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Environmental, Technical, and Resources Challenges Facing Agroforestry: A Case of Sustainable Land Management in Malaysia

Zaleha Othman[1], Arfan Shahzad[2], Subramaniam A/L Sri Ramalu[3]

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Corresponding Author:

Zaleha Othman
Othman Yeop Abdullah Graduate School of Business Universiti Utara Malaysia, Kuala Lumpur. Email: zaleha@uum.edu.my

Abstract: Sustainable Land Management (SLM) plays a crucial role in mitigating land degradation and fostering food security. While previous research has primarily concentrated on SLM's scientific application, there remains a lack of insight into the specific challenges encountered in agroforestry practices. Addressing this knowledge gap, our qualitative research employed a multimethod approach, integrating Gioia methodology with case studies, to investigate the obstacles within agroforestry. We utilized diverse data sources, including surveys, interviews, and field observations. A total of ninety-eight respondents contributed to the survey, the results of which underwent descriptive analysis. Furthermore, we conducted three focus group interviews involving stakeholders from government bodies and private plantation sectors. Our findings indicate that agroforestry stands as a vital strategy for food security. However, its implementation faces several barriers, notably environmental challenges such as climate change impacts and soil fertility degradation. Technical hurdles, including deficiencies in expertise and knowledge, were significant, as were constraints in resources like land availability, labor force, and financial investment. Two primary conclusions were drawn from our research: Agroforestry is substantially beneficial for food security, yet it encounters several challenges that restrict its full potential within the agriculture industry. Consequently, there is an urgent need to address the environmental, technical, and resource-related challenges to optimize the advantages of agroforestry in achieving sustainable land management and bolstering food security.

Keywords: Agroforestry, Sustainability, Government, Fertilizer and Environmental, Land Management

1. Introduction

Pollution, climate change, and ecological crises are the planetary challenges we face today, with global food insecurity being a direct consequence of these crises. Empirical evidence supports this claim. Studies have demonstrated that these planetary challenges lead to massive land desertification, soil erosion, and land degradation (Mirzabaev, Strokov, & Krasilnikov, 2023; Mirzabaev, Wu, Evans, Garca-Oliva, Hussein, Iqbal, Kimutai, Knowles, Meza, Nedjraoui, Tena, Türkeş, Vázquez, & Weltz, 2019). Predictions also indicate that global soil erosion rates could increase by up to 66% during the period 2015–2070 (Borrelli, Robinson, Panagos, & Ballabio, 2020).

These findings are alarming because they suggest that these disturbances to land have far-reaching consequences for food security. Climate variations, including rising temperatures and shifting global weather patterns, have a significant impact on food production (Sinclair, Wezel, Mbow, Chomba, Robiglio, & Harrison, 2019; Mirzabaev et al., 2023). Additionally, the expected increase in the world's population, with a predicted two billion-person increase by 2040 and Malaysia's population projected to reach 41.5 million, adds further complexity and challenges to the issue (Zamri & Mustaffha, 2022). Overall, this underscores the importance of the agricultural sector's sustainability in ensuring food stability and security.

The need for transformation in the agricultural sector to address food insecurity is widely acknowledged as an urgent issue. Scholars and practitioners, including researchers like Plieninger, Muñoz Rojas, Buck, and Scherr (2020), as well as Sanz, De Vente, Chotte, Bernoux, Kust, Ruiz, Almagro, Alloza, Vallejo, Castillo, Hebel, and Akhtar-Schuster (2017), emphasize the critical role of transforming agriculture in tackling food security challenges. One proposed approach for this transformation is sustainable land management (SLM).

Sustainable land management, as defined by the United Nations during the Earth Summit in 1992, involves "the use of land resources, including soils, water, animals, and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (Sanz et al., 2017). This definition highlights the dual objectives of SLM, which involve meeting current human needs

[1]Othman Yeop Abdullah Graduate School of Business Universiti Utara Malaysia, Kuala Lumpur. Email: zaleha@uum.edu.my
[2]Malik Firoz Khan Noon Business School University of Sargodha Pakistan. Email: arfan.shahzad@uos.edu.pk
[3]School of Business Management, Universiti Utara Malaysia, Malaysia. Email: subra@uum.edu.my

for agricultural production while ensuring the long-term sustainability of land resources and the preservation of environmental functions. SLM emphasizes a holistic approach that takes into account the interconnectedness of soil, water, plants, and animals in the context of agricultural production.

Alternative intensification models, such as SLM, advocate a departure from traditional agricultural practices that may lead to environmental degradation and resource depletion. Instead, these models promote practices that are environmentally sustainable and have the potential to address long-term food security concerns. The call for transformation in agriculture, particularly through sustainable land management, reflects a growing recognition of the need to balance production goals with environmental sustainability to ensure food security for current and future generations.

Previous studies have indicated that SLM enhances the efficiency and resilience of agricultural production systems (World Bank, 2006; Woodfine, 2009; Branca, Lipper, McCarty, & Jolejole, 2013). SLM represents a promising approach in the agricultural sector (Oduniyi & Tekana, 2021), promoting increased agricultural yields and food security while mitigating the susceptibility of agricultural systems to climatic risks. Importantly, empirical evidence underscores the imperative of optimizing land use in the 21st century. According to the report by Xiaoxia and Dosdogru (2021) for the United Nations Convention to Combat Desertification, SLM emerges as a key solution to address climate change. They argue that 'nature-based solutions can contribute 37% of cost-effective CO2 mitigation by 2030, thus reducing global warming. Through the restoration of land and investments in sustainable land management, it is possible to leverage the potential of healthy land to serve as a carbon sink and protect the atmosphere '(p.12).' However, there is a scarcity of studies addressing specific challenges of agroforestry. Consequently, the primary objective of this study is to investigate the challenges facing agroforestry to enhance SLM in Malaysia.

1.1. Agroforestry Practice in Malaysia

The Malaysian agriculture sector has witnessed a decline in its gross domestic product, plummeting from 43.7% to 7.1% between 1960 and 2021, resulting in concerns about rice shortages in Malaysia. In 2021 alone, Malaysians reportedly spent $583 million on imported rice, highlighting the nation's heavy reliance on rice imports (Akhtar, 2023). Sustainable Land Management (SLM) presents a potential solution for the Malaysian government. Empirical evidence suggests that agroforestry, a form of SLM, has the capacity to revolutionize Malaysian agriculture and address food shortages. Agroforestry focuses on optimizing land use through various methods, including the integration of trees into croplands, bush and tree fallows, and the establishment of live barriers and buffer strips with woody species. It is highly recommended for resolving food security issues as it enhances agricultural ecosystem productivity and mitigates the effects of climate change through increased carbon sequestration (Branca et al., 2013). Additionally, agroforestry offers co-benefits such as reduced greenhouse gas emissions and improved carbon storage in soils and biomass.

While Malaysia has embraced various forms of agroforestry, including agrosilvicultural, silvopastoral, silvofisheries, and agrosilvopastoral practices (Ahmad, 2001), the widespread adoption of agroforestry has been limited. With the current rice shortage issue, the importance of agroforestry becomes evident. Malaysian researchers have stressed the need for this sector's attention and evolution to align with the socioeconomic context (Noor, Koter, Othman, Hai, & Yahya, 2012). However, progress has been slow as the government has focused on other contemporary sectors like industry and automotive.

Scholars recommend that Malaysia's agroforestry sector should concentrate on improving the agroforestry system to remain competitive in the global economy and international trade. Addressing challenges in this sector, such as ensuring sustainable income for farmers to alleviate poverty, is crucial. Effective land use can have a positive impact on the ecosystem. Several Malaysian studies (e.g., Noor et al., 2012) have highlighted the challenges within local agroforestry, yet limited attention has been given to this sector, resulting in slow progress.

Moreover, there has been limited research on the challenges facing the agroforestry sector, as studies have often focused on its scientific applications. Consequently, knowledge regarding the challenges in this sector is relatively scarce (Keat, Nath, & Jose, 2018). This study has revealed that the understanding of agroforestry among people is somewhat shallow. Aminuddin, Ghulam, Abdullah, Zulkefli, and Salama (2005), who studied agroforestry in Malaysia over two decades ago, found that rural communities were often unaware that they were practicing agroforestry. Smallholders in the East Coast area were found to possess limited knowledge and skills in agroforestry practices (Aminuddin et al., 2005). Educating farmers in agroforestry is essential due to their limited knowledge and skills, as previous literature has shown that proper knowledge of agroforestry practices enhances the productivity and stability of smallholder agricultural production (Branca et al., 2013). Traditional agricultural models employing single agricultural methods are deemed insufficient in the present century, demanding more resilient and practical solutions. Addressing these challenges requires a multi-stakeholder approach involving government agencies, NGOs, research institutions, and local communities.

Recognizing that agroforestry can contribute significantly to Sustainable Land Management (SLM) in Malaysia, overcoming these challenges is imperative to unlock its full potential. Studies (Haregeweyn, Tsunekawa, Tsubo, Fenta, Ebabu, Vanmaercke, Borrelli, Panagos, Berihun, Langendoen, Nigussie, Setargie, Maurice, Elias, Sun, & Poese, 2023) have indicated that agroforestry has the potential to address food security, climate change adaptation, and mitigation. The successful adoption of agroforestry in various regions of Africa further underscores its importance. Given the significance of agroforestry and the limited understanding of the challenges it faces in maintaining sustainable businesses in Malaysia (Noor et al., 2012), this study aims to explore

these challenges and provide insights into the field's challenges using the Gioia methodology and a case study conducted in the northern part of Malaysia.

2. Literature Review

Agroforestry serves as a dynamic agricultural system in Malaysia, promoting sustainable food production by seamlessly integrating tree cultivation, crop farming, and livestock rearing (Vijayanathan, Rawichandran, Abdullah, Hazmi Anuar, Koter, & Ahmad, 2022). Given Malaysia's tropical rainforest climate, agroforestry has become an essential method due to its climate suitability. The range of agroforestry practices in Malaysia includes agrosilviculture (crop-tree mixture), silvopastoral (tree-animal combination), and agrosilvopastoral (crop-tree-animal combination). These practices offer various advantages, including efficient land use, improved soil health, and diversified income sources through the production of wood and fruits in agrosilviculture. Silvopastoral systems integrate grazing animals with trees, providing shade, additional feed, and erosion prevention. Agro-silvopastoral systems encompass all three elements, embodying a holistic farming approach that maximizes productivity and environmental sustainability. Malaysia's climate and abundant rainforest resources make agroforestry invaluable for promoting sustainable food production and harnessing the nation's rich natural assets.

2.1. Agroforestry

Agroforestry has long been recognized as a source of income generation, providing safe and healthy food while creating job opportunities (Keat, Nath, & Jose 2018). Nair (1993) emphasized tree planting as a strategy within agroforestry to enhance farmers' quality of life by efficiently utilizing available resources. Nair (1993) conceptualized agroforestry as an integrated land use system combining trees, shrubs, crops, and/or livestock to generate multiple benefits, such as increased agricultural productivity, improved environmental sustainability, and enhanced livelihoods for farmers.

In Malaysia, as in many other countries, specific challenges and considerations are associated with agroforestry practices. Despite the crucial role of agroforestry systems in transforming agriculture towards achieving Sustainable Development Goals (SDGs), particularly in terms of climate change mitigation and adaptation (Waldron, Garrity, Malhi, Girardin, Miller, & Seddon, 2017), the challenges facing this sector have not received adequate attention. Most agroforestry literature tends to be local and often focuses on agricultural sciences, lacking a business model perspective.

2.2. Sustainability Land Management

Earlier studies have highlighted the significance of Sustainable Land Management (SLM) in achieving SDGs, particularly from a food security perspective (Bürgi, 2017; Thaxton, Shames, & Scherr, 2017). Empirical studies have demonstrated significant societal benefits associated with multifunctional land use (Van Noordwijk, 2019). SLM offers long-term benefits in addressing land degradation, with tangible results in 3-10 years (Mirzabaev et al., 2023). Collaborative efforts involving multiple stakeholders are essential for optimizing SLM, necessitating landscape-level governance platforms and partnerships (Angelstam, Munoz-Rojas, & Pinto-Correia, 2019). Such collaborations are vital to overcoming challenges in implementing, scaling, and sustaining agroforestry systems.

2.3. Challenges in agroforestry as part of SLM

The agroforestry system exhibits resilience to climate-related risks and has been a long-standing component of SLM. However, despite its longevity, several challenges hinder the full potential of agroforestry. Empirical evidence reveals multiple challenges faced by farmers, yet these challenges remain underexplored. One primary challenge is the shortage of superior planting materials and improved seed varieties (Sharma, Singh, Tiwari, & Verma, 2017). Studies indicate that only about 10% of planting materials meet high-quality standards, leaving the majority lacking quality guarantees. This challenge is common in developing countries like India and Malaysia. Additionally, land size plays a significant role, with studies showing that larger plots are more effective in agroforestry, posing a challenge for developing countries like Malaysia. Small plots tend to be less productive (Puri & Nair, 2004). Moreover, there is a lack of long-term experiments and laboratory work aimed at improving agroforestry practices, impacting progress and understanding (Puri & Nair, 2004). The marketing aspect of agroforestry products also merits attention.

2. Methodology

To gain additional insight into the topic, this study adopted a qualitative methodology. Considering the nature of the research questions, which are an inquiry-based and interpretivist, qualitative methodology is most appropriate. The study expands on the literature because of this unique intepretivist nature. In addition, we adopted multiple methods to execute qualitative research (Gioia methodology and case study). This is because the objective of the study is to examine the challenges facing agroforestry. The Gioia methodology is suitable as the Gioia methodology is a method designed to develop new knowledge or theory (Gioia, Corley, & Hamilton, 2012), which is exactly the intention of the study, i.e., to develop new knowledge from the perspective of the participants on the challenges facing agroforestry in Malaysia. To gain a rich and thick description of the data, we also conducted a case study. This study conducted a case study at one of a private plantation that adopted multi-cropping. The following section delves into the process of both methods.

2.4. Method 1: Gioia methodology

Given the limited research addressing challenges in Malaysian agroforestry, the Gioia methodology has been identified as the most suitable approach for this study. This methodology, designed to uncover new insights, aligns well with the research questions focusing on the challenges in agroforestry in Malaysia. The primary aim is to develop a fresh perspective on these challenges and understand how individuals involved in agroforestry navigate

this theme. The establishment of a customized Gioia methodology for our study is driven by the overarching goal of generating new knowledge. We have embraced the foundational assumption proposed by Gioia et al. (2012), which asserts that the organizational world is socially constructed and involves 'knowledgeable agents.' This assumption posits that individuals within organizations possess the capacity to articulate their thoughts, intentions, and actions. By adopting this perspective, we aim to gain a deeper understanding of how knowledgeable agents in the agroforestry sector in Malaysia perceive and address challenges, contributing to a more nuanced comprehension of the social constructs within this context.

2.5. Data Collection Methods

The study employed two distinct data collection methods: surveys and face-to-face interviews. By utilizing multiple data collection methods, we aimed to enhance the validity of our study and gain a comprehensive understanding of the challenges faced by agroforestry agents, including farmers, government agencies, and private plantations.

We gave extraordinary voice to informants, treating them as knowledgeable agents, in order to capture the reality as constructed by the people within the organization. This approach is central to the Gioia methodology, where the participants' voices are of utmost importance, and research deliverables revolve around conveying these voices. Granting participants, a voice in depicting their reality aligns with the analytical discipline of interpretive study, thereby bolstering the credibility of our data interpretations.

The triangulation of data collected from surveys and interviews enhances the validity of the new knowledge developed in our study (refer to the analysis section). This adoption of data source triangulation aligns with Gioia et al. (2012) strategy of establishing new knowledge and ensuring that our conclusions are both plausible and defensible (p.15).

Perhaps most significantly, Gioia et al. (2012) emphasize that the Gioia methodology is designed to ensure that the concept development in organizational studies brings meaning and coherence to organizations. This study's overarching goal is to provide meaning to the concept of challenges faced by actors involved in this setting, whether they are practitioners experiencing agroforestry, researchers investigating it, or theorists developing models. The aim is to enable readers to understand these agents' challenges as described, explained, and contextualized within the setting.

2.6. Qualitative Survey

This study conducted qualitative surveys to gather information about the challenges faced by agroforestry farmers. The survey tool was divided into three sections: one focused on demographic information, while the others delved into details relevant to addressing these challenges (please refer to Appendix 1). A total of 100 questionnaires were distributed among participants from two major agroforestry plantations in the northern region of Malaysia, aiming to represent various plantations across the country. Subsequently, 98 fully completed questionnaires were received and analyzed. The survey instrument comprised 13 questions, incorporating a combination of open-ended and closed-ended queries. The data obtained were subjected to descriptive analysis (for the qualitative survey questions, see Appendix 1).

2.7. Interviews

The second approach involved conducting purposeful face-to-face interviews. Interviews were conducted using the purpose-sampling method, where participants were chosen based on their ability to address the research questions. Prior to the interviews, permission was sought, and voluntary consent was obtained from the interviewees. Participants were selected based on their roles in agroforestry, aligning with the axiological assumption in qualitative research that allows value-laden perspectives to enrich the description of the subject under study.

For data collection, two government agencies from northern Malaysia were selected, and focus group discussions were conducted. Each focus group consisted of two to five individuals relevant to the research topic. Representatives of each group held positions responsible for providing information on the challenges faced by the agroforestry sector. Selection criteria included their knowledge, skills, and experience in agroforestry.

Using a structured interview protocol, semi-structured face-to-face interviews were conducted, inviting participants to share their experiences and opinions. Probing questions were consistently used to obtain in-depth information about the challenges within agroforestry. Each focus group discussion session lasted approximately 60 minutes. The interviews were audio-recorded and transcribed verbatim with the participants' permission, after thorough communication about the study and assurance that their personal or company identities would not be disclosed without prior consent. In addition to the interviews, site visits were conducted to gain further insights into the agroforestry context.

2.8. Method 2: Case Study

In conjunction with the Gioia methodology, this study incorporated a single case study located in Segamat, Johor, a state in southern Malaysia. The chosen case is a privately owned plantation specializing in the cultivation of various plant species categorized into four main groups (see Table 1). This specific estate operates under the governance of a larger conglomerate. The primary focus of the plantation encompasses diverse agricultural activities, including multi-cropping, palm oil cultivation, coconut, and pineapple farming, among others. Additionally, the estate integrates approximately twenty additional plant varieties, including fruits, root trees, and various types of vegetation.

Table 1: Different plant species under four major categories

Tree Species	Types of multiple cropping
Woody tree	Palm Oil, Coconut, Rambutan, Guava, *Cempedak*, etc
Vegetation	Green leafy
Perennial	Pineapple
Nursery	Multiple shoots, rooted plantlets transferred to soil and plantlets are being maintained at the nursery

Source: Research data

2.9. Observation

The third approach employed in the study is observation. Details of this observational process, including the setting, duration, specific aspects observed, and its contribution to a broader understanding of the challenges faced by agroforestry agents, are discussed in the following section.

To gain additional insights, this study conducted on-site visits accompanied by estate managers and officers, focusing on the observation of multi-cropping practices and climate change mitigation measures. The primary objective was to triangulate the data obtained through the interviews. The observations unveiled diverse multi-cropping systems and the estate's proactive measures to minimize climate change risks through the implementation of irrigation and technology adoption. The nursery, which operates as an incubator, played a pivotal role, guided by the headquarters in conducting research and development initiatives aimed at enhancing the productivity of the estate.

Observation was conducted, accompanied by estate managers and officers, for 1.5 to 2 hours of touring, covering approximately one-third of the estate plantation. The purpose was to triangulate the data obtained from the interviews. The observations highlighted the variability in the implementation of multi-cropping systems at the site. It is also noted that the estate's mitigation measures to reduce climate change risks, involving strategic irrigation practices and the adoption of technology to address calculated and unexpected risks.

The nursery was identified as a crucial incubator, overseen by the headquarters, conducting ongoing research and development initiatives to enhance the productivity of the estate plantation. Triangulation of data sources served to improve the validity of our findings, promoting trustworthiness, credibility, and supporting the transferability, dependability, and confirmability of the research results. These measures align with the trustworthiness criteria proposed by the Four Dimensions Criteria (FDC) (Lincoln, 1995).

2.10. Gioia Analysis Method

This study applied the Gioia analysis process to scrutinize the data collected from various sources, employing three main analytical stages: first-order analysis, second-order analysis, and aggregate dimension.

First-order analysis: In the initial phase of the research, a plethora of informational terms, codes, and categories surfaced, constituting raw data elements extracted from interviews and observations (refer to Table 2, column first-order theme). This process involved organizing and grouping similar elements to form meaningful units.

Second-order analysis: After establishing the categories (refer to Table 2, column second order theme), the analysis progressed to the second-order phase. Here, the focus shifted to identifying commonalities and distinctions among the developed categories. Second-order analysis delved into the theoretical realm, with the aim of describing and explaining the observed phenomenon. As a result, relevant categories emerged, representing higher-level concepts or themes derived from the initial data analysis. This step advanced beyond surface-level categorization to a deeper understanding of the underlying theoretical framework or principles. Following the second-order analysis, the subsequent step involved condensing these themes into aggregate dimensions, indicating a process of consolidating theoretical insights into broader perspectives.

Aggregate Dimension: With the complete set of first-order terms and second-order themes, the study developed the final process of the Gioia analysis process, that is, aggregated dimensions. In this process, the study laid the foundation for the construction of a data structure. This structure serves as an organized and systematic representation of the information analyzed, providing a framework for further interpretation and discussion. The analysis concludes with the aggregation of dimensions, which leads to the construction of a comprehensive data structure for further interpretation. At the aggregate dimension, three main variables appeared as themes representing the challenges in agroforestry in Malaysia.

Table 2: Thematic analysis

Thematic Analysis Using Gioia analysis method		
First Order Theme	**Second Order Theme**	**Aggregate Dimensions**
• Concern on the type of woody and non-woody agroforestry is developing. The mix-match of crops is quite a concern.	Developing Suitable Crops Mix Matched	

• Agent scope of work • Need technical skills • Engagement with farmers requires technical knowledge • Most of the agent who are engaged and interact with farmers have management knowledge.	Role Of Agent As Intermediary To Help Farmers	Resources challenges
• Educate farmers to use modern technology, new technology • To give training to farmers • The farmers previously used the traditional tools. • Educate farmers to optimise the small scale land used	Adopting New Technology To Optimise Land Use	Technical
• Sharing input from university and government to farmers. • Transfer knowledge and giving insentif • Giving certificate mygap or my organic • Supply chain • Teach how to develop business model • Teach how to process, packaging, etc	Transfer Of Knowledge	
• Training • MyGap certificate. • Managing the field • Food security requirement • Climate change • The know how about environment	Environmental Issue	Enviornment
• Import from Thailand because of limited produce	Limitation in production	Resources
• Mindset of farmers and entrepreneurs	Change Mindset	
• Lack of collaboration between industry, university, business	Lack Of Shared Value	
• Migran workers permit difficult to get	Migrant issue	

Source: Research Data

3. Results and Findings

Agroforestry is a system that holds significant importance, particularly from a scientific perspective. Studies have consistently demonstrated that agroforestry contributes to increased carbon levels, surpassing the levels found in land use scenarios without trees. Furthermore, agroforestry has been shown to mitigate soil carbon losses resulting from erosion, thereby enhancing the organic carbon content of the soil. However, it is worth noting that certain studies have indicated that the profitability of agroforestry varies, with it being more advantageous on marginally used land compared to prime land. The agroforestry systems examined in this study serve as microcosms that provide insights into larger sustainability challenges faced in Malaysia.

Through the triangulation of data from various sources, including surveys, interviews, case study, and supplemented by observations, this study has identified and developed three main themes that describe the challenges encountered in agroforestry practices as a form of sustainable land management. These themes emerged organically from the richness of the collected data and provide a comprehensive understanding of the obstacles faced within the Malaysian agroforestry sector. Table 3 presents these three themes along with their descriptions.

Table 3: Main Challenges in Malaysia Agroforestry

Themes	Description
Environmental	Primarily encompassing weather changes and soil fertility challenges, highlighting the impact of environmental factors on agroforestry practices.
Technical	Focusing on challenges related to skills and knowledge gaps, underlining the importance of technical expertise in sustaining agroforestry systems.
Resources	Encompassing various challenges such as limited land availability, capital constraints, shortage of workers, issues in crop sales, and inadequate government support.

Source: Research Data

These themes encompass the multifaceted nature of challenges in the agroforestry sector, emphasizing the intricate interplay between environmental, technical, and resource-related factors. The holistic approach to theme development ensures a nuanced understanding of the obstacles faced by agroforestry practices in Malaysia, laying the foundation for targeted solutions and sustainable land management strategies.

2.11. Challenges in Agroforestry in Malaysia

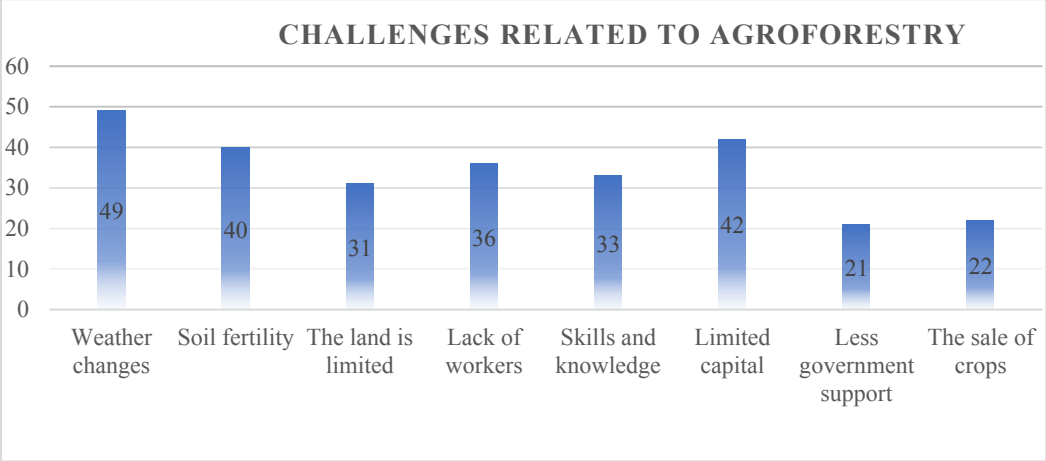
Our survey data, as illustrated in Figure 1, serve to triangulate and validate the findings from interviews, observations, and surveys providing a comprehensive understanding of the challenges facing agroforestry in Malaysia. Triangulating data sources enhance the validity, trustworthiness, and credibility of our findings while also supporting the transferability, dependability, and confirmability of the results, aligning with the four dimensions criteria suggested by Lincoln (1995).

2.12. Theme 1: Environmental Challenges

The survey, conducted with participants from two agroforestry plantations (as detailed in the methodology section), revealed significant variations in the challenges.

Survey Results (refer to Figure 1): Descriptive data from the survey highlighted weather changes as the major challenge in agroforestry, followed by limited capital and soil fertility. Subsequent challenges included a shortage of workers, skills and knowledge gaps, limited land, issues related to the sale of crops, along inadequate government support.

Figure 1: Challenges related to agroforestry



Source: Research Data

2.12.1. Weather Change

The descriptive analysis indicates that the agriculture sector is vulnerable to changing conditions, especially climatic variability. Congruent with the survey results, the interview analysis indicates a similar finding that climate change is becoming a major concern in agroforestry practices. Triangulating with the interview data, it is confirmed that this sector faces challenges related to uncertain weather patterns, which impact productivity. The participants, from both government agencies and private estate planning, confirmed that climate instability caused a reduction in production. To minimize the risk of lower productivity, our case study participant transformed the practice into implementation and experimentation with root tree planting. This was the result of collective collaboration with stakeholders. The private sector adopted the multi-cropping agroforestry methods, innovating its root tree structure. The plantation innovated its strategy by focusing on integrating planting; palm oil as the primary source of income and coconut as the secondary source of income. Taking collective action (from the headquarters, stakeholders, and agents) to another level, the estate changed its agroforestry practices, integrating root trees and woody structures in agricultural cropland, where they focus on coconut due to its resilience to climate change. This showed that private estates have opportunities to capitalize on agroforestry practice. The long-lived nature of coconut provides multiple varieties of produce from the estate; therefore, it has become one of the mechanisms to manage its climate risk. The estate manager claims that farmers and communities must be creative and innovative and create the versatility of the plantation strategy as a measure of managing the risk of weather changes. On the other hand, there is difficulty echoed by the government agencies as they claimed limited support from the government in terms of budget, and opportunities limit their evolution and progress in this sector. In addition to natural phenomena like drought and flood, which have affected productivity, the challenges are greater. They claimed that weather changes and the volume of rain have, to some extent, affected the size and volume of production in their plantations.

Previous studies (such as Zamri and Mustaffha, 2022) also claimed that weather uncertainty creates an imbalance in the agricultural sector, i.e., negative side effects on food production supply. Sharing similar challenges, previous studies revealed that natural disasters such as tropical cyclone-related floods have become a new norm in developing countries along the tropics with devastating economic consequences, globally (Pangapanga-Phiri, Mungatana, Pangapanga, & Nkoka, 2022; Fahad & Wang, 2018). Past studies claimed that climate projections for the 21st century pose serious challenges to agricultural development, especially in developing countries (Fahad and Jing, 2017; Fahad and Wang, 2018). According to Pangapanga-Phiri et al. (2022), for more than two decades, climate change has been responsible for nearly half of natural disaster losses worldwide. Thus, it supports the findings that found that weather variability caused a decrease in productivity.

2.12.2. Limited capital

Limited capital is another challenge facing agroforestry and has been rated as the second major challenge in the agroforestry sector. The data indicated that financial limitation is one of the biggest challenges facing farmers and government agencies. Similarly, the interview data indicated the same pattern that limited capital is one of the major drawbacks of agroforestry in Malaysia. As mentioned above, government agencies have greater difficulty

in regard to capital. Interviews (based on the Northern region) revealed that the reduction in the budget affected their innovations. The officers voiced that the budget cut affected their ability to innovate and thus limits their innovation which possibly hinders the adoption of effective agroforestry. Participants suggest that access to affordable credit and subsidies can help overcome this challenge.

As mentioned earlier, the interview data collected from the private company indicated that research and development at its head office create a new way of agroforestry measures. Because capital investment is not a problem, the estate experimented with multiple crop planting. As a result, they adopted multiple crops with appropriate varieties, and moving from monoculture systems to polyculture or integrated crops (coconut, pineapple, and palm oil) benefits the company as an individual and a group. The surrounding fields were continuously used for production, with crop rotations that included perennials, etc. The geometry is also innovated from the experiment data for mapping tree roots, where they planted pineapples with coconut (see picture 1). A crucial finding discovered is that leadership support and capital availability are the two positive factors to realize private plantation success in the implementation of agroforestry. However, the private company did face the challenge of cost and risk during the transition, particularly during the first three years. The estate manager declared that it took around three years to gain the yield due to the harvesting time (3-5 years), which delayed the financial gain. However, the long-term benefits compensate for it.

2.12.3. Soil fertility

The data indicate that the third challenge facing agroforestry is soil fertility. Interestingly, the interview analysis also indicates a similar result that soil fertility is another concern for farmers, government agencies, and private companies (estate plantations). All three stakeholders claimed that soil fertility affects productivity. In particular, our interview data indicated a similar finding that climate change hinders the ability of soil to maintain fertility. For example, the ability of specific soil to sustain plant growth is uncertain. Our observation is that the research and development of private companies guide the estate to adapt to the environment, while government agencies have difficulty adapting to soil sustainability due to the inadequacy of technology and research development. The private company adapted the soil to the most productive plant growth, thus optimizing crop yield. Guided by experts hired in the estate, together with the research and development conducted at the headquarters, the private company used the soil fertility management approach. This approach maximizes crop production while minimizing land degradation, including soil erosion. The use of crop rotation, combined with the knowledge of how to adapt these practices to local conditions, improves the productivity of the estate. Hugenschmidt and Kay (2023) study found that intercropping 'allows crop and tree roots to colonize different soil horizons when managed by root pruning. Consequently, the resilience of the combined production systems is enhanced (p.9).

Past studies also revealed similar results (Hugenschmidt and Kay, 2023; Haregeweyn, Tsunekawa, Tsubo, Fenta, Ebabu, Vanmaercke, Borrelli, Panagos, Berihun, Langendoen, Nigussie, Setargie, Maurice, Elias, Sun, & Poesen, 2023; Bergeron, Lacombe, Bradley, Whalen, Cogliastro, Jutras, & Arp, 2011) that soil fertility reduces productivity. For example, Hugenschmidt and Kay (2023) in their study revealed that the tree rooting systems of old trees (fruit) gave nutrients and water to the crop, thus providing a positive effect on nutrient uptake within poplar agroforestry systems aged 5 to 8 years. Past studies also found similar effects in a field study comparing maize-soybean rotation with fruit and nut alley cropping systems (Wolz, Branham, & DeLucia, 2018). Haregeweyn et al. (2023) also revealed a similar result that agroforestry can address these issues by improving soil quality but requires careful selection of tree species and management practices. Congruent with the present research, in particular, the private company conducted exactly that: selecting tree species and optimizing experts in management practice. Evidently, we observed that the producers planted woody trees, a kind of tree species (palm oil and coconut), and perennial shrubby bush (pineapple) simultaneously. Past studies also confirmed that a combination of tree and crop species resulted in spatiotemporal improvements in soil health. This is because placement and proper agroforestry practices control soil erosion (see Appendix picture). At the more advanced level, Hugenschmidt and Kay (2003) found soil fertility using a nondestructive investigation of tree roots using a 400 MHz antenna, and full 3D data acquisition and processing were a success in increasing soil fertility.

2.13. Theme 2: Technical Challenges

Confirmation of the thematic analysis (refer to Table 2): Corroborating with the thematic analysis derived from interviews and observations, two overarching themes emerged: technical challenges (skills and knowledge) and resource challenges (financial, collaborative, and innovative limitations).

2.13.1. Skills and knowledge

The survey and interview data revealed a critical challenge that hinders progress in agroforestry production in Malaysia: the scarcity of skilled workers. Private plantations, in particular, mentioned difficulties in securing proficient foreign workers, posing a significant hurdle to their operations. Both the private and the public sectors agreed that the shortage of skilled labor leads to harvest delays, thereby adversely affecting overall productivity. The insights from the interviews further illuminate the connection between government policies on foreign workers and their cascading impact on planning productivity. The study underscores a spillover effect, illustrating how policy decisions influence on-the-ground challenges. The data also highlighted a substantial skill and knowledge gap that hinders farmers' adoption of agroforestry practices. Insufficient technical development has emerged as a specific area that needs improvement in Malaysia in terms of agroforestry. Despite the potential benefits of scientific applications, the study found that limited technical skills impede the optimal implementation of agroforestry practices.

Noteworthy distinctions between government agencies and private planning surfaced, particularly in terms of technical skills and knowledge. Private planning was described as well-equipped with technology and research development, fostering knowledge dissemination. On the contrary, government agencies expressed limitations due to the lack of technical support, which limits the effectiveness of agroforestry adoption in plantations. Furthermore, the study highlighted disparities in research and innovation capabilities. The dedicated private plantation laboratory conducting research at the headquarters, facilitating advances in knowledge and technology, helped minimize limitations. On the contrary, government agencies faced impediments stemming from limited research, hampering their capacity for innovation.

2.14. Theme 3: Resources Challenges

The dynamic of productivity involves human resources, indicating that the critical roles of workers in maintaining sustainable agroforestry systems are crucial. Our study found that the labor issue is also one of the main problems facing the agroforestry sectors, although as serious as climate change. The data indicate that the lack of workers is another challenge facing both government agencies and private companies. The labor shortage is caused by the regulatory limitation on the hiring of foreign workers. Triangulation of data sources (surveys and interviews) indicated that planters face severe labor shortages, which affects the productivity of agroforestry. For example, a management estate voiced his concern that the labor shortage delayed harvests, thus curbing output, which affected productivity. The plunge in the Malaysian currency and the restriction of labor coming to Malaysia are adding to the factors affecting the labor force. The fluctuation of the Malaysian currency also does not attract foreign workers. The legal perspective of foreign labor is not helping to solve the labor shortage either.

2.14.1. Financial, Collaborative, and Innovative Limitations

Adding to this issue is the lack of government funding. According to our participants, the reduction in the budget for this year affected the agroforestry process. The lack of funding resulted in them not being able to carry out experiments. Data indicate that the shortage of superior planting material and improved seed varieties are several of the limitations resulting from the lack of innovation. The study conducted in India also found a similar consequence that the lack of innovation resulted in the shortage of superior planting material and improved seed varieties (Sharma et al., 2017). They found that the small-scale research conducted in agroforestry affected its potential. The small plot and small laboratory research limit the potential for production. Sharma et al. (2017) claimed that the lack of research affected the agroforestry models suitable for the diverse agroclimatic regions, for indigenous and multipurpose species (viz. Prosopis cineraria), or on the domestication of particular sepsis.

Another major drawback is that our participants expressed their concerns about the scale of the research conducted. The government agency officers said they are conducting research on a small scale and that there is a lack of collaboration between the actors involved in agroforestry. One of the participants highlighted that "everyone is working in silo. There is no collaboration between universities and agencies. The university commonly conducted research in isolation, so they do not share their findings and experimental design with the agencies". This work-in-silo attitude limits the advancement of knowledge and productivity. We believe that to mitigate the lack of knowledge, there should be sufficient technical support and educational exposure given to farmers and agencies to develop skills and knowledge in this area. The potential of agroforestry could be improved with the application of new technology and a better understanding of the perceptions of landowners of climate change.

4. Conclusions

The study aimed to explore the challenges in the agroforestry sector in Malaysia. Integration of survey, interview, and observation data provides a comprehensive and nuanced picture of the challenges of agroforestry in Malaysia. Three main challenges facing agroforestry, namely; environmental, technical, and resource challenges, emerged as problems and that it could affect food security in Malaysia. Understanding the variations between government-controlled and private plantations offers valuable insights for addressing sector-specific challenges and implementing effective solutions for sustainable agroforestry practices. The results suggest that while agroforestry contributes to food security, challenges in the sector limit its potential and opportunities. In particular, climate change emerges as a significant factor that affects sustainable landscape management, particularly in agroforestry. Two overarching conclusions are drawn from the study. Firstly, agroforestry plays a vital role in ensuring food security. Secondly, the challenges faced by agroforestry hinder the potential of the agricultural sector. The primary finding underscores climate change as a major obstacle to sustainable landscape management, emphasizing the global urgency to find solutions, including rehabilitating degraded land. The study envisions that addressing these challenges requires collaboration between government agencies, stakeholders, and the private sector to promote the adoption of agroforestry systems.

5. Implications

The study implicates government policies in the context of food security and offers insight to the agriculture ministerial department. The findings advocate for the development of mitigation strategies to improve sustainable land use, positioning agroforestry as a solution. Collaborative efforts from various stakeholders are recommended to effectively manage challenges in the agroforestry sector, with implications for both government agencies and private plantations.

6. Limitations of the Study

The study acknowledges limitations, particularly the restricted scope to the northern area of Malaysia. This may affect the generalizability of the results to the entire agroforestry landscape. However, the researchers argue that

typical characteristics and the nature of business in the region may mitigate this limitation. Another limitation relates to the sample size, which is addressed through data triangulation and the integration of multi-methods to enhance the depth of understanding.

7. Future Research

Several avenues for future research are proposed. Increasing the sample size and expanding the sample location could enhance the generalizability of the findings. Expanding case studies to include more cases is suggested for a deeper exploration of research questions. In addition, future studies are encouraged to focus on biomass productivity in agroforestry interventions, particularly in relation to environmental services such as mitigation of climate change and conservation of biodiversity.

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About the Author(s)

Professor. Dr. Zaleha Othman is a Professor of Sustainability. She possesses a Ph.D. in ethics and corporate governance, a master's in business law, and a Degree in Accountancy. She completed her postdoctoral at Cass Business School, London (UK). Her areas of research are sustainability, corporate governance, ethics, and accounting fraud. She is a prolific qualitative researcher and has more than 30 research projects, funded by international and national agencies. She produced about sixty publications, which include Scopus journals, peer-reviewed journals, and proceedings, and co-authored several chapters in books. Frequently presented at international conferences and national events on topics related to her research fields. Frequently invited as speaker and workshop facilitator on qualitative research, and Sustainability (ESG), both at the International and National level. Also been appointed as an internal and external examiner in several higher education institutions. She received several awards including the UUM Excellence Service Award in 2017 and Best Research Award OYAGSB in 2019. Previously received articles of Merit Award, in 2016, 2013 (Malaysian Institute of Accountants), and 2022 UUM award for MOOC Development. Editor board members in several Scopus journals such as Public Integrity (Q2), The Qualitative Report(Q1), and GBMR (Mycite).

Professor. Dr Arfan Shahzad is a Professor of Management at the Malik Firoz Khan Noon Business School University of Sargodha Since August 2023. Formally, I have worked as an International senior lecturer/assistant Professor at the Othman Yeop Abdullah Graduate School of Business at the Universiti Utara Malaysia (AACSB, AMBA) for 10 Years (August 2013- August 2023). I hold a Master of Science (Information Technology) Degree from Universiti Utara Malaysia, and a Doctor of Business Administration degree from University Utara Malaysia (Accredited AACS, AMBA and ABEST21). I have taught Strategic Management, Business Management, E-Business, Research Methodology and quantitative methods, advanced quantitative research, Global Business, and data analysis to MBA/MSC/DBA/Ph.D. I have successfully supervised 20 doctoral students (PhD/DBA) and more than 12 master's and MBA students. I have served as Director of alumni and corporate relations and Director of Doctors program. I have published over 70 research papers in international peer-reviewed and indexed Scopus and web science journals. I have served on the editorial board of several international journals. I have also conducted training on data analysis using SmartPLS 3.0 and SPSS in Malaysia, Thailand, and Pakistan for postgraduate students/Faculty. I have experience developing a curriculum, a modern way of conducting classes, building a research network, and establishing a strong network with alumni. Before joining academia, I was Chief Technology Officer at R & D SerindIT.com, Malaysia. There, I handled ICT infrastructure projects during 2006-2013 of value USD 1 million per year. I continued to work with an erstwhile company as a consultant for ICT infrastructure from 2013 to 2014.

Professor. Dr. Subramaniam Sri Ramalu is a Professor of Organizational Behavior and Leadership. He is a Fellow of the Chartered Management Institute (CMI), UK. Prior to joining Universiti Utara Malaysia (UUM) in 2006, Prof. Subramaniam worked for several multinational companies in a managerial capacity. He is a Certified Professional Trainer and a Member of the Malaysian Institute of Management. He is also a Certified Trainer of the Human Resources Development Fund, an agency under the Ministry of Human Resources Malaysia. He has held various administrative positions at the University. His current position is Director of the Postgraduate Studies Unit, College of Business, Universiti Utara Malaysia (UUM). Also a deputy dean of Othman Yeop Abdullah Graduate School of Business, UUM. In recognition of his leadership in academics, he has been admitted as a Certified Executive Academy Teaching and Learning Professional by The European Foundation for Management Development (EFMD), an accreditation body for business schools based in Brussels, Belgium. He also attended the Global Executive Workshop for Higher Education Management and Administration at Michigan State University, USA. His research interests include leadership, organizational behavior, and human resource management. He has successfully supervised 15 doctoral students and more than 20 Master students. To date, he has completed 16 research projects and published more than 60 articles in both local and international journals. He also serves as an editor and board member in several international journals and is frequently invited to review articles for reputable journals such as the Journal of Global Mobility, the International Journal of Cross-Cultural Management, and the Journal of Management & Organization.

Appendix 1:

SURVEY

BAHAGIAN A: LATAR BELAKANG RESPONDEN

Mark (/) in the relevant box or write your answer in the space provided for the following questions.

1. Gender

   ◯ Male ◯ Female

2. Age

   ◯ Less than 25 tahun ◯ 26-35 years

   ◯ 36-45 years ◯ 46-55 years

   ◯ More than 56 years

3. Highest Education

   ◯ PMR ◯ O' Level

   ◯ Diploma ◯ Bachelor Degree

   ◯ Postgraduate

4. Monthly income from agro-field*

   ◯ Less than RM 1000 ◯ RM 1001- RM 3000

   ◯ RM 3001-RM 5000 ◯ RM 5001-RM 7000

   ◯ More than RM 7001

5. Experience in the agro-field

   ◯ Less than 5 years ◯ 5-10 years

   ◯ 11-15 years ◯ 16-20 years

   ◯ More than 21 years

6. Do you practice mixed farming*?

   ◯ Yes ◯ No

* The agro-field refers to industries based on agriculture. * Mixed farming is the farming practice of planting two or more crops, livestock, and aquaculture which are suitable in one area.

7. If you answered yes to question 8, what kind of mixed farming do you practice?

   ◯ Two types of different crops ◯ More than two types of different crops

   ◯ Combination of crops and livestock ◯ A combination of plants and livestock

8. Have you ever received financial assistance or incentives from the government to develop your business in mixed farming?

   ◯ Yes ◯ No

9. Have you received training and exposure related to mixed farming from relevant government agencies?

   ◯ Yes ◯ No

10. How did you get exposure to mixed farming?

    ◯ Family ◯ Government Agencies ◯ Own

11. What are the challenges in cultivating mixed agriculture? Can mark more than one answer?

    ◯ Change of weather ◯ Fertile Land ◯ Skill and Knowledge

    ◯ Lack of government support ◯ Limited Land ◯ limited capital

    ◯ Lack of labour ◯ sales of crops

12. Can mixed farming be a sustainable business model in the future?

◯ Yes ◯ No

13. Your suggestion for improving the mixed agriculture system as a sustainable business model

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