to plant new species using a new arrangement for each time of the replanting process in order to experience and evaluate its potential both for food, income, and landscape benefits. As such, the composition and arrangement are not only focusing on the diversification of products, but also become more efficient by using the systematic management of land, labor, and other farm resources.

In terms of landscape setting, it involves the consideration of planning issues that consist of plant composition, arrangement, and management schedule (Wilkinson and Elevitch, 2000). The systems create different level of stratification with different types of plant range from simple to complex agroforestry systems. It consists of crops with single understory crops, multiple crops with understory crops, and multi-species of crops and understory crops. Meanwhile, single crops are best known as monoculture system. Straight (2011a) highlighted in his study that the complex systems of agroforestry systems through intensive management involved four level agriculture system of underground, ground level, intermediate level, and upper level. As a whole, Lambeck (1999) identified a strong relationship between vertical and horizontal diversification in agricultural systems. On the basis of these relations, the width and structural complexity of the vertical strata should be maximized, while the distance between horizontal compositions should be minimized in order to create good agroforestry planning and design.

2.4.2 Area and Shape of the Agricultural Land

In general perspectives, large area of the monoculture system likely contains more species than a small area of agroforestry systems in smallholdings. However, owing to the issues raised by the monoculture system, that it only supports fewer species of flora and fauna (Grain, 2006; Fitzherbert et al., 2008), the potential of agroforestry systems can be seen through its environmental benefits in creating natural habitat for diverse species of flora and fauna (van Noordwijk and Hairiah, 2000; Straight, 2011a).

Study on landscape planning in agriculture by Lambeck (1999) further explained that the availability of diverse species in an agricultural land either large or small area is depending on planning and design for the vertical and horizontal diversification of the agricultural land. Since the monoculture system only concentrates of single species plantation, the system unable to provide diverse strata and composition of species. In contrast, agroforestry systems involve three components that can produce different level of strata include belowground and aboveground interaction (van Noordwijk and Hairiah, 2000). As such, agroforestry systems are seen as an alternative farming system in agriculture sector to reduce the negative impact of monoculture system.

In terms of shape of agricultural land, it refers to the selection of arrangement that could contribute to the functional basis of the agroforestry systems for environmental, social, and economic benefits. It includes soil conservation for environmental benefits, and fire breaker, windbreaker, shelterbelts, food, fodder, and fuel wood for socioeconomic benefits (Hasanuzzaman, n.d.; Nair, Gordon, and Mosquera-Losada, 2008; Straight, 2011b). However, the suitability of the arrangement is directly influenced by the area and shape of the agricultural land. Referring to this study, the attention on the agricultural crops as main components should be paid to maintain the purpose of agroforestry systems in oil palm smallholdings. In addition, these systems only studied in small scale of oil palm cultivation in which the selection of arrangement must be compatible and adaptable with the area of the agricultural land.

2.5 AGROFORESTRY SYSTEMS IN OIL PALM SMALLHOLDINGS

Referring to the previous sections, agroforestry systems are acknowledged as sustainable agriculture practices since it holds the principles of sustainability. It covers three aspects of environment, social, and economic to provide a better quality of life, especially for poor and rural communities. In the context of study on agroforestry systems, Narayanan and Gulati (2002) characterized smallholder as a farmer who practices mix farming system or integrates crops, plant, and livestock together for commercial and subsistence purposes. Ahmed Azhar et al., (2008) stated that agroforestry systems have been recognized as an approach that is suitable to be implemented by smallholder farmers due to its benefits. They are able to enhance the agricultural production, as well as increase farm income. The systems which mainly involve natural components encouraged the smallholder farmers to use the resources in an appropriate way in order to improve their livelihood. Thus, agroforestry systems are recognized as the only approach that promotes land maximization for a diverse agriculture product using sustainable practices.

The study by Yeoh (2003) claimed that the integration is frequently practiced by small and medium size farms. Accordingly, the implementation of agroforestry systems in oil palm cultivation is carried out in response to the economic stimulus program proposed by the Ministry of Primary Industries and MPOB in 2002 (Suboh, 2003). The objectives are to increase food production and increase income of the smallholder farmers, especially in the rural areas. The program involves five agroforestry systems projects, which are the integration of (i) dryland paddy (*Oryza sativa*), (ii) peach palm (*Bactris gasipeas*), (iii) free-range chicken, (iv) beef cattle, and (v) lemongrass (*Cymbopogon citratus*), fish, and free-range chickens in oil palm cultivation.

Therefore, in this section, the focused of the study is on the implementation of agroforestry systems among oil palm smallholdings in Malaysia. A selected sub-system for this research is an agrisilviculture sub-system since oil palm crops are a dominant component in this study. The explanation consists of the structural basis of agrisilviculture sub-system involving plant composition and arrangement that is suitable for oil palm smallholdings.

2.5.1 Plant Composition

This sub-section reviews the composition between oil palm crops and plant species. The selection of plant species to be integrated with oil palm crops involves a high range of cash crops and cover crop species. The purpose of cash crop integration into oil palm cultivation is on the commercial value rather than being used by the grower. Unlike cash crops, cover crops are planted for the improvement of agroecosystem services. Balance composition between oil palm crops, cash crops, and/or cover crops provides sustainable agriculture practices through the agrisilviculture sub-system.

2.5.1.1 Cash Crop

Cash crops consist of perennial and annual crops. A number of studies have found that perennial and annual crops are the types of plant species suitable for agroforestry systems (Vergara, 1985; Petry, 1991; Faridah Ahmad, 2001; Merem, 2005; Ahmad Fauzi and Huda Farhana, 2006; Hasanuzzaman, 2009).

i. Perennial crops

   Perennial crops are plants that can live for three years or more. It can be either short-term or long-term perennial crops. It can be categorized into commodity crops, forest trees, and fruit trees (David, n.d.). Detailed examination of plant composition with oil palm crops by Ahmad Fauzi and Huda Farhana (2006) and Ahmed Azhar et al. (2008) showed that oil palm crops are suitable to be integrated with forest and fruit tree species using an agrisilviculture sub-system which focuses on the oil palm crops as the main component. Several studies also have investigated that perennial crops are suitable to be integrated with oil palm crops as tabulated in Table 2.6.

Table 2.6
Perennial crop species suitable to be integrated with oil palm crops

Author	Scientific name	Common name	Description	Category
Long-term perennial crop				
Ahmad Fauzi and Huda Farhana, 2006; Ahmed Azhar et al., 2008	*Hevea brasiliensis*	Rubber	Rubber is among major commodities crops plantation in Malaysia. The integration of rubber with other agricultural crops has been encouraged by the Rubber Industry Smallholders Development Authority (RISDA).	**Commodity crops**
Lee et al., 2005	*Neolamarckia cadamba*	Laran	Laran and binuang are recommended to be planted in the area of devoid regeneration of timber species and in the area where other crops cannot be grown due to pest and disease infection.	**Forest tree**
	Octomeles sumatrana	Binuang		
Ahmed Azhar et al., 2008	*Azadirachta excelsa*	Sentang	Sentang is mostly planted by farmers due to the availability of sentang seedlings that can be found in the local market and at the Department of Forestry.	
Ahmed Azhar et al., 2008; Chia, 2011	*Tectona grandis*	Teak	Teak has been recommended to be integrated with oil palm since 1990s due to its characters, which are fast growing nature, clear bole, erect growth, small and sparse canopy, as well as high market value.	
Norkaspi Khasim et al., 2009	*Eurycoma longifolia*	Tongkat Ali	The nature of tongkat Ali which is usually harvested in the wild habitat for herbal and medicinal purposes has encouraged farmers to plant it in the oil palm area.	

Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	*Bactris gasipaes*	Peach palm	Peach palm is often cultivated for its palm heart as vegetables from the inner core of the palm trees, and the fruits can be processed for production.	**Fruit tree**
Short-term perennial crop				
Ahmad Fauzi and Huda Farhana, 2006	*Musa acuminate* 'Dwarf Cavendish'	Pisang berangan	The banana is one of the favorable local fruits and it is readily available at all times since it is not a seasonal fruit.	
	Ananas comosus	Pineapple	Pineapple is a favorable crop that has a high market demand both in Malaysia and other countries.	
Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	*Ipomoea batatas*	Sweet potato	The production of sweet potatoes increased in 2008 due to the increase of wholesale prices. It is a traditional food crop that is important for Malaysian society.	

ii. Annual crops

Annual crops refer to the plants that can complete their life cycle within one year (David, n.d.). Most of the annual crops are planted during the immature phase of oil palm crops. The purpose is for additional income since there is no oil palm production during immature phase (Suboh Ismail, Omar Idris, and Wahid Omar, 2010). Usually, annual crops elevate farm productivity and income both during immature and mature phases of oil palm cultivation, and it depends on the plant arrangement. Several studies on the composition between oil palm crops and annual crops are shown in Table 2.7.

Table 2.7
Annual crop species suitable to be integrated with oil palm crops

Author	Scientific name	Common name	Description
Suboh Ismail, Omar Idris, and Wahid Omar, 2010	*Saccharum officinarum*	Sugar cane	Sugarcane has high commercial value in the manufacture of sugar since it is rich in sucrose.
Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	*Oryza sativa*	Dry land paddy	Dry paddy is one of the oldest crops cultivated by smallholder farmers as Malaysian main food.
	Zea mays	Maize	Maize has a high market demand due to its affordable price and easily available in the local market.
	Citrullus lunatus Schard	Watermelon	Watermelon is one of the nine fruits that are given priority for the development in the NAP3 1998-2010. It is the fruit that has the highest export value in Malaysia.
	Lagenaria leucantha	Calabash	Federal Agricultural and Marketing Authority have begun to explore the market value and promote on a large scale to encourage people to use it as a food ingredient.

2.5.1.2 Cover Crop

Cover crops can be divided into three types which are grasses, legumes, and non-legume broadleaves (Ministry of Agriculture and Food, n.d.). Among those, grasses and leguminous cover crops are easily established, effective, and provide more good nutrient in return compared to non-legume cover crops. It shows that the production of fresh fruit bunches yield and vegetative growth of oil palm with leguminous cover crops are higher compared to the area that is not integrated with cover crops (Hasnol Othman, Farawahida, and Zulkifli Hashim, 2012). The integration of grasses and leguminous cover crops in belowground of the oil palm area can increase soil, water storage, and reduce soil erosion on steep slope area (Ahmad Tarmizi and Wahid Omar, 2009). This is due to its function to improve soil fertility by fixing nitrogen and making it available to the main crops, as well as reduce the competition of noxious weeds. Among cover crops species that are suitable to be integrated with oil palm are shown in Table 2.8.

Table 2.8
Cover crops that are suitable to be integrated with oil palm crops

Author	Scientific name	Common name	Description
Leguminous cover crop			
Hasnol Othman, Farawahida, and Zulkifli Hashim, 2012	*Calopogonium caeruleum*	Jicuma	Mostly suitable to be grown on mineral soil and not commonly used on peat soil due to their poor growth performance.
	Calopogonium mucunoides	Wild groundnut	
	Centrosema pubescens	Butterfly pea	
	Pueraria javanica	Kudzu	
	Pueraria phaseoloides	Tropical kudzu	
	Mucuna bracteata	-	*Mucuna bracteata* is a slow starter, but performed well under oil palm cultivation on peat soil. The establishment of *Mucuna bracteata* on peat soil gives better early oil palm growth and yield.
Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	*Arachis hypogea*	Groundnut	Groundnut is an important cover crop as it has good nutritional value, which is in line with the increase of human population and lack of local groundnut production.
Grass			
Ahmad Salihin et al., 1998; Kamil Azmi et al., 2012	*Pennisetum purpureum*	Napier grass	Napier grass mostly planted as belowground component. It is used as a source of food for ruminant feed especially for farmers who integrate livestock in their oil palm cultivation.

2.5.2 Plant Arrangement

This sub-section reviews the arrangement between oil palm crops and plant species. A number of studies have found that there are four types of arrangement of agroforestry systems that have been developed in Malaysia (Lee et al., 2005; Norkaspi Khasim et al., 2009; Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010; Chia, 2011; Hasnol Othman, Farawahida, and Zulkifli Hashim, 2012). Those are alternate row or triangular planting system, alternate strips or double avenue planting system, perimeter or boundary planting system, and random mixture planting system as shown in Figure 2.6 (Vergara, 1985).

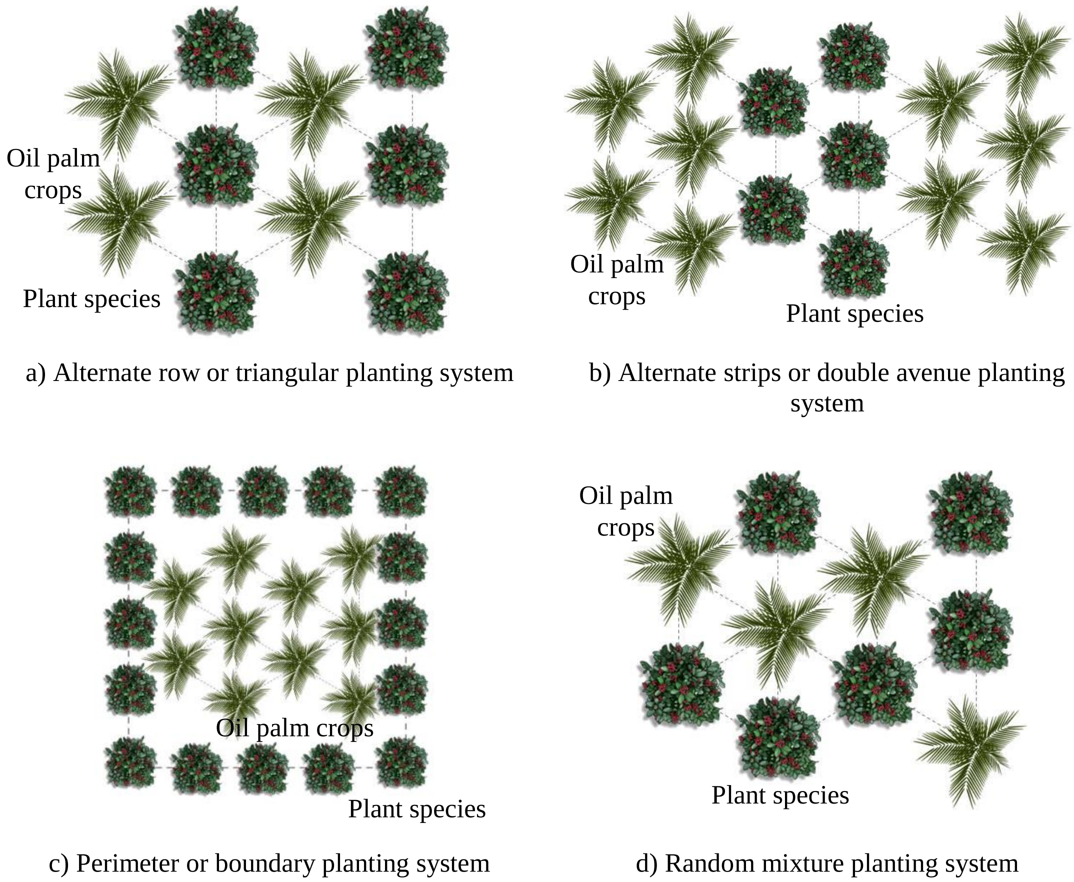


Figure 2.6: Arrangement of agroforestry systems between oil palm crops and plant species
Source: Modified from Vergara, 1985

However, a study conducted by Ahmed Azhar Jaafar et al. (2008) throughout Peninsular Malaysia on the plant arrangement for oil palm smallholdings, found that there are only three types of arrangement that were suitable to be implemented in the oil palm area. Those are alternate strips, perimeter, and mixed planting systems. The most frequent arrangement that was practiced by smallholder farmers was alternate strips planting system (69.7%), followed by mixed planting system (18.2%), and perimeter planting system (12.1%). In the interim, another similar study by Ahmad Fauzi and Huda Farhana (2006) showed that alternate row, alternate strips, and boundary planting systems are the arrangement that can be applied within the area of oil palm crops. However, the suitability of the arrangement is based on the selection of plant species. Only certain types of species are suitable for each arrangement.

In contrast, Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim (2009) argued that the integration within the area of oil palm crops can be arranged either using triangular or double avenue planting system. Another arrangement is unsuitable to be applied as it will decrease the number of oil palm crop density and disturb the oil palm growth. Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim (2010)in their study again emphasized that there are only two arrangements that are suitable for oil palm crop integration. It involves a triangular planting system that only suitable for integration during the immature phase of oil palm cultivation and double avenue planting system that is suitable for both immature and mature phase of oil palm cultivation. Thus, the selection of suitable plant arrangement depends on the oil palm planting technique and the age of oil palm crops.

For the purpose of this study, it is agreed that two types of arrangement are considered as the suitable plant arrangement that can be applied in oil palm smallholdings which are triangular and double avenue planting systems. The term used for this arrangement may differ, but in Malaysian oil palm cultivation, triangular and double avenue planting system are used as formal term for academic and documentation purposes (Khairuman Hashim, 2009). Different terms are used to explain similar arrangements. It is supported by the description of Lee et al. (2005) that triangular planting is similar to the alternate row planting system. Meanwhile, other arrangement of alternate strips (Lee et al., 2005) and double avenue planting (Norkaspi Khasim et al., 2009) share similar arrangement layout.

2.5.2.1 Triangular Planting System

The triangular planting system is also known as an alternate row planting system. This system is commonly practiced during the immature phase (less than three years) of oil palm cultivation (Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). The triangular planting system is planted using the spacing distance of 9.1 meter x 9.1 meter x 9.1 meter with oil palm density of 138 palms ha^{-1} of agricultural land as shown in Figure 2.7. The implementation of the triangular planting system is influenced by the structure of oil palm crops and light penetration factor. Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim (2010) analyzed that there is limited growth of oil palm fronds and roots during the immature phase. This situation allows sufficient sunlight to penetrate to the ground areas between the oil palm rows for only less than 3 years. This is because the percentage of light penetration during the immature phase is 50 to 98%, but it decreases drastically during mature phase (10 to 55%). Among the example of a triangular planting system in oil palm cultivation is shown in Table 2.9.

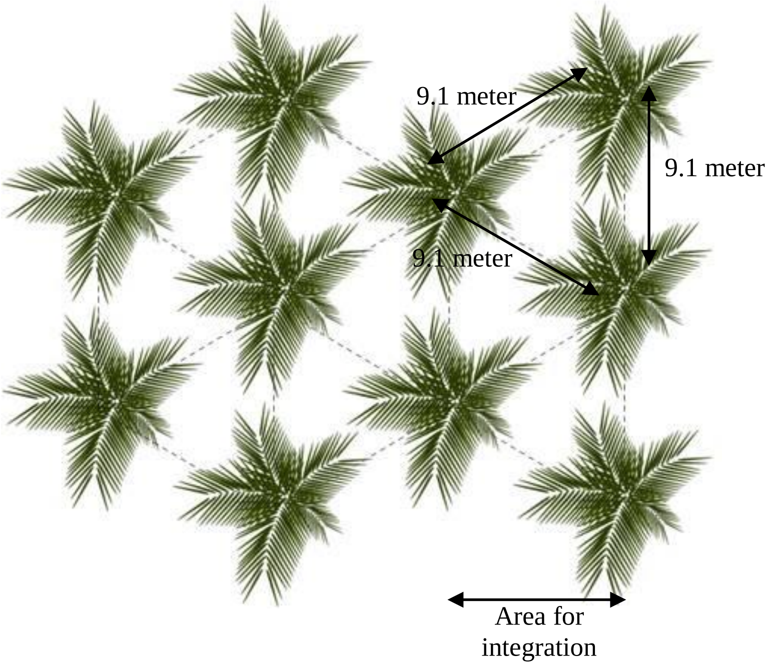
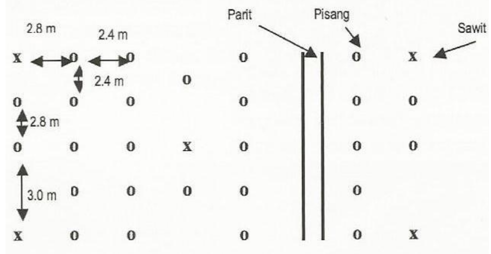
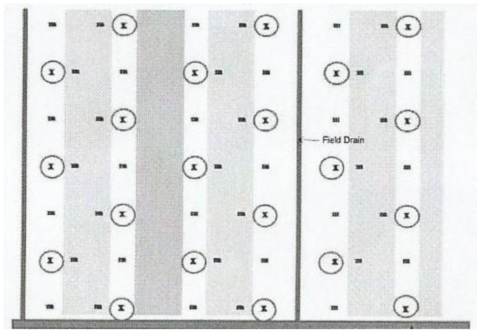


Figure 2.7: Layout of triangular planting system for oil palm cultivation

Table 2.9
Suitable plant composition of the agrisilviculture sub-system with oil palm crops for the arrangement of the triangular planting system

Author	Integration	Spacing	Planting density/hectares	Description	Image
Lee et al., 2005	Oil palm + forest tree	9 m x 9 m	Oil palm: 138 Forest tree: 138	A row of forest trees is planted roughly at the center of each triangular form of oil palm.	-
Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	Oil palm + watermelon	Oil palm: 6.1 m x 9.1 m x 9.1 m	-	Watermelon is planted during the immature phase, which is for the first three years. A row of watermelon is planted roughly at the center of each triangular form of oil palm.	-
	Oil palm + calabash	Oil palm: 6.1 m x 9.1 m x 9.1 m	Oil palm: 136	Calabash is planted during the immature phase, which is for the first three years. A row of calabash is planted roughly at the center of each triangular form of oil palm.	-
	Oil palm + banana	Oil palm: 6.1 m x 9.1 m x 9.1 m Banana: 2.4 m x 2.4 m	Oil palm: 136 Banana: 1,344	A row of banana is planted with the spacing distance of 2.65 m from the point of each oil palm.	
Hasnol Othman, Farawahida, and Zulkifli Hashim, 2012	Oil palm + *Mucuna bracteata*	Two seedling per oil palm planting point	*Mucuna bracteata:* 320	After three months planting, weeds need to be maintained within 1 m around each seedling. For the first year and onwards, circle weeding needs to be applied monthly.	

2.5.2.2 Double Avenue Planting System

Double avenue planting is also known as alternate strips planting system. It is commonly practiced for the whole phase of oil palm crops (Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). The planting system is recommended for the flat to undulating terrain area with the average slope is 0^0 to 6^0 (Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). Oil palm crops are planted by following the slope in order to provide an area for the preparation and maintenance of alternative crops, especially cash crops. The double avenue planting system uses the spacing distance of 6.1 meter x 9.1 meter x 15.2 meter (Norkaspi Khasim et al., 2009). The oil palm crop density is 136 palms ha^{-1} of agricultural land. The double avenue planting system provides a wide space between two row avenues of oil palm crops, which allows several rows of plant species to be planted in the particular wider spaces as shown in Figure 2.8. Usually, 15.2 meter wide avenues clear of undergrowth and weed to grow another plant species, especially trees and shrubs (Norkaspi Khasim et al., 2009).

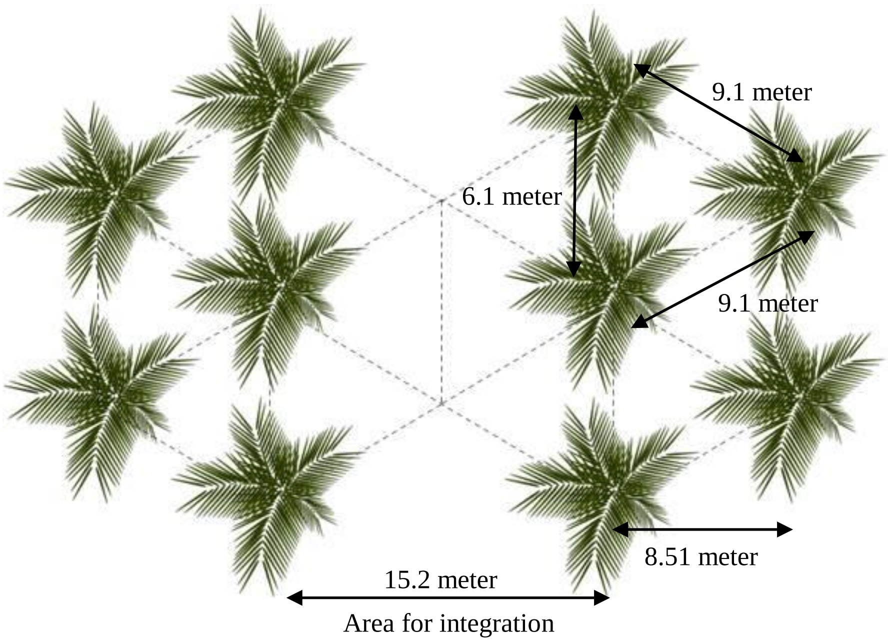
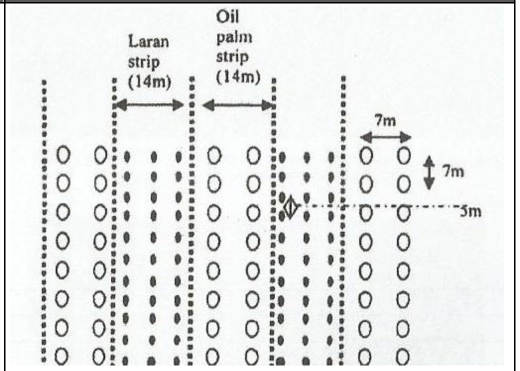
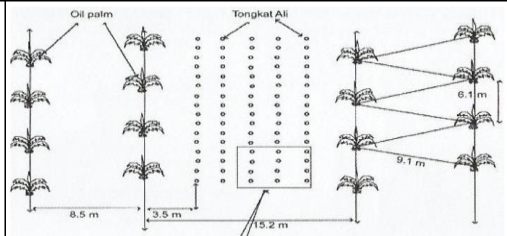
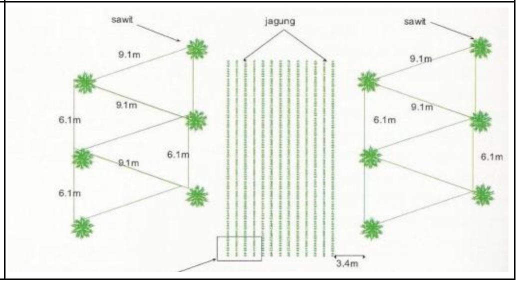
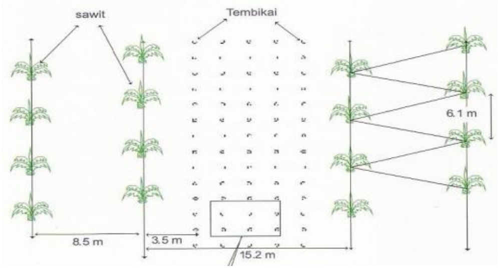
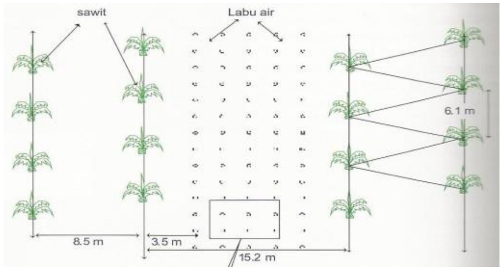
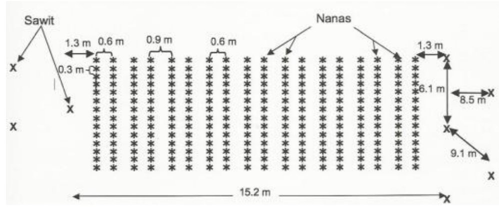
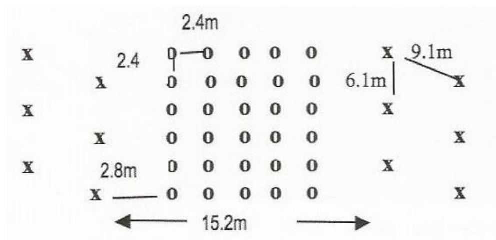


Figure 2.8: Layout of double avenue planting system for oil palm cultivation

Similar to triangular planting, the implementation of a double avenue planting system is also influenced by light penetration. After three years, the canopy of oil palm fronds is getting bigger and overlaps with other fronds (Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). This situation reduces the light penetration to the ground area drastically, especially between oil palm rows, thus restricts the integration of plant between the rows. Therefore, double avenue planting system is implemented to overcome this problem. In double avenue planting system, wide space between two oil palm avenues can be used to plant several rows of plant species for the whole phase of oil palm crops, either during immature or mature phase. Among plant species that are suitable to be integrated within the area of oil palm cultivation using double avenue planting system are shown in Table 2.10.

Table 2.10
Suitable plant composition of the agrisilviculture sub-system with oil palm crops for the arrangement of double avenue planting system

Author	Integration	Spacing	Planting density/hectares	Description	Image
Lee et al., 2005	Oil palm + forest tree	Oil palm: 7 m x 7 m x 9.8m Forest tree: 5.5 m x 5.5 m Wide avenue: 14 m	Oil palm: 102 Forest tree: 214	The row for both oil palm and forest tree are 14 m wide, while the row between oil palm and forest tree are 5 m wide.	
Norkaspi Khasim et al., 2009	Oil palm + tongkat Ali	Oil palm: 6.1 m x 9.1 m x 9.1 m Tongkat Ali: 2 m x 1 m Wide avenue: 15.2 m	Oil palm: 136 Tongkat Ali: 1,900	The 15.2 m wide avenue is cleared of undergrowth and weeds. Tongkat Ali is planted during the immature phase of oil palm and it is ready to be harvested at the age of four years.	
Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	Oil palm + maize	Oil palm: 6.1 m x 9.1 m x 9.1 m Maize: 0.7 m x 0.2 m Wide avenue: 15.2 m	Oil palm: 136 Maize: 42,850	The 15.2 m wide avenue is cleared of undergrowth and weeds. The 15.2 m wide avenues can be planted with 13 rows of maize. Maize is suitable to be planted during both immature and mature phases of oil palm and it is ready to be harvested at the age of 68-72 days.	

	Oil palm + watermelon	Oil palm: 6.1 m x 9.1 m x 9.1 m Watermelon: 2 m x 1.5 m Wide avenue: 15.2 m	Oil palm: 136 Watermelon: 2,000	The 15.2 m wide avenue is cleared of undergrowth and weeds. The 15.2 m wide avenues can be planted with 5 rows of watermelon. Watermelon is suitable to be planted during both immature and mature phases of oil palm, but can only be sustained for 5-7 years.	
	Oil palm + calabash	Oil palm: 6.1 m x 9.1 m x 9.1 m Calabash: 2 m x 2 m Wide avenue: 15.2 m	Oil palm: 136 Calabash: 1,500	The 15.2 m wide avenue is cleared of undergrowth and weeds. The 15.2 m wide avenues can be planted with 5 rows of the calabash. Calabash is suitable to be planted during both immature and mature phases of oil palm, but can only be sustained for 5-7 years.	
	Oil palm + pineapple	Oil palm: 6.1 m x 9.1 m x 9.1 m Pineapple: 0.9 m x 0.6 m x 0.3 m Wide avenue: 15.2 m	Oil palm: 136 Pineapple: 26,100	The 15.2 m wide avenue is cleared of undergrowth and weeds. The 15.2 m wide avenues can be planted with 18 rows of pineapple. Pineapple is suitable to be planted during both immature and mature phases of oil palm, but can only be sustained for 4-5 years.	
	Oil palm + banana	Oil palm: 6.1 m x 9.1 m x 9.1 m Banana: 2.4 m x 2.4 m x 2.8 m	Oil palm: 136 Banana: 880	The 15.2 m wide avenues can be planted with 5 rows of banana. Banana is suitable to be planted during both immature and mature phases of oil palm. It can be sustained based on the age of oil palm: 1-2 years of oil palm = 5 rows 2-5 years of oil palm = 3 rows > 6 years of oil palm = 2 rows	

2.6 AGROFORESTRY SYSTEMS AS SUSTAINABLE AGRICULTURE PRACTICE

The integration of agricultural crops with other plant species are known as alternative crops is a strategy to maximize the utilization of agricultural land. The implementation of agroforestry systems contributes extensively to the achievement of Malaysian agriculture goals in increasing the food production to achieve self-sufficiency. This is in line with the Third National Agricultural Policy (NAP3) 1998-2010 (Faridah Ahmad, 2001; Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). In this context, the role of plant as alternative crops are distinguished more on environmental protection of water management in temperate regions. In the interim, in tropic regions such as Malaysia, the focus is on the clarification of soil issues such as soil fertility improvement, soil conservation, degraded soil reclamation, and saline-acid fixation (Nair, 2011). Based on the principles of sustainability, this section reviews the potential benefits of agroforestry systems to be acknowledged as sustainable agriculture practices in three aspects, namely environmental, social, and economic benefits.

2.6.1 Environmental Benefit

The practice of agroforestry systems is beneficially proven for environmental improvement and recognized as an approach in environmental protection (Nair, 2011). The systems have become a foundation for improvement and development of sustainable agriculture practices into industrialized nations in the world. Numerous studies have attempted to express the importance of agroforestry systems in the environmental aspect across the environmental quality and ecosystem services. It has been suggested that major environmental benefits of agroforestry systems control soil degradation and desertification, reduce of ground water pollution, reduce pressure on forest margins through tree products supply, reduction in the atmospheric carbon-dioxide and other greenhouse gases, and increase biodiversity at the agriculture and landscape scale (Young, 1984). Another study conducted by Anizah and Nor Zalina (2013) suggests that there are five main environmental benefits in agroforestry systems which can be classified as air quality, water quality, carbon sequestration and climate change mitigation, biodiversity conservation, and soil improvement.

For the purpose of this study, only related environmental benefits are considered in line with the contribution of plant composition and arrangement based on its planning and design in creating sustainable agriculture practices. The positive, neutral, or negative interaction between the aboveground and belowground components has a potential in creating a natural habitat for flora and fauna conservation (van Noordwijk and Hairiah, 2000; Straight, 2011a). The concentration of these environmental benefits is in response to the issues and limitation of the study. According to Callo-Concha, Denich, and Vlek (2009), agroforestry systems are the provision of environmental services in agriculture sector through its benefits of conserving the flora and fauna. The system can help to preserve a higher level of flora and fauna, as well as provide sustainable landscape connectivity through the encouragement and intensification of agricultural practices.

In details, the integration of agroforestry components in agricultural land can tolerate a certain level of disturbance by providing sustainable and productive agriculture practices instead of practicing monoculture system. This is because the systems involve the clearance of natural forests, as well as disturb the habitat of various flora and fauna species. The rationale behind the positive response towards the flora and fauna conservation of agroforestry systems is based on three factors (Nair, 2011):

i. accumulation of agroforestry systems preserves protected areas from any corruption actions;
ii. expansion of agroforestry systems increases the land area for flora and fauna habitation in relation to landscape purposes; and
iii. diversification of plant species in farming systems.

The analyses in the work of Callo-Concha, Denich, and Vlek (2009) again found that species diversifications are among the factors that influence the availability of habitat for various flora and fauna in agricultural land. It is based on the advantages of plant composition and arrangement that provides different structure and dynamic natural cycle, thus, is able to reduce deforestation through its successful implementation. In addition, by integrating various types of tree species in agricultural land, it has the potential to provide a sustainable supply of the diverse range of tree products which are formerly harvested in forest area.

Other than that, the potential for natural habitat for flora and fauna indirectly encourages the integration of livestock within the area of agricultural land. This is due to its different structural stratification of agricultural crops and plant species that can decrease the heat problem faced by tropic livestock (Dahlan Ismail, 2009; Dahlan Ismail and Kamal Hisyam, 2014). Moreover, plant that is planted in linear lines act as fire breaker, windbreaker, and shelterbelts to protect the agricultural crops and livestock (Nair, Gordon, and Mosquera-Losada, 2008; Straight, 2011b). The plant are further could mitigate odor from dung and urine of the livestock. Therefore, the integration of suitable plant composition in agricultural land is proven not reducing but increasing the quality of the systems in environmental aspects due to its positive and neutral interaction between the aboveground and belowground components.

In other perspectives, diversification of species through agroforestry systems generate many sources of nitrogen fixing for agricultural land improvement (Montagnini, Eibl, and Fernandez, 2005). Basically, the natural use of nitrogen from plant reduces the need for nitrogen fertilizer of agrochemical products. Hasnol Othman, Farawahida, and Zulkifli Hashim (2012) stated in their study that leguminous cover crops have beneficial effects on soil by fixing and providing nitrogen to the main crops, improve crop growth, and reduce competition from harmful weeds. This is because soil nutrient absorption depends on the selection of suitable plant composition. In this case, the presence of aboveground and belowground cash and cover crops affects soil stability in agricultural land through its positive and neutral interaction (Nair, 2011). For example, in another study conducted by Chia (2011), the integration of teak with oil palm crops is able to reduce the soil nutrient competition due to its strong tap root. Thus, the integration of various plant species can maintain and improve soil productivity and performance due to its different level of tolerance in soil pH.

2.6.2 Social Benefit

The benefits acquired from the environmental aspects of agroforestry systems defeat the sustainable agriculture issue of food security and food safety simultaneously (Yue, 2009; Handayani and Prawito, 2011). This is due to the goal of agroforestry systems, which is to fulfil human needs in food consumption and maintain the standard environmental quality of the surrounding ecosystems (Handayani and Prawito, 2011).

Thus, the diversification of output production from the agricultural land provides additional income, early cash flow, and better return on the investment for the farmers (Ahmad Fauzi and Huda Farhana, 2006).

In addition, the practice of sustainable agriculture through agroforestry systems is solving the issues of inequitable and poor food production and distribution. High food productions are needed to execute the increase of human population by 925 billion in 2050 (Wollenberg et al., 2011). In a study conducted by Sharashkin and Gold (2005), 70% of the population in Russia practiced agriculture in order to produce food for the country. Besides that, agroforestry systems were implemented among Bolivian farming communities in order to overcome the issues of poverty and hunger by generating employment and income for the rural communities (Oxfam Case Study, 2011). These studies have shown that agroforestry systems have been implemented in many countries as an alternative to increase the quality of life among poor rural communities. Therefore, the benefits of agroforestry systems on environmental and social aspects are closely linked to each other in order to provide a better nation in developing countries.

2.6.3 Economic Benefit

The agriculture sector is continuously being the main supplier of food since it contributes a major proportion of the GDP for all developing countries. Currently, the implementation of agroforestry systems is urgently needed to increase agricultural productivity (Montagnini, Eibl, and Fernandez, 2005; Ahmad Fauzi and Huda Farhana, 2006) and generate additional income, especially among smallholder farmers (Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). In the recent study by Nair

(2011), proper composition and arrangement of agricultural crops and plant could improve the yields productivity, as well as sustain the integrity between ecosystems. Kassie and Zikhali (2009) highlighted that the economic benefits of agroforestry systems can be defined into short- and long-term benefits. The short-term benefits are gained through yields production once the farm has excellent soil and crop rotation management. On the other hand, the value of farm increased as the farm has good soil quality and water availability for long-term benefits. Therefore, it can be said that economic benefits are related to the environmental and social benefits.

In conclusion, the value of agroforestry systems has emerged as an alternative in sustainable agriculture practices that addresses many benefits to ensure environmentally friendly, socially responsible, as well as economically efficient and profitable. The presence of agricultural crops, plant, and livestock on the same agricultural land provides better benefits for the people and surrounding environment, especially among small communities as shown in Table 2.11. At the global level, agroforestry systems provide environmental values, including air quality, water quality, carbon sequestration and climate change, soil improvement, and biodiversity conservation. Therefore, this approach can be practiced by the smallholder farmers who faced the problems of poverty, including full time smallholder farmers to improve their basic quality of life.

Table 2.11
Benefits of agroforestry systems and its relation to the smallholder farmers

Category	Benefit	Relation to Smallholder Farmer
Environment	- Agroforestry systems preserve a higher level of flora and fauna since it combines and interact with various species both in aboveground and belowground components - The soil of agricultural land can be improved through the diversification of plant species, which generates many sources of nitrogen fixing.	- Wide range of plant integration on farms can help to encounter deforestation and the impact of climate change, reduce soil erosion, and help to capture nutrient and water, as well as support flora and fauna of the surrounding area. - The integration of various plant species such as leguminous cover crops is not only provides a source of nitrogen fixing, but it also provides a source of animal feed, especially ruminant animal such as cattle, sheep and goat. - Leguminous cover crops are planted at the belowground of the oil palm crops to improve the soil fertility since it is suitable for low input conditions and fragile environment.
Social	- Agroforestry systems are fulfilling human needs in food consumption, as well as solving the issues of inequitable and poor food production and distribution. - Agroforestry systems are alternative ways to increase the quality of life, especially among poor rural communities.	- The integration of other plant species instead of focusing on oil palm crops provides additional income, early cash flow and better return on investment for the first three years of cultivation to the farmers, especially during the immature phase of oil palm cultivation. - Additional nutrition is provided through the use of organic fertilizer from dung and urine animals, as well as waste from green manure. - The integration of other plant species besides oil palm can be managed by women. The farm management for other crops are easier than managing the oil palm crops.
Economic	- The implementation of agroforestry systems is mainly to increase agricultural productivity and generate additional monthly income.	- The integration of medicinal plant in oil palm cultivation provides an opportunity for the farmers to increase their income since medicinal plants are commonly found in the forest area. - Agroforestry systems create a flexible agricultural system where the risk of having crop failure is overcome by other crops.

2.7 SUMMARY

Based on the review, agroforestry systems are diverse, natural, and sustainable agricultural practices which hold the principles of sustainability. Agroforestry systems provide benefits to the environment, social, and economic aspects, especially among smallholder farmers. The suitable selection of plant composition and arrangements has the ability to improve the performances and the advantages of agroforestry systems. As such, in this study, it is important to identify the value of agroforestry systems based on the sustainable plant composition and arrangement as part of sustainable agriculture practices in oil palm cultivation. It can be explained through the theoretical framework of this study as shown in Figure 2.9.

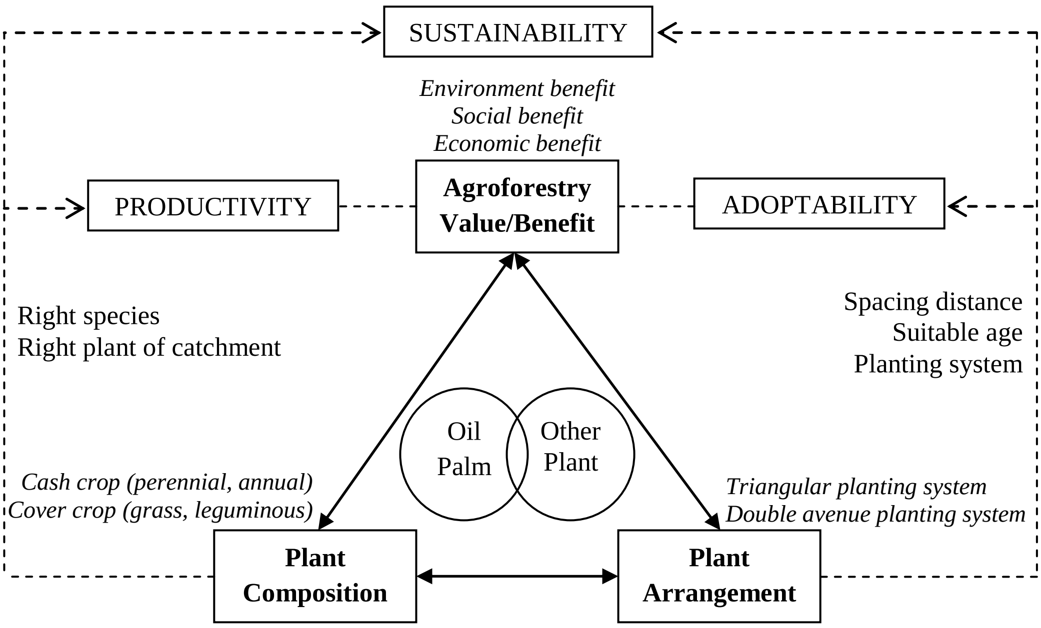


Figure 2.9: Theoretical framework of plant composition and arrangement for agroforestry systems in oil palm smallholdings

The integration of various species in one unit of agricultural land by considering its landscape planning and design creates a complex and competitive interaction among the components. There is a competition between agricultural crops, plant, as well as animal species. There are also some ways in which these components are balanced and mutually beneficial to each other. It can be achieved through the appropriate planning and design of the agricultural land. The role of landscape architecture is applied in this process, where the planning stage involves early planning of natural resources use and correct selection of composition and arrangement in getting positive or neutral impacts on environment, social, and economic. Therefore, the implementation of agroforestry systems is not only involving forestry and agricultural fields, but also landscape planning field.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 INTRODUCTION

This chapter explains the methods applied in the study in response to the research questions and objectives of the study. The research design is explained in Section 3.1, which includes parameters of the study, methodological approach, and data collection technique that focuses on sustainable agriculture practices and agroforestry systems among smallholder farmers. Later, the inquiry strategy that consists of the pilot study and sites study are discussed in Sections 3.2 and 3.3. Explanation on observation, interview, and document analysis that is applied as the method of data collection is further described in Sections 3.4, 3.5, and 3.6 respectively. Data analysis is clarified in Section 3.7. Finally, the chapter ends with the conclusion in Section 3.8.

3.1 RESEARCH DESIGN

Based on the research questions, this study applied exploratory research that employed qualitative research approach. Exploratory research was utilized for three purposes; to clarify any intrusiveness of the study for better understanding, to test the feasibility of the study, and to develop the methods to be implemented in other range of study (Babbie, 1999). In addition, Elijido-Ten (2007) also identified other purpose of exploratory research, which was to observe patterns, ideas, or propositions of the study. It was also decided that exploratory research suggests inductive reasoning. According to Babbie (1999), inductive reasoning involves the identification of variables or parameters before conducting research. It entails making predictions for novel situations by using existing knowledge and observations (Hayes, Heit, and Swendsen, 2010). Therefore, this study used exploratory research approach to provide a better understanding on how two or more variables are related each other in a situation through the application of inductive reasoning based on empirical evidence through site study.

Hence, this research design further discussed the parameters of the study, the methodological approach of the study, and the data collection techniques involved in the data collection as described below:

3.1.1 Parameters of the Study

The primary purpose of this study is to explore the potential of agroforestry systems to be implemented in oil palm smallholdings by focusing on the plant composition and arrangement for the agrisilviculture sub-system. Based on the review in Chapter 2, the parameters involved in the selection of suitable plant composition and arrangements for agroforestry systems that harmonize in the context of oil palm smallholdings, thus contributes to sustainable agriculture development.

Parameters of the study were derived from reviews of literature and were developed based on each research objective formulated in Chapter 1. Three aspects were considered, which include (i) the implementation of agroforestry systems in oil palm cultivation, (ii) plant composition and arrangement practiced in oil palm smallholdings, and (iii) benefits of agroforestry systems to smallholder farmers (Table 3.0).

Table 3.0
Consideration and parameters to be measured in this study

Author	Consideration	Parameter
Faridah Ahmad, 2001; Merem, 2005; Ahmad Fauzi and Huda Farhana, 2006; Kusters et al., 2008; Nair, 2011	Implementation of agroforestry systems in oil palm cultivation	- Definition of agroforestry systems - Components of agroforestry systems - Sub-system in agroforestry systems
Lee et al., 2005; Ahmad Fauzi and Huda Farhana, 2006; Norkaspi Khasim et al., 2009; Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim, 2010	Plant composition and arrangement practiced in oil palm smallholdings	Plant composition: - Cash crops (perennial and annual crops) - Cover crops (leguminous cover crops and grasses)
		Plant arrangement: - Triangular planting system - Double avenue planting system
Dahlan Ismail, 2009; Nair, 2011; Anizah and Nor Zalina, 2013; Dahlan Ismail and Kamal Hisyam, 2014	Benefits of agroforestry systems to smallholder farmers	- Environmental benefits in creating natural habitat for flora and fauna and soil improvement through the diversification of suitable plant composition and arrangement - Socioeconomic benefits of self-sufficiency production from other plant product

3.1.2 Methodological Approach

The selection of suitable methodological approach was based on the review of previous studies on sustainable agriculture and agroforestry systems throughout the world (Table 3.1). Reviews on methodological approaches for agroforestry systems as sustainable agriculture practices showed that most of the studies were conducted using qualitative rather than quantitative approach. This is because the studies did not engage with numerical data (Best and Khan, 1989), but through narratives, phenomenology, ethnographic, grounded theory, or case study inquiry (Babbie, 1999; Creswell, 2003). Hence, qualitative approach is seen as the most suitable approach applied in this study since the study did not engage with numerical data through experimental method, which requires such a long period. As such, the approaches consider three elements of inquiry, which are alternative knowledge claims, strategies of inquiry, and specific methods of data collection as shown in Figure 3.0.

Constructivism was applied as the alternative knowledge claims for this study. Constructive knowledge claims concerns on the aspect of understanding, multiple participant meaning, social and historical construction, and theory generation of the subject studied (Creswell, 2003). In 2004, Cooperstein and Kocevar-Weidinger reported constructive learning is guided by four principles, namely (i) learners construct their own meaning, (ii) new learning builds on prior knowledge, (iii) learning is enhanced by social interaction, and (iv) meaningful learning develops through real tasks. Thus, constructive knowledge claims refer to the process of learning from the experience to knowledge by considering the understanding of old and new knowledge, enhancing the knowledge through social interaction, and practicing it in the real life.

For the purpose of this study, constructive learning was applied to explore the experiential knowledge, understanding, and awareness on the plant composition and arrangement of oil palm crops and plant species, which is also known as agrisilviculture sub-system. It covers various sources of documentations that are manipulated, discovered, and adapted to fit the knowledge with the scope of this study. An attempt to discover the knowledge involved the social interaction with many experts in different specialization in agriculture field, as well as a participant, in this case, the smallholder farmers. Hence, the strategy of inquiry in this study involved the participation and response of smallholder farmers in the selected site studies, as well as experts in agriculture field on their experience with agroforestry systems. Hence, this study involved in-depth exploration of a process by employing observation, interview, and document analysis as methods of data collection to facilitate the specific direction of the research design as shown in Figure 3.0.

Table 3.1
Methodological approaches in the studied range of agroforestry systems as sustainable agriculture practices

Methodological approach	Strategy of inquiry	Parameter measured	Author
Qualitative approach	Document analysis, system analysis	Impacts on the environment	Grain (2006); Fitzherbert et al. (2008); Sheil et al. (2009); Dahlan Ismail (2009); Handayani and Prawito (2011)
	Document analysis, case study, observation	Benefits of components integration	Merem (2005); Thakur et al. (2005); Antichi et al. (2008)
	Document analysis	Present position and future prospects	Wong and Moog (2001); Nagayets (2005)
Quantitative approach	Experimental	Growth performance	Hasnol Othman, Farawahida, and Zulkifli Hashim (2012)
		Components arrangement	Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli (2009); Norkaspi Khasim et al. (2009)
Mixed methods approaches	Case study, experimental, sampling design	Suitability of agroforestry systems	Smith and McDonald (1998); Amekawa (2010); Nurul Ain et al. (2011)
	Case study, experimental	Benefits of component integration	Montagnini, Eibl, and Fernandez (2005)
	Survey questionnaires, field observation	Components integration and arrangement	Ahmed Azhar et al. (2008)

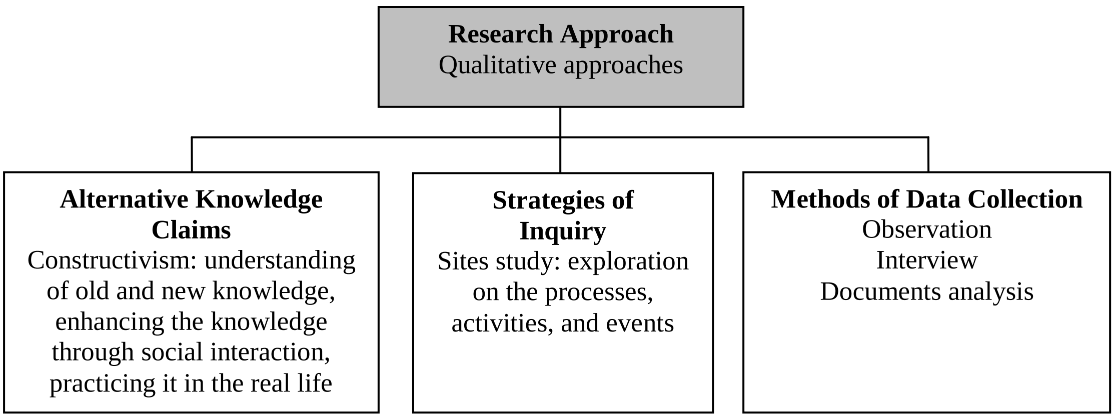


Figure 3.0: A framework for qualitative approach

3.1.3 Data Collection Technique

The procedures of data collection for a qualitative approach involved sites study as a strategy of inquiry. It employed three types of data collection techniques, namely observation, interview, and document analysis that examined the parameters described in Section 3.1.1. The selection of data collection techniques is based on its various options and advantages as summarized in Table 3.2.

Table 3.2
Data collection techniques for qualitative approach using sites study as strategies of inquiry

Data collection	Options	Advantages	Relevance to the study
Observation	- Non-participant observation: researcher observes without participating	- The researcher can record information as it is revealed	- The usage of plant species and its arrangement are observed and recorded to analyze the most preferable and suitable species to be integrated with oil palm crops
		- Uncomfortable and unusual aspects for participants to discuss can be noticed during observation	- Any unusual aspects that are not explained or found in the interviews and documentation can be added as supported information for the study
Interview	- Face-to-face: one on one in-person through semi-structured interview	- Useful when participants cannot be observed directly	- The process of integrating and arranging the agroforestry systems relatively takes a long time since it involves farm preparation, management, and production
		- Participants can provide historical information	- Historical information about oil palm and agroforestry systems in terms of its term usage and practice to represent agroforestry systems
		- Allows researcher to control over the line of questioning	- The questions are generally on the oil palm and agroforestry systems, but the specific questions are on the agrisilviculture sub-system
Documents analysis	- Public documents: newspaper - Private documents: journals, proceedings, guidelines - Email discussions	- Enables a researcher to obtain the language and words of participants	- Integration is often used to represent agroforestry systems by various authors
		- Can be accessed at a time convenient to the researcher	- The process of gaining and source of knowledge can be done anytime and anywhere throughout the study period parallel with the new knowledge or information on the subject studied
		- Represents data that are thoughtful, in which participants have given attention to compile	- The compilation of data is focused and manipulated on the composition and arrangement of the agrisilviculture sub-system and its environmental benefits in the context of oil palm smallholdings
		- As written evidence, it saves a researcher the time and expense of	- The evidence and fact related to the oil palm smallholdings and agroforestry systems can be used by

		transcribing the information	quoting the fact, as supported data of the study, especially in the definition and environmental benefits of agroforestry systems

3.2 PILOT STUDY

Before the actual final on-site interview and observation were carried out, a preliminary set of questions concerning the parameters of the study was tested using convenient samplings to a small sample of participants as the pilot study. It was conducted to evaluate the practicability, acceptance, removal, or replacement of certain parameters (Dantsis et al., 2010). The governmental organization of FELCRA in Paya Laman was selected as a site for the pilot study. FELCRA Paya Laman consists of a group of supported smallholdings managed by the FELCRA Berhad with its total area of oil palm cultivation of 1,245 hectares. There are 132 supported smallholdings with 10 hectares of oil palm cultivation.

FELCRA Paya Laman was selected as a pilot study based on its category as smallholdings and fulfillment of the parameters of the study. The objective of FELCRA is to develop rural sector through community participation in the national economic activities for the improvement of the standard of living. The agricultural development is done by FELCRA concerns the strategies to create sustainable agriculture practices which can be beneficial to the environment, social, and economic aspects. One of the approaches taken is through the implementation of agroforestry systems in the oil palm cultivation. It shows that FELCRA is basically supporting the implementation of agroforestry systems due to its benefits of the environment, social, and economic.

For the purpose of pretest of observation and interview, supported smallholdings that practiced agroforestry systems in FELCRA Paya Laman was observed and two participants of FELCRA officers were interviewed respectively, based on the information provided by the management of FELCRA Paya Laman. Supported smallholdings defined as oil palm farms in the total area less than 10 hectares (Department of Standards Malaysia, 2013). The smallholdings are supervised, organized, and managed by the FELCRA. The observation and questionnaires were carried out to explore the availability of agroforestry systems in Malaysia, especially for oil palm smallholdings. In addition, it also aims to identify the knowledge, understanding, awareness, and experience of smallholder farmers in applying agroforestry systems in their oil palm farm.

The smallholder farmers are highly encouraged by the FELCRA to integrate diverse types of plant species within the oil palm crops. They are facilitated with a certain financial assistant that can be applied throughout the year. This is to improve their quality of life since most of the smallholder farmers are in the range of rural and poor local community. However, the finding showed that only certain types of agroforestry systems were implemented by a small number of farmers. The checklist for observation technique was improved by adding the necessary and removing the unnecessary list to be observed by the researcher. Meanwhile, the participants were able to answer the questions, but later the improvement was made in terms of language usage since the questions were applicable to the experts and farmers based on their specializations. The anticipated improvement for both observation checklist and interview questionnaires were explained in Table 3.3. This is to ensure that the questions are easy to be interpreted and understood by the participants. Hence, it is essential to conduct pre-test field observation and interview in order to accommodate the researcher with basic perspectives of the site, thus enables the researcher to make necessary preparations for the final investigations.

Table 3.3
Anticipated improvement of observation checklist and interview questionnaires

Problem	Solution
Language barriers A set interview questionnaires were prepared for both the experts and smallholder farmers. The questions were asked based on their specialization. The term of 'agroforestry systems' is normally used by the experts, but unfamiliar among the smallholder farmers.	**Usage of common term** In order to provide comfortable interview sessions, the term of 'agroforestry systems' are changed into 'integration' for verbal communication. Integration has been used frequently to explain the similar meaning of agroforestry systems.
Interview participant The interview session requires detail explanation on the implementation of agroforestry systems by the smallholder farmers. However, there is no direct involvement of the supported smallholder farmers on the implementation of agroforestry systems as the smallholdings are fully managed by the FELCRA officers.	**Direct involvement in farm management** Smallholder farmers that are registered with the MPOB are selected as interview participant and their smallholdings are observed as sites study. They are full-time smallholder farmers who managed their oil palm farm themselves and monitored by the MPOB officer. Their direct involvement in oil palm cultivation and agroforestry systems validate the data gained from the interview sessions.
Concentration of components Plant species are the component that will be observed to explore the selection of suitable species to be integrated in oil palm smallholdings. Some smallholding integrates other component of livestock together with plant species in their oil palm farm.	**Complex observation on the components** By considering the complex components of agroforestry systems, certain types of plant integration and interaction may influence the existence of the other components in the systems such as livestock. In overall, all components that exist in the systems will be observed, jotted down, and analyzed for data collection and analysis. The interaction of other components with oil palm crops and plant species will be explained briefly. Still, the concentration is on the integration between oil palm crops and other plant species.

3.3 THE SITES STUDY

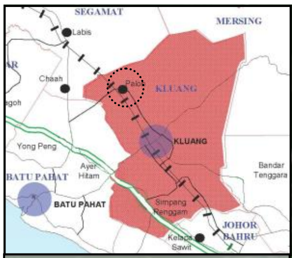
The smallholdings registered to MPOB have been selected for the sites study. Smallholder farmers in this study were characterized as a farmer who owned oil palm cultivation less than 10 and not more than 40 hectares (Department of Standards Malaysia, 2013). The smallholdings in Malaysia are divided into six zones, namely north, south, east, west, central, and Sabah and Sarawak. Approximately, there are about 15,000 smallholder farmers that have already registered with MPOB. However, only smallholdings in the south zone were selected as a sample for the sites study.

As such, this study was conducted in Kluang district in Johor, Malaysia, but focusing in Paloh Township as shown in Figure 3.1. In general, the district is located amidst of the Johor and surrounded by Johor Bahru in the north, Batu Pahat in the east-southeast, Mersing in the west, and Segamat in the south. It is inhabited by 288,364 population, which is covered by the most ethnic of Malay (138,223), Chinese (86,690), and Indians (24,102) respectively in 2010 (Department of Statistic Malaysia, 2010). Except for oil palm cultivation in Kluang, the study area consists of a huge number of smallholder farmers. The latest data showed Kluang as the highest district of oil palm smallholdings with the total area of 46,515 hectares planted by 13,053 smallholder farmers (Table 3.4). Meanwhile, the selection of Paloh Township as a focus of study is subject to the suggestion by the MPOB officer as the oil palm smallholdings are continuously applied agroforestry systems and among the most successful smallholder farmers in Kluang.

Table 3.4
Smallholdings: number of smallholder farmers and oil palm planted area in Johor districts as of December 2013

District	Farmer	Oil palm planted area (hectares)		
		Mature	Immature	Total
Batu Pahat	15,504	36,897	216	37,114
Johor Baru	3,483	13,049	97	13,146
Kluang	13,053	46,043	471	46,515
Kota Tinggi	2,356	10,537	128	10,666
Kulaijaya	224	538	110	649
Ledang	2,316	5,604	83	5,688
Mersing	1,550	4,969	37	5,007
Muar	14,654	39,413	149	39,562
Pontian	9,335	26,532	235	26,768
Segamat	3,322	11,517	228	11,746
Total	**65,797**	**195,103**	**1,761**	**196,865**

Source: MPOB (2014)

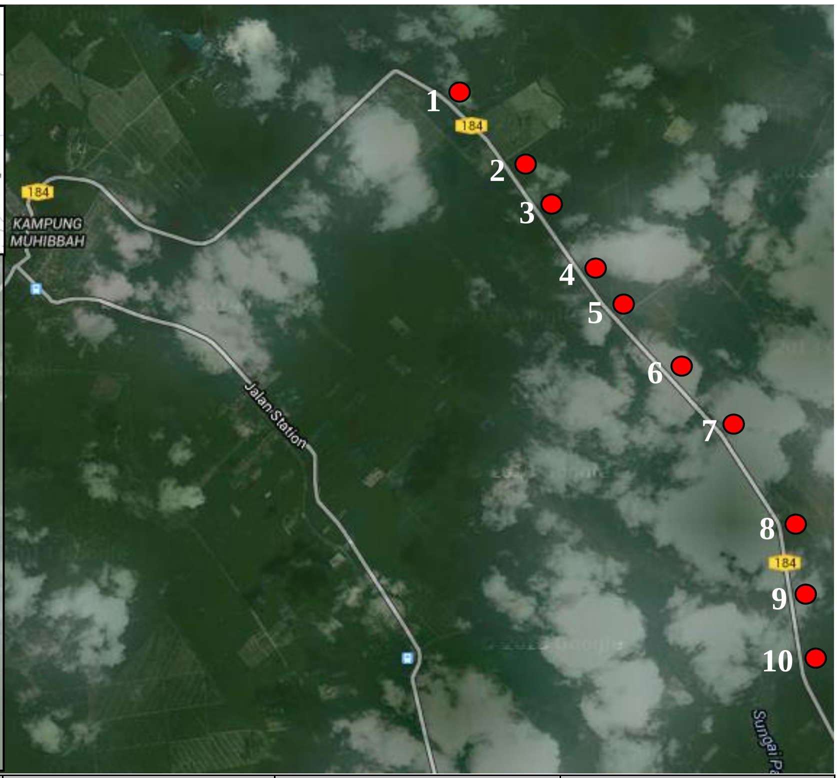


Sites study area: Paloh Township

Small town that located at Kluang district

It has balanced population of Chinese, Malay, and Indian

Oil palm cultivation and rubber plantation are the town’s main activities



Smallholdings	Oil palm area (hectare)	Spacing distance	Oil palm age (month/year)
 Smallholding 1	3 hectares	9.1 meter x 9.1 meter x 9.1 meter	3 months
 Smallholding 2	1 hectare	9.1 meter x 9.1 meter x 9.1 meter	1 month
 Smallholding 3	2 hectares	6.1 meter x 9.1 meter x 15.2 meter	9 years
 Smallholding 4	1 hectare	9.1 meter x 9.1 meter x 9.1 meter	4 months

 Smallholding 5	2 hectares	6.1 meter x 9.1 meter x 15.2 meter	15 months
 Smallholding 6	2 hectares	6.1 meter x 9.1 meter x 15.2 meter	10 years
 Smallholding 7	1 hectare	6.1 meter x 9.1 meter x 15.2 meter	20 months
 Smallholding 8	1 hectare	9.1 meter x 9.1 meter x 9.1 meter	2 months
 Smallholding 9	1 hectare	9.1 meter x 9.1 meter x 9.1 meter	2 months
 Smallholding 10	1 hectare	9.1 meter x 9.1 meter x 9.1 meter	2 months

Figure 3.1: Location of the sites study

The sites study was established in oil palm smallholdings that implements agroforestry systems in their oil palm cultivation. In April 2014, a field survey was conducted at 10 oil palm smallholdings, including 6 sites from 1 to 10 months of age, 2 sites from 11 to 20 months of age, and another 2 sites from 5 to 10 years of age. All agroforestry systems were implemented after one or two weeks of replanting phase of oil palm cultivation. Oil palm crops were cleared for replanting after 25 to 30 years of oil palm age, in which it is the maximum age of oil palm crops for good quality of fresh fruit bunches production. The area for oil palm cultivation for each smallholding is range from 1 to 4 hectares with the flat soil condition. The oil palm crops were planted with a spacing distance of 9.1 m x 9.1 m x 9.1 m in a triangular arrangement for the triangular planting system and 6.1 m x 9.1 m x 15.2 m in a triangular arrangement for double avenue planting systems, which resulted in a plant density of 138 and 136 palms ha^{-1}.

3.4 OBSERVATION

Based on the reviews, it was found that the observation technique is the most basic technique in research methodologies. Observation is a process of monitoring and recording the subject studied without influencing or disturbing the surrounding (Yount, 2006). Hanna (2006) highlighted that observation becomes an important technique that must be conducted in a field and site study research. It is to provide explanations and understanding of the natural human behavior by eliminating the bias to come up with the predictions of the situations. The process of gathering data from observation involves interpretation of five human sense organs of vision, hearing, smell, taste, and touch (Fox, 1998). The purpose of the observation is to support the data provided in the analysis of the interviews and triangulated with document analysis.

For this study, non-participant observation was chosen as an option in data collection for observation technique. It was chosen to obtain clear and precise data and avoid biased perspective on individual or group behavior, as well as the activities of the surrounding study area. The observation engaged with the physical character of the oil palm smallholdings and its implementation of agroforestry systems within the surrounding area. The selections of parameters that need to be observed referred to the study conducted by Fox (1998) and Reeves, Kuper, and Hodges (2008). They pointed out that observation techniques involve the dimension of space (physical layout of the place), actor (range of people involved), activity (a set of related activities that occur), object (the physical things that are present), act (single actions people undertake), event (activities that people carry out), time (the sequencing of events that occur), goal (things that people are trying to accomplish), feeling (emotions felt and expressed), and reflection (personal response to any of the above). Hence, the observation looked for relevant physical character of the oil palm smallholdings and structural basis of the agroforestry systems that reflected the sustainability of the systems as sustainable agriculture practice. The observation focused on the plant composition and arrangement to determine the suitability and potential of the system to be implemented in oil palm smallholdings.

3.4.1 Observation Checklist

A checklist was provided for the researcher to record and illustrate the parameters to be observed in the sites study area. The University of Texas (2011) on their observational data research stated that the reliability of the observation is higher through the checklist than rating techniques because it involves observer's judgment.

The checklist was prepared in order to answer research questions and objectives 1, 2, and 3. It was supported by photographic data for reliable and valid data. The observation checklist divided into two sections to facilitate data collection is explained as follows (refer Appendix A):

i. Section A: Physical character of oil palm smallholdings

   Section A provides the identification of physical characteristics of oil palm smallholdings. The parameters to be observed involved area of farm, oil palm age, and spacing distance of oil palm crops. The observation also covered the impact of the environment and socioeconomic elements either contribute to the positive, neutral, or negative impacts.

ii. Section B: Agrisilviculture sub-system

   Section B involves the identification of plant composition and arrangement by focusing on the oil palm crops as the main component. The plant species were observed by identifying its vegetative habits either annual, perennial, grass, or leguminous cover crops. Meanwhile, the arrangement was illustrated to provide better understanding of the layout selection.

3.5 INTERVIEW

The interview is the process of data gathering technique which explores the participant's perception on the research topic (Morgan and Guevara, 2008). It is a conversation with a specific purpose of gathering information (Berg, 2004). As highlighted by Brinkmann (2008), interviews are the most prevalent technique of knowledge-producing practices in social science research. As such, this study employed semi-structured interview technique. Semi-structured interview carries verbal estimation of questionnaires with precise research goals (Fetterman, 2008) that encourage the participants to answer more spontaneously (Brinkmann, 2008).

Semi-structured interview approach that was conducted for this research refers to the Spradley's interviewing approach. Spradley's interviewing approach always embarks on 'grand tour' question, followed by 'mini tour' questions (Morgan and Guevara, 2008). 'Grand tour' question is a fundamental question about the research topic. The question is followed by 'mini tour' questions which are more detail on the specific research questions about the study. An example of 'grand tour' question is "tell me about a typical example of agroforestry systems", while the example of 'mini tour' question is "you mentioned about the agrisilviculture sub-system, can you tell me more about plant species integration in the agrisilviculture sub-system?" Thus, an interview is the most important data gathering techniques for the strategies of inquiry in a site study, which is explained in details in Section 3.5.1.

3.5.1 Interview Design

Before the interview was conducted, a set of questionnaires was prepared as the interviewer's guide. Topic-based guide approach was applied in this process during the preparation of questionnaires. The preparation of the questions was based on the interviewer's interest of the research topic (Morgan and Guevara, 2008). Moreover, the questions were prepared in an organized format to avoid repeated questions asked by the interviewer. The interview questionnaires that consist of 18 questions which are divided into four sections to facilitate data collection are explained as follows (refer Appendix B):

i. Section A: Oil palm cultivation in Malaysia

Section A (Questions 1 to 4) contains general questions related to the oil palm cultivation in Malaysia. The questions intended to identify the categories of oil palm cultivation in Malaysia, its management aspects, challenges, and strategies taken by the local and private authorities.

ii. Section B: Sustainable agriculture

Section B (Questions 5 to 8) contains a general overview of sustainable agriculture. The questions are intended to determine the current position of sustainable agriculture and its acceptability to be applied in oil palm smallholdings in Malaysia.

iii. Section C: Agroforestry systems

Section C (Questions 9 to 12) aims to understand the detail overview and structural basis of agroforestry systems in order to be acknowledged as sustainable agriculture practice. Question 12 remains as independent variables by getting an opinion of the participants on the suitability and potential of agroforestry systems in the oil palm smallholdings context.

iv. Section D: Plant composition and arrangement

Section D (Questions 13 to 18) aims to investigate the suitability of plant composition and arrangement with oil palm crops. It also covers the identification of factors that influence the selection of the integration and arrangement, as well as its advantages on oil palm crops agroecosystem and the benefits to the smallholder farmers.

3.5.2 Interview Procedure

Semi-structured interview was conducted individually (face-to-face interview) to serve comparative data collection. The purpose is to compare different responses and classify them in the context of knowledge, understanding, and awareness in agroforestry systems. The interview questionnaires are intended to answer the research questions and objectives 1, 2, and 3. The interview was conducted in bilingual of English and Malay. All interviews were recorded and the information gathered from the interview was explained in the form of interview scripts in order to extract the related information.

Basically, the experts were asked about the whole overview, perspectives, and development of the agroforestry systems as sustainable agriculture practices in oil palm smallholdings context. However, the selection of the questions was prioritized to their specialization of knowledge. Meanwhile, the interview with smallholder farmers focused on the implementation of agroforestry systems that have been adopted in their oil palm smallholdings. As the Spradley’s interviewing approach is referred to, the interview questionnaires fluctuated depending on the answers provided by the participants. The answers may assist the researcher to respond with ‘mini tour’ questions for details explanation of the subjects.

3.5.3 Interview Participant

The interview was conducted with seven experts of local authorities from the Universiti Putra Malaysia (UPM) and MPOB. Another two participants of smallholder farmers were interviewed as the owner of the sites study as shown in Table 3.5. Participants were selected to meet specific criteria of the participant’s selection through purposive or judgmental sampling. The participants had to meet the following criteria to be selected as a sample:

i. Experts:

   a. The minimum qualification of the experts must be college graduate: to ensure that the experts are able to provide reliable and valid data of the study.

   b. The experts have an experience more than ten years in their specializations (sustainable agriculture, oil palm cultivation, agroforestry systems): to ensure that the experts are able to share and explain their experience in agricultural fields, including related issues, challenges, strategies taken, impacts, and their point of views on the agroforestry systems as sustainable agriculture practices.

   c. The experts are involved directly or indirectly in the farm management of oil palm cultivation: to ensure that all the information gain during the interview is related to the scope of study, which is on oil palm smallholdings.

ii. Smallholder farmers:

   a. The main occupation is as smallholder oil palm farmers: the participant must be a full-time oil palm farmer to ensure that the participant is able to share their experience in preparing and managing the oil palm crops. The interview questionnaires require them to answer and explain in details on the process of implementing agroforestry systems in their oil palm smallholdings.

b. The smallholder farmers are the farmers that have been recommended by the MPOB due to their successfulness in implementing agroforestry systems in their oil palm smallholdings.

Table 3.5
List of participants in the interview

Credibility	Specialization	Code
Experts		
Group Leader of Extension and Training Unit, MPOB Bandar Baru Bangi	- Agronomy and fertilizer of oil palm - Crop and animal integration in oil palm	Expert 1
Research Officer of MPOB Bandar Baru Bangi	- Oil palm plantation management - Sustainable agriculture	Expert 2
Group Leader of Crops Integration, MPOB Bandar Baru Bangi	- Suitable crop for integration - Crop integration in oil palm - GAP for crop integration - Economies of integrated production system	Expert 3
Research Officer of MPOB Bandar Baru Bangi	- Oil palm plantation management - Crop integration in oil palm	Expert 4
Research Officer of MPOB Bandar Baru Bangi	- Oil palm cultivation - Sustainable agriculture - Good agricultural practices	Expert 5
Research Officer of TUNAS, MPOB Kluang	- Oil palm cultivation - Farm management - Crop integration in oil palm cultivation	Expert 6
Professor of Animal-Agricultural Systems, UPM Serdang	- Animal production - Integrated livestock-crops production systems - Biodiversity and conservation - Wildlife conservation	Expert 7
Smallholder farmer		
Owner of site study	- Experience in oil palm cultivation and livestock-crops integration more than 35 years	Farmer 1
Owner of site study	- Experience in oil palm cultivation and livestock-crops integration more than 15 years	Farmer 2

Based on the credibility of the participants, 100% were involved directly and indirectly in oil palm cultivation, 78% of agroforestry systems, and 33% in sustainable agriculture (Table 3.6).

Table 3.6
Characteristic of the participants from the interview

Participant	Code	Credibility		
		Oil palm cultivation	Sustainable agriculture	Agroforestry systems
Malaysian Palm Oil Board (MPOB)				
Expert 1	Expert 1	√		√
Expert 2	Expert 2	√	√	
Expert 3	Expert 3	√		√
Expert 4	Expert 4	√		√
Expert 5	Expert 5	√	√	
Expert 6	Expert 6	√		√
Universiti Putra Malaysia (UPM)				
Expert 7	Expert 7	√	√	√
Smallholder farmer				
Smallholder farmer 1	Farmer 1	√		√
Smallholder farmer 2	Farmer 2	√		√
Total percentage		100%	33%	78%

3.6 DOCUMENT ANALYSIS

Document analysis involves describing, summarizing, evaluating, and clarifying the report of the studies in a related subject area (Boote and Beile, 2005). The documentation was gathered from various resources including books, bulletins, journals, lecture notes, magazines, newsletters, proceedings, and reports. The reviews were also provided and suggested by the experts during an interview session for a better understanding of the agroforestry systems. Most of the documentations were accessed from the International Islamic University Malaysia's online databases including Proquest Dissertations and Theses, SpringerLink, ScienceDirect, Scopus, and Wiley Online Book. The data also cover the governmental reports and publications from a governmental organization, including MPOB to study the nature of oil palm cultivation, sustainable agriculture, and agroforestry systems.

The reviews of the related studies concerning: history, definitions, classifications, and sub-systems of agroforestry; agricultural planning and design; composition and arrangement of oil palm crops and other plant species; and the benefits of agroforestry systems; and The documentations were made to strengthen and complement the results and findings from the interview and observation techniques. Hence, the triangulation design was conducted during the data analysis in order to obtain reliable and valid findings from the data collection techniques.

3.7 DATA ANALYSIS

Referring to the previous section, three methods of data collection were adopted for this study, namely observation, interview, and document analysis by using site study as the strategies of inquiry. The data collected were analyzed using thematic analysis by conducting different process of qualitative data analysis (QDA) to understand, represent, and formulate an interpretation on the better meaning of the data (Creswell, 2003). The process involves documentation, categorization, connection, corroboration, and representation of the data throughout the study (Schutt, 2012). Hence, the examination of the data analysis for this study includes documentation, conceptualization, coding, and categorizing; examining relationship and displaying data; and triangulation (Table 3.7).

3.7.1 Documentation

Documentation is the first formal step in QDA. It involves the process of data saving and listing from various sources of data collection including observation, interview, and written documents. Documentation is a vital technique in QDA based on three purposes (Schutt, 2012). The purposes are to keep track of the subject studied, provide a way for developing and outlining the idea or parameters of the subject, and encourage conceptualization of the subject.

In this study, the data collected from the observation and interview were recorded from the original observation and comments from the sites study and participants. The information or texts were transcribed from the observation checklist, photograph, and audiotapes. Two hour interview session can produce up to 20 to 25 pages of single-spaced text of interview transcripts. The interviews were transcribed in Malay and were translated into English for easier conceptualization, coding, and categorizing process.

3.7.2 Conceptualization, Coding, and Categorizing

Conceptualization is the process of identifying and sorting the important data or concept of the subject studied (Schutt, 2012). Large amount of data is organized and the patterns of data are discovered through the process of coding and categorizing (The University of Texas, 2011). The focus is to provide a detailed explanation of the parameters and its importance to the study.

For the purpose of this study, more attention was given to the understanding of the agroforestry systems by investigating the meaning, benefits, and its implementation with oil palm crops. The conceptualization, coding, and categorizing processes were conducted using QDA software programs of ATLAS.ti. ATLAS.ti is among the most popular software programs for QDA (The University of Texas, 2011). It helps in conducting systematic and efficient coding, as well as complex analyses of the data collection. During the coding process, a special vocabulary from the participants needs to be considered because it may signify important theme. Hence, the process of conceptualization, coding, and categorizing data helps in discovering the important parameters of the study by coding and categorize them in a systematic manner.

3.7.3 Examining Relationship and Displaying Data

Examining relationships is an important stage in QDA. It allows the researcher to present complex analysis by identifying and explaining the relationship between parameters, concepts, and themes of the subject (The University of Texas, 2011). The focused is to generate relationship of the parameters to ensure that those aspects are dependable on each other.

In this study, the process of examining relationship can be achieved through network view in ATLAS.ti software and developed further manually. The network view helps in generating a complex analysis by relating all parameters to become one systematic concept of the study. It involves the identification of strong parameters relationship for an improvement of knowledge which can be evaluated in the real life situation. Hence, the findings were manipulated to fulfill the aim of the study, which is to study the suitability of the implementation of agroforestry systems in oil palm smallholdings based on the strong relationship of the parameters.

3.7.4 Triangulation

Triangulation is the last stage in QDA. Triangulation is a method used to verify and establish validity of the study (Guion, 2002). The triangulation model is formed in order to explain the research interest and response to research questions and objectives. In social sciences research, triangulation is a metaphor used to describe multiple methods used for data collection (Bechhofer and Paterson, 2000; Berg, 2004;

Leong and Austin, 2006). Each data collected from different methods of data collection tends to contain inaccuracy, but the idea of triangulating data or analyzing data together will provide more accurate data analysis. Thus, the application of triangulation allows the researcher to minimize the degree of inaccuracy and provide more reliable and valid information.

In this study, triangulation involves the evaluation of different sources of data collection as shown in Figure 3.2. Observation, interview, and documents analysis were adopted in this study by applying constructive knowledge claims and sites study as a strategy of inquiries that has been explained in the previous sections. The data gain from these three methods of data collection were analyzed and triangulated to provide systematic, efficient, and accurate data analysis. Furthermore, the comprehensive data were examined through data triangulation by comparing and contrasting different types of techniques to understand the phenomena of study area (Reeves, Kuper, and Hodges, 2008).

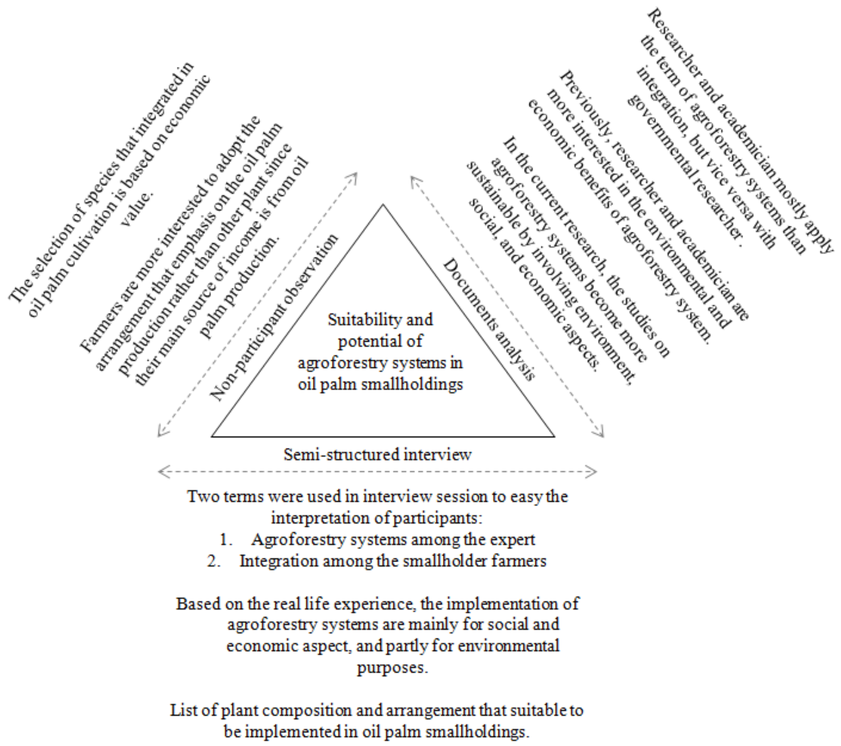


Figure 3.2: Triangulation design

Table 3.7
Techniques of qualitative data analysis

Research question	Research objective	Parameter of the study	Observation	Interview	Documents analysis
How agroforestry systems contribute to the agricultural sustainability in oil palm smallholdings?	To investigate agroforestry systems as sustainable agriculture practices in oil palm smallholdings.	Implementation of agroforestry systems in oil palm cultivation: - Terms used by the expert and local farmers to define agroforestry systems - Oil palm preparation, management, and production for the implementation of agroforestry systems - Current sub-system of agroforestry systems practiced by smallholder farmers - Environmental benefits of the agrisilviculture sub-system (concentrating on the integration between oil palm crops and plant species) - Influence of environmental benefits to the surrounding area of social and economic aspects concurrently	*Documentation:* - Data collected were recorded from the original observation at site studies area.	*Documentation:* - Data collected were notes jotted down from the original comments of the participants. - The interview session was transcribed into text from audiotapes.	*Documentation:* - Documents by well-known scholars on the oil palm cultivation, sustainable agriculture, agroforestry systems, and agricultural landscape planning and design from which it can be contributed to the study.
			Conceptualization, coding, and categorizing: - Generate important keywords or codes by referring to the parameters using ATLAS.ti software.	*Conceptualization, coding, and categorizing:* - Generate important keywords or codes by referring to the parameters using ATLAS.ti software. - Identify important quotation that can be used for the study, especially in the definition and scientific fact of the benefits of the systems. - Identify the benefits of agroforestry systems in environmental aspects and their relation to the social and economic aspects.	
How to integrate oil palm crops and other plant species in terms of its composition and arrangement?	To explore plant composition and arrangement of agroforestry systems for a sustainable oil palm smallholdings.	Suitable species to be integrated in oil palm smallholdings: - Cash crops (annual and perennial crops) - Cover crops (grasses and leguminous cover crops) The suitable planting system	*Documentation:* - Data collected were recorded from the original observation at site studies area. - Data supported with audiovisual materials of photographs.	*Documentation:* - Data collected were recorded from the original comments of the participants. - The interview sessions were transcribed into text from audiotapes.	*Documentation:* - Documents by various scholars on the integration and arrangement of plant species and oil palm crops.

		to be implemented in oil palm smallholdings: - Triangular planting system - Double avenue planting system	*Conceptualization, coding, and categorizing:* - Generate codes by referring to the parameters using ATLAS.ti software. - Identify the suitable plant composition for each type of arrangements.
What is the most sustainable plant composition and arrangement to be implemented in oil palm smallholdings?	To recommend sustainable plant composition and arrangement of agroforestry systems that can be implemented in oil palm smallholdings.	- Preferred plant composition and arrangement that practiced by smallholder farmers. - Selected plant composition and arrangement were further improved based on the consideration on the agricultural sustainability of the systems.	*Documentation:* - The findings were further analyzed for the recommendation of sustainable agrisilviculture sub-system for oil palm smallholdings by considering the influential factor of agricultural sustainability. *Conceptualization, coding, and categorizing:* - Generate a new systematic plant composition and arrangement that can positively benefit the environment, social, and economics of the smallholder farmers without negatively affecting the oil palm productivity.

Examining relationship and displaying data:
- Examine the relationship between plant composition, arrangement, and its environment and rural benefits to the oil palm farmers.
- Support the relationship with illustration of the diagram on the sustainable layout of arrangement.

Triangulation:
- Data from observation, interview, and document analysis were compared and differentiated based on the similar concept, code, and category.
- The analyses were integrated as findings that represent the whole idea of the study.
- Triangulation was needed to enhance the reliability and validity of the study.

For the analysis purpose, the findings were further categorized into two themes referring to the literature review that has been done in Chapter 2. The themes were organized into three chapters, which will be explained in details in the next chapter. Each chapter aims to answer the research objectives and questions of this study (Table 3.8).

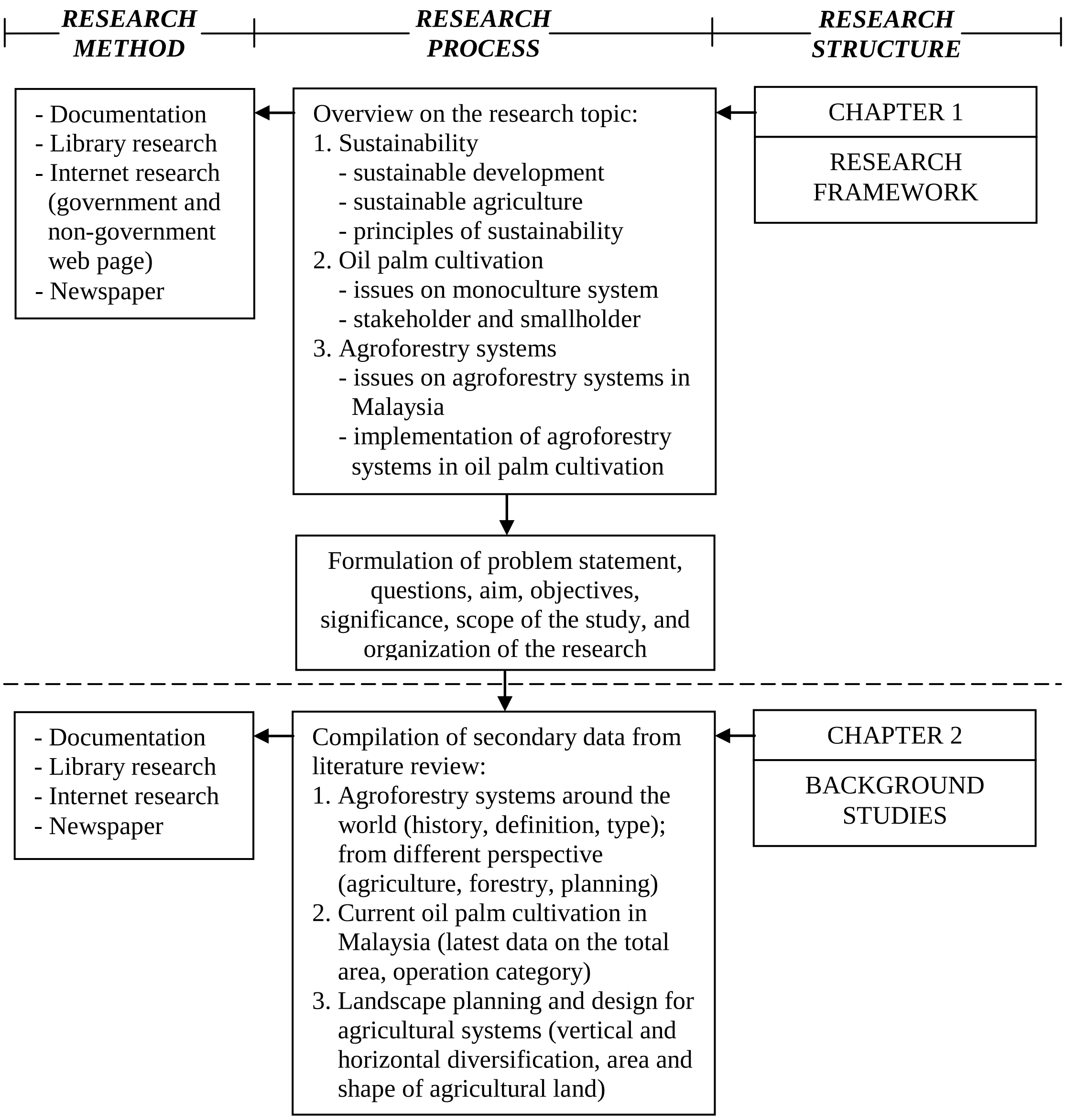
Table 3.8
Development of theme for analysis

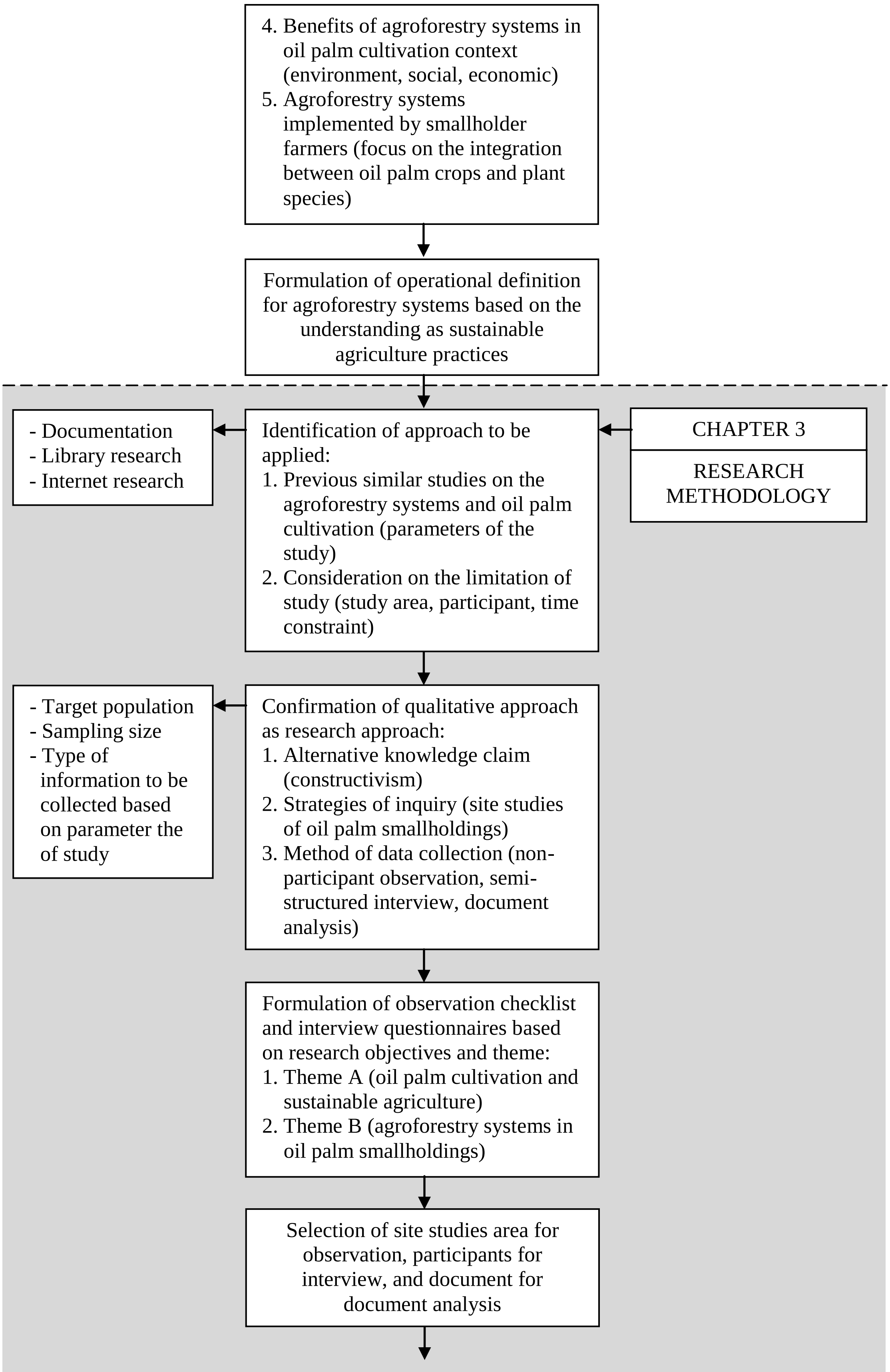
Theme	Research objective (RO) & Research questions (RQ)		
	1	2	3
Theme A: Oil palm cultivation and sustainable agriculture			
Definition and representation of agroforestry systems as sustainable agriculture practices (Chapter 4)	√		
Theme B: Agroforestry systems in oil palm smallholdings			
Implementation of agroforestry systems among independent smallholder farmers (Chapter 5)		√	
Recommendation on the systematic concept of agroforestry systems consisting sustainable composition and arrangement between oil palm crops and other plant species (Chapter 6)			√

3.8 SUMMARY

The summary of the chapter explains the overall plan of the study. The organization of the study involved research structure, process, and method that encompass six stages, namely research framework, background studies, research methodology, results and findings, and conclusion and recommendation. Figure 3.3 shows the process of the research design.

In details, the methodology of the study employed qualitative approach as the research approach. The concept of the study was designated to be an exploratory research by suggesting inductive reasoning. The application of inductive reasoning was based on the empirical evidence that can be obtained through sites study as the strategies of inquiry. The data collection involved in-depth exploration of the subject by employing observation, interview, and document analysis as methods of data collection. The triangulation design was applied for describing and analyzing the data to minimize the degree of inaccuracy and provide more reliable and valid information. The results and findings of the study were explained and discussed in the next chapter by applying descriptive description as types of analysis.




4. Benefits of agroforestry systems in oil palm cultivation context (environment, social, economic)
5. Agroforestry systems implemented by smallholder farmers (focus on the integration between oil palm crops and plant species)
Formulation of operational definition for agroforestry systems based on the understanding as sustainable agriculture practices
- Documentation
- Library research
- Internet research
Identification of approach to be applied:
1. Previous similar studies on the agroforestry systems and oil palm cultivation (parameters of the study)
2. Consideration on the limitation of study (study area, participant, time constraint)
CHAPTER 3
RESEARCH METHODOLOGY
- Target population
- Sampling size
- Type of information to be collected based on parameter the of study
Confirmation of qualitative approach as research approach:
1. Alternative knowledge claim (constructivism)
2. Strategies of inquiry (site studies of oil palm smallholdings)
3. Method of data collection (non-participant observation, semi-structured interview, document analysis)
Formulation of observation checklist and interview questionnaires based on research objectives and theme:
1. Theme A (oil palm cultivation and sustainable agriculture)
2. Theme B (agroforestry systems in oil palm smallholdings)
Selection of site studies area for observation, participants for interview, and document for document analysis

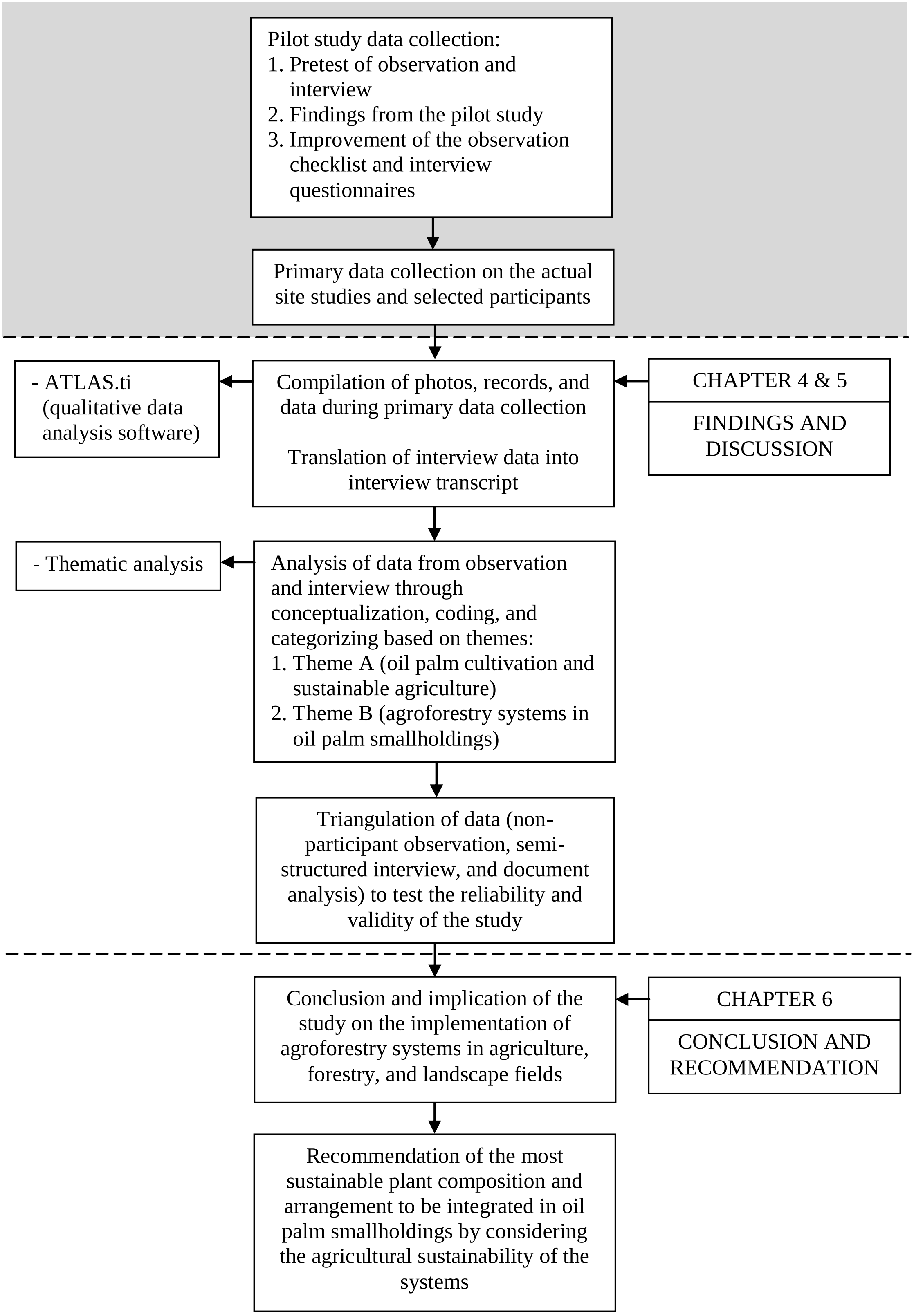


Figure 3.3: Research methodology: structure, process, and method

CHAPTER FOUR

FINDINGS AND DISCUSSION 1: AGROFORESTRY SYSTEMS AS SUSTAINABLE AGRICULTURE PRACTICES IN OIL PALM SMALLHOLDINGS

4.0 INTRODUCTION

This chapter presents the findings gathered from interviews and observation techniques. The data were further discussed and triangulated with document analysis. The purpose of this chapter is to answer the research question and objective 1 on the implementation of agroforestry systems in oil palm smallholdings. The findings are associated with the 10 sites study of oil palm smallholdings located in the Paloh Township in Kluang, Johor. Accordingly, the chapter starts with the understanding on the definitions of agroforestry systems by seven experts and two smallholder farmers in Section 4.1. It is followed by Section 4.2 which presents the concept of agroforestry systems for oil palm smallholdings. Next, Section 4.3 discovers the values of agroforestry systems in environmental aspects, as well as its simultaneous positive impacts on socioeconomic. Lastly, the summary of the chapter is presented in Section 4.4.

4.1 DEFINITION OF AGROFORESTRY SYSTEMS

The definition of agroforestry systems is determined based on the participants' knowledge, understanding, and awareness of the systems as one of the alternatives for sustainable agriculture practices. It discovers how the systems are valued as one of the balanced agricultural systems in oil palm cultivation context. Thus, this section aims to identify the definition of agroforestry systems as sustainable agriculture practices by concentrating on the integration of plant species within oil palm smallholdings.

Agroforestry systems are the ontology of the monoculture system. The term ‘agroforestry’ is rarely used among agriculture practitioners, but is frequently applied in academic disciplines. Different fields use different terms to describe similar meaning of agroforestry systems. The interview results revealed that ‘integration’ was commonly used to explain the practices of agroforestry systems. Most of the interview participants are more comfortable to use ‘integration’ rather than ‘agroforestry’ in explaining the understanding of the systems during interview sessions. Furthermore, ‘integration’ is preferred in communication and ‘agroforestry’ formally used in documentation.

Based on the interview with the participants, the study generated nine definitions that were identical on the viewpoint of agroforestry systems as sustainable agriculture practices shown in Table 4.0. It indicates all participants agreed on agroforestry systems as sustainable agriculture practices. Although there was a significant agreement on the following definitions, differences were found in the viewpoint of agroforestry systems where it can be considered either sustainable or unsustainable agricultural practices. Through definition, the sustainability was determined based on oil palm crops as the main component, diverse benefits, selection of species, and types of arrangements.

Table 4.0
Definition of agroforestry systems

Participant	Definition	Viewpoint	
		Sustainable	Unsustainable
Expert 1	Agroforestry systems are farming practices through the integration of oil palm crops with other crops with oil palm crops as the main component for the integration. Integration is an alternative term used by MPOB to explain the practice of components diversification in an agricultural land.	√	
Expert 2	Agroforestry systems are the practice of integration between oil palm crops with other crops and livestock. The systems are considered as sustainable agriculture since the system produces more profit and diverse production than monoculture system.	√	
Expert 3	Agroforestry systems are an extensive definition that consists of various agricultural activities that involved other crops and livestock where oil palm crops are considered as the main component in the system.	√	
Expert 4	Agroforestry systems involve the integration between oil palm crops and other components, including plant materials and livestock. The systems are considered as sustainable agriculture if the integration is between oil palm crops and other species, excluding commodities and permanent crops.	√	√
Expert 5	The practice of integrating different crops in the oil palm cultivation must consider three aspects of sustainability, which are planet, people, and profit from the systems acknowledged as sustainable agriculture practices.	√	√
Expert 6	The implementation of agroforestry systems in oil palm cultivation must consider the selection of species and types of arrangement in order for the system to become successful, which will the benefit the smallholder farmers.	√	√
Expert 7	Agroforestry systems in oil palm cultivation are considered as a dynamic concept at which point the system changes according to the oil palm ages. As a whole, it is a combination of forestry and agriculture practices.	√	
Farmer 1	Integration in oil palm cultivation is done to avoid no monthly income during the early phase of oil palm crops so that the yield from the integration can accommodate and ensure the farmer to have a secure monthly income.	√	
Farmer 2	Integration is done in oil palm cultivation during the immature phase of oil palm crops. This is because the smallholder farmers are not getting any source of income during that phase. By integrating suitable species within the area of oil palm crops, it will secure the monthly income from other sources.	√	√

4.1.1 Oil Palm Crops as the Main Component

One of the main factors that contribute to the sustainability of agroforestry systems in oil palm smallholdings is oil palm crops as the main component of the systems. The concentration of the agroforestry components focuses on the agricultural crops as the main component and other plant species as a secondary component. The focus of the systems known as an agrisilviculture sub-system. Thus, the main component of agroforestry systems for oil palm smallholdings is the oil palm crops itself. The sustainability of the composition and arrangement was subjected to the ability of the systems to concentrate on oil palm crops as a central crop production and other plant species as alternative crop production. The extent to which participant mentions oil palm crops as the main component is observed from a response by the Expert 1 who works with the MPOB:

> *"Integration is how we are farming oil palm crops with other plant species. It is not necessary of forest trees. But, when we do the integration, there must be oil palm crops. So, the main component is oil palm".*

Another response by Expert 3 expressed a very detail description in the presence of oil palm crops as one of the agroforestry components in oil palm smallholdings. The need for integrating other plant species within the area of oil palm crops without affecting negative impact on oil palm crops were accepted as sustainable agriculture practices. He explained by relating the current concept of integration for oil palm cultivation:

> *"Based on the current concept of integration that has been practiced in oil palm context, the oil palm farm is the medium of the integration practices. That means we need the oil palm farm in order to practice agroforestry systems. Therefore, we have oil palm crops as the main components. Besides that, we have other components. For example, the integration of other components such as plant and animal species. But, the main agricultural production of this system must be from oil palm crops".*

The response suggests that the integration of plant species in oil palm smallholdings can be considered as sustainable agriculture practices if the integration are not giving negative impact on oil palm growth performance and yield production. It is clear that all agricultural crops are involving unproductive and productive phases during its growth process. Farmers' interest to integrate other plant species in their oil palm smallholdings engages with the unproductiveness of oil palm crops. As such the integration of plant species in oil palm smallholdings is mainly implemented during the immature phase (1 to 3 years) rather than mature phase (4 to 30 years). As the oil palm crops become mature after 3 years, the concentration on the crop production is normally back to agricultural crops of oil palm as it is the main component of the systems. As an officer who directly involved in the oil palm management, Expert 6 explained:

> *"Oil palm crops at the age of 4 years and above are not suitable to be integrated with other plant. The farm is only suitable for oil palm crops. If you go to any oil palm farm that has reached at this age, there was no more integration practiced in that farm area. The integration of other plant within the oil palm area only planted at the early stages of oil palm cultivation, which is under 3 years old".*

Similarly, a farmer since 1979, Farmer 1, when asked about integration processes answered most of the farmers only concentrate on other plant composition and arrangement during the unproductive phase of oil palm crops. His responses indicate that the consideration on oil palm ages is influencing the suitability of the agricultural land to be integrated with other plant species:

> *"I start to integrate other plant species in my farm during the replanting process. When the oil palm reaches at the age of 30 years, I will cut and replanted with new oil palm seedlings. During that stage, young oil palm crops were integrated with other plant species for 3 years. I will only concentrate on oil palm crops starting from the 4^{th} years of oil palm age. Besides, I also integrate my oil palm farm with other plant when I open a new land for oil palm cultivation. The integration only last for the first 3 years of oil palm planting".*

The study further reveals that integrating other plant species in the same unit of agricultural land will result in positive (+), neutral (0), or negative (-) interactions. These interactions influence the growth performance and yield production of oil palm crops as the main component of the systems. The present study by van Noordwijk and Hairiah (2000) was designed to determine the effect of agroforestry interaction that further lead to the subdivision of interactions, including mutualism, facilitation, commensalism, neutralism, parasitism, and competition.

However, negative interaction through unplanned agroforestry systems eventually becomes environmentally, socially, and economically unsustainable system. It leads to common sudden decline of agroforestry values to the surroundings and farmers. The effects of the interaction of the population by considering oil palm crops as the main components further determine the agricultural sustainability of the systems. Based on the observation and interview, the selection of plant composition either intentionally or accidentally integrated in oil palm smallholdings could create positive, neutral, or negative interactions as described in Table 4.1. Only four interactions are considered as sustainable agriculture practices as the interaction is not giving negative impact to the oil palm growth performance. Those are mutualism, facilitation, commensalism, and neutralism.

Table 4.1
Interaction between components of agrisilviculture sub-system in oil palm smallholdings

Interaction	Effect of the interaction		Nature of the interaction	Status of the interaction
	A	B		
Mutualism	+	+	- Interaction is favorable to both crops. - *Arachis hypogaea* acts as a nitrogen fixer through the communication between legume and Rhizobium that can improve the soil fertility. - Both crops are cultivated for food production.	Sustainable
	Oil palm	*Arachis hypogaea*		
Facilitation	+	0	- Interaction is favorable for oil palm, but not obligatory and *Areca catechu* is not affected. - Oil palm integration is considered favorable, but not obligatory during the immature phase of oil palm cultivation since it is an unproductive phase of oil palm crops. - Integration of *Areca catechu* using boundary planting system facilitates the agricultural land as the functional basis of protective purposes for windbreaks and benchmark of live fencing.	Sustainable
	Oil palm	*Areca catechu*		
Commensalism	+	0	- Interaction is obligatory for oil palm and *Mucuna bracteata* is not affected. - *Mucuna bracteata* is planted between the rows of oil palm due to its benefits in the enhancement of soil nutrient, efficient recycling of soil nutrients, enhancement of nutrient retention, and improvement of soil structure and root development, thus increased the oil palm yields.	Sustainable
	Oil palm	*Mucuna bracteata*		
Neutralism	0	0	- None of the crops affect other crops in cropland. - *Musa spp.* is planted between the rows of immature oil palm crops as alternative crops for additional source of income during an unproductive phase of oil palm crops.	Sustainable
	Oil palm	*Musa spp.*		
Parasitism	-	-	- Interaction is obligatory for oil palm and *Ganoderma* is inhibited. - *Ganoderma* appeared as pest and disease for oil palm crops that attacks the basal stem root, thus decreased the oil palm production through the decreased of oil palm crops.	Unsustainable
	Oil palm	*Ganoderma*		
Competition	-	-	- Both oil palm crops and fruit trees are inhibited due to similar structural character and strong competition for natural resources of soil, nutrient, and light.	Unsustainable
	Oil palm	Fruit tree		

4.1.2 Diverse Benefits

The diverse benefits of agroforestry systems can be achieved through the diversity of food, product, and services for alternative crop production of other plant species. It is the central purpose of agroforestry systems in producing diverse benefits without decreasing the quality of oil palm primary products. It shows that other plant species that integrated in oil palm smallholdings, especially during the immature phase is done to overcome the issues of no monthly income caused by unproductive of oil palm crops. For the first three years, farmers are actively integrating other plant species in their oil palm smallholdings mostly for socioeconomic benefits. Farmer 2 expressed his positive enjoyment with the implementation of agroforestry systems as the systems accommodate and ensure their monthly income during the immature or unproductive phase of oil palm crops:

> *"I have practiced integration in my oil palm farm approximately for 10 years. But it only last for the first 3 years of oil palm age. At that time, the oil palm crops still young and do not produce any fruit. A young oil palm crops have narrow canopy. So, I able to integrate other plant species between the rows of oil palm crops in order to get another source of income. As you know…in that age, there is no revenue that I can gain from the oil palm crops. So, I need to find an alternative to get a temporary income while waiting for the oil palm crops to produce yields".*

As a whole, the implementation of agroforestry systems is maximizing the utilization of land and minimizing the disadvantages of the oil palm crops during unproductive phase. The integration is seen as a driver in solving problems for a continuous source of income for full time smallholder farmers. The following response gathered from a word of Expert 2, who has experience in sustainable agriculture practices for oil palm cultivation. She stressed that the sustainability of agroforestry systems is valued due to its ability in producing additional income to the smallholder farmers:

> *"In oil palm industry, we only have 2 systems. First, the systems concentrate on oil palm itself. Second, oil palm integrated with other plant or animal species. This integrated system considered as one of the sustainable agriculture approaches that can be practiced in oil palm cultivation. The integration is to get more profit rather than only focus on oil palm revenue. The integration of other plant species in between the oil palm crops is considered as additional income. In the early stage while waiting for oil palm produce yields, it will be a source of income to the smallholder farmers".*

The underlying concept of the agrisilviculture sub-system is that plant species are allowed to be integrated in oil palm smallholdings during the immature phase of oil palm crops to generate a source of income for rural farmers (Suboh Ismail, Omar Idris, and Wahid Omar, 2010). While this concept is well accepted during the decline of oil palm price, in reality, the integration is kindly beneficial for full time smallholder farmers, which their source of income is solely from oil palm production. Based on the understanding, it can be suggested the implementation of agroforestry systems in oil palm smallholdings for diverse benefits is subjected to the new product diversification, enhancement of existing enterprises, resource protection, and conservation and beauty (Abel et al., 1997).

In this study, another important finding was that the farmers implement agroforestry systems for the profitability purposes from other farm enterprises. It includes alternative crop production of other plant species rather than focus on oil palm primary products especially during the immature phase. The diversification of products can be obtained from fruits, nuts, leaves, or woods of the plant species. The integration of various components is not only for direct cash values, but also beneficial in improving the soil quality of agricultural land through organic farming and farming system. A strong relationship between the integration of diverse components and agroforestry values in environment, social, and economic aspects has been reported in the literature.

4.1.3 Selection of Plant Species

Considering plant species as secondary components in this agrisilviculture sub-system, the sustainability of the system was influenced by the appropriate selection of plant species for integration purposes. Various types of plant species are suitable to be integrated within the area of oil palm smallholdings. It involves cash and cover crops include perennial crops, annual crops, grasses, and leguminous cover crops. The sustainability of plant composition is depending on the maturity status of the oil palm crops as well as types of arrangement planned and designed. A group leader of TUNAS Centre, Expert 1 described the relationship between plant species and its suitable arrangement that can be implemented by smallholder farmers:

> *"All short-term crops such as banana, peanut and pineapple are suitable, but the maximum duration is until the age of oil palm is 3 years. All short-term crops that will be harvested within 1 year are suitable to be integrated in triangular planting system".*

With mixture integration between oil palm crops and other plant species, oil palm crops are more suitable to be integrated with short-term cash and cover crops rather than long-term cash crops. This preference is mainly due to the structural character of the species that are not disturbing oil palm crops, thus successfully creating win-win situations through mutual interaction. Among the species are banana (*Musa spp.*), groundnut (*Arachis hypogea*), and pineapple (*Ananas comosus*). The interest to integrate short-term cash crops is strongly agreed by the Expert 6:

> *"We have a list of smallholder farmers who requested to replanting and do the integration in their oil palm farms. Most of the farmers have an interest to integrate banana species, while waiting for the oil palm yields".*

In contrast, long-term cash crops, including other commodity and permanent crops such as rubber (*Hevea brasiliensis*) and durian (*Durio kutejensis*) are unsuitable to be integrated in oil palm cultivation since it has firm and erect structural character.

The integration consequently disturbing the growth performance of oil palm crops by cause of strong competition between both crops. Both species were further neither oil palm crops nor commodity and permanent crops are resulting to negative interaction. Prior to this consideration, Expert 4 prevailed his explanation of the suitable selection of plant species leads to sustainable agriculture practices:

> "Okay, *sustainable agriculture…on the aspect of tree growth, it can be disrupted due to the different species of the same character. For example, the integration of oil palm and rubber. Both species are a major commodity crops. It will cause strong competition and the tree cannot grow well".*

Comparison on the sustainability of plant species to be integrated in oil palm smallholdings suggest that the yields of short-term crops can be harvested after 3 months of planting of the earliest period and not more than 13 months for the longest harvesting period. Meanwhile, long-term cash crops can only be harvested as early as 5 years after planting. It was found that the main objective of agroforestry systems among smallholder farmers is to gain quick profits from the alternative crops of plant species, especially during the immature phase of oil palm crops (Suboh Ismail, Omar Idris, and Wahid Omar, 2010). This is due to no source of income due to the unproductiveness of oil palm crops.

At the same time, the planting management of short-term crops is not required details and particular management as long-term crops. The findings also indicated that certain types of short-term crops are seen to have great market values and demand from local and international market. The present findings seem to be consistent with other research which found that short-term crops of banana and pineapple are favorably integrated within the rows of oil palm crops as the species readily available at all times since it is not seasonal fruit and highly demanded both in Malaysia and other countries (Ahmad Fauzi and Huda Farhana, 2006).

4.1.4 Types of Arrangements

Other than the selection of plant species for composition, the consideration on plant arrangement also recognized as a factor in contributing to the sustainability of agroforestry systems. Both aspects are closely related to each other since the suitability for plant composition indirectly influenced by arrangement and vice versa. The consideration on plant arrangement highlighted the importance of land use management by considering the oil palm ages either immature or mature phase. Besides integrating during the immature phase of oil palm crops, some farmers are found to continuously integrate other plant species until the mature phase of oil palm crops. It is depending on the selection of suitable plant arrangement.

For Expert 1, two types of arrangement involving triangular and double avenue planting systems are considered as the most suitable plant arrangement that can be implemented in oil palm cultivation. He stressed that the arrangement has become a standard planting system for those who interested to implement agroforestry systems in their oil palm smallholdings:

> *"Only 2 types of planting system are recommended by the MPOB which are triangular planting system and double avenue planting system. These 2 systems are commercial".*

Part of the reason why there are only two types of arrangement recommended by the MPOB is a limitation on the farm size. The average size of the oil palm smallholdings in the sites study is mostly between 1 to 6 hectares. With those small scales of farms, it limits the choice for selection of plant arrangement. The smallholdings can only be managed for triangular planting system and less suitable for double avenue planting system. This is because double avenue planting system required larger area of integration than triangular planting system. An area of 15.2 meters is needed for the interval of 2 rows of oil palm crops for integration purposes.

Thus, most of the smallholder farmers are only focusing on the integration by using the triangular planting system in order to maintain their main purposes of agricultural in oil palm crop productions. As a smallholder farmer that actively integrates other plant species in his oil palm smallholdings, Farmer 1 explained:

> *"We only have less than 6 hectares of oil palm land. So, we would rather use triangular than double avenue planting system. It is hard to find a farm that uses double avenue planting system. It has its own advantages and disadvantages. When we use a double avenue planting system, we can integrate up to 10 years of integration. But, triangular planting system only suitable for 3 years of integration. If we use double avenue, we will gain less revenue from oil palm cultivation…because much of the land area is already being used for the integration. Sometimes, there is a farmer who only does the integration for a few years…but they are using double avenue planting system. That land area will be abandoned until replanting of 25 years. For that reason, we would rather use the triangular planting system. Within 3 years we will focus on integration and after that focus on oil palm cultivation".*

A better understanding of this consideration encourages farmers to focus on the production of alternative crops during the immature phase, which is then continued with the concentration on oil palm production during the mature phase since oil palm crops can only be harvested after 2.5 years of planting (Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). The current study found that complementary integration between oil palm crops and other plant species produce positive or neutral interaction, since both agroforestry components play their high potential roles depending on the maturity of the oil palm crops. The agroforestry interaction of agricultural crops and alternative crops can provide various sub-division of positive and neutral interaction that will enhance the farm natural resources. Meanwhile, negative interaction occurred if the integration was implemented without considering the land-use management, maturity of oil palm crops, and arrangement of the components even though it will provide an aesthetic agricultural landscape setting.

Clearly, the definitions of agroforestry systems from different perspectives have established sustainable agriculture practices in terms of its understanding on oil palm crops as the main component, diverse benefits, and appropriate selection of plant species and types of arrangements. This result suggests that the implementation of agroforestry systems in oil palm smallholdings is not only for food and income production purposes, but it has underlay the advantages on the importance of agroforestry systems in relation to the principles of sustainability in sustainable agriculture practices. Such account indicates that the plant composition and arrangement in oil palm smallholdings can be valued for environmental quality, as well as its positive impacts towards socioeconomic of the smallholder farmers.

4.2 CONCEPT OF AGROFORESTRY SYSTEMS

Based on the understanding on the definition of agroforestry systems for oil palm smallholdings, agroforestry systems are defined as sustainable more than unsustainable agriculture practices. This was mainly due to four considerations which directed to the formulation of agroforestry concept. Those are associated technology adaptation, structural stratification, multiple output concepts, and code of practices. This section further analyzed the concept of agroforestry systems that focused on the oil palm smallholdings context.

4.2.1 Associated Technologies Adaptation

Agroforestry systems are a combination of agriculture and forestry technologies in one unit of agricultural land. The combination of agriculture and forestry activities has resulted the systems being acknowledged as man-made forestry or forest plantation.

Man-made forestry may involve the integration of diverse species in the crop commodities cultivation, including oil palm plantation, coconut plantation, and rubber plantation. The systems structurally involved diverse stratification of components with different growth habit, including trees, shrubs, and grasses. Thus, the systems are not a natural forest, yet it is considered as sustainable forest. This justification has been made by Expert 3 in which the more complicated the integration the more sustainable the systems:

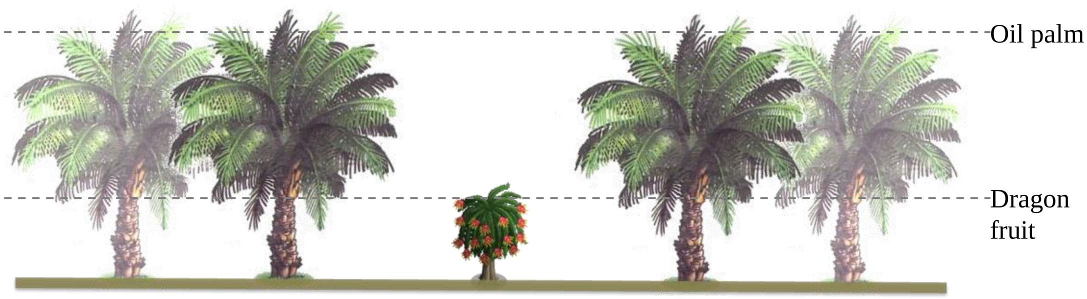
> *"Oil palm is the main system. It has a sub-system within it…annual crops, perennial crops, pastoral, or aquaculture. In other words, we use integration as an extensive definition. There is agriculture activities…there are forestry activities. The process involves agriculture and forestry practices. If we limit agroforestry only on crops and trees, it is not right. It does have more".*

Different point of view, but in similar idea of agroforestry systems, the systems are considered as a dynamic agricultural concept. It was due to the extra activities involved within the agroforestry landscape setting. For example, the practice of recreation as part of extra activities that can be done within the agricultural land, such as integrated animal-wildlife production and recreational systems. This remark emphasized that resource-oriented recreation for animal-wildlife integration must be based on natural resources that occurred in natural settings. As a result, agricultural land is not only purposely act as crop producer, but also as a place for relaxation through natural interaction of aesthetic and greenery agricultural landscape views, meditation of natural sounds, and fresh natural air quality. For an academician who has experience in bio-park concept of harmonious ecosystem, Expert 7 explained the value of integrating different components in one unit of agricultural land:

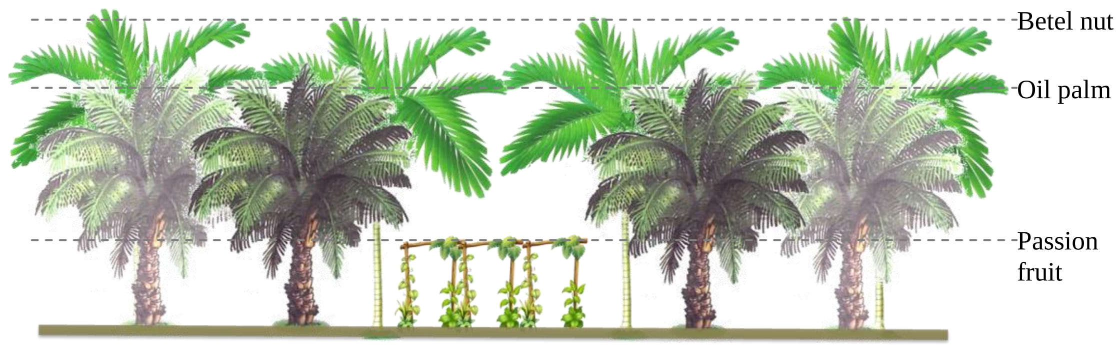
> *"Integration…this is related to the environment. It is a sustainable recreation. At the same time, you can conserve the plant and animal. The integration is not creating a zoo, but a biopark. The integration of various components in one unit of land is part of the elements of*

recreation. We don't necessarily adopt expensive or beautiful types of animals…it can be either wildlife animal or production livestock. But, in an agricultural context, the wildlife animals could accidently stay in that environment which, later on, creating an aesthetic value…the landscape is almost like a natural one".

While the experts acknowledged that agroforestry systems involved a combination of agriculture and forestry technologies and activities, most of the integration in oil palm smallholdings only implementing agrisilviculture sub-system instead of other sub-system. It shows that the smallholder farmers tend to adopt simple agroforestry systems rather than complex agroforestry systems. Figure 4.0 that derived from the observation in 10 oil palm smallholdings has identified that 9 oil palm smallholdings only integrating one or two plant species and another 1 oil palm smallholdings combine the integration between plant species and livestock. The farmers, perhaps, are viewed by the TUNAS Officer that it is a positive action done by the smallholder farmers in improving their oil palm smallholdings into more sustainable agriculture practices. More efforts are needed in educating the farmers starting from knowledge, understanding, and awareness.

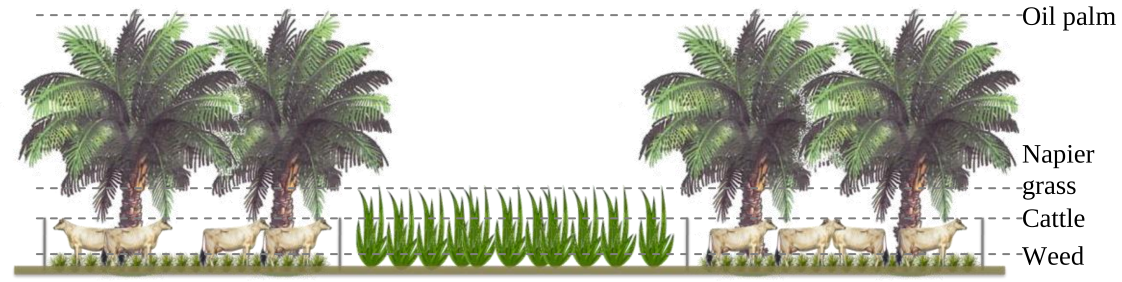


Integration with one plant species



Integration with two plant species

a) Simple agroforestry systems of one or two plant species integration in oil palm smallholdings



Integration between plant species and livestock

b) Complex agroforestry systems of the integration of two different components in oil palm smallholdings

Figure 4.0: Different between simple and complex agroforestry systems that has been practiced by the smallholder farmers in the 10 oil palm smallholdings

The study on the implementation of agroforestry systems in oil palm smallholdings show a fair of similarity in their components where the distinctive feature of the components involves an interaction between oil palm crops, other plant species, and livestock. This also accords with the literature, which showed that the components that involve in agroforestry systems are representing the combination of agriculture and forestry activities. The interaction of these two fields creates a dynamic agricultural concept based on the diversification of various growth habit integrated into these systems. It is supported in the study conducted by Harrington and Tow (2011) that different intensity, productivity, and capacity of continuous production in agroforestry systems make the systems become an extremely dynamic agroforestry landscape.

Kohli et al. (2008) and Straight (2011) further explained that agroforestry systems are considered as one of the sustainable approaches that deliberately integrates different types of plant classification. Ecologically, the interaction of both fields may provide mutualism, facilitation, commensalism, neutralism, parasitism, competition, and interference interaction (van Noordwijk and Hairiah, 2000). Diversity and complexity of its visible form have made agroforestry systems became a sustainable approach that suit to be integrated in oil palm smallholdings.

In terms of recreational activities, agroforestry systems are seen in agricultural landscape perspectives. Interaction of components in complex agroforestry systems involving oil palm crops, other plant species, and livestock may create ideal and natural landscape views. For example, the bio-park concept can be implemented using agroforestry systems in agricultural land. In parallel to Dahlan Ismail (2004) study of animals and wildlife recreation, bio-park recreation is depending on the availability of natural resources and settings. The role played by those three components is not only providing high quality food and dairy protein, but also sustaining balance ecosystem as well as greenery landscape settings. However, in this case, oil palm smallholdings are more appropriate to practice simple agroforestry systems due to small scale farm size and its position in focusing on the oil palm production. Other components are integrated for short-term additional income purposes, yet the values of recreational still can be perceived indirectly.

4.2.2 Structural Stratification

Referring to the definition of agroforestry systems, the implementation of the systems is regarded as being particularly important in the selection of plant composition and arrangement. The composition and arrangement offer diversity of agroforestry interaction through multiple uses of its vertical spaces. The interactions can be divided into aboveground and belowground interactions of oil palm crops and plant species that indirectly draw attention the animals to create a habitat in this system. Expert 7 expressed a strong connection to the implementation of agroforestry systems in oil palm smallholdings especially on the use of vertical spaces. This suggests that the selection for plant composition could be varied according to the oil palm age:

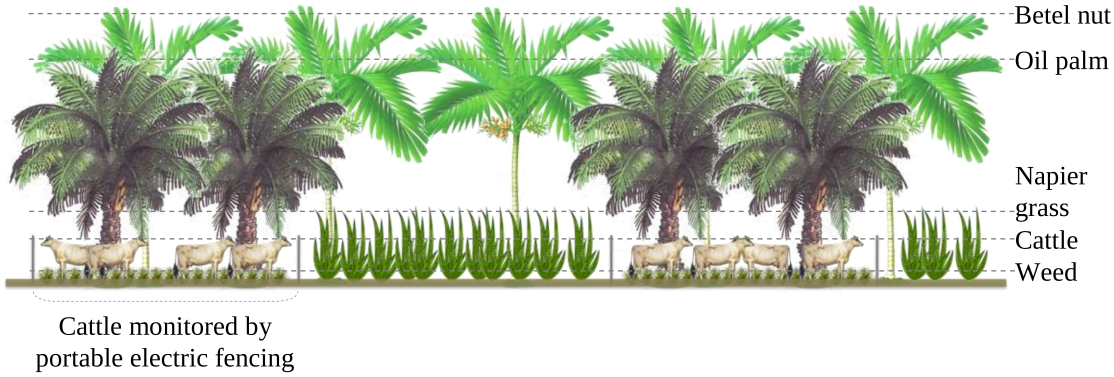
> *"Agroforestry systems are a dynamic concept in oil palm integration. The integration changes according to oil palm age. Oil palm crops are planted in triangular layout. So, the integration was done in the center of the layout…in rows, the plant species are planted between the rows of oil palm crops. Okay, the leaves of oil palm actually have a module. The diameter of the oil palm canopy will increase, according to age. Gradually, the canopy will overlap each other. This is basically the structure of oil palm…that appears in the module. So…the selection of species that suitable to be integrated may vary from short term to long term crops. It's also possible to allow cattle in this integration. If there are cattle, then it would be perfect. The bushes on the ground area can be sources of food for the cattle".*

The above comment highlight the agroforestry interaction in terms of vertical stratification is influenced by canopy shape, canopy foliage, and tree spacing. Oil palm crops have a rounded crown with dense canopies, but create dappled sunlight or light shade due to its canopy foliage. Meanwhile, the consideration for plant composition includes species growth rate, rooting pattern, and life cycle to create compatible and noncompetitive interaction. Therefore, smallholder farmers prefer to diversify their oil palm crops with other plant species by utilizing the area between the oil palm rows. A Farmer 1, who actively practiced complex agroforestry systems in his oil palm smallholdings had a very exciting feeling in explaining the important of having aboveground and belowground interaction. One of the most striking phrases indicates his enjoyment is as ‘upper level canopy could design the belowground environment’:

> *“I do the integration after the replanting process. I integrated the plant between the rows of oil palm crops. I do that integration for the first 3 years only. When the trees reach the level of maturity. I did not do anymore integration with plant. I change into cattle integration. Why?...during immature phase, the oil palm still young. The cattle can eat the young leaves. But when it reaches into mature phase, I allow the cattle to enter the farm. I can get 2 benefits in 1 time. Weeds in the ground area of the farm can be sources of food for the cattle…and at the same time the farm was clean. I did not need to use fertilizers. That was the upper level interaction to create the ground area environment”.*

Regarding the integration of livestock in oil palm smallholdings, Expert 3 has expressed a positive reaction on this situation. Based on his experience and supported by the observation in one oil palm smallholdings, it is proved that smallholder farmers are either accidentally or intentionally integrating livestock in their oil palm smallholdings (Figure 4.1). This is mainly due to functional basis provided and the selection of plant species integrated into the systems. It was found that livestock were only suitable to be integrated in the mature oil palm crops at the age of 4 until 30 years old. A closer understanding showed that the young shoots of oil palm leaves are easily accessed by the livestock as their source of food. As such, immature oil palm cultivation is mainly for plant integration.

a) Livestock accidentally integrated in oil palm smallholdings for natural weed control



b) Napier grass intentionally integrated in oil palm smallholdings as a source of food for livestock

Figure 4.1: Livestock is integrated either accidentally or intentionally by the smallholder farmers creates complex agroforestry systems with aboveground and belowground interaction

The findings reveal that smallholder farmers associated the components of oil palm, plant species, and livestock for domestic purposes. The integration of those components demonstrated accidentally or intentionally integration depending on the interest of the smallholder farmers. As proposed by Straight (2011), continuous integration of diverse components within its compatible arrangement may enhance the potential of simple into complex agroforestry systems. The predominance of complex agroforestry systems in this case consists of the ideas of four-story agriculture. Clearly, intensive management of the systems can be harvested into associated soil condition (underground level), livestock forage (ground level), alternative crops of plant species such as Napier grass (intermediate level), and fruits, nuts, and leaves of oil palm crops (upper level).

Based on the intensive management of four-story agricultural systems, the interaction can be divided into aboveground and belowground interactions. It refers to the systematic plant composition and arrangement by getting the right number of oil palm crops and plant species, the right species of plant to be integrated within oil palm crops, and the right arrangement to integrate oil palm crops and plant species in an agricultural land (Abel et al., 1997). In another study conducted by Jose, Allen, and Nair (2008), they claimed that the interactions of different level in agroforestry systems are guided by the utilization of light, water, soil, and nutrients. Accordingly, aboveground interactions involved light availability, competition, and facilitation; microclimate modification; weed density; and insect density. The roles were performed by the upper level components of betel nut and oil palm crops.

Shade provided by the oil palm crops influenced the intermediate and ground level light penetration. At the same time, it acts as shelterbelt for livestock through its role in microclimate modification. Meanwhile, belowground interactions knotted the interactions of soil structure modification; water availability, competition, and facilitation; and nutrient availability, competition, and cycling (van Noordwijk and Hairiah, 2000). This finding supports previous research into this brain area which links the diverse of components in creating a natural habitat for flora and fauna as well as improves the soil condition through belowground interaction. Thus, positive interaction of both aboveground and belowground interactions in biophysical processes and mechanism may enhance the productivity of agroforestry systems.

Understandably, the selection of valuable and subsistence plant composition for belowground is subjected to the shade and light tolerant. In addition to that, belowground plant composition must be able to tolerate partial shade, shorter than aboveground crops, and will not cause any damage to the aboveground crops in both growth performance and harvest production. Potentially, there are ways in which farmers could benefit from the shadier environment through reduction of evapotranspiration, moisture conservation, crop protection from winds, and suppression from the invasive weed problem.

4.2.3 Multiple Output Concepts

The oil palm crops offer oil palm primary products and by-products comprise of palm press fibre, palm kernel cake, oil palm fronds, and empty fruit bunch. In the interim, the idea of integrating other plant species in oil palm smallholdings is intentionally practiced for alternative crop product and food sources for local people. As oil palm crops are the main component in these systems, the concern of the integration is to diversify the crop production from other plant species without decreasing the fresh fruit bunches quality of oil palm crops. The benefits of agroforestry systems as sustainable agriculture practices are due to its advantages on multiple output concepts. Rather than focusing on the production of oil palm primary products, agroforestry systems also contributed to other crops and food production thus increase farm productivity. Similarly, Expert 3 referring to the indication of agroforestry systems as a combination of agriculture and forestry practices, the systems produces at least two or more crop production:

> *"The integration is done in order to get more than one profits…not only in socioeconomic perspectives, but also in environmental benefits. For example, some farmers may interest to integrate soy beans or groundnuts. Both crops can produce revenue through nuts yield…apart from that, the integration is indirectly supply the nitrogen sources to the agricultural land".*

From other point of views, the waste from oil palm fronds and empty fruit bunch were utilized as a source of food for the livestock. The waste was processed into ruminant feed as pellets. As a farmer who also integrates cattle in oil palm smallholdings, Farmer 1 shared his opinion on the oil palm-plant-livestock integration:

> *"During the immature phase, I integrate banana species…later on when the oil palm reaches mature phase, I plant Napier grass as a source of food for cattle. I also do integrate the cattle in my farms as the cattle will eat the weeds in that farm. Other than that, the waste from oil palm is processed into pallets to be used as their feeds. I do have the machine to process that waste".*

The outputs are not only on oil palm primary products and alternative crop products, but also in secondary products of meat and dairy from livestock. The concept was positively affected the farm productivity of the oil palm smallholdings (Figure 4.2).

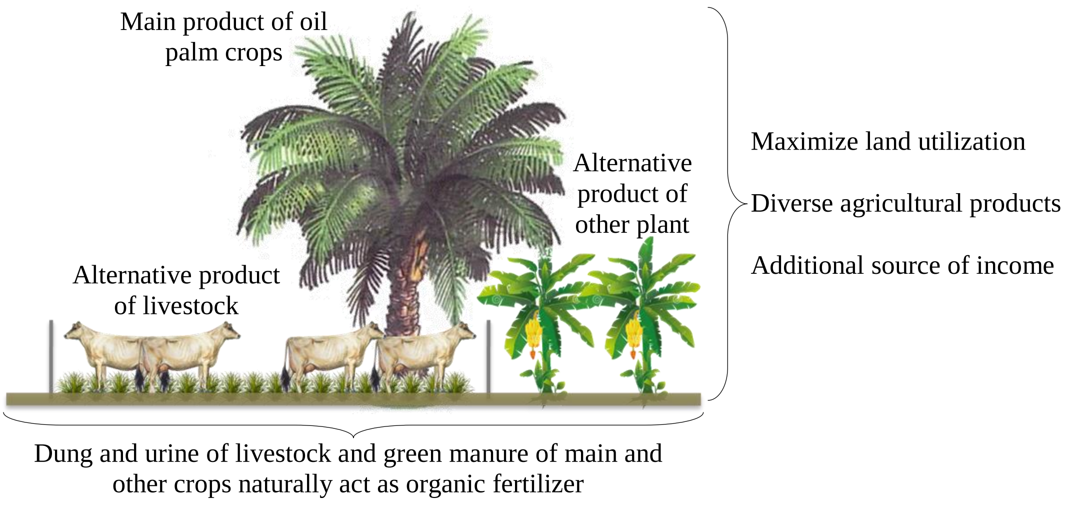


Figure 4.2: Multiple output and benefits can be gained from the integration of various components in one unit of oil palm smallholdings

The implementation of complex agroforestry systems with more than two outputs encompasses livestock were influenced by the availability of belowground vegetation within the rows of oil palm crops (Ayob and Hj Kabul, 2009). The availability of weeds that can be utilized as a source of food for livestock increased the practicality of animal integration in oil palm smallholdings without depending solely on processed oil palm waste. As the study shows that the integration of livestock produce another output of agroforestry systems, the integration was done intentionally by the farmers during the mature phase of oil palm smallholdings. Matured oil palm crops that produce a wider canopy than immature oil palm crops form shade tolerant thus naturally reduce the heat problems of the animals (Dahlan Ismail and Kamal Hisyam, 2014).

The findings also have shown that positive and neutral interactions between the agroforestry components are considered as part of a broader attributes of multiple output concept in agricultural sustainability. The underlying reason is that the interactions provide facilitation on environmental aspects to increase agricultural land values by improving the nutrient cycle, litter production, mulch, nitrogen supply, reduces weeds, reduce pest and disease, effects on microclimate, and reduce erosion (van Noordwijk and Hairiah, 2000). While these interactions create positive and environmentally friendly situation, it simultaneously forms win-win situation in which the integration will not disturb the growth performance of oil palm crops.

4.2.4 Code of Practices

The practiced of agroforestry systems that response to the sustainable agriculture practices is rooted in the principle of sustainability. More importantly, the consideration of 3P has been documented in the manual book of Code of Good Agricultural Practice for the Oil Palm Estates and Small Holding that published by MPOB. Expert 5 when requested for her reaction on how to define sustainability in sustainable agriculture practices. She replied in quite interesting opinion:

> *"The sustainability can only be acknowledged if the farmers are practicing balance aspects of the planet, people, and profit (3P) in the systems. The planet is elaborated through the importance of taking care of the environment, including soil, water, air, plant, animal, and energy. The evaluation of people is on the farmer's awareness in taking care of their safety and the improvement of their basic quality of life which are closely related to the profit aspect".*

Similarly, the idea is elaborated by the Expert 4 on the environmental perspectives and its simultaneous impact on socioeconomic aspects. He linked the idea with the application of chemical fertilizers in oil palm farms:

> *"When we talk about environment, there are many things that can be linked to this sector. For example, chemical fertilizers and pesticides. But now we encourage smallholder farmers to minimize the utilization of chemicals. We encourage them to use of other technology such as the utilization of organic fertilizer. Actually, we must use chemical fertilizer. At least 40%. The smallholder farmers will use chemical fertilizer, but we will control the limit usage. We will inform them on how much they can use chemical fertilizer and how much they need to use organic fertilizer. Therefore, it is important to have sustainable agriculture practices in oil palm cultivation. Now, we are in the process to achieve RSPO standard. So it is important to be able to meet the necessary standards for all cycles. Meaning that the cycle of oil palm product, starting from the early stage of planting and nursery. At this stage, we are adopting GAP. If farmers meet the criteria of GAP, we will value and pay based on premium prices set by the RSPO or GAP standard. So, the price is better for the smallholder farmers who practices GAP".*

A strong sense of sustainability in agriculture sector was actually expressed through the implementation of agroforestry systems. Agroforestry systems are highly encouraged and assisted for oil palm smallholdings as one of the criteria of good agricultural practices (GAP). Smallholder farmers who are registered with MPOB and practicing agroforestry systems will be receiving an assistance and support from

TUNAS Center of MPOB. The TUNAS Center is responsible to provide continuous financial assistance, knowledge and advice, and moral and personal advice to the farmers that have an interest in implementing agroforestry systems in their oil palm cultivation.

For example, the practices of fertilization involved separation of fertilizer usage for both oil palm crops and plant species. The following practices need to be scrutinized since different species acquired different balance fertilizer that suit with the nutrient usage. This consideration may avoid nutrient competition among the crops for better growth performance. In addition, the importance of practicing GAP depends heavily on the smallholder farmers who implement agroforestry systems widely in their oil palm smallholdings. By referring to the oil palm-livestock integration, the animal manure was recycled as organic fertilizer to fertile the agricultural land naturally. This practice is not only reducing the cost of fertilizer, but also improving the environment in a natural way.

In the interim, code of practices through GAP is not only focusing on the environmental aspect, but also involving the consideration of people and profit. Closer inspection of the farmer and worker welfare is among an important aspect in creating sustainable agricultural practices. By applying best management practices in pesticides and fertilizer storage and handling, it also remarked as one of the points in GAP as people are among the consideration that need to be considered in the principles of sustainability. As an example, Farmer 1 expressed his concern on the safety aspects, especially during pesticide and chemical fertilizer storage and handling:

> *"My workers are provided with knowledge and training in the safety procedures and handling equipment to avoid any damage and incident to themselves".*

Consistent with previous research, Khalid Haron and Chan (2011) concluded that the consideration of applying GAP provides a solution to various environmental issues, including global warming, loss of biodiversity, water pollution, soil erosion, and land-use change. In this case, farmers' knowledge, understanding, and awareness on the importance of practicing GAP have largely giving positive impact on a global level. In this scale, smallholding farms were played its role as a stepping stone in creating a sustainable agricultural land by following an appropriate code of practices as suggested by the governmental organizations. Furthermore, the encouragement of practicing GAP is in line with the Code of Practices on Good Agricultural Practices and RSPO that are referred by the MPOB in their oil palm operations (Khalid Haron and Chan, 2011).

4.3 ENVIRONMENTAL AND RURAL VALUES OF AGROFORESTRY SYSTEMS

The agricultural sustainability on the implementation of agroforestry systems in oil palm smallholdings can never be achieved without understanding its underlying dynamic concept that comprises both human and natural resources. This is mainly due to its rural values toward smallholder farmers who always faced problems with monthly income instability. In addition, the diversification of agroforestry components also contributed to environmental values, including soil, water, air, plant, animal, and energy. Although the study has so far defined the consideration factors of agroforestry systems to be acknowledged as sustainable agriculture practices, it is not sufficient enough to understand its significance values in the details. Therefore, this section is undertaken to study the values of agroforestry systems that can be divided into hospitable natural habitat that involve environmental values and rural community enhancement for socioeconomic values.

4.3.1 Agroforestry Systems for Hospitable Natural Habitat

The responses shown in this sub-section indicate the range and values of species in agroforestry systems are seen as very attractive, thus further provide hospitable natural habitat for flora and fauna. The agroforestry interactions can be seen from side to side when oil palm crops are creating a shelter belt for livestock based on facilitating interaction. Meanwhile, the waste and manure of livestock can be used as organic fertilizer for oil palm growth and the weeds around oil palm crops become a source of food for livestock. These livestock also considered as a natural weed control for oil palm crops to decrease nutrient competition among oil palm crops and weeds. An Expert 7 who has done much research on animal integration expressed his deep sense of satisfaction on sustainability if the oil palm farms integrate with various agroforestry components:

> *"Integration is not only for economic benefit…not only for social benefit…but more importantly for all benefits of environmental, social, and economic. This is what we call sustainability…barakah. The barakah is actually sustainable. Barakah for the Muslim. This is the reason why it is good to have various components in the integration. For example, immature oil palm crops have a small canopy…the area can be planted with other plant as it can receive enough sunlight and nutrient. For the mature oil palm crops, it could provide shade to the livestock. An interesting strata of agricultural land is not only become habitat for the other plant and animal, but also could be developed as a recreational area…natural recreational area. People will love this".*

The majority of smallholder farmers are seen associated with the integration of various plant species by conveying their sustainable agriculture practices in their oil palm smallholdings. As Farmer 1 shared his experience on the best way to diversify the values of agroforestry systems, he determined that it can be achieved through the integration of livestock in oil palm smallholdings. He suggests that the implementation of plant species in oil palm smallholdings through the agrisilviculture sub-system is indirectly influenced the implementation of the agrisilvopastoral sub-system by adding animals as one of the components.

> *"Personally, I do integrate Napier grass as a source of food for the cattle. At the same time, I also integrate banana for short-term additional income. This area I plant Napier grass, meanwhile in this area I plant banana. Napier grass for the cattle and banana for the market. I also do allow my cattle to enter the mature oil palm farms. They can clean up the weeds in the farms".*

Physically, agroforestry systems are considered as a natural way in increasing the amount of flora and fauna through the planned and designated system. Plant composition and arrangement were planned and designated since in the planning stage to ensure the sustainability of the integration. In accordance to suitable composition and the arrangement, different levels of vertical stratification were created and found to be parallel with a study conducted by Rosli Awaludin and Shariffhuddin (2003). The study confirmed that a good weed management and systematic integration of livestock is actually creating habitat and beneficial to each other agroecosystem. In sum, the presence of trees, shrubs, and cover crops in aboveground and belowground level within oil palm smallholdings thus enhanced the diversity by providing shelter and habitat for diverse species of flora and fauna.

In order to understand the values of agroforestry systems in providing a natural habitat for flora and fauna in detail, Khalid Haron and Chan (2011) postulated that the integration of diverse agroforestry components, including plant, livestock, and microorganisms in the oil palm smallholdings increased the agricultural values through its functional diversity. Functional diversity in agroforestry systems involves the ecological interaction between species that influence the ecosystem functioning, including ecosystem dynamics, stability, productivity, and nutrient balance (Tilman, 2001). The flora and fauna in agroforestry systems can be conserved through its tolerance for a certain level of disturbance, reduce the rates of natural habitat conversion, create corridors connectivity between agricultural and natural habitat, and conserve the ecosystem through reduction of erosion to prevent habitat degradation and loss. Therefore, this study found that agroforestry systems become a fundamental planned and designated habitat for flora and fauna conservation since the systems naturally imitate the ecosystem of natural forest. Prior studies that have noted the earlier practice of agroforestry systems by imitating natural forest has been reported in the literature.

4.3.2 Agroforestry Systems for Rural Community Improvement

Back to the history, agroforestry systems were first implemented in Asia through the *taungya* method in Myanmar. The wealthy owner of teak plantation allowed their poor workers to grow annual crops between the rows of teak plantation for their daily use and additional income purposes. Later, these systems were developed in response to the issues of hunger and ecological degradation. This provides an opportunity of plant species, one of the three components for agroforestry systems, integrated within oil palm crops that can be selected for high economic value, or low economic value but create high aesthetic value depending on its arrangement.

The interest among smallholder farmers to implement agroforestry systems in their oil palm cultivation is influenced by its ability to provide additional income, low investment cost, and good marketing values and demand. This view is discernible from the words of Expert 4:

> *"There are 3 factors that influenced smallholder farmers to integrate plant on their farms. First, to add an additional income. Second, because of interest…interest to plant cash crops. Third, they were encouraged by the project group, support from the Department of Agriculture, which in turn allows them to do this crop integration. The supports are in terms of financial assistance and agricultural inputs. Those factors encourage them to implement integration".*

Similarly, Expert 1 responded that some of the smallholder farmers have an attempt to integrate other plant species in their oil palm smallholdings after receiving some information from the government officers:

> *"One of our responsibilities is to give information and encourage the smallholder farmers to do the integration. We also continuously provide advice and knowledge to new smallholder farmers and helping in obtaining financial assistance for those who are needed. Some of the farmers who earnestly do the integration have become successful. They happy, we are happier since we are able to help them".*

Apart from that, the successfulness of smallholder farmers in practicing agroforestry systems is indebted to the effort made by the TUNAS officer. Smallholder farmers who are registered with the MPOB have high priority in getting an advice and knowledge from the MPOB officer. The advice and knowledge is not limited to the technical aspects of agricultural planting design, but also include tangible and intangible aspects involving financial assistance and moral and personal support. Other than that, through continuing advice from the officer, smallholder farmers have gradually improved their technical skills in agricultural planning and design in response to the effort for creating sustainable agriculture practices.

Overall, the efforts made by the experts in these fields of study are to enhance the rural quality of life for a better settlement. These findings confirm through the definition and concept of agroforestry systems that the diversification of integration in oil palm smallholdings could provide varied benefits and produce multiple output concepts. It is evident from the study conducted by Sharashkin, Gold, and Barham, (2005) that most and foremost, the main reason why smallholder farmers integrate alternative crops in their oil palm smallholdings is their ability for self-reliance by producing multiple outputs in one agricultural land. Garrett, Walter, and Godsey (2011) further demonstrated that the integration of various species in an agricultural land is not extraordinary for people through conventional or unconventional purposes. Rather, the systems are stand-alone ordinary sustainable agriculture practices that are designated as a source of income, visual appearance, conservation, and environmental values (Nair, 2011).

Moreover the findings also agreed that those advantages can be obtained from positive and neutral interaction of different structural stratification of the components. Clearly, regardless of the values, agroforestry systems have something to offer for rural community improvement in terms of source of income and landscape setting thus acknowledged as a driver for poverty alleviation. The impact of product diversification of agroforestry systems significantly improves livelihoods of poor rural farmers (Ahmad Fauzi and Huda Farhana, 2006), as well as enhanced food production and security especially for food and cash crop production (Oxfam Case Study, 2011). These have been seen as an opportunity for low income farmers who solely depend on oil palm production as the main source of income which consequently leads to food and economic security.

As an example, although only a few farmers are interested to integrate other plant species in their oil palm smallholdings, but there are some farmers who started to implement agroforestry systems earnestly. Surprisingly, these farmers intentionally approached other farmers to guard their unproductive immature oil palm crops since other plant species can only be planted in the first three years of an immature phase of the triangular planting system. This case illustrated the brightness of agroforestry systems through its potential in increasing the diversification of product, economic stability, and rural skills. As a whole, it is related to the one of the objectives of agroforestry systems in the NAP3 that various components can be integrated within the area of agricultural land for maximum utilization and returns on the same unit of land (Faridah Ahmad, 2001).

4.4 SUMMARY

Agroforestry systems are known as a new name in traditional farming practices that combine agriculture and forestry activities in the same unit of agricultural land. It is adopted preferentially by local smallholder farmers as it emphasizes intensive component management to provide balance environmental protection and food production. One characteristic of agroforestry systems is that it generates complimentary resource-capture of ecological and economic interaction of the components. The interaction is designed and promoted as a sustainable approach in land management by maximizing the positive and neutral interaction between agricultural crops and plant species. Elaboration on the overriding interaction of ecological and economic in sustaining the agricultural sustainability of agroforestry systems is discussed through its definition, concept, and environmental and rural values.

In sum, the evolution and development of agroforestry systems from old agricultural practices have been acknowledged as sustainable agriculture practices. The systems have a special attribute of associated technologies adaptation of agriculture and forestry field, structural stratification of aboveground and belowground interaction, multiple output concepts from diverse interaction of components, and the application of GAP in code of practices. Based on the responses and analyses of previous documents, these attributes were considered as a path in sustaining the rural smallholder farmers, as well as the environmental values. The advantages of agroforestry systems are not only in environmental aspects of providing a natural habitat for flora and fauna, but also play an important role in rural community improvement.

CHAPTER FIVE

FINDINGS AND DISCUSSION 2: IMPLEMENTATION OF AGRISILVICULTURE SUB-SYSTEM AMONG SMALLHOLDER FARMERS

5.0 INTRODUCTION

This chapter presents the findings gathered from interviews and observation techniques and further discussed with document analysis. It answers research objective 2 of the study on how to integrate oil palm crops and other plant species in terms of its composition and arrangement. The findings focus on the result of the implementation among smallholder farmers in the selected 10 sites study. It identifies and discusses the participant's experiences from the implementation of the agrisilviculture sub-system in oil palm smallholdings. The responses enable the researcher to determine the most suitable plant composition and arrangement for oil palm smallholdings.

Accordingly, the chapter starts with the overall findings on the plant composition and arrangement of the agrisilviculture sub-system in Section 5.1. The suitable plant composition and arrangement that contributes to the agricultural sustainability for oil palm smallholdings is discussed in Section 5.2. Section 5.3 explains the unsuitable plant composition and arrangement that can be defeated into suitable plant composition and arrangement. Later on, Section 5.4 and 5.5 discussed preferred plant composition and arrangement, and environmental benefits of the plant composition and arrangement for oil palm smallholdings. Lastly, the chapter ended with summary in Section 5.6.

5.1 PLANT COMPOSITION AND ARRANGEMENT OF AGRISILVICULTURE SUB-SYSTEM

This section focuses on the composition and arrangement involved in the implementation of the agrisilviculture sub-system among smallholder farmers in oil palm smallholdings. First and foremost, the findings reveal that oil palm crops are normally planted in triangular rather than square layout (Figure 5.0). In contrast, other commodity crops such as coconut and rubber trees are regularly planted in a square layout. Optimum crop density and uniform sunlight penetration has motivated Farmer 2 to share his view on why oil palm crops are planted in triangular layout is vitally important:

> *"Why do we plant oil palm in triangular layout instead of square layout? Most of people planted coconut tree in square layout, but we plant oil palm in triangular layout. It is to get enough sunlight penetration. Second, to increase oil palm crop density".*

Along these lines, the percentage of canopy overlapping and light obstructing could be reduced by applying triangular layout. In this layout, trees are planted in a midway instead of opposite lines. The response from the Expert 1 further explained that the number of crops planted using triangular layout was 15% higher than square layout. He further emphasized that this layout becomes a standardized layout for all arrangements in oil palm smallholdings:

> *"For every 100 palms that are planted in square layout will be increased more 15 palms when we switch to triangular layout. It means that it will go up 15%. The crop density between triangular and square layout are different, even though planted in similar hectares of agricultural land area".*

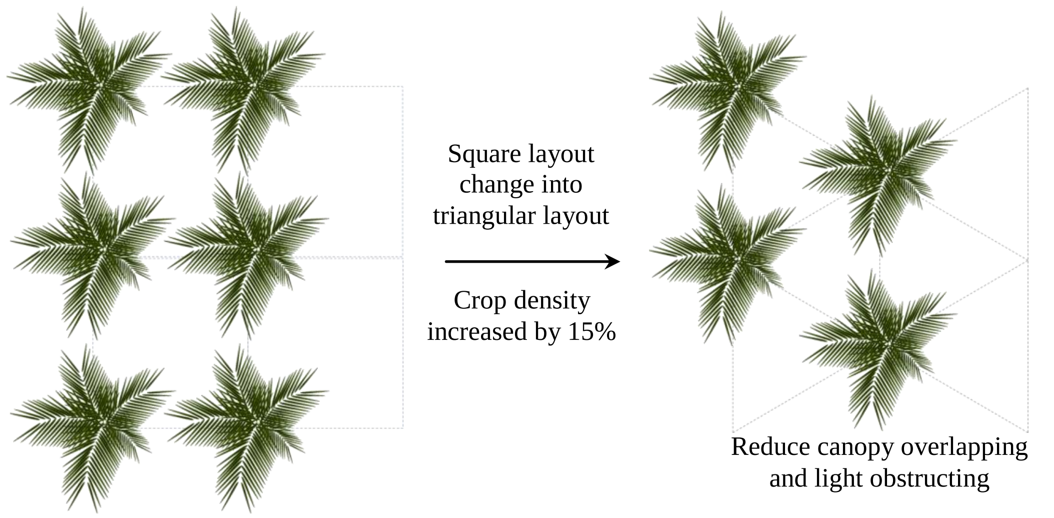
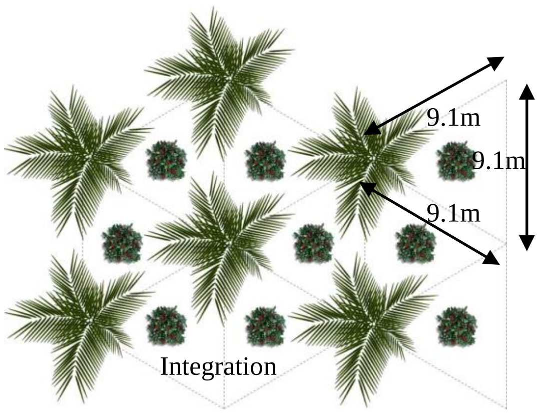


Figure 5.0: Oil palm crops are normally planted in a triangular layout for high crop density and sunlight recipient

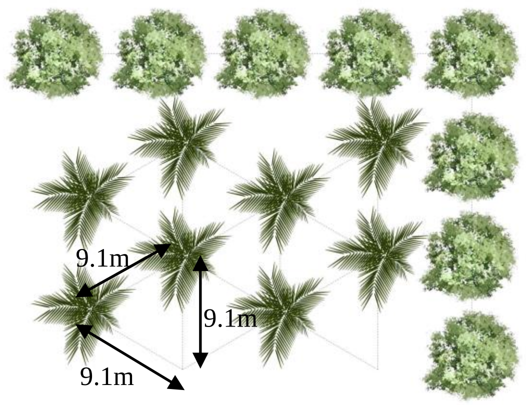
While the oil palm crops are planted in triangular layout, a total of 50 plant species and 3 arrangements were recorded during data collection (refer Appendix C). The plant species ranged from cash crops (perennial and annual crops) and cover crops (leguminous cover crops and grasses) species. Meanwhile, the arrangement involved triangular, double avenue, and boundary planting systems. The integration of plant species presented by 25 species of perennial crops, 13 species of annual crops, 10 species of leguminous cover crops, and 2 species of grasses. In the meantime, the arrangement for the integration involving 21 species for triangular planting system, 16 species for double avenue planting system, 2 species for boundary planting system, and another 11 species can be integrated either using triangular or double avenue planting system. The arrangement, expressed by Expert 1, the spacing distance is significantly different depends on soil fertility yet planted in similar layout (Figure 5.1):

“Oil palm is planted in triangular layout. It had 3 densities. The density depends on soil types. If the soil is fertile, we do a little planting. It is because oil palm crops are vigorous trees. If you planted a lot in fertile soil, its mean that you planted it very close each other. It will cause low yield production of the oil palm crops”.



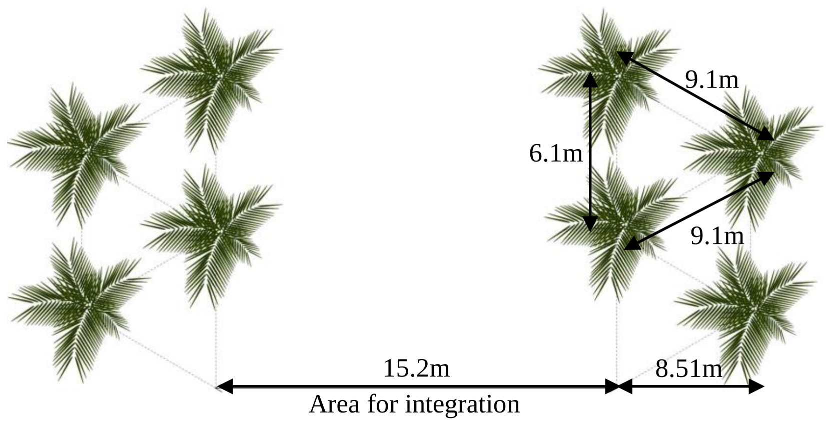
Other crops are integrated in the inter-rows of the oil palm crop with or without measurement

a) Triangular planting system



Integration at the boundary of the oil palm farm

b) Boundary planting system



Other crops are integrated within the area of 15.2 meters after each 2 rows of oil palm crops

c) Double avenue planting system

** Spacing distance and oil palm crop density*

Fertile soil:	*Less fertile soil:*	*Infertile soil:*
Spacing distance of 9.1 x 9.1 x 9.1 m	*Spacing distance of 8.8 x 8.8 x 8.8 m*	*Spacing distance of 8.5 x 8.5 x 8.5 m*
Crop density is 138/hectare	*Crop density is 148/hectare*	*Crop density is 159/hectare*

Figure 5.1: The arrangement of the agrisilviculture sub-system in oil palm smallholdings involves (a) triangular planting system, (b) boundary planting system, and (c) double avenue planting system

The spacing distance of oil palm crops refers to the soil fertility of the agricultural land. It will influence the oil palm crop density as shown in Figure 5.1. Fertile soil cannot be planted with many oil palm crops because of its character as vigorous plants. The crops tend to compete each other to gain the most advantages from the farm natural resources, especially in fertile soil. It will then affect the yield productivity, where fruits are not produced in good quality as the fruits do not get the proper amount of nutrient from the soil. In contrast, agricultural land with infertile soil such as peat soil needs to be planted with closer spacing distance due to its low bulk density, soil depletion, and sedimentation. More nutrients from agrochemical products are needed for soil renovation and improvement. It follows that the more fertile the soil, the wider diameter of the spacing distance, but fewer crop density per hectares.

Among 50 plant species, only 10 plant species were integrated in 10 oil palm smallholdings (Table 5.0). Most of the oil palm smallholdings are integrated with cash crops with the triangular planting system rather than cover crops, and some of the plant composition involves more than one species thus create a complex agroforestry system. Based on the observation, there are differences in documentation and practices done by the previous study and smallholder farmers in terms of plant arrangement. There were some evidences for how the arrangement is done in oil palm smallholdings as explained by Expert 4:

> *"There are 2 types of arrangement recommended by the MPOB. One, triangular planting system. Two, double avenue planting system. However, as I have monitored the oil palm farms, some smallholder farmers interested to use boundary planting system. They plant betel nut as a border for their oil palm area. They do not use artificial fence…but they use natural fence. That was something new as MPOB did not include this planting system as standard arrangement. It depends on the purpose…the function".*

Table 5.0
Plant composition and arrangement implemented in 10 oil palm smallholdings

Smallholding	**Plant composition**		**Plant arrangement**			**Spacing distance**	**Plant density (trees ha^{-1})**	**Layout (Figure)**
	Cash crop	**Cover crop**	**Triangular**	**Double avenue**	**Boundary**			
1	Oil palm + *Pisang susu*		√			Oil palm: 9.1 m x 9.1 m x 9.1 m *Pisang susu:* 2.4 m x 2.4 m	Oil palm: 138 palm ha^{-1} *Pisang susu:* 1,344 trees ha^{-1}	Figure 5.17 Figure 5.18
2	Oil palm + *Pisang berangan*		√			Oil palm: 9.1 m x 9.1 m x 9.1 m *Pisang berangan:* 2.4 m x 2.4 m	Oil palm: 138 palm ha^{-1} *Pisang berangan:* 1,344 trees ha^{-1}	Figure 5.13 Figure 5.14
3	Oil palm + Dragon fruit			√		Oil palm: 6.1 m x 9.1 m x 15.2 m Dragon fruit: 3 m x 3 m	Oil palm: 136 palm ha^{-1} Dragon fruit: 300 trees ha^{-1}	Figure 5.7 Figure 5.8
4	Oil palm + *Pisang tanduk*		√			Oil palm: 9.1 m x 9.1 m x 9.1 m *Pisang tanduk:* 2 m x 2 m	Oil palm: 138 palm ha^{-1} *Pisang tanduk:* 1,575 trees ha^{-1}	Figure 5.15 Figure 5.16
5	Oil palm + Agarwood			√		Oil palm: 6.1 m x 9.1 m x 15.2 m Agarwood: 2 m x 2 m	Oil palm: 136 palm ha^{-1} Agarwood: 866 trees ha^{-1}	Figure 5.11 Figure 5.12
6	Oil palm + Betel nut + Passion fruit			√	√	Oil palm: 6.1 m x 9.1 m x 15.2 m Betel nut 1.2 m x 1.2 m	Oil palm: 136 palm ha^{-1} Betel nut: -	Figure 5.2 Figure 5.3 Figure 5.5

						Passion fruit: 3 m x 1.5 m	Passion fruit: -	Figure 5.6
7		Oil palm + Napier grass		√		Oil palm: 6.1 m x 9.1 m x 15.2 m Napier grass: 0.1 m x 0.1 m	Oil palm: 136 palm ha^{-1} Napier grass: -	Figure 5.9 Figure 5.10
8	Oil palm + *Pisang berangan*		√			Oil palm: 9.1 m x 9.1 m x 9.1 m *Pisang berangan:* 2.4 m x 2.4 m	Oil palm: 138 palm ha^{-1} *Pisang berangan:* 1,344 trees ha^{-1}	Figure 5.14 Figure 5.15
9	Oil palm + *Pisang berangan* + *Pisang rastali*		√			Oil palm: 9.1 m x 9.1 m x 9.1 m *Pisang berangan:* 2.4 m x 2.4 m *Pisang rastali*: 2.4 m x 2.4 m	Oil palm: 138 palm ha^{-1} *Pisang berangan:* 1,344 trees ha^{-1} *Pisang rastali*: -	Figure 5.20 Figure 5.21
10	Oil palm + *Pisang berangan* + *Pisang rastali* + *Pisang emas*		√			Oil palm: 9.1 m x 9.1 m x 9.1 m *Pisang berangan:* 2.4 m x 2.4 m *Pisang rastali*: 2.4 m x 2.4 m *Pisang emas*: 2.4 m x 2.4 m	Oil palm: 138 palm ha^{-1} *Pisang berangan:* 1,344 trees ha^{-1} *Pisang rastali*: - *Pisang emas*: -	Figure 5.19 Figure 5.21

Looking across participant's responses described in the findings, it can be suggested that from the observation, most of oil palm smallholdings is applying triangular rather than double avenue planting system. By applying the triangular planting system in fertile soil, the crop density is estimated at 138 palms ha^{-1} for spacing distance of 9.1 meter x 9.1 meter x 9.1 meter. Howbeit, oil palm crops were planted at a spacing distance of 6.1 meter x 9.1 meter x 15.2 meter for double avenue planting system with crop density of 136 palms ha^{-1}. A very strong evident was shown from the observation that all oil palm smallholdings in sites study applied a spacing distance for fertile soil. It is mainly due to the farmer's effort in improving the soil condition through intercropping practices of agroforestry systems.

The result has confirmed that the application of triangular layout for oil palm crops was intertwined between holding capacity and crop density. Plant holding capacity was subjected to the light penetration of canopy conditions and available area for plant composition that involves the immature and mature phase of oil palm crops. The light penetration for immature phase is 50 to 98% (1 to 3 years), while mature phase only 10 to 55% (4 to 30 years). Meanwhile, the available area for plant composition is decreasing as the oil palm crops become mature. This influential factor was further influenced the selection of plant composition and arrangement to be implemented in oil palm smallholdings. Based on the result from 10 oil palm smallholdings, Table 5.1 further present the findings on the plant composition, plant arrangement, spacing distance, holding capacity, and crop density that can be referred by smallholder farmers to be implemented in their oil palm smallholdings. However, suitable arrangement only involves triangular and double avenue planting systems as the system has been proven recommended by the MPOB.

Table 5.1

Plant composition and arrangement with its holding capacity and crop density that can be referred by smallholder farmers for their oil palm smallholdings

Plant species	Spacing distance	Holding capacity										
		Triangular planting system					Double avenue planting system					
		Immature			Mature		Immature			Mature		
		Light (50-98%)			Light (10-55%)		Light (50-98%)			Light (10-55%)		
		Available area (m)			Available area (m)		Available area (m)			Available area (m)		
		0-1	1-2	2-3	3-4	>4	0-1	1-2	2-3	3-4	>4	
		9,000	**7,000**	**4,000**	**0**	**0**	**8,200**	**7,200**	**5,500**	**3,500**	**3,000**	
Cash crop: Long-term perennial crop												**Crop density (trees ha^{-1})**
Agarwood	2 meter x 2 meter	2,250	1,750	1,000	-	-	2,050	1,800	1,375	875	750	
Dragon fruit	3 meter x 3 meter	1,000	778	445	-	-	911	800	611	389	333	
Passion fruit	3 meter x 1.5 meter	2,000	1,556	889	-	-	1,822	1,600	1,222	778	667	
Cash crop: Short-term perennial crop												
Pisang berangan *Pisang emas* *Pisang rastali* *Pisang susu*	2.4 meter x 2.4 meter	1,563	1,215	694	-	-	1,424	1,250	955	608	521	
Pisang tanduk	2 meter x 2 meter	2,250	1,750	1,000	-	-	2,050	1,800	1,375	875	750	
Cover crop: Grass												
Napier grass	0.9 meter x 0.6 meter	16,667	12,963	7,407	-	-	15,185	13,333	10,185	6,482	5,556	

***The crop density is adjustable reflected in the spacing distance of the plant and the available area of the oil palm maturity*

Method of calculation for plant composition:

$$\textit{Crop density} = \frac{\textit{Available area (m)}}{\textit{Spacing distance (m)}}$$

As the findings from the application of triangular layout agreed by the Malaysian agriculturist, the findings of arrangement showed signs of differences with the previous studies in the earlier chapter. Compared to the study conducted by Lee et al., (2005), Norkaspi Khasim et al. (2009), Suboh Ismail, Omar Idris, and Wahid Omar (2010), only two types of arrangements were suitable to be implemented in oil palm smallholdings. Those arrangements are triangular and double avenue planting systems. One unanticipated finding was that in the real life experience, some of the smallholder farmers were interested to implement boundary planting system. The cognition about boundary planting system was clearly affirmed as it is more suitable for rubber than oil palm crops. A group leader of TUNAS Centre portrayed boundary planting system mostly practiced by RISDA and not suitable for the oil palm smallholdings context:

> *"Boundary planting system is a hedge planting system. The system is practiced by RISDA. It integrates oil palm with rubber tree. Rubbers are planted as the boundary. In the center are oil palm crops. But in MPOB we did not practice this system. We do not recommend this planting system".*

The implementation of this planting system was best explained for the functional basis of protective purposes. The arrangement of boundary planting system was then supported by a study based on the spatial arrangement of crops by Vergara (1985). It was found that alternative crops are integrated along the border of agricultural land for boundary markers and live fences purposes. Besides, the integration of other plant species also plays its roles in protecting or stabilizing the agricultural land through it functions as wind- or fire breakers.

Since the inquiry on the composition and arrangement concerned the sustainable agriculture practices, various plant species and arrangements were implemented, and their implementation emerged as significant plant composition and arrangement of the agrisilviculture sub-system in the oil palm smallholdings context. Thematic analysis of the study suggested that the integration of oil palm crops and other plant species were tapped into two main categories identified as (i) suitable plant composition and arrangement, and (ii) unsuitable into suitable plant composition and arrangement. In addition to that, preferred plant composition and arrangement, and environmental benefits of the plant composition and arrangement can be identified based on the findings of suitable plant composition and arrangement for oil palm smallholdings. These categories were presented in the next section and finally directed to the agricultural sustainability of agroforestry systems. The findings further suggested the recommendation for a systematic concept of sustainable plant composition and arrangement for an agrisilviculture sub-system that presented in the next chapter.

5.2 SUITABLE PLANT COMPOSITION AND ARRANGEMENT

Appropriate composition and arrangement of plant species to be integrated with oil palm crops creates suitable plant composition and arrangement for the agrisilviculture sub-system. Among 50 plant species, a total of 40 plant species was recorded as suitable plant composition in oil palm smallholdings as shown in Table 5.2. It traced that perennial crops were considered as the most suitable plant species with a total of 15 species. Next, it's followed by annual crops of 13 species, leguminous cover crops of 10 species, and grasses of 2 species. The arrangement involved 21 species for triangular planting system, 7 species for double avenue planting system, and 1 species for boundary planting system. It addressed that another 11 species can be integrated either through triangular or double avenue planting system.

Table 5.2

A list of suitable plant composition and arrangement to be integrated with oil palm crops

Types of plant species	**Plant composition**		**Plant arrangement**					
	Common name	**Scientific name**	**Triangular planting system**		**Double avenue planting system**		**Boundary planting system**	
			Oil palm phase					
			Immature	**Mature**	**Immature**	**Mature**	**Immature**	**Mature**
Cash crop								
Perennial crop	Long-term perennial crop							
	Betel nut	*Areca catechu*					√	√
	Dragon fruit	*Hylocereus undatus*			√	√		
	Passion fruit	*Passiflora edulis sim*			√	√		
	Peach palm	*Bactris gasipaes*			√	√		
	Salak	*Salacca edulis*			√	√		
	Tongkat Ali	*Eurycoma longifolia*			√	√		
	Short-term perennial crop							
	Chives	*Allium schoenoprasum*	√					
	Lemongrass	*Cymbopogon citratus*	√					
	Pineapple	*Ananas comosus*	√		√	√		
	Pisang berangan	*Musa acuminata* 'Dwarf Cavendish'	√		√	√		
	Pisang emas	*Musa acuminata* 'Lady Finger'	√		√	√		
	Pisang rastali	*Musa sapientum* Cv Rastali	√		√	√		
	Pisang susu	*Musa sapientum fixa lacte*	√		√	√		
	Pisang tanduk	*Musa paradisiaca*	√		√	√		
	Sweet potato	*Ipomoea batatas*	√					
Annual crop	Calabash	*Lagenaria leucantha*	√		√	√		
	Chili	*Capsicum annuum*	√					
	Dry land paddy	*Oryza sativa*	√					
	Long bean	*Vigna unguiculata subsp. sesquipedalis*	√					
	Maize	*Zea mays*	√		√	√		
	Papaya	*Carica papaya*	√					

	Sugarcane	*Saccharum officinarum*	√					
	Tapioca	*Manihot esculenta*	√					
	Taro	*Colocasia esculenta*	√					
	Tobacco	*Nicotiana tabacum*	√					
	Tomato	*Solanum lycopersicum*	√					
	Watermelon	*Citrullus lanatus*	√		√	√		
	Yam	*Dioscorea spp.*	√					
Cover crop								
Leguminous cover crop	Butterfly pea	*Centrosema pubescens*	√					
	Groundnut	*Arachis hypogaea*	√		√	√		
	Jicuma	*Calopogonium caeruleum*	√					
	Kudzu	*Pueraria javanica*	√					
	Mucuna	*Mucuna bracteata*	√					
	Mung bean	*Vigna radiata*	√					
	Split pea	*Pisum sativum*	√					
	Soybean	*Glycine max*	√		√	√		
	Tropical kudzu	*Pueraria phaseoloides*	√					
	Wild groundnut	*Calopogonium mucunoides*	√					
Grass	Betari	*Sorghum spp.*			√	√		
	Napier grass	*Pennisetum purpureum*			√	√		

5.2.1 Oil Palm and Perennial Crops Composition and Arrangement

The data presented in Table 5.2 indicate that suitable plant composition for oil palm smallholdings was monopolized by perennial crops with 15 species. The species mostly can be integrated either using triangular or double avenue planting system involving 6 species. In the interim, another 5 species suitable for double avenue planting system, 3 species for triangular planting system, and another 1 species for boundary planting system. Integration using the triangular planting system is only suitable to be integrated during the immature phase. However, double avenue and boundary planting systems are interestingly can be integrated either during immature or mature phase of oil palm crops.

It was found that smallholder farmers are more interested to integrate short-term perennial crops (9 species) rather than long-term perennial crops (6 species). Expert 3 provides an explanation by sharing an opinion on the availability and the competency of the seedling that can be fertile and produce by the smallholder farmers itself. It is among the reason why short-term perennial crops are mostly integrated in oil palm smallholdings:

> *"Most of the smallholder farmers are more interested to integrate cash crop species that can be harvested within the period of 1 year. For example, banana and pineapple. The seedling can be easily bought at the any Agricultural Department, local market, or even can be produce by themselves…meaning that they may have their own small nursery to fertile the seedlings".*

Just as the experts and farmers stressed the significance of short-term perennial crops as the most integrated plant species in oil palm smallholdings, so did the significance for long-term perennial crops. The findings from the interview with Expert 1 remarked that range of long-term perennial crops suitable to be integrated within the area of oil palm smallholdings is directed to its similar structural character and selection of arrangement:

> *"By referring to the trial plot that has been done by us (MPOB) and what has been practiced by the farmers, we found few long-term crops are suitable to be integrated with oil palm. Betel nut, peach palm, salak…it is similar to oil palm. But only integrated in double avenue…sometimes in boundary planting system. Why double avenue? Because these species have similar character with oil palm…wide canopy when it reaches mature phase. So it has a wide canopy…if you want to integrate these species, you must use double avenue".*

Further, the finding from observation reveals that 8 sites study are integrating perennial crops in their oil palm smallholdings which are Smallholding 1, 2, 3, 4, 6, 8, 9, and 10. It involves 5 banana species of short-term perennial crops and another 3 plant species of long-term perennial crops. All short-term perennial crops are integrated in triangular planting system. Meanwhile, long-term perennial crops both integrated either in double avenue or boundary planting system. These findings are further analyzed that the integration of banana species with the triangular planting system is considered as a preferred plant composition and arrangement for oil palm smallholdings. It will be explained in details in the Section 5.4. The integration of long-term perennial crops that implemented by smallholder farmers are involving dragon fruit (*Hylocereus undatus*) with a double avenue planting system in Smallholding 3. In the meantime, betel nut (*Areca catechu*) is integrated by using boundary planting system and passion fruit (*Passiflora edulis*) with a double avenue planting system in Smallholding 6.

Accordingly, the only betel nut is integrated using boundary planting system as can be shown in Figures 5.2 and 5.3. The species were intentionally planted for protective purposes. As explained by Farmer 2, the value of natural live fencing through the integration along the border of oil palm smallholdings is seen as a benchmark and a windbreaker for agricultural land:

> *"I plant betel nut not for profit…only to create a benchmark of my farms. As I did not integrate cattle, it is not necessary for me to border my farm with electric or wood fences".*

Figure 5.2: *Areca catechu* were integrated along the border of the oil palm farm to mark the territory of the agricultural land

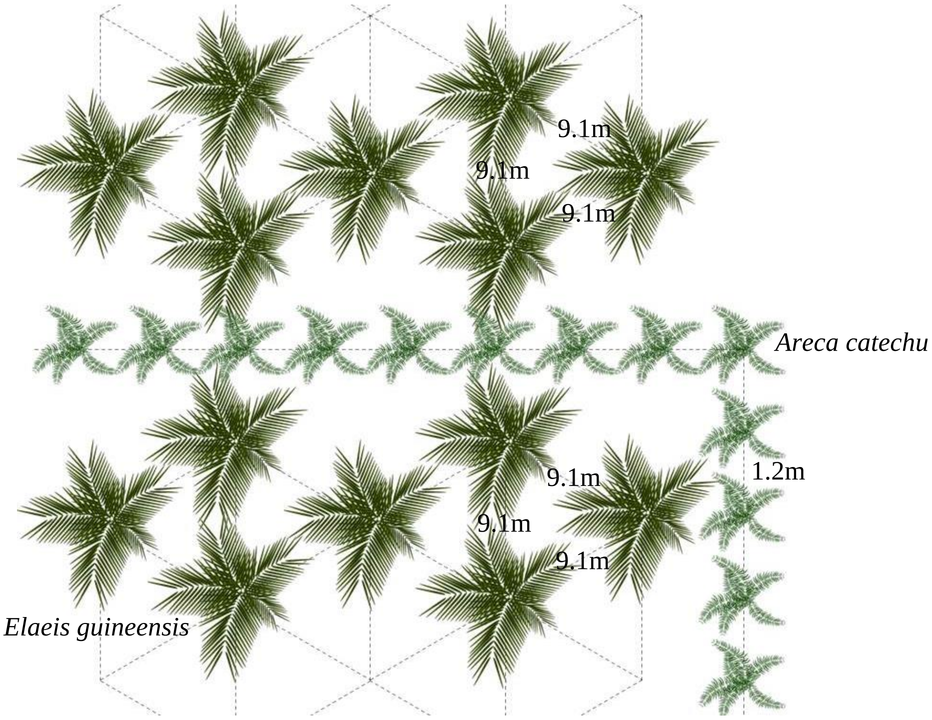


Figure 5.3: *Areca catechu* integrated using boundary planting system for the functional basis of protective purposes

As it is only suitable to be integrated with betel nut, this holds true experience that the implementation of boundary planting system depending on its function or purposes. For most smallholder farmers, low wooden fences were attached to mark the boundaries. Meanwhile, electric fences were installed as a paddock to limit the movement of cattle for farmers who integrate livestock in their oil palm smallholdings. The integration of perennial crops for live fencing purposes are hardly found in the sites study as it alternatively can be replaced with wood or wire fencing.

In the similar smallholding that integrated with betel nut, another plant species of passion fruit were also integrated with the implementation of a double avenue planting system. What is surprising is that the integration was done in response to the oil palm disease of basal stem rot known as *Ganoderma* (Figure 5.4). *Ganoderma* is a white rot fungus that attacks weak and undamaged oil palm crops, thus causes the economic loss of oil palm production (Chung, 2011). It grows in non-living tissues of oil palm crops, thus weaken the oil palm condition and prone to the wind damage (Paterson, 2007). As a result, the infection inflicted considerable yield losses, and oil palm crops became consistently unproductive and died one by one. The Expert 6 explained that the fungus was easily spread within the oil palm smallholding through spores:

> *"Oil palm crops are exposed to the oil palm disease…we call it white mushroom…or in the scientific name, Ganoderma. Once the oil palm crop affected with this disease, it easily spreads to other oil palm crops until the whole oil palm in that farm damaged and died. It is hard for us to define which oil palm is affected in the early stage…only after it totally affected as we can see the white mushroom in the oil palm bark…because the fungus spreads through spores in wind".*

Figure 5.4: *Ganoderma* weakens the oil palm condition and become prone to wind damage

For local farmers, facing this disease caused a huge economic loss in their oil palm production. The disease was uncontrollable since the fungus spreads through spores. Hence, with an initiative to gain profit in abandoned land of affected oil palm crops, the farmer makes an effort by integrating passion fruit in their oil palm smallholdings. The yields of passion fruit were mainly for local market demand. The integration was done in a double avenue planting system with spacing distance of 3 meter x 1.5 meter (Figures 5.5 and 5.6). The trees can climb to 2.1 meter, and can be productive for 2 years. The fruits were ready to be harvested after 8 months of planting.

Figure 5.5: *Passiflora edulis* integrated in an abandoned oil palm area that caused by *Ganoderma* disease

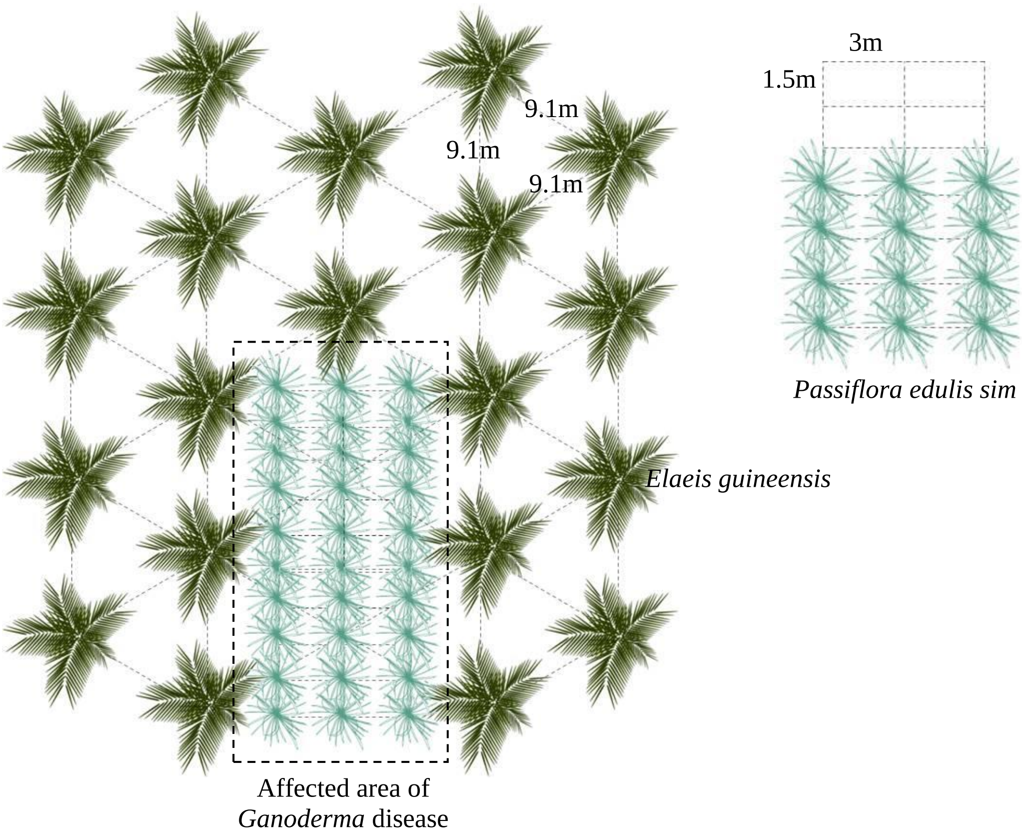


Figure 5.6: *Passiflora edulis* integrated within the spacing distance of 3 meter x 1.5 meter in the affected area of *Ganoderma* disease

The other species of long-term perennial crops that has been integrated by the smallholder farmers was dragon fruit in Smallholding 3. Dragon fruit is climbing long-term perennial crops that rarely integrated in oil palm smallholdings. According to the Expert 6 from TUNAS officer at MPOB Kluang, fewer farmers have interests to integrate dragon fruit due to its low market demand from local people:

> *"Not many farmers interested to plant dragon fruit…not many people demanded for dragon fruit. More farmers interested to plant banana…because its high competition and high market values and demand. However, the farmers only use double avenue planting system because it requires large area…and this is also among the reason why farmers not interested to integrate it".*

Based on the observation, the integration of dragon fruit applied double avenue planting system within the total area of 2 hectares of oil palm smallholdings. The oil palm crops were planted with a spacing distance of 6.1 meter x 9.1 meter x 15.2 meter, which resulted in an estimated crop density of 136 palms ha^{-1}. Meanwhile, dragon fruit was integrated within the area of 15.2 meter with a spacing distance of 3 meter x 3 meter accordingly in 3 rows and produced 300 trees ha^{-1} of crop density (Figures 5.7 and 5.8). The spacing distance from field planting was similar to the study reported by Gunasena, Pushpakumara, and Kariyawasam (2007) on the guidelines for dragon fruit plantation.

Figure 5.7: *Hylocereus undatus* systematically integrated using double avenue planting system

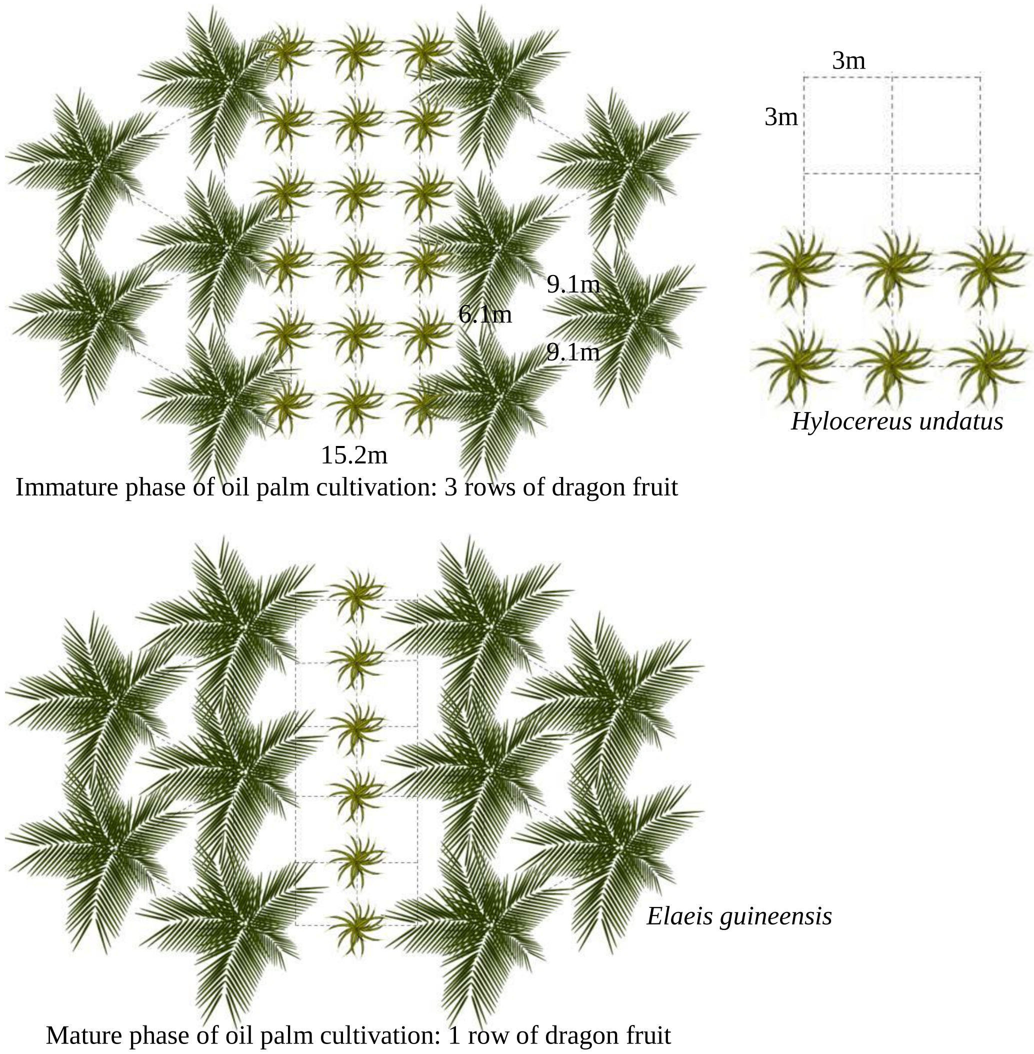


Figure 5.8: *Hylocereus undatus* integrated within the area of 15.2 meter with a spacing distance of 3 meter x 3 meter that consists of 3 rows during immature phase and decreased into 1 row during the mature phase of oil palm crops

In terms of suitable oil palm age of integration, dragon fruit was ready to be integrated after 4 months of oil palm planting and can last for about 20 years, near to the maximum age of oil palm crops. It was suggested that dragon fruit can be integrated during both immature and mature phases of oil palm crops. Dragon fruits were known as fast return long-term perennial fruit crops as the fruits were ready to be harvested once in 2 weeks after 9 months of integration. In oil palm smallholdings, the integration was planted with a constant rows repetition of both oil palms (2 rows) and dragon fruit (3 rows) for the first 3 years of oil palm immaturity. However, the dragon fruit rows were reduced into one row due to the decreased of light penetration. This was due to the increase of crown radius of oil palm crops when it reached the mature phase.

As overall, it is evident from the finding that most and foremost, the main reason why the smallholder farmers integrated other plant species in their oil palm smallholdings is the ability for them to generate additional income rather than rely on oil palm crop production. Expert 4 expressed his concern over this issue:

> *"Smallholder farmers are tending to use triangular planting system. Not all smallholder farmers are using double avenue planting system. The aim of using a double avenue planting system is to add additional incomes of the smallholder farmers. Meaning that, other than profit from oil palm crops, they will get additional income through harvesting the cash crops that are planted between rows of the oil palm crops. The reason is that we can use the land between the rows in double avenue planting system for 10 years. Within 10 years they can get other income apart from oil palm crops. Some of the smallholder farmers now using double avenue planting system. But not all can afford it. So they use the triangular planting system. The integration only suitable during the immature phase".*

The improvement of the crop production for self-sufficiency is in line with the NAP3 (Faridah Ahmad, 2001; Suboh Ismail, Norkaspi Khasim, and Raja Zulkifli, 2009). This has been seen as an opportunity to the smallholder farmers to increase their monthly income through the integration of perennial crops. The study further reveals how some long-term perennial crops are considered as suitable species for agrisilviculture sub-system in oil palm smallholdings. As participants has commented that betel nut can only be integrated in boundary planting system and other species in a double avenue planting system, the species has less integrated among smallholder farmers. When looking into closer perspectives, the situation is totally agreed by Suboh Ismail, Raja Zulkifli, and Norkaspi Khasim (2010) who has proved that peach palm suitable to be integrated with oil palm crops. The trial plot has been conducted by integrating peach palm through double avenue planting system. The competition for sunlight, space, and nutrient has made the species unsuitable for the triangular planting system even though both are palm tree species. High competition of both species can cause unproductiveness in term of growth performance and fruits quality and quantity.

5.2.2 Oil Palm and Annual Crops Composition and Arrangement

The data provided in Table 5.2 show 13 species out of 50 species of annual crops are considered as suitable species to be integrated in oil palm smallholdings. A large numbers of 10 species were suitable for the triangular planting system while the remaining 3 species can be integrated either using triangular or double avenue planting system. In triangular planting system, the species can only be planted within the rows of oil palm crops for the first three years of oil palm crops which was during the immature phase. In this case, Expert 1 elaborated that mature oil palm fronds overlapped each other and prevented the belowground of annual crops from receiving enough light sources and soil nutrients:

> *"In triangular planting system, alternative crops can be planted in the center of the triangular layout of oil palm crops. But when the oil palm reaches the age of 3 years, the area cannot be planted any more. This is because the oil palm leaves already overlap the area. When this situation happens, the alternative crops below oil palm crops will unable to get nutrient from the sun".*

In contrast, Expert 3 stressed that the species are continually planted within the area of 15.2 meter of a double avenue planting system, both during immature and mature phases of oil palm crops. It can be implemented since the early age up until the maximum age of oil palm crops between 25 to 30 years old. Specifically, among the annual crops that has been proven suitable to be integrated with oil palm crops are:

> *"The interval area for double avenue planting system is 15.2 meter. The oil palm planting distance is 6.1 meter x 9.1 meter x 15.2 meter. The interval can be planted with other plant. This is what we call integration. At 15.2 meter, it can be planted with many species for a long time, maybe for the whole time…for example, calabash, maize, watermelon, yam…but this type of species also suitable for the triangular planting system. We call this group as annual crops".*

However, based on the observation, smallholder farmers are less interested to integrate annual crops but more interested to integrate short-term perennial crops as has been mentioned earlier. According to the Farmer 2, even though those species are acknowledged and proven as suitable species by the expert and issued in the publication, but this testimony unable to persuade the farmers' interest due to its low current market value and demand:

> *"Yes…the MPOB officer has told us that many plant species can be integrated with oil palm. They provide us the proof based on their trial plot. But for me…I'm more interested to integrate species that have high market values and demand. I feel more secure".*

Although participants among smallholder farmers disinterested with the integration of annual crops as their alternative crops, it is still among the most cited species as a suitable plant composition for oil palm smallholdings. Indeed, the integration of such combination helps in enhancing the environment and socioeconomic of the agricultural land and rural community, respectively (Suboh Ismail, Raja Zulkifli, Norkaspi Khasim, 2010). The mutual interaction of both crops could increase soil productivity and generate additional income and food sources to the local farmers. In addition, the green manure waste from harvested annual crops can be used to improve soil structure and fertility through the application of agroforestry techniques such as mulching (Petry, 1991). As a whole, the integration between annual and oil palm crops can be done in small scale through a triangular planting system or in large scale through a double avenue planting system.

5.2.3 Oil Palm and Cover Crops Composition and Arrangement

The findings in Table 5.2 also suggest that 10 species of leguminous cover crops and 2 species of grasses were listed as a suitable composition for oil palm smallholdings. Among the species, 8 species of leguminous cover crops are suitable to be integrated using the triangular planting system specifically during the immature phase of oil palm crops. Meanwhile, another 2 species can be integrated either using triangular or double avenue planting system. Those two flexible species are groundnut (*Arachis hypogaea*) and soybean (*Glycine max*). On the other hand, 2 species of grasses are only suitable for double avenue planting system and can be integrated both during immature and mature phase of oil palm crops.

It is evident from the findings that all experts acknowledged the value of cover crops in environmental benefit in terms of its ability to improve the fertility of the agricultural land and its contribution in nitrogen fixation. However, there are 2 species of leguminous cover crops were highly encouraged by the expert to be integrated within the area of oil palm smallholdings which are groundnut and soybean. As mentioned earlier, these two species are considered as flexible species due to its tolerances that can be integrated either using triangular or double avenue planting system. In details, responses from the Expert 3 shared his opinion that groundnut and soybean have the other value on socioeconomic instead of focusing on the environmental improvement:

> *"By integrating groundnut and soybean, it has a potential for economic purposes in which the nuts can be yielded for commercial values. It also*

contributes for nitrogen fixation of the agricultural soil. Instead on integrating cover crops that do not have any economic values, it is better to integrate species that both produce social, economic, and environmental values".

Similarly, 2 species of grasses which are betari (*Sorghum spp*.) and Napier grass (*Pennisetum purpureum*) also expressed as the most encouraged grasses species to be integrated especially for smallholder farmers who also integrate livestock in their oil palm smallholdings. This encouragement was intensively practiced in Smallholding 7 as the grass will be used as a source of food for the livestock. The integration of livestock can be done accidentally or intentionally by the smallholder farmers depending on the availability of the source of food. According the Farmer 1, the integration of grasses and oil palm crops are promoted through double avenue planting system and not suitable for triangular or boundary planting system:

"I plant Napier grass both during immature and mature phases of oil palm crops. But I have allowed the cattle to enter the oil palm farm only during the mature phase as the oil palm already grows taller than the cattle. So that, the cattle unable to eat the young oil palm leaves. Most importantly, I can plant the Napier grass as a source of food for my cattle throughout the year since I use double avenue planting system".

Based on the observation, Napier grass was integrated with the oil palm crops through double avenue planting system for the functional basis of productive purposes. The grass was integrated by one farmer who also integrates livestock of cattle and buffalo in their oil palm smallholdings. The integration did not only focus on the oil palm and other plant species, but also reared livestock. As such, the grasses were harvested as a food source for the livestock that may decrease the food cost, as well as improved the soil fertility, nutrient, and moisture. In terms of spacing distance, the grass was integrated within the area of 15.2 meter without any specific distance but preferred 0.9 meter x 0.6 meter (Figures 5.9 and 5.10). It can be integrated both during immature and mature phases of oil palm crops without being affected by the light penetration. The grass was easily grown and can be harvested after 3 to 4 months after planting. Then, it can be continued for the next harvesting at an interval of 6 to 8 weeks for 3 to 5 years.

Figure 5.9: *Pennisetum purpureum* was integrated as a food source for livestock rearing

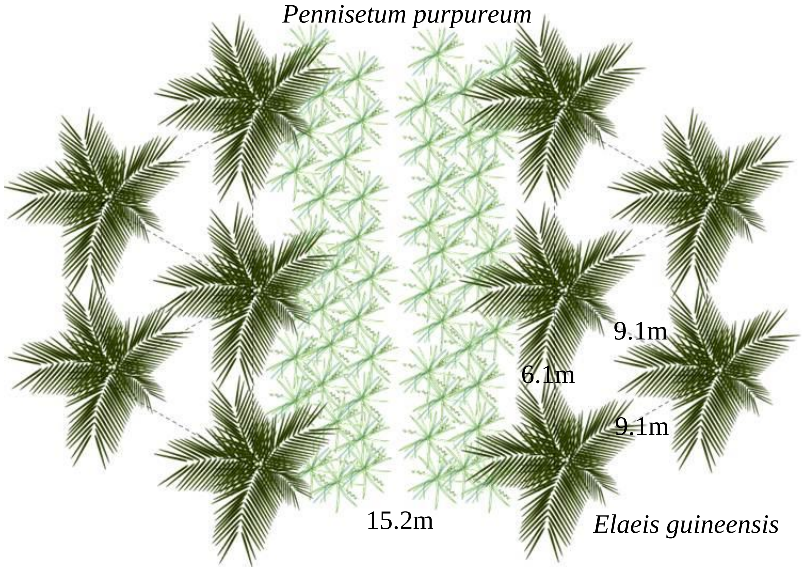


Figure 5.10: *Pennisetum purpureum* were integrated within the area of 15.2 meter in double avenue planting system

Clearly, leguminous cover crops and grasses carry environmental values as it has the ability to improve the agricultural land through soil fertility and nitrogen fixation. The environmental values were subjected to the objectives of cover crops for integration purposes as stated by Hasnol Othman, Farawahida, and Zulkifli Hashim (2012) on their study regarding the application of leguminous cover crops as ground cover crops for oil palm smallholdings. In that study, leguminous cover crops are objectively integrated for soil moisture conservation, peat content minimization, peat drying prevention, and peat fire risk reduction. Therefore, based on these objectives, it can be concluded that the adaptation of leguminous cover crops has become one of the most important components of agroforestry systems in oil palm smallholdings. In addition, most of the suitable species can be integrated both during immature and mature phase of oil palm crops.

Apparently the integration of grasses in oil palm smallholdings was integrated using double avenue planting system. Areas of 15.2 meter were used to integrate the grasses, both during immature and mature phase of oil palm crops. The integration of grasses was further encouraged the adaptation of other components of livestock. A good environmental and socioeconomic image of oil palm-cover crop-livestock integration presented through its mutualism and facilitation interaction (Devendra, 2011). This means that positive and neutral impacts can be seen when grasses has the ability to improve the soil condition of agricultural land and provide sources of food to the livestock. Meanwhile, the dung and urine from livestock also could improve the soil fertility and crop growth. This finding is in agreement with Dahlan Ismail and Kamal Hisyam's (2014) findings, which showed that the shade provided by the mature oil palm crops are naturally reduced the heat stress problems faced by the livestock in tropical countries.

Overall, when interpreting these results, attention should be given to the fact that the plant arrangement was influenced by the oil palm age either immature or mature phase of oil palm crops. The suitability of the arrangement depends on the encouragement from the organizations, as well as interest and market strategy of the smallholder farmers based on the concept of comparative advantages. Other than that, the consideration of farm size also influencing the selection of plant species and types of arrangement. As a small scale agricultural land, triangular planting system considered as the most valuable arrangement. While the implementation of a double avenue planting system is encouraged for the agrosilvopastoral sub-system that consist of oil palm crops, plant species, and livestock as the components. In the interim, boundary planting system is rarely used and mostly avoided in an agricultural planting system due to its uneconomically values. The results of the analysis were in line with the statement by the participants that MPOB only recommended two types of arrangements for agroforestry systems, which are triangular and double avenue planting systems.

Finally, the findings suggested that cash crops of perennial and annual species (28 species) contained the most suitable composition for oil palm smallholdings compared to the cover crops (12 species). Only few farmers were interested to integrate oil palm crops with cover crops. These findings further support the idea of cash crops offer a better return of profit than cover crops through yield production that can be regarded as additional income to the farmers as has been mentioned in the literature. The agricultural researchers from Zambia and the United States of America, Govereh and Jayne (2003) also mentioned that the high value of cash crops contributes to the high potential productivity and farm income to the smallholder farmers in Africa. Furthermore, appropriate selection of species needs to be adopted to improve soil fertility and efficiency, as well as prevent water pollution on the agricultural land (Tanaka et al., 2009). Thus, it can be pointed out that the integration of cash crops with oil palm crops represents the avenue of crop intensification and diversification of agricultural land for benefits in the environment, social, and economic aspects.

5.3 UNSUITABLE INTO SUITABLE PLANT COMPOSITION AND ARRANGEMENT

The study justified 10 species of long-term perennial crops were considered as unsuitable plant composition and arrangement. Nevertheless, the species could be improved to become a suitable plant composition and arrangement. The suitability of the integration depends largely on the structural characteristic of the plant species and its arrangement either using triangular, double avenue, or boundary planting system. The integration of different structural character of long-term perennial crops with oil palm crops is considered as unsuitable plant composition. The species involve the integration of other commodity crops, forest trees, and fruit trees in oil palm smallholdings as oil palm crops itself is known as the commodity crops (Table 5.3).

In this case, long-term perennial crops are mostly leading into the diameter of breast height, tree height, trunk height, crown length, and crown radius. This prominent character causes high competition in terms of nutrient consumption, space utilization, and light penetration. Consequently, the integration affects growth performance along with the decrease of oil palm yield production. Thus, unsuitable selection of plant species for the integration with oil palm crops creates an unsuitable integration for agrisilviculture sub-system.

Table 5.3

List of unsuitable plant composition and arrangement that can be improved into suitable plant composition and arrangement to be integrated with oil palm crops

Types of plant species	**Plant composition**		**Plant arrangement**					
	Common name	**Scientific name**	**Triangular planting system**		**Double avenue planting system**		**Boundary planting system**	
			Oil palm phase					
			Immature	**Mature**	**Immature**	**Mature**	**Immature**	**Mature**
Perennial crop	Long-term perennial crop							
	Agarwood	*Aquilaria sinensis*			√	√		
	Binuang	*Octomeles sumatrana*			√	√		
	Durian	*Durio kutejensis*			√	√		
	Jackfruit	*Artocarpus heterophylus*			√	√		
	Langsat	*Lansium domesticum*			√	√		
	Laran	*Neolamarckia cadamba*			√	√		
	Pulasan	*Nephelium mutabile*			√	√		
	Rubber	*Hevea brasiliensis*					√	√
	Sentang	*Azadirachta excelsa*			√	√		
	Teak	*Tectona grandis*			√	√		

However, the issues of unsuitable plant composition can be defeated through the selection of suitable plant arrangement either using double avenue or boundary planting system. Long-term perennial crops are not suitable for the triangular planting system as the species require large and specific area for integration due to its wide canopy that will obstruct the light penetration. The observation in Smallholding 5 proved that farmers who integrate long-term perennial crops of agarwood (*Aquilaria sinensis*) in their oil palm smallholdings are practicing double avenue planting system (Figures 5.11 and 5.12). The agarwood were planted with a spacing distance of 2 meter x 2 meter which result an estimated crop density of 866 trees ha^{-1}. The trees are ready to be harvested for agarwood oil after 3 years of planting and for wood and leaves products after 10 years of planting, respectively.

Figure 5.11: *Aquilaria sinensis* was integrated for oil, leaves, and wood products

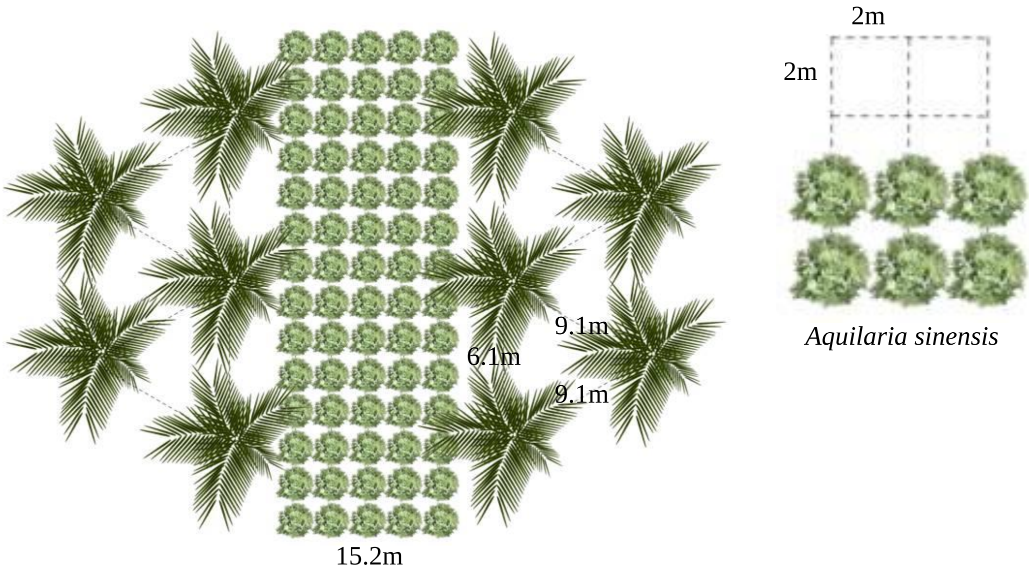


Figure 5.12: The unsuitable composition of *Aquilaria sinensis* can be improved into suitable composition and arrangement through the application of double avenue planting system

In addition, the identified arrangement was strongly highlighted by the governmental participants during the interview, in which boundary planting system was frequently applied by RISDA for the integration between oil palm crops and rubber trees (*Hevea brasiliensis*). Expert 4 emphasized on how to identify the unsuitable plant composition and he even mentioned that agarwood as one of the examples:

> *"The integration of oil palm with other commodities such as rubber, coconut, and cocoa is not very good. But, it is okay for the integration of oil palm with cash crops. Meanwhile, the integration with perennial crops such as sentang and agarwood is more on not good. It interferes both crops' growth performance. So, what I can say is:*
>
> *Oil palm + short-term perennial crop = sustainable*
> *Oil palm + long-term perennial crop = unsustainable*
> *Oil palm + commodity crop = unsustainable*
>
> *The reason why oil palm suitable to be integrated with short-term crops is because the integration did not disturb each other. There are in win-win situation and beneficial each other".*

Therefore, these species can be considered as a suitable plant composition by implementing the plant arrangement of double avenue or boundary planting system. Nevertheless, it is considered as an unsuitable plant composition for the triangular planting system. However, the selections are depending on the farmers' interest and farm size. Careful selection of plant composition and arrangement has shed some information on the unsuitability of long-term perennial crops to be integrated in oil palm smallholdings. The result provides perspectives that accounts for how the species can be acknowledged from unsuitable into suitable plant composition and arrangement. The study at the same time found that recommended long-term perennial crops were a fast growing tree that has clear bole, small and erect growth of bark, sparse canopy, and has a different root habit from oil palm crops (Chia, 2011). Based on tree structure and application of a double avenue planting system, it allows the oil palm crops to receive enough light penetration. Meanwhile, strong tap root owned by the perennial crops are reducing the soil nutrient competition in which the roots are going through below the oil palm roots regime.

5.4 PREFERRED PLANT COMPOSITION AND ARRANGEMENT

Based on the findings in the previous section, the most suitable plant composition was short-term perennial crops with the implementation of the triangular planting system. This is due to the interest of smallholder farmers who tends to integrate short-term perennial crops for only the first three years of immature oil palm crops. The period is also compatible with the complete life cycle of the species. The finding was supported by the statement of Expert 4:

> *"About 85-90% of the smallholder farmers are using the triangular planting system. It's only suitable to be integrated with short-term*

crops. The duration is less than 3 years, which is during the immature phase of oil palm".

Immature phase of oil palm crops known as unproductive phase in which it does not produce revenue for the first 3 years of oil palm planting or replanting process. With an increasing need to obtain monthly income during that phase, a significant of agroforestry systems has increased. The smallholder farmers had interest to integrate short-term perennial crops due to its short-term profit production that could evade no monthly income during the first three years of oil palm planting. This tendency was also influenced by the growth performance of oil palm crops, in which the integration did not give negative impact to the oil palm crops since it is the main component of the system. After that phase, the concentration is only on oil palm management and production. This remark was given by the Expert 6 who involves directly in oil palm smallholdings:

"Triangular planting system has a planting distance of 9.1 meter x 9.1 meter. We will only get the profit from the integration for the first 3 years only. Then, we will only be able to harvest oil palm yields when it reaches the maturity phase".

Another different view was pointed out by Farmer 2 that have 15 years' experience in agrisilviculture sub-system for oil palm smallholdings. He personally expressed that the main reason he implemented the triangular planting system is due to the limited size of the agricultural land:

"I only have 1 hectare of oil palm farm. It is impossible for me to use double avenue planting system. I only integrate banana when I do not have any income…meaning that during the immature phase. After that I totally focus on the oil palm management".

The farm size was a clear proof that the smallholder farmer unable to implement a double avenue planting system due to the required area for integration of 15.2 meter after each 2 rows of oil palm crops. Furthermore, priority must be given to the oil palm crops as the main crop production since the integration of short-term perennial crops is to obtain additional income, especially during the immature phase of oil palm crops. Therefore, it pointed out that short-term perennial crops were best to be integrated with the triangular planting system.

The findings in Table 5.4 reports the pattern of integration from 6 out of the 10 sites study are integrating with banana species. Evidently, there are 5 banana species are found as preferred plant composition among smallholder farmers by implementing the triangular planting system as can be seen practiced in Smallholding 1, 2, 4, 8, 9, and 10. Banana species of *pisang berangan* (*Musa acuminata* ‘Dwarf Cavendish’), *pisang emas* (*Musa acuminata* ‘Lady Finger’), *pisang rastali* (*Musa sapientum* Cv Rastali), *pisang susu* (*Musa sapientum fixa lacte*), and *pisang tanduk* (*Musa paradisiaca*) were recorded as frequent integration by the smallholder farmers.

Table 5.4
Pattern of integration for banana species in 6 oil palm smallholdings

<table>
<tr><th rowspan="4">Total: 6</th><th>Pisang berangan</th><th>Pisang rastali</th><th>Pisang emas</th><th>Pisang tanduk</th><th>Pisang susu</th></tr>
<tr><td>2</td><td>-</td><td rowspan="2">-</td><td rowspan="3">1</td><td rowspan="3">1</td></tr>
<tr><td colspan="2">1</td></tr>
<tr><td colspan="3">1</td></tr>
</table>

In each smallholding, smallholder farmers showed an insignificant variation in the pattern of integration, indicating that farmers were more interested to integrate *pisang berangan* in their oil palm smallholdings with a total number of 2 smallholdings. The variation in pattern of integration in other banana species was relatively low for each species. On the other hand, several farms were attracted to integrate various banana species within a farm unit. The integration varied between *pisang berangan*, *pisang rastali*, and *pisang emas*. When asked about the integration of banana species, Farmer 2 replied:

> *"I integrate 3 types of banana species in my farm…pisang berangan, pisang emas, and pisang rastali. Pisang rastali is the easiest species to be identified…it has a solely green bark color. Pisang emas has a combination of green and red bark color. Pisang berangan has a combination of red and black bark".*

Based on the oil palm age given by the smallholder farmers, estimated 12 to 14 months oil palm seedlings were ready to be planted in the farm. The earliest duration for integration after oil palm planting process was within 1 month and the longest were 3 months after the planting. The suitable oil palm phase of integration was similar to those reported in a study conducted in the same country (Khairuman Hashim, 2009), but the duration for integration was gradually planned after 1.5 to 2 years after oil palm planting (Suboh Ismail, Omar Idris, and Wahid Omar, 2010). Regarding the suitable oil palm age for integration, the age up to 3 years represents immaturity phase, and the most suitable duration for integration using the triangular planting system was within that age.

5.4.1 *Pisang Berangan* (*Musa acuminata* 'Dwarf Cavendish')

The integration of oil palm crops and *pisang berangan* was integrated in Smallholdings 2 and 8. The popularity of *pisang berangan* was highly demanded by the Malaysian locals and made them at the market throughout the year (Suboh Ismail and Roslan Arshad, 2004). The statement agreed by the Farmer 2 as the current market value for *pisang berangan* was highly reasonable and quite expensive:

> *"Market demand for pisang berangan was not limited to the Malaysian market, but also demanded by Singapore. The current price also good…a bunch of banana could reach 18kg…RM2.10 per kg…so a bunch we can get RM30".*

In another aspect, farmers tended to integrate *pisang berangan* due to its adaptable character. The species can be grown on a wide range of soil condition with good soil drainage and flat to gentle soil topography, but unsuitable on sandy and flood prone area (Suboh Ismail and Roslan Arshad, 2004).

The plant composition done by smallholder farmers showed *pisang berangan* was systematically integrated between the rows of oil palm with a spacing distance of 2.4 meter x 2.4 meter through a triangular planting system (Figures 5.13 and 5.14). The crop density of oil palm and *pisang berangan* were estimated at 138 palms ha^{-1} and 1,344 trees ha^{-1}, respectively. The species can be integrated within the first 3 years of oil palm crops with 2 plant cycles and harvesting stage. The first fruit harvesting can be done during 9 to 12 months after planting and the following 5 to 6 months should be ready for second harvesting stage. After the second harvest, the trees were cleared and the land was prepared for the second plant cycle with similar spacing distance as the first plant cycle. It took about 20 months to complete the integration.

Figure 5.13: *Musa acuminata* 'Dwarf Cavendish' can be physically recognized through its combination of red and black bark color and systematically integrated between oil palm rows

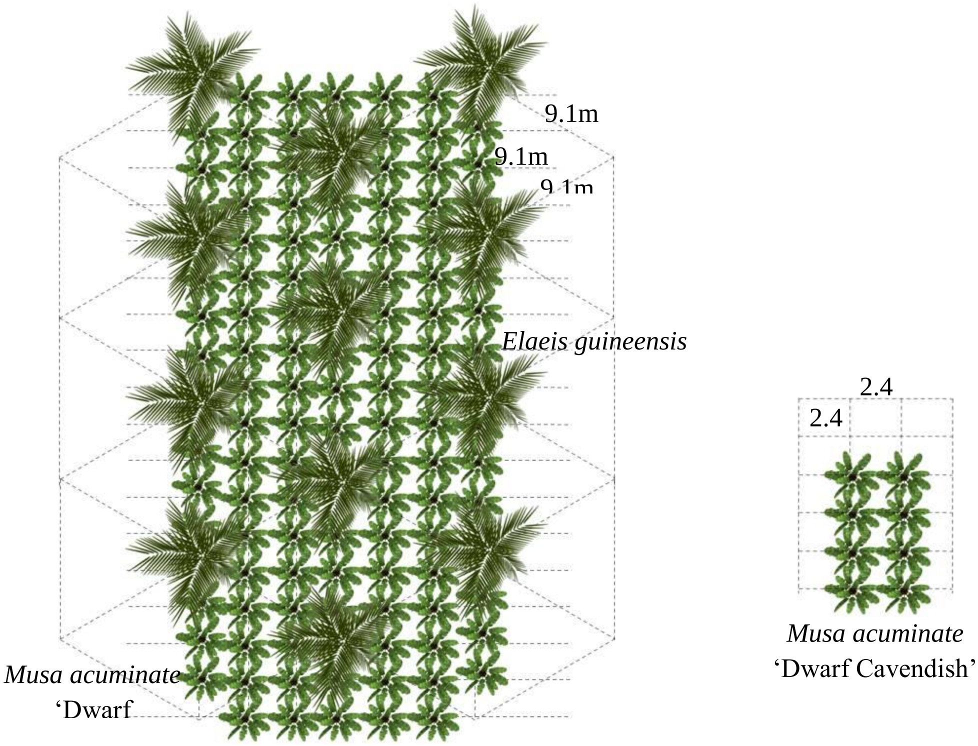


Figure 5.14: *Musa acuminata* 'Dwarf Cavendish' systematically integrated with spacing distance of 2.4 meter x 2.4 meter in both Smallholding 2 and 8

5.4.2 *Pisang Tanduk* (*Musa parasidiaca*)

Based on the observation, only Smallholding 4 integrated with *pisang tanduk*. Roslan Arshad and Suboh Ismail (2003) addressed that *pisang tanduk* is one of the banana species that is commonly commercialized other than *pisang berangan*. In terms of spacing distance, both findings from observation and document analysis showed a clear contradiction. According to Roslan Arshad and Suboh Ismail (2003), the spacing distance of *pisang tanduk* for both triangular and double avenue planting systems was 2.3 meter x 2.3 meter, and the trees were systematically planted between the oil palm rows. The estimated crop density was 1,200 trees ha^{-1} and 1,450 trees ha^{-1} respectively.

In contrast, at the current integration, *pisang tanduk* was randomly integrated between the rows of oil palm crops in a triangular planting system with spacing distance of 2 meter x 2 meter (Figures 5.15 and 5.16). The estimated crop density was 138 palms ha^{-1} for oil palm and 1,575 trees ha^{-1} for *pisang tanduk*. Although, these results differ from a study by Roslan Arshad and Suboh Ismail (2003), the consistent findings showed that the species can be integrated using the triangular planting system. In the meantime, Farmer 1 agreed that *pisang tanduk* was intentionally planted in random arrangement between the rows of oil palms:

> *"Yes…pisang tanduk can be planted randomly. Because it has thin and high tree bark. So, it only required small spacing distance compared to other banana species".*

In detail, the integration of *pisang tanduk* can be done for 2 life cycles, but only suitable for one harvesting stage. The trees of *pisang tanduk* were cleared and chopped down for every harvesting period. This is due to the thin and high structure of *pisang tanduk* that was unsuitable for 2 harvesting stages. The fruits were harvested after 12 to 13 months after planting. Meanwhile, other trees of *pisang tanduk* for second life cycle were prepared through vegetative propagation. The selection process for good quality of *pisang tanduk* trees for the second life cycle was started after 5 months of the first life cycle. Only one tree was selected for each spot during the second life cycle to replace the harvested *pisang tanduk.*

Figure 5.15: *Musa parasidiaca* can be physically recognized through its thin and high tree bark and randomly integrated between oil palm rows

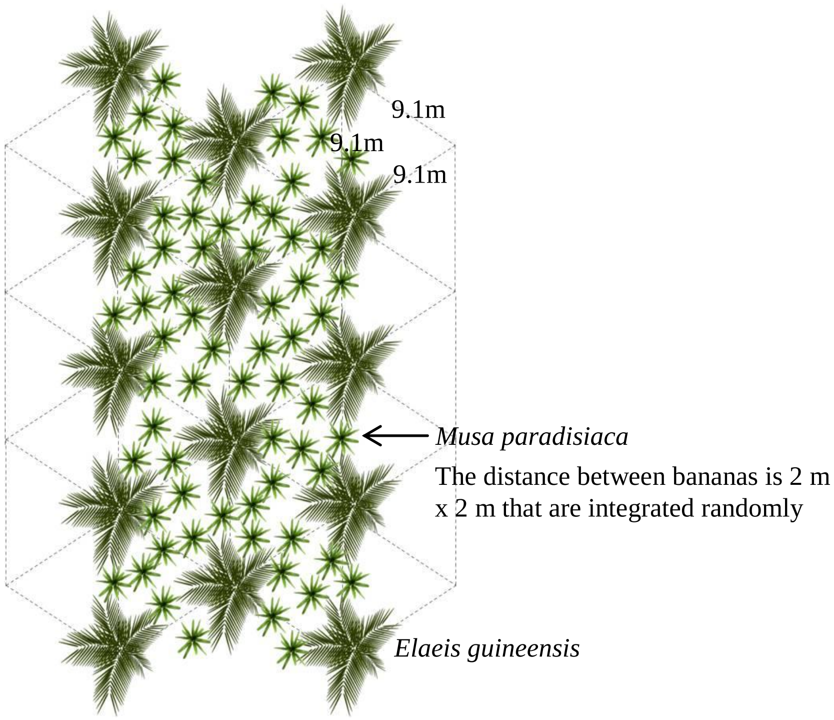


Figure 5.16: *Musa parasidiaca* is randomly integrated between the rows of oil palm crops with a spacing distance of 2 meter x 2 meter for each banana tree in Smallholding 4

5.4.3 *Pisang Susu* (*Musa sapientum fixa lacte*)

The integration of *pisang susu* was only integrated in Smallholding 1 with the implementation of the triangular planting system. Smallholder farmers were less interested to integrate *pisang susu* in their oil palm smallholdings due to low demand and market value. In terms of the arrangement, *pisang susu* applied similar spacing distance with *pisang berangan* of 2.4 meter x 2.4 meter with crop density of 1,344 tree ha^{-1}. The arrangement resulted in 2 rows of banana trees between the rows of oil palm crops that were integrated systematically (Figures 5.17 and 5.18).

Figure 5.17: *Musa sapientum fixa lacte* are systematically integrated between the rows of oil palm crops

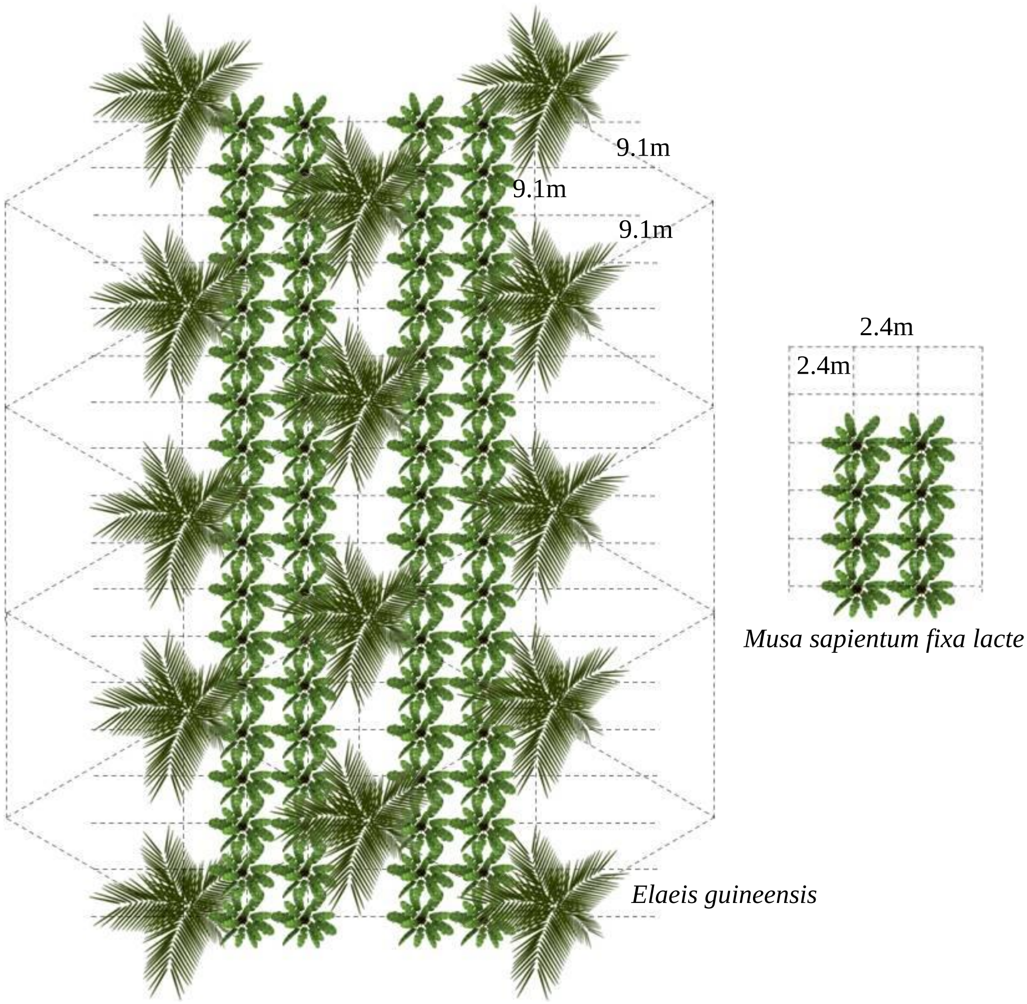


Figure 5.18: Two rows of *Musa sapientum fixa lacte* are systematically integrated between the rows of oil palm crops with a spacing distance of 2.4 meter x 2.4 meter in Smallholding 1

5.4.4 *Pisang Emas* (*Musa acuminata* 'Lady Finger') and *Pisang Rastali* (*Musa sapientum* Cv Rastali)

Banana species of *pisang emas* and *pisang rastali* were rarely integrated as a single integration, but frequently integrated together with *pisang berangan* in oil palm smallholdings. Two integration patterns were integrated by farmers, which are the integration of *pisang berangan* and *pisang rastali in* Smallholding 9, and the integration of *pisang berangan*, *pisang emas*, and *pisang rastali* in Smallholding 10. These species were commonly integrated together due to its similar structural character that can grow without high competitive desires.

Similar to *pisang berangan*, both *pisang emas* and *pisang rastali* were applied to the spacing distance of 2.4 meter x 2.4 meter (Figures 5.19, 5.20, and 5.21). However, the crop density for this pattern of integration may differ since 2 or 3 banana species were integrated in one unit of oil palm smallholding. Other than spacing distance, these banana species also applied 2 plant cycles and harvesting stage like *pisang berangan*. However, the fruits were harvested in different period. *Pisang emas* can be harvested after 6 months of planting, and followed by *pisang rastali* and *pisang berangan* both after 7 months and 9 months of planting, respectively.

Figure 5.19: *Musa acuminata* 'Lady Finger' has a combination of red and green bark color and systematically integrated between oil palm rows

Figure 5.20: *Musa sapientum* Cv Rastali has green bark color and systematically integrated between oil palm rows

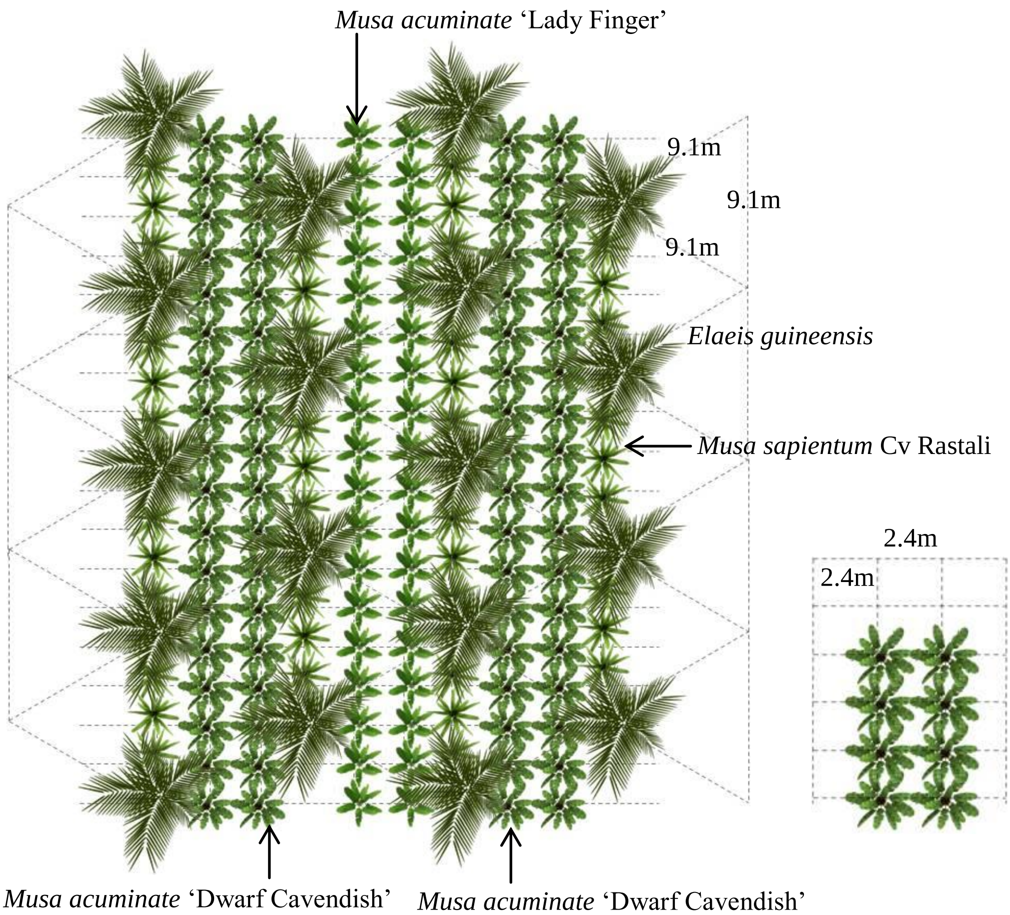


Figure 5.21: *Musa acuminata* 'Dwarf Cavendish', *Musa sapientum* Cv Rastali, and *Musa acuminata* 'Lady Finger' shared similar spacing distance and can be integrated together in the same smallholdings

The extended excerpts from interviews and observation agreed that the triangular planting system offered the most sustainable plant arrangement for oil palm smallholdings by referring to the total land area. Here, the range of land area of 1 to 4 hectares for each oil palm smallholding limits the planning for double avenue planting system. This implies that the implementation of agroforestry systems in oil palm smallholdings is on the right track with the definition of agrisilviculture sub-system defined in the previous chapter. It implies that the integration of banana species with oil palm crops in the same unit of agricultural land was implemented as the secondary components by focusing on the oil palm production as the main crop productivity.

To conclude, different plant composition has different suitable plant arrangement by considering the oil palm age either in immature or mature phase of oil palm crops. The integration for different oil palm age is drawing huge influence on the oil palm growth performance and yield production. This consideration can be defined as an indicator for sustainable plant composition and arrangement for the agrisilviculture sub-system in the oil palm smallholdings context.

5.5 ENVIRONMENTAL BENEFIT OF PLANT COMPOSITION AND ARRANGEMENT

The present situation on the integration of banana species as the preferred plant composition in real life experience among smallholder farmers has been observed and studied mostly for socioeconomic benefits. Banana species was selected based on its comparative advantages of giving huge positive impacts to the smallholder farmers, especially during the immature phase of oil palm crops. However, less attention and effort have been paid to the integration between oil palm crops and cover crops (leguminous cover crops and grasses) even though the integration might influence the agroecosystem services through the actual field management in the oil palm smallholdings. The fact was strongly agreed by the Expert 7:

> *"Farmers more interested to integrate cash crops rather than cover crops. Why? Because they can get the profit from the integration…but not with cover crops. But yes…some farmer still allows the existence of cover crops. But they did not plant it…the species naturally grown on the farm. And when oil palm has reached maturity, the cover crops will be removed to reduce soil nutrient competition. Most of them think that cover crops did not produce any profits".*

The integration of oil palm crops and cover crops is a window of opportunity for the conservation and enhancement of the flora and fauna in oil palm smallholdings. As such, the findings demonstrated that there exist diverse types of cover crops in sustainable agriculture interest that are rich in the sustainability of agroecosystem services. It was found that the integration was frequently distributed with leguminous cover crops (10 species) than grasses (2 species), and integrated more using the triangular planting system (8 species) than a double avenue planting system (2 species). Other than that, another 2 species are suitable to be integrated using both triangular and double avenue planting systems. In particular, leguminous cover crops were preferred to be integrated using the triangular planting system during immature phase than mature phase of oil palm crops. Meanwhile, grasses of betari (*Sorghum spp.*) and Napier grass (*Pennisetum purpureum*) was more suitable for double avenue planting system arrangement during both immature and mature phases.

The suitability of the plant species that create sustainability for the agrisilviculture sub-system is recognized by the both experts in the publications and is proven suitable during the experimentation of the trial plot by government agencies for agroecosystem services. With the commitment to the agroecosystem services, leguminous cover crops have become a prime consideration in helping the oil palm land in environmental aspects including soil fertility, soil moisture, weed control, and nitrogen supply. For example, leguminous cover crops are known as a good measure for an enhancement of oil palm farm in soil erosion, soil fertility, and waterway sedimentation (Khalid Haron and Chan, 2011). Using the data on bird diversity in oil palm farm by Lian (2008), he summarized that the presence of leguminous cover crops was identified as an indicator for the variety of bird species richness. It was calculated that 0.6 to 53.3% of the variation of bird richness was covered by the surrounding young farm. These leads and matches to the findings that leguminous cover crops were ideal for the integration during the immature phase.

Profitability, which is included in the sustainable agricultural development, can be measured and expressed in the composition and arrangement of oil palm crops and leguminous cover crops. The interchange of non-profitable leguminous cover crops into profitable leguminous cover crops enhances the sustainability of the agricultural land. It is valuable to integrate groundnut (*Arachis hypogaea*), mung bean (*Vigna radiate*), split pea (*Pisum sativum*), and soybean (*Glycine max*) with oil palm crops as the crops are producing revenue, as well as functions as agro-ecosystem services. Therefore, the sustainability of the integration of leguminous cover crops is determined by the interaction of the profitability, yet ecologically functioning in the immature phase of oil palm cultivation.

5.6 SUMMARY

The study reveals that suitable agrisilviculture sub-system has evolved in response to the appropriate selection of plant composition and arrangement. Over time, the suitability also depending on the oil palm age, farm size, and market values and demand of the plant species. In its organization, three types of plant arrangements have been involved to create a suitable composition for perennial crops, annual crops, leguminous cover crops, and grasses. In oil palm smallholdings like in Paloh Township, the smallholder farmers are more interested to integrate short-term perennial crops in the triangular planting system. In addition to its farm size, the comparative advantages concepts of market values and demand are influencing the selection of plant species for short-term perennial crops to be selected as preferred plant composition and arrangement. As such, the integration of 5 banana species is considered as the most frequent integration done by the smallholder farmers and certainly integrated using the triangular planting system. The integration has high socioeconomic values since the fruits commercially produce for local and international market.

In the interim, leguminous cover crops and grasses have become the most environmental benefit plant composition that is suitable to be integrated for both triangular and double avenue planting systems. The integration of cover crops is not only subjected to environmental values of soil improvement and nitrogen fixation. However, certain types of cover crops have the socioeconomic values through the production of nuts. This consideration has also been recommended by the governmental agencies in which 4 species of groundnut, mung bean, split pea, and soybean are highly encouraged for the agrisilviculture sub-system in oil palm smallholdings. Therefore, it is suggested that the sustainability of the plant composition and arrangement can be seen from belowground and aboveground interaction that create win-win situation.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.0 INTRODUCTION

This chapter sets out to deliver the conclusion and recommendation of the research. Section 6.1 presents the conclusion with 3 research objectives. It involves the recommendation on the sustainable plant composition and arrangement for oil palm smallholdings in research objective 3. Then, Section 6.2 explains the limitation of the study. Next, Section 6.3 further discusses the contribution of the study and followed by the suggestion for future research in Section 6.4. Finally, Section 6.5 concludes the chapter.

6.1 CONCLUSION

The findings of this study offer several understandings regarding the significance of agroforestry systems as sustainable agriculture practices in oil palm smallholdings that can be summarized based on the research objectives:

6.1.1 Objective 1: To investigate agroforestry systems as sustainable agriculture practices in oil palm smallholdings

The development of agriculture sector in becoming a sustainable agriculture has been started since the planning stage. A dynamic interaction from the combination of agriculture and forestry activities is emphasized through agricultural landscape planning and design. The initiatives that consider productivity, sustainability, and adoptability are based on a greater structural and functional complexity of the plant composition and arrangement of the systems. It refers to the systematic composition and arrangement by getting the right number of oil palm crops and plant species, the right species of plant to be integrated within oil palm smallholdings, and the right arrangement to integrate oil palm crops and plant species in an agricultural land.

Agroforestry planning and design, which involves the consideration of composition and arrangement, is both an artful science of sustainable agriculture development. This consideration is based on the notion that agroforestry systems apply to the integration of belowground and aboveground interaction that involves perennial crops, annual crops, leguminous cover crops, and grasses. The positive and neutral interactions that contribute to the suitability of the systems involved mutualism, facilitation, commensalism, and neutralism interaction. Numerous and diverse plant composition can be found in each level of stratification, partly because of its environmental benefits and the socioeconomic factors such as food and income production. Unlike monoculture system, the integration of agroforestry systems ranges from a simple to complex systems with many layers of plant composition.

The diversity and profitability of agroforestry potentially make it as an alternative farming system that is locally acceptable by smallholder farmers. It further creates a sustainable agricultural practices based on the principles of sustainability involving environment, social, and economic aspects. The diversification of plant composition and arrangement has significantly generated profit and economic return to the smallholder farmers either for self-sufficiency or commercial purposes (Figure 6.0).

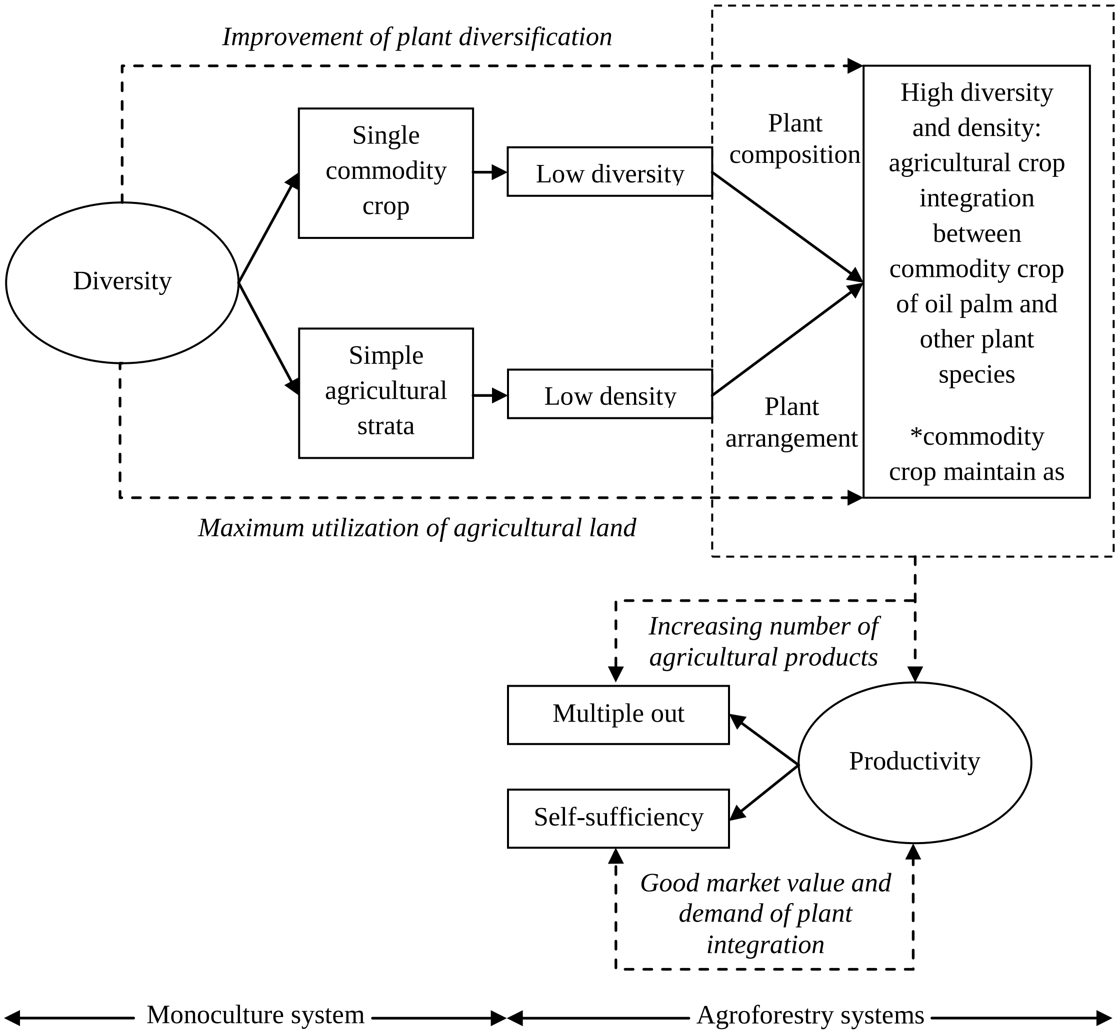


Figure 6.0: The process of creating sustainable agriculture practices for oil palm smallholdings through agroforestry systems

The figure demonstrates on how the output return of agroforestry systems can be reasonably generated in a short period. These circumstances indeed have resulted in a systematic concept for agroforestry systems where the revenue of agroforestry systems can be gained from a short or long period depending on the selection of plant composition and arrangement. As a result, currently agroforestry systems have become little more important farming system among the smallholder farmers subjected to its ability for rural environment improvement based on its reasonable short period for economic return.

6.1.2 Objective 2: To explore plant composition and arrangement of agroforestry systems for a sustainable oil palm smallholdings

In terms of plant arrangement, normally one to three short-term perennial crops was integrated with 2 life cycles in oil palm smallholdings to optimize crop productivity and enhance the environmental conditions. Smallholder farmers are more interested to concentrate on one or two crop production by ensuring a good quality of the product instead of cultivating many crops in the same land. In parallel, the integration of more than two plant species in oil palm smallholdings was only among the same plant family but different species of banana. The plant arrangement that involved in agroforestry systems is the process of cultivating a series of different belowground plant composition over time. Compared to monoculture system, belowground integration of plant species was systematically integrated using triangular and double avenue planting systems instead of boundary planting system.

Meeting the needs of a continuous source of income for smallholder farmers will require the integration of various plant species. Currently based on site study, the oil palm smallholdings are integrated with 10 plant species with the implementation of triangular, double avenue, and boundary planting systems. The integration is done either during immature phase only or both during immature and mature phase of oil palm smallholdings. The triangular planting system offered the most suitable plant arrangement for oil palm smallholdings by referring to the total land area owned by the farmers. Here, the range of land area of 1 to 4 hectares for each oil palm smallholdings limits the planning for double avenue planting system. This implies that the implementation of agroforestry systems in oil palm smallholdings is on the right track with the definition of an agrisilviculture sub-system. It implies that the integration of plant species with oil palm crops in the same unit of agricultural land was implemented as the secondary components by focusing on the oil palm production as the main crop productivity. This is due to the actuality of the agroforestry systems in producing diverse output, but concentrating on the oil palm production.

The most preferred plant composition and arrangement for oil palm smallholdings is the integration of banana species with the triangular planting system. There are five banana species of *pisang berangan* (*Musa acuminata 'Dwarf Cavendish'*), *pisang tanduk* (*Musa parasidiaca*), *pisang susu* (*Musa sapientum fixa lacte*), *pisang emas* (*Musa acuminata 'Lady Finger'*), and *pisang rastali* (*Musa sapientum Cv Rastali*) is eventually preferred as the most species integrated by smallholder farmers. The integration also becomes financially sustainable as an alternative source of income for smallholder farmers during the immature or unproductive phases of oil palm crops.

Among all, *pisang berangan* becomes the most preferred plant species integrated in oil palm smallholdings using the triangular planting system. Many factors are involved in the selection of *pisang berangan* as preferred plant species by smallholder farmers. The preference to integrate *pisang berangan* is positively associated with its flexible character, farm size, market value and demand of the crops, and it can be relatively integrated for both immature and mature phases of oil palm crops. Despite that, farm size and market perfection on the value and demand relatively become the main factors in influencing the selection of *pisang berangan* as the most common plant species integrated in oil palm smallholdings. Farm size has a significant and huge influence on the selection of suitable plant composition and arrangement for oil palm smallholdings. Oil palm smallholdings with less than 4 hectares of agricultural land, particularly with smaller farms, are more sustainable in the use of short-term perennial crops and triangular planting system for plant arrangement.

Comparative advantages concept occurs when smallholder farmers select plant species intentionally for the integration in oil palm smallholdings based on its short-term direct contribution. Under the conditions of limited farm area owned by smallholder farmers, selection of plant species may depend on its ability to improve the environment and socioeconomic condition of the surrounding and smallholder farmers, respectively. Due to the influence of comparative advantages concept, agroforestry systems in oil palm smallholding are developed effectively by fulfilling the needs of rural farmers. At the same time, it meets the natural resources as well as creating a competitive market in the agriculture industry. This concept highlights the development of environmentally friendly, socially capable, and economically viable agroforestry systems through a suitable selection of plant species by considering the encouragement from government, multiplication of output in short term revenue, and perfection in market value and demand.

As a whole, the agricultural sustainability of agroforestry systems for oil palm cultivation is influenced by 5 factors as follows (Figure 6.1):

i. Oil palm crops as main component: oil palm crops considered as central crop production and other plant species as alternative crop production.
ii. Maturity of oil palm crops: the suitability of plant composition and arrangement depends on the oil palm age that involving the immature and mature phase of oil palm crops.
iii. Belowground and aboveground interaction: agroforestry systems produce positive or neutral interaction between oil palm crops and other plant species

which involving mutualism, facilitation, commensalism, and neutralism interaction.

iv. Agricultural landscape planning and design: integration is not decreasing the oil palm growth performance through appropriate management of plant composition and arrangement.

v. Market values and demand: farmers' interest in selecting profitable plant species.

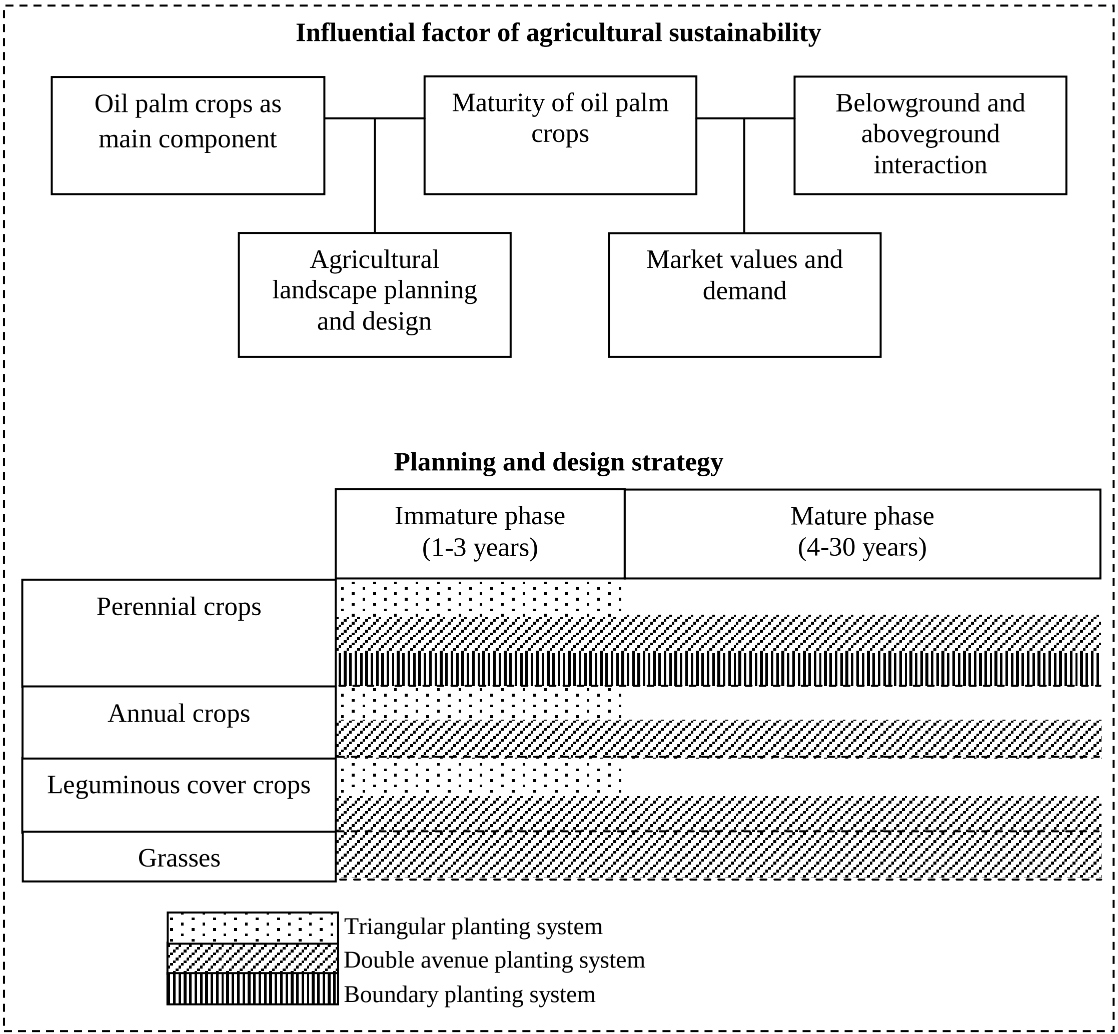


Figure 6.1: Influential factor and planning and design strategy for agricultural sustainability of agroforestry systems for oil palm smallholdings

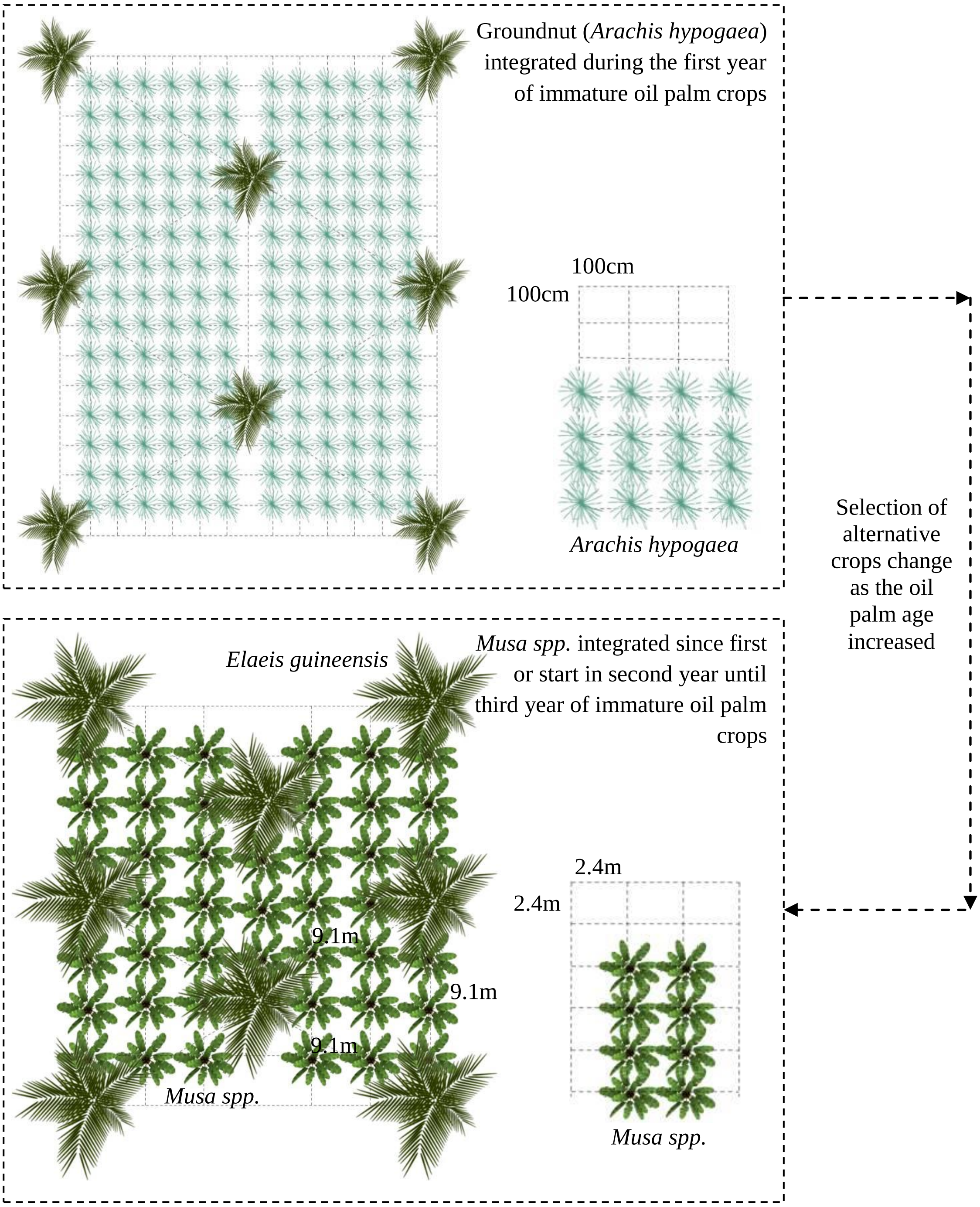
6.1.3 Objective 3: To recommend sustainable plant composition and arrangement of agroforestry systems that can be implemented in oil palm smallholdings

The implementation of agroforestry systems in small scale agriculture practices suggests that intensive utilization of agricultural land among smallholder farmers is in response to the willingness of farmers to integrate alternative crops of other plant species, attentiveness advice given by the governmental agencies on appropriate farming system, and farmers' attitudes on sustainable agriculture practices. In response to this concern, the needs for genuine and accurate studies on positive, neutral, or negative impacts of plant composition and arrangement should become important concerns in agroforestry planning and design. Furthermore, it is important to justify that the selection of plant species and its suitable arrangement is clearly defined for sustainable plant composition and arrangement.

Agroforestry systems in general and agrisilviculture sub-system in particular are an alternative option for sustainable farming practices that is suitable to be implemented among smallholder farmers. The presence of more than one plant species with different levels of stratification are powerful means of achieving friendly environment and profitable socioeconomic values. The integration of suitable then creates sustainable plant composition and arrangement thus considered as a medium in combating rural poverty and increasing food security.

In the other perspectives, scenic and aesthetic landscape view of agroforestry systems indirectly improved the monocultures view of static oil palm smallholdings. The continuity of this systematic diversification acts significantly as recreational values and aesthetic quality of agricultural landscape that benefits the smallholder farmers and society. As such, recommended sustainable plant composition and arrangement for oil palm smallholdings can be a strong incentive in the development of agricultural landscape scenic view, as well as improvement of sustainable agriculture practices.

Accordingly, the efforts in creating sustainable agroforestry systems through balance integration of cash and cover crops must be based on the principles of sustainability involving environmental, social, and economic values. Thus, the integration of cash and cover crops should be encouraged as some of the cover crops species are valuable for economic values. These knowledge and understanding may help smallholder farmers to consider the importance of practicing agroforestry systems as one of the sustainable agriculture practices that suitable for small scale agriculture. These could also enhance and revitalize local and social daily life of farmers through farming practices and the environment of the society. In sum, the study was then presented by recommending a sustainable plant composition and arrangement that suitable to be implemented by oil palm smallholdings appropriate with the farm size and reflection of oil palm crops as main crop production (Figure 6.2).



Year	Integration 1	Integration 2
1	*Pisang berangan*	Groundnut
2		*Pisang tanduk / pisang susu / pisang rastali / pisang emas*
3		

**Total harvesting pisang berangan is 36 months*
**Total harvesting pisang tanduk, pisang susu, pisang rastali, and pisang emas is between 24 to 28 months*
**Groundnut can be harvested after 3 to 5 months after planting and can be planted 2 to 3 life cycles in a year*

Figure 6.2: Recommended sustainable plant composition and arrangement for oil palm smallholdings

As a whole, recommended sustainable plant composition and arrangement in oil palm smallholdings involving the integration of groundnut (*Arachis hypogaea*) and banana species (*Musa spp.)* with the application of triangular planting system. It is based on the consideration of its productivity, sustainability, and adoptability that can be practiced by smallholder farmers in creating a good agroforestry design. Banana species are maintained as preferred species integrated by smallholder farmers as the species has high market values and demand that can be commercialized in local and international market.

In the interim, groundnut is selected as an integrated option to be integrated with oil palm crops and banana species due to its structural character as leguminous cover crops. This is in response to the earlier findings that sustainable composition is involving balance integration between cash and cover crops. However, groundnut is only suitable to be integrated during the first year of oil palm planting. This is because it requires high sunlight penetration for its growth performance. During the first year of oil palm planting, it still does not have large and wide frond canopy, thus suitable for groundnut integration between the rows. Meanwhile, the triangular planting system selected as a sustainable arrangement by referring the farm size owned by smallholdings. As the main crop production is oil palm crops, the consideration need to be paid in selecting suitable arrangement to avoid any decreased in oil palm crop production.

In details, groundnut is selected as an option for sustainable composition due to its environmental and socioeconomic values. In environmental perspectives, groundnut is seen as a tool for soil improvement and nitrogen fixation in which leguminous cover crops are acknowledged as an important tool in improving the natural resources of soil. The application of this natural tool is further could reduce the economic cost of agrochemical products and defeat environmental problems. On the other hand, by referring to socioeconomic perspectives, groundnut can be harvested for nut products that are highly demanded by local market. The integration is highly encouraged since the total land area planted with groundnut is decreasing year by year, but vice versa to the total groundnut import. Thus, groundnut has both potential in environmental and socioeconomic values which are highly beneficial for smallholder farmers in soil fertilization and socioeconomic improvement.

6.2 LIMITATION OF THE STUDY

The limitation of this study can be divided into four aspects as described below:

i. This study is focusing on the implementation of agroforestry systems in oil palm smallholdings among smallholder farmers. Smallholder farmers registered with MPOB are selected as sample and the population consists of the stallholder farmers who practice agroforestry systems located in the Paloh Township in Kluang, Johor. The study shall not discuss the implementation of agroforestry systems in stakeholder sector.

ii. Since the core of the study is on the agriculture and forestry field, the definition of agroforestry systems is taken from the sustainable development, sustainable agriculture, and landscape architecture fields, which reflects a dynamic and complex operational definition of the systems.

iii. The implementation of agroforestry systems in oil palm smallholdings is studied in response to the issue of habitat fragmentation caused by deforestation of natural forest area. It occurred due to unsustainable agriculture practices that are applied by some of the oil palm growers. As such, the benefits of agroforestry systems in creating natural habitat for agroforestry components are explored in detail, as well as its simultaneous positive and neutral impacts on socioeconomic aspects.

iv. The most preferred plant composition and arrangement that contributes to the sustainable agroforestry systems are obtained from the real life experience of the smallholder farmers. The components studied are only concerning the composition and arrangement between oil palm crops and other plant species. Other experience on the components of livestock is not included in this study, but its close relationship that leads to this sub-system discussed briefly.

6.3 CONTRIBUTION OF THE RESEARCH

There are four important contributions of the research:

i. The research has expanded our understanding regarding the relationship between oil palm smallholdings and agroforestry systems. It has succeeded in identifying agroforestry systems as an alternative farming system in combating the issues brought up by monoculture oil palm cultivation especially for smallholder farmers. Apart from that, the systems capture the attention of farmers in creating sustainable oil palm cultivation with locally and socially acceptable farming system.

ii. The research has also succeeded in proving how plant composition and arrangement affect the agricultural sustainability of oil palm smallholdings without negatively influencing the oil palm production. Suitable or unsuitable integration of perennial crops, annual crops, leguminous cover crops, and grasses with oil palm crops using triangular, double avenue, or boundary planting system leads to a huge impact on competition, complexity, sustainability, and profitability of the systems.

iii. A major outcome from this research is that short-term perennial crops systematically integrated using the triangular planting system are justified as the most suitable then sustainable composition and arrangement to be implemented by smallholder farmers based on the consideration of maturity of oil palm crops, structural character and market perfection of short-term perennial crops, as well as farm size of the agricultural land.

iv. Finally, all outcomes gathered from the research are hoping to create an awareness among the public, in particular and smallholder farmers in general on the advantages of agroforestry systems in particular and agrisilviculture sub-system in general. The implementation of the systems among smallholder farmers could improve the environmental and agroecosystem values of oil palm smallholdings, enhance the basic quality of life on food production and food security, and develop their source of income through diversification of crop production.

6.4 SUGGESTION FOR FUTURE RESEARCH

This study has prepared several suggestions for future research that are related to landscape-agriculture based study which are as follows:

i. National Landscape Policy involves agriculture, forestry, township, environment, biodiversity, and green technology. These elements nevertheless can be achieved through the implementation of agroforestry systems since it involves the interaction of agricultural crops and plant species and/or animals from where the systems are further acknowledged as a new name of traditional agricultural practices. Therefore, a study on the identification and adoption of agroforestry technologies involving agroecosystem services that are beneficial for agriculture, forestry, environment, and biodiversity sector in synergism with positive economic return can be further investigated.

ii. Since the result shows that smallholder farmers seem to provide functional basis quality for productive and protective function, therefore this acknowledgment could be used as an advantage in future agroforestry research. A survey among smallholder farmers is needed to fully understand the purpose of the integration rather than concentrating on the economic values of the integration. Results from such studies can be used to educate farmers in designing more sustainable farming systems.

iii. In large scale perspectives, the result gained from this study that concentrate on the smallholding sector can be explored in stakeholder sector. As the farm size is more valuable for double avenue planting system, the selection of components and concentration of values may differ from the smallholding.

6.5 CONCLUSION

Agroforestry systems are a new name of old agricultural practices which include shifting cultivation, intercropping, and mixed farming. The term is derived from a combination of agriculture and forestry activities and involved multiplicity of environment, social, and economic interaction. This interaction makes people recognize agroforestry systems as an approach in creating sustainable agriculture practices. In terms of oil palm smallholdings, rapid development and expansion of natural forest into oil palm land has decreased the agricultural sustainability of Malaysian oil palm production. In this study, it shows that diverse plant species can be integrated with oil palm crops in creating and balancing the sustainable agriculture land. The detailed examination indeed has highlighted that only certain types of plant species were chosen by the smallholder farmers as their alternative crops. As a whole, their selection was influenced by the reflection of oil palm crops as main crop production, agricultural landscape planning and design, and comparative advantages concept of the alternative crops.

In broader aspect, as plant species being integrated within the area of oil palm crops, the revenue obtain is socially alleviating poverty among the rural smallholder farmers. It is expected that implementation of agroforestry systems in oil palm smallholdings is considered as a potential sustainable approach to create a better environmental and socioeconomic values. Therefore, it is vitally important for agriculturists, planners, and farmers to plan and design suitable plant composition and arrangement in order to create sustainable agriculture land use system. Likewise, enhancing the positive values and avoiding negative values with the proper planning and farming system may present an environmentally friendly, socially capable, and economically viable sustainable agriculture practice.

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APPENDIX A: OBSERVATION CHECKLIST

DEPARTMENT OF LANDSCAPE ARCHITECTURE
KULLIYYAH OF ARCHITECTURE AND ENVIRONMENTAL DESIGN
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

OBSERVATION SURVEY LOG

PLANT COMPOSITION AND ARRANGEMENT OF AGROFORESTRY SYSTEMS IN OIL PALM SMALLHOLDINGS AT KLUANG, JOHOR

Aim: to study plant composition and arrangement for agroforestry systems as sustainable agriculture practices in oil palm cultivation of smallholdings.

These observations are intended to gather information on the suitability of the implementation of agroforestry systems in oil palm smallholdings as one of approach towards sustainable agriculture. There are three objectives to be achieved in this study: (1) to investigate agroforestry systems as sustainable agriculture practices in oil palm smallholdings, (2) to explore plant composition and arrangement of agroforestry systems for a sustaianble oil palm smallholdings, and (3) to recommend sustainable plant composition and arrangement of agroforestry systems that can be implemented in oil palm smallholdings.

Agroforestry systems consist of three main components which are agricultural crops (oil palm), plant species, and livestock either ruminants, non-ruminants, fishes and bees. The operational definition of agroforestry systems of this study is "the integration of agricultural crops and plant and/or animals in the same unit of land management in the form of spatial arrangements that produce two or more outputs which contribute positive, neutral, or negative impacts on the environment, social, and economic".

Reference number	
Date / Time	

SECTION A: PHYSICAL CHARACTER OF OIL PALM SMALLHOLDING

Area of oil palm smallholding:

> 10 hectares	☐
10 – 20 hectares	☐
20 – 30 hectares	☐
30 – 40 hectares	☐

Oil palm age:

Immature phase	☐	months/years
Mature phase	☐	months/years

Spacing distance of oil palm crops:

9.1 m x 9.1 m x 9.1 m	☐
8.8 m x 8.8 m x 8.8 m	☐
8.5 m x 8.5 m x 8.5 m	☐
6.1 m x 9.1 m x 15.2 m	☐
Other:	
____________________	☐

Environmental, social, and economic benefits:

Category	Parameter	Impact		Remark
		Positive	Negative	
Environment	Habitat for flora			
	Habitat for fauna			
	Aboveground interaction			
	Belowground interaction			
Socioeconomic	Oil palm crops production			
	Other crops production			
	Job opportunity			
	Continues source of income			
	Self-sufficiency products			
	Market demand and value			

SECTION B: AGRISILVICULTURE SUB-SYSTEM

Cash crops and oil palm crops:

Species		Vegetative habit		Oil palm phase		Layout of arrangement (illustration)
Common name	Scientific name	Perennial	Annual	Immature	Mature	

** Plant species supported with photographic data.*

** The measurement of the layout must be mentioned in the illustration.*

Cover crops and oil palm crops:

Species		**Type**		**Oil palm phase**		**Layout of arrangement (illustration)**
Common name	**Scientific name**	**Legumes**	**Grasses**	**Immature**	**Mature**	

** Plant species supported with photographic data.*
** The measurement of the layout must be mentioned in the illustration.*

APPENDIX B: INTERVIEW QUESTIONNAIRES

DEPARTMENT OF LANDSCAPE ARCHITECTURE
KULLIYYAH OF ARCHITECTURE AND ENVIRONMENTAL DESIGN
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

INTERVIEW SHEET

PLANT COMPOSITION AND ARRANGEMENT OF AGROFORESTRY SYSTEMS IN OIL PALM SMALLHOLDINGS AT KLUANG, JOHOR

Aim: to study plant composition and arrangement for agroforestry systems as sustainable agriculture practices in oil palm cultivation of smallholdings.

These interviews are intended to gather information on the suitability of the implementation of agroforestry systems in oil palm smallholdings as one of approach towards sustainable agriculture. There are three objectives to be achieved in this study: (1) to investigate agroforestry systems as sustainable agriculture practices in oil palm smallholdings, (2) to explore plant composition and arrangement of agroforestry systems for a sustaianble oil palm smallholdings, and (3) to recommend sustainable plant composition and arrangement of agroforestry systems that can be implemented in oil palm smallholdings.

Agroforestry systems consist of three main components which are agricultural crops (oil palm), plant species, and livestock either ruminants, non-ruminants, fishes and bees. The operational definition of agroforestry systems of this study is "the integration of agricultural crops and plant and/or animals in the same unit of land management in the form of spatial arrangements that produce two or more outputs which contribute positive, neutral, or negative impacts on the environment, social, and economic".

Respondent's name	
Reference number	
Interviews location	
Date / Time	

SECTION A: OIL PALM CULTIVATION IN MALAYSIA

1. What are the categories of oil palm industry in Malaysia?
   ………………………………………………………………………………………..

2. What are the management aspects that need to be considered for the oil palm cultivation management?
   ………………………………………………………………………………………..

3. What are the challenges that faced by the oil palm farmers especially independent smallholder in Malaysia?

   Environment:
   ………………………………………………………………………………………..

   Social:
   ………………………………………………………………………………………..

   Economic:
   ………………………………………………………………………………………..

4. What are the strategies taken to overcome those challenges?

   Environment:
   ………………………………………………………………………………………..

   Social:
   ………………………………………………………………………………………..

   Economic:
   ………………………………………………………………………………………..

SECTION B: SUSTAINABLE AGRICULTURE

5. What is the definition of sustainable agriculture?
   ………………………………………………………………………………………..

6. What is the consideration that needs to be applied by the agricultural land in order to be acknowledged as sustainable agriculture?
   ………………………………………………………………………………………..

7. What are the benefits of sustainable agriculture practices?

   Environment:
   ………………………………………………………………………………………..

   Social:
   ………………………………………………………………………………………..

   Economic:
   ………………………………………………………………………………………..

8. The practices of sustainable agriculture have been acknowledged in the 3rd National Agricultural Policy by means to maximize income through optimal utilization of resources. The practices also encouraged to be applied in the oil palm cultivation context in all level of production. Is sustainable agriculture practices are accepted by the independent oil palm smallholder in Malaysia?
   ………………………………………………………………………………………..

SECTION C: AGROFORESTRY SYSTEMS

9. Based on the operational definition described earlier, do you agree with the definition of agroforestry systems? What is your understanding of agroforestry systems in oil palm smallholdings?
   ………………………………………………………………………………………..

10. What are the components in agroforestry systems?
    ………………………………………………………………………………………..

11. How many sub-systems are suitable to be practiced in oil palm cultivation? Why?
    ………………………………………………………………………………………..

12. In your opinion, are agroforestry systems suitable to be implemented in oil palm smallholding?
    ………………………………………………………………………………………..

SECTION D: PLANT COMPOSITION AND ARRANGEMENT (AGRISILVICULTURE SUB-SYSTEM)

The focus of this study is on the integration of plant species and oil palm crops which also known as agrisilviculture sub-system in oil palm smallholdings. However, oil palm crops are maintained as the main product of the agricultural land.

13. Based on the knowledge and experiences, what types of plant species that are suitable and unsuitable to be integrated with oil palm crops? Why?
…………………………………………………………………………………………..

14. Based on the knowledge and experiences, what types of arrangement that is suitable and unsuitable for agrisilviculture sub-system? Why?
…………………………………………………………………………………………..

15. When is the most suitable time to implement the plant composition and arrangement?
…………………………………………………………………………………………..

16. Oil palm crops can be planted in both mineral and peat soil even though peat soil is considered as problematic soil. Is soil type influence the selection of plant species to be integrated in oil palm smallholdings?
…………………………………………………………………………………………..

17. What are the advantages and disadvantages of plant integration towards oil palm crops?
………………………………………………………………………………………......

18. What are the benefits of agrisilviculture sub-system to the smallholder farmers?

    Environment:
    …………………………………………………………………………………………

    Social:
    …………………………………………………………………………………………

    Economic:
    …………………………………………………………………………………………..

APPENDIX C: RESPONSE ON THE PLANT COMPOSITION AND ARRANGEMENT FOR AGRISILVICULTURE SUB-SYSTEM IN OIL PALM SMALLHOLDINGS

Types of plants	Plant composition		Plant arrangement						Data collection		
	Common name	Scientific name	Triangular planting system		Double avenue planting system		Boundary planting system		Document analysis	Semi-structured interview	Non-participant observation
			Oil palm phase								
			Immature	Mature	Immature	Mature	Immature	Mature			
Cash crop											
Perennial crop	Long-term perennial crop										
	Agarwood	*Aquilaria sinensis*			√	√				√ / ×	√
	Betelnut	*Areca catechu*					√	√		√	√
	Binuang	*Octomeles sumatrana*			√	√			√	√ / ×	
	Dragon fruit	*Hylocereus undatus*			√	√				√	√
	Durian	*Durio kutejensis*			√	√				√ / ×	
	Jackfruit	*Artocarpus heterophylus*			√	√				√ / ×	
	Langsat	*Lansium domesticum*			√	√				√ / ×	
	Laran	*Neolamarckia cadamba*			√	√			√	√ / ×	
	Passion fruit	*Passiflora edulis sim*			√	√				√	√
	Peach palm	*Bactris gasipaes*			√	√			√	√	
	Pulasan	*Nephelium mutabile*			√	√				√ / ×	
	Rubber	*Hevea brasiliensis*					√	√		√ / ×	
	Salak	*Salacca edulis*			√	√				√	
	Sentang	*Azadirachta excelsa*			√	√			√	√ / ×	
	Teak	*Tectona grandis*			√	√			√	√ / ×	
	Tongkat Ali	*Eurycoma longifolia*			√	√			√	√	
	Short-term perennial crop										
	Chives	*Allium schoenoprasum*	√							√	
	Lemongrass	*Cymbopogon citratus*	√							√	
	Pineapple	*Ananas comosus*	√		√	√				√	

	Pisang berangan	*Musa acuminata* 'Dwarf Cavendish'	√		√	√			√	√	√
	Pisang emas	*Musa acuminata* 'Lady Finger'	√		√	√				√	√
	Pisang rastali	*Musa sapientum* Cv Rastali	√		√	√				√	√
	Pisang susu	*Musa sapientum fixa lacte*	√		√	√				√	√
	Pisang tanduk	*Musa paradisiaca*	√		√	√				√	√
	Sweet potato	*Ipomoea batatas*	√						√	√	
Annual crop	Calabash	*Lagenaria leucantha*	√		√	√			√	√	
	Chili	*Capsicum annuum*	√							√	
	Dry land paddy	*Oryza sativa*	√						√	√	
	Long bean	*Vigna unguiculata subsp. sesquipedalis*	√							√	
	Maize	*Zea mays*	√		√	√			√	√	
	Papaya	*Carica papaya*	√						√	√	
	Sugarcane	*Saccharum officinarum*	√						√	√	
	Tapioca	*Manihot esculenta*	√							√	
	Taro	*Colocasia esculenta*	√							√	
	Tobacco	*Nicotiana tabacum*	√							√	
	Tomato	*Solanum lycopersicum*	√							√	
	Watermelon	*Citrullus lanatus*	√		√	√			√	√	
	Yam	*Dioscorea spp.*	√							√	
Cover crop											
Leguminous cover crop	Butterfly pea	*Centrosema pubescens*	√						√		
	Groundnut	*Arachis hypogaea*	√		√	√			√	√	
	Jicuma	*Calopogonium caeruleum*	√						√		
	Kudzu	*Pueraria javanica*	√						√		
	Mucuna	*Mucuna bracteata*	√						√		
	Mung bean	*Vigna radiata*	√							√	
	Split pea	*Pisum sativum*	√							√	
	Soybean	*Glycine max*	√		√	√				√	
	Tropical kudzu	*Pueraria phaseoloides*	√						√		
	Wild groundnut	*Calopogonium mucunoides*	√						√		
Grass	Betari	*Sorghum spp.*			√	√			√	√	
	Napier grass	*Pennisetum purpureum*			√	√				√	√

√ *Suitable composition and arrangement*
× *Unsuitable composition and arrangement*