ANALYSIS OF CROP DIVERSIFICATION AMONG COCOA, OIL PALM AND RUBBER FARMERS IN ATIWA WEST DISTRICT AND KWAEBIBIREM MUNICIPALITY

BY

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DECLARATION

I, Mawuli Kodzo Ericson Sevor, do hereby declare that except for the references cited, which have been duly acknowledged, this work, "**ANALYSIS OF CROP DIVERSIFICATION AMONG COCOA, OIL PALM AND RUBBER FARMERS IN ATIWA WEST DISTRICT AND KWAEBIBIREM MUNICIPALITY**", is the results of my own research. It has never been presented anywhere either in part or whole for the award of any other degree in this University or elsewhere.

Signature..............................

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Date..17-10-23..........................

This work has been submitted for examination with our approval as supervisors:

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(Major Supervisor)	(Co-Supervisor)
Date..17-10-2023..........................	Date..17-10-2023..........................

DEDICATION

I dedicate this work to my family, especially Mawunya, Mawunyo, Mawulolo, Mawuena-Sika and Mawukoenya for their patience, sacrifice and continued support in all my endeavours.

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ABSTRACT

Lots of studies have been conducted on arable crop diversification but little work exists on diversification among tree crop farmers and its effects on farmer welfare. In the study area of Kwaebibirem Municipality and Atiwa West District in the Eastern region of Ghana, not much literature exists on tree crop diversification and its effects on household food insecurity and farm incomes. This study, therefore, sought to ascertain the extent of diversification practiced by tree crop farmers, the factors that influence diversification and the effect of diversification on farm income and household food insecurity (access) status. The study further explored the strengths, weaknesses, opportunities and threats of tree crop production in order to design strategies that can help tree crop farmers to be more food secure and more resilient to market and climate risks. Structured interviews with 740 farmers, in-depth interviews and focus group discussions were tools used for data collection for the study. A Crop Diversification Index (CDI) based on the Herfindahl Index, gross profit analysis, z-tests, Tobit regression and SWOT-TOWS analysis were used to analyse the data. The Household Food Insecurity Access Scale (HFIAS) was used to assess the access dimension of household food insecurity. Low crop diversification was observed among tree crop farmers with an average CDI of 0.23. Majority (96.89) of farm households belong to the low diversification group with more than 95% of lands allocated for the production of tree crops. The study identified number of farm plots, distance to farms, frequency of information access, sex, and dependency ratio as factors that influenced the extent of crop diversification among tree crop farmers. Low levels of food insecurity was observed among tree crop farmers with a mean HFIAS score of 3.91. Farmers who produced only one type of tree crop recorded the highest average gross profit (GHS 6377.60) and also had the highest HFIAS score (4.31) in the access dimension of food insecurity. Slightly diversified farming presents a good compromise for food insecurity (2.79) and for gross profit (GHS 5727.50). The gross profits of highly diversified farmers were significantly different (lower) from that of lowly diversified farmers. However there was no significant difference in the household food insecurity status of farmers. Farmers practice temporal diversification during the immature stage of tree crop farms while mature tree crop farms are maintained as monocrops due to closed canopies. The study recommends that tree crop farmers should diversify mature farms by including leguminous cover crops to fix organic nitrogen into the soil in order to reduce the rate of fertiliser application, labour for weed control and other variable costs. Research should be conducted on the inclusion of groundnuts, sweet potato and *Aframomum melegueta* (fom wisa) in tree crop farms. Further research should be conducted to modify tree crop density per acreage in order to enable intercropping with other tree or food crops. Research institutions should establish model farms of diversified tree crop farm systems in order to conduct research to influence policy. Market-oriented diversication should be the objective of research since the tree crops in this study area are cash crops. The OVCF and other funding sources should include crop diversification in the design of funded portfolios for tree crop production.

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LIST OF ACRONYMS

CDI	Crop Diversification Index
CHED	Cocoa Health and Extension Division
CRIG	Cocoa Research Institute of Ghana
COCOBOD	Cocoa Board, Ghana
CODAPEC	Cocoa Disease and Pest Control
CPO	Crude Palm Oil
DRE	Dry Rubber Equivalent
FAO	Food and Agriculture Organisation
FFB	Fresh Fruit Bunch
FSP	Free Seedlings Programme
GML	Governing Multifunctional Landscape
GREL	Ghana Rubber Estate Limited
GOPDC	Ghana Oil Palm Development Company
HFIAP	Household Food Insecurity Access Prevalence
HFIAS	Household Food Insecurity Access Scale
HFSSM	Household Food Security Survey Module
IFPRI	International Food Policy Research Institute
ILO	International Labour Organisation
LBCs	Licensed Buying Companies

MOFA	Ministry of Food and Agriculture
OFSP	Orange-Fleshed Sweet Potato
OLS	Ordinary Least Squares
OVCF	Outgrower and Value Chain Fund
PKC	Palm Kernel Cake
PKO	Palm Kernel Oil
PERD	Planting for Export and Rural Development
PCs	Purchasing Clerks
ROOA	Rubber Outgrowers Agents Association
RPGL	Rubber Plantations Ghana Limited
RSC	Rural Service Center
RSPO	Roundtable for Sustainable Palm Oil
SPD	Seed Production Division
SDG	Sustainable Development Goal (SDG)
SWOT	Strengths, Weaknesses, Opportunities and Threaths
TOWS	Threats, Opportunities, Weaknesses and Strenghs
TCDA	Tree Crops Development Authority
WFP	World Food Programme

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CHAPTER ONE

INTRODUCTION

1.1 Background

Apart from previous season yields, most small scale farmers also consider food consumption needs and ease of crop management to guide the extent to which they diversify their farming activities (Ahimbisibwe et al., 2019). Some of these factors and risks that farmers consider are not systemic because they are specific to crops and the extent of crop or farm management practiced by the farmer. It is believed that non-systemic risks are therefore easier to manage through diversification of farming activities (Burbano-Figueroa et al., 2022).

Crop diversification is the production system whereby the farmer increases the types of crops cultivated such that no single crop dominates production and output (Czyżewski & Smędzik-Ambroży, 2015). Rural farmers diversify their farms to produce several and different food crops at the same time using the resources available to provide food for household consumption (Adjimoti & Kwadzo, 2018; Bellon et al., 2020; Dessie et al., 2019; Schroth & Ruf, 2014) while others use this system of diversified production to increase household income (Bellon et al., 2020; Dessie et al., 2019; Mandal & Bezbaruah, 2013; Schroth & Ruf, 2014). Diversified farming activities present benefits from economies of scope (Roest et al., 2018) and diversification is identified as a tool that farm households use to improve their livelihoods (Dessie et al., 2019; Mekuria & Mekonnen, 2018).

(Czyżewski & Smędzik-Ambroży, 2015). This is done such that even if multiple produce and or products are the final outputs, one or two crops make up more than two-thirds of the final produce or product (Czyżewski & Smędzik-Ambroży, 2015). Specialisation helps the farmer to benefit from economies of scale (Roest et al., 2018). Specialisation (or quasi-monoculture) is very common in tree crop production systems where farm managers, through a process called "forest rent", are able to produce so much by relying on the natural resources inherited from the previous forest that was on the farmland (Schroth & Ruf, 2014).

Depending on the social, ecological and market characteristics of the farm environment, farmers may diversify production activities to improve livelihood or they may use specialisation (or quasi monoculture) to improve livelihoods. The narrative about diversification is gaining ground steadily taking into consideration its potential to mitigate the risks associated with climate change (Bellon et al., 2020; Makate et al., 2016; Schroth & Ruf, 2014) and market failure (Schroth & Ruf, 2014).

Diversification of farming activities, if not done properly, can have adverse effects. It can result in higher transaction costs to the farm manager (Schroth & Ruf, 2014). If the farm manager spreads resources too thin, yields and profits can reduce. Even when yields are good, profitability can be negatively affected because agricultural markets do not always function as expected (Schoneveld, 2020). In rural Ghana, for example, market imperfections hinder farmers ability to separate food consumed by the farm household from what they produce on the farm (Ecker, 2018). Therefore, relying on profitability alone as the reason for diversification can also negatively affect household food security and this can present a distorted or skewed understanding of how farmers select the crops included in their farming activities (Bellon et al., 2020). For example,farmers also use cost of entry as a criteria to select what they produce such that farmers will select the crop with a lower entry cost (Ruben & Pender, 2004).

A good farm diversification strategy, must therefore take into account the interaction of several variables such as reasons for diversification, opportunities for and constraints to diversification, and characteristics of the farmer (Schroth & Ruf, 2014). This study therefore analysed diversification of tree crop production systems among cocoa, oil palm and rubber farmers in Atiwa West and Kwaebibirem to provide insight that can guide development of diversification strategies to improve profits, food security and the environment.

1.2 Problem Statement

Decision-making about diversification is a multi-dimensional process (Zander, 2008) that involves trade-offs. In sub-Saharan Africa, income from the farm (Bellon et al., 2020; Dessie et al., 2019; Mandal & Bezbaruah, 2013; Schroth & Ruf, 2014) and food security are some of the important livelihood factors that farmers are likely to consider in determining their crop system (Adjimoti & Kwadzo, 2018; Bellon et al., 2020; Dessie et al., 2019; Schroth & Ruf, 2014). Tree crop farmers, therefore make trade-offs between producing their own food crops or producing more cash crops in order to buy food. Food insecurity may not be a problem for large-scale tree crop farmers because large-scale farmers can spread seasonal income over several months. Large-scale farmers may also have other income sources. In addition, large-scale farmers are better positioned to influence and negotiate for favourable prices when they are compared to smallholders. Crop diversification is a powerful tool to reduce food insecurity among poor farmers. Crop diversification is important for farmers who are highly dependent on a single or limited number of crops with strong seasonal price variations and poor value chain organisation (MOFA, 2012).

Wiggins *et al*. (2015) reported that tree crop farming provides farmers with cash with which they can buy food to improve food security. However, improvement of food security of tree crop farmers depends on access to land, labour, capital, reasonable and stable market prices (Wiggins et al., 2015); conditions that more likely apply to smallholders. A study of cocoa farming in the Forest-Savannah Transition Zone of Ghana, shows that cash crops do improve household food security of smallholders. However, income from only cocoa is not enough. Cocoa income is also not properly spread throughout the year to ensure household food security. Farmers rather use cocoa as a source of finance for entry into cashew and food crop production in order to improve food security (Hashmiu et al., 2022). Smallholders who earn income from only cocoa may not have enough income throughout the year to ensure household food security (WUR, 2020). The literature (Hashmiu et al., 2022; Wiggins et al., 2015; WUR, 2020), so far, shows the potential of tree crops to improve food security of farmers, provided certain conditions (access to land, labour, capital, reasonable and stable market prices, diversified farms) are met.

However, even if tree crop farmers are able to earn higher incomes from their farms in order to buy food (Hashmiu et al., 2022; Wiggins et al., 2015), they will not be able to buy food if there is a thin market or market failure. Most arable crop farmers in Ghana produce foodstuffs mostly for home consumption (Ghana Statistical Service, 2019). It means that, if more arable crop farmers switch to produce cash crops, there will be less food crop production. This can increase food scarcity in the market.

From a study of tree crop farming in the Akyemansa-Kwaebibrem landscape of the Eastern region of Ghana, it is reported that food crop land is lost as more farmland is used to expand cocoa and oil palm production (Asubonteng et al., 2018). This land use change can have medium to long term effects on the ability of farm households to produce food crops on the same parcels of farmlands, considering the duration that cocoa (up to 50 years) and oil palm (about 25 years) can remain commercially productive on the land (Asubonteng et al., 2018). An impact assessment by the Ghana Oil Palm Development Company (GOPDC) in the study area shows that the introduction of commercial oil palm production to new areas, leads to the reduction in land for food crop farming and destruction of immature food crops. Thishas negative effects on food security and also cause increase in food prices (GOPDC, 2014).

Farm diversity positively influences food security in rural Ghana (Ecker, 2018), but that depends on the socio-economic and bio-physical characteristics of the local farming system. For example, farmers may not practice diversification if they can use other strategies to achieve farming objectives (Waha et al., 2022). A drastically changing climate and its negative effects, however, tilts the scale in favour of farm production diversification as a likely option for consideration by farmers.Data available from the Ghana Census of Agriculture shows that majority (about 97%) of tree crop farmers practice mono cropping and more than a third of all tree crop farms in Ghana are less than 2 acres in size with about

71% of all tree crops being cultivated on parcels that are below 5 acres (Ghana Statistical Service, 2019). The relatively small acreages of tree crops produced as mono crops (Ghana Statistical Service, 2019) contribute to the reason why farm specialisation, especially into non-food cash crops, is risky if farm households want to meet their food needs (Ecker, 2018). While several studies on diversification have been conducted recently (Adjimoti & Kwadzo, 2018; Bellon et al., 2020; Hashmiu et al., 2022), there is gap in literature with respect to tree crop production diversification in general and specifically in terms of tree crop farming in the study area of Kwaebibirem and Atiwa West.

This study therefore examines tree crop production in Atiwa West and Kwaebibirem from a diversified farming perspective using the following research questions:

- What factors influence the extent of crop production diversification of cocoa, oil palm and rubber farmers in the study area?
- Is there a difference in the food insecurity status of tree crop farmers?
- Is there a difference in the gross profits of farmers?
- What strengths, weaknesses, opportunities and threats of tree crop farming influence crop production diversification in the study area?

1.3 Objectives of the Study

The main objective of the study is to examine the effect of crop diversification on food security and income of cocoa, oil palm and rubber farmers in Atiwa West District and Kwaebibirem Municipality of Ghana.

Specifically, the study is intended to:

1. Determine the factors that influence the extent of crop diversification among cocoa, oil palm and rubber farmers in the study area.
2. To determine whether there is a difference in the food insecurity status of lowly and highly diversified farmers.
3. To determine whether there is a difference in the gross profits of lowly and highly diversified farmers.
4. Conduct Strengths, Weaknesses, Opportunities, Threats (SWOT) and Threats, Opportunities, Weaknesses and Strengths (TOWS) analysis for tree crop diversification in the study area.

1.4 Justification of the Study

The negative effects of global warming makes it important for tree crop farm managers to consider strategies that can protect their investments in the farm. Production diversification is identified as one of the Climate Smart Agriculture (CSA) strategies that farmers can use (Makate et al., 2016). However, diversification can reduce incomes for certain specialised high-value cropping systems (Alletto et al., 2022). So diversification strategies must be properly designed to ensure that farm managers do not have their revenues negatively impacted. This is very important for farm managers of high-value crops such as cocoa, oil palm and rubber because these are multi-year crops. It is much easier for an arable crop farmer to diversify their production system because most arable crops are annual crops. However, multi-year crops have longer gestation periods and effects of diversification may not be easily and quickly corrected. Incomes are important for farm businesses. In cocoa production for example, it is reported that farmers, earn less than is needed each year to buy food and take care of other essential needs (WUR, 2020). Diversification of cocoa farms must therefore not make farmers to be worse off.

In 2016, 27.4% of the population in Africa were food insecure (FAO & OECD, 2018). Unfortunately, food insecurity in sub-Saharan Africa has increased to 66.2% since COVID-19 began; with Africa recording the highest percentage (21%) of undernourished people (UN DESA, 2021). If this negative trend continues, the second goal of the Sustainable Development Goals (SDGs) will not be met in sub-Saharan Africa. In Ghana, food insecurity mostly occurs in rural areas (WFP, 2021a), where most farming activities are done.

Food insecurity is a developmental challenge for Africa and this is complicated by climate change (Yaro, 2013). In Ghana, reports by the Ghana Statistical Service (GSS) show that about 12% of households across the nation are food insecure (Mensah, 2021). It is therefore important that we understand the diversification strategies that can help farmers to become more income secure and food secure, since cocoa farmers earn less than is needed each year to buy food and take care of other essential needs (WUR, 2020). This will be helpful for policy formulation and agricultural extension service delivery.

Food security is suggested as one of the indicators to be considered in designing cocoa agroforestry (Kolavalli & Vigneri, 2011). Asubonteng et al., (2018) also suggested that tree crop development policies should consider how food production is affected by the geographical distribution of tree crop production at the landscape level. Furthermore, it is also recommended that studies on cocoa production should consider food security of farmers in order to help farmers to earn living incomes (Fountain & Huetz-Adams, 2020). In addition, farm diversification is identified as an important Climate Smart Agriculture (CSA) option that can improve food security and climate resilience of smallholder farmers (Makate et al., 2016). These suggestions mean that incomes from farming and food security are important factors to be considered in designing tree crop production systems.

This study is also inline with the second Sustainable Development Goal (SDG) of the United Nations (UN) to end hunger, achieve food security and improved nutrition and promote sustainable agriculture[1]. Achieving food security can also contribute to reduction in poverty in order to achieve the first goal of the SDGs. Understanding the crop diversification systems practiced by farmers can help us to design better strategies to achieve the SDGs. An understanding of the strengths, weaknesses, opportunities and threats of the tree crop systems observed in the study area will also help farm managers and policy makers design better production and market systems that will maximise the strengths and opportunities of diversification for farmers and other value chain actors of the various commodities.

1.5 Organisation of the Study

The report continues with Chapter Two, within which relevant literature is reviewed to give an appropriate context for the study. The literature discussed include diversification and specialisation of production, tree crop development, the concept and factors that affect food

[1] https://sdgs.un.org/goals/goal2

security and measures of food security. Further literature is also reviewed on empirical studies previously conducted on food security, diversification, SWOT and TOWS analysis .

In Chapter Three, the methodology of the study is presented. It includes the theoretical and conceptual framework, methods of data collection and analysis, sampling strategy and a brief description of the study area. Chapter Four is a presentation of the results from data analysis and discussion of results realised from the study. Finally, Chapter Five gives a summary of the findings, presents the conclusion and makes recommendations for stakeholders to consider.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature is reviewed on diversification and specialisation systems of production, tree crop development in Ghana, food security, and empirical studies that have been conducted previously on diversification, food security, SWOT and TOWS analysis.

2.2 Farm Diversification and Specialisation

2.2.1 Diversified agricultural systems

Agricultural diversification is the production system whereby no single agricultural produce or product dominates production and output (Czyżewski & Smędzik-Ambroży, 2015). Diversification can be at the plot-level whereby the farmer practices mixed cropping or intercropping (Schroth & Ruf, 2014). It can be at the farm level whereby different plots are cropped with specific crops or at the landscape level whereby each farmer in the community specialises in a specific crop resulting in a diversified land use mosaic (Schroth & Ruf, 2014). Agricultural diversification might also be a mixed farming system whereby the farm household has a portfolio of crops and animals (Mekuria & Mekonnen, 2018; Roest et al., 2018; Wiebe et al., 2019). Diversification can also be temporal in the form of a crop rotation system (Roest et al., 2018) whereby the farm plot is planted with a different crop in different seasons.

Crop rotation, as a diversification strategy, is easy to practice with arable crops and not tree crops. Crop rotation and intercropping in a conventional tree crop system is only possible during the establishment stages of tree crops. For cocoa, farmers intercrop food crops into young cocoa farms. For example, plantain and banana are planted in cocoa farms to provide shade to protect young cocoa plants from harsh weather (Asubonteng et al., 2018). Similarly, young oil palm farms are intercropped with food crops until the oil palm trees are about five (5) years old (ETA & TBI, 2021). Permanent integration of arable crops into tree crop production systems require that plant spacing is modified to ensure that canopy from the tree crop does not prevent the arable crops from accessing sunlight. Such a system can be described as an alley cropping system.

In a diversified system where one crop or product is clearly the most profitable, any dedication of land, labour and capital to other crops will result in inefficient allocation of resources which will reduce total farm revenue, at least in the short term. Diversification, therefore, reduces economies of scale and leads to higher transaction costs in poorly developed markets (Schroth & Ruf, 2014). On the other hand, a diversified production system uses production cost complimentarities to achieve economies of scope (Roest et al., 2018). Economies of scope in tree crop farms is possible if diversification is done at the plot level. Such a system enables the farmer to apply the same weed management, fertiliser application and, possibly, insect pest management to two or more crops on the same plot. It ultimately reduces production cost and results in higher production cost efficiency when it is compared with specialised farms (Roest et al., 2018).

Farming diversification helps households to minimise and spread risk among several farming enterprises, while they gain access to multiple food items and improve nutrition

(Asante et al., 2018; Dessie et al., 2019). As part of risk mitigation, production diversification is a climate adaptation strategy that provides multiple sources of income and improved food security (Mango et al., 2018; Waha et al., 2018).

Diversification of agricultural production also provides several benefits to the farm ecosystem. For example, intercropping or crop rotation improve soil fertility and help the farmer to better manage pests (Ecker, 2018). In terms of diversification involving a mix of crops and livestock, farmers have the opportunity to use animal droppings from livestock as manure for soil fertility improvement. Farmers also feed animals with crop residue after harvest or after copicing of tree crops. A diversified mix of crops and animals is therefore identified as the best potential livelihood strategy for farm households (Mekuria & Mekonnen, 2018). In the long run, improved soil fertility and better pest management result in improved climate resilience (Makate et al., 2016), lower cost of production, better yields for household consumption and or higher incomes from the sale of farm produce.

2.2.2 Specialised agricultural systems

Agricultural specialisation means committing the bulk of resources available into the production of one or two crops such that even if multiple produce and or products are the final outputs, one or two crops make up more than two-thirds of the final produce or product (Czyżewski & Smędzik-Ambroży, 2015). Specialisation helps the farmer to benefit from economies of scale (Roest et al., 2018). A specialisation strategy simplifies the production process and can lead to higher efficiency of the specialized farm when it is compared with a more diversified one (Czyżewski & Smędzik-Ambroży, 2015).

Specialisation (quasi-monoculture) is very common in tree crop production systems, but when the "forest rent" is exhausted, farmers abandon the farm and clear new forests for farming (Schroth & Ruf, 2014) unless market systems are efficient to make it worthwhile for the farmer to invest in higher use of farm inputs. Specialisation therefore makes the farm business vulnerable to market risks due to high dependence on one commodity market. Specialised farm enterprises experience significant revenue shocks when market failure occurs (Roest et al., 2018). Managers of specialised farm enterprises may, however, use post-production value addition to diversify revenue generation by producing different finished or semi finished products from the same crop or livestock.

2.2.3 Measurement of production diversity

There are several ways of measuring diversity. Indices used to measure diversity include Species richness (S), Shannon's diversity (H'), Simpson's diversity (D_1), Simpson's dominance (D_2), Simpson's evenness (E), and Berger–Parker dominance (BP) (Morris et al., 2014). However agricultural production diversification is commonly measured using Berger-Parker, Composite Entropy, Crop Diversification Index, Entropy, Herfindahl, Margalef, Modified Entropy, Ogive and Simpson's indices (Dessie et al., 2019) or a simple count of crops (Ecker, 2018) or animal groups that the household produces. Due to the multiplicity of indices, it is suggested that multiple indices should be employed for simultaneous analyses to provide greater insight from data collected (Morris et al., 2014).

2.2.4 Decision making about diversification strategies

Farm business managers make decision about the production strategy based on a multi-dimensional set of variables. Schroth and Ruf (2014) indicate that decision making about diversification strategies involves an interaction between diversification objectives, opportunities for, and constraints to diversification and farmer characteristics.

In terms of diversification objectives, farm managers adopt a strategy that can increase and stabilise incomes over the year (Dessie et al., 2019; Schroth & Ruf, 2014), maintain food security, especially, during phases when the tree crops are not fully productive (Asubonteng et al., 2018; ETA & TBI, 2021; Schroth & Ruf, 2014), and reduce risk of weather and market failures (Ahimbisibwe et al., 2019; Schroth & Ruf, 2014).

The environmental (characteristics of farm site) and socio-economic context of the farm business can present context-specific opportunities and constraints that guide farm managers in deciding on diversification strategies (Bellon et al., 2020; Schroth & Ruf, 2014). For example, tree crop farmers tend to farm oil palm on low-lying lands that have the tendency of being water-logged (Schroth & Ruf, 2014). In other words, such lands are equally suitable for rice, sugarcane or dry season vegetable production, but the decision is made by the farm household or landowner to use them for tree crops.

Farmer characteristics such as age of the farm manager, exposure of the farm household and manager to improved systems, farm size and household composition can affect the diversification strategy employed (Schroth & Ruf, 2014). The aspirations and perceptions of the farm manager also influence production (Anyidoho et al., 2012) and hence diversification strategy adopted. For example, a farmer who sees farming as an investment and capital accumulation is market oriented in decision-making about production. Such farmers specialise more than they diversify. Likewise, a farm manager who is interested in ecological benefits and environmental sustainability of farming will adopt a diversification strategy (Czyżewski & Smędzik-Ambroży, 2015; Schroth & Ruf, 2014).

2.2.5 Constraints to tree crop diversification

Inadequate knowledge, skills and other resources make it difficult for farmers to practice crop diversification. Tree crop diversification requires the farm manager to be skilled in the production of different crops. Crop diversification also requires more labour compared to a mono-cropping system (Birthal et al., 2015; Dai et al., 2017). Farmers who are engaged in or interested in off-farm income generation activities do not want to spend more time in the farm (Dai et al., 2017). As such, it becomes difficult for farmers to adopt diversification if labour requirements for the additional crop(s) are not complementary to the labour requirements of the existing crop (Schroth & Ruf, 2014).

Research shows that farmers find it difficult to practice crop diversification if there is no concerted effort of extension service and other forms of support from government. Increased use of farm inputs is required for the success of a diversified farm (Clément et al., 2023). The provision of extension services (Mandal & Maity, 2022) and government support make farmers more efficient in practicing crop diversification (Clément et al., 2023; Mandal & Maity, 2022). Resource poor farmers will, therefore, find it difficult to practice crop diversification without support.

Due to increased competition for light (Blaser-Hart et al., 2021), intercrops are only cultivated during the establishment phase of commercial mono tree crop farms. In oil palm plantations, for example, intercrops are not included after five (5) years (ETA & TBI, 2021). However, less attention has been paid to the development of commercialised agroforestry systems that will optimise productivity through improved shade and canopy management (Blaser-Hart et al., 2021). Most tree crop farmers are market-oriented due to relatively efficient market systems. Market and governmental incentives have been structured to favour crop production under monoculture as against diversified cropping systems (Lin, 2011). In Ghana, the policy and market incentives provided by Cocobod and the Tree Crops Development Authority affect how farmers practice their production systems. The absence of properly developed markets for staple food crops is a disincentive for market-oriented tree crop farmers to modify spacing of trees to accommodate food crops beyond the tree crop establishment phase. Inadequate data and information on optimal spacing and canopy architecture management of a multi-crop system is therefore a constraint for market-oriented farmers to practice tree crop farm diverisification.

Land tenure systems influence decision-making of farm managers (Adjei-Nsiah, 2006; Alufah, 2015). Farmers with short-term access to lands are not efficient in practicing crop diversification (Mandal & Maity, 2022). Under a sharecropping arrangement such as *abunu* or *abusa* (Alufah, 2015), the landowner determines the type of crop that is cultivated. It is therefore difficult for a sharecropper to practice diversification that will affect the yield of the major crop approved by the landowner. Local or indeginous farmers even disagree with inmigrant farmers who want to change the production system practiced, even if such migrant farmers have long-term lease (Schroth & Ruf, 2014). Even with some form of governmental support, farmers in China with short-term access to land were reluctant to invest resources into incorporating fruit trees into grain or cotton farms; though government provided subsidies to reduce costs incurred by farmers (Dai et al., 2017).

2.3 Tree Crop Production

2.3.1 Introduction

Tree crops are “trees grown for some type of economic or environmental benefit”. Apart from fruit or nut trees, trees may also be grown as crops for other purposes – for example the production of nitrogen-rich manure and fuel wood (Sibale et al., 2013).

Several tree crops are suitable for production in the tropics. Such tree crops include cocoa, oil palm, rubber, cashew, mango, coconut, avocado and pawpaw (Molnar et al., 2013) commonly produced in Ghana. The tree crops policy of Ghana however identified cocoa, rubber, oil palm, citrus, coffee, kola and avocado as tree crops mostly produced in the forest zone; cashew and mango as tree crops suitable for and mostly planted in the transitional zone; while the northern savannah zone is suitable for cashew, shea, dawadawa, baobab and tamarind, the coastal savannah is mostly planted with coconut and mango (MOFA, 2012). In Ghana, oil palm, cocoa and rubber are mostly produced as cash crops to provide inputs for export and industry (Ghana Statistical Service, 2019). In this section, literature is reviewed generally on cocoa, oil palm and rubber.

2.3.2 Cocoa production

Cocoa is produced by about 80.9% (765,885) of all tree crop farmers in Ghana and it contributes about 26% (1,130,137 metric tonnes) out of a tree crop yield of 4,316,450 mt in

Ghana (Ghana Statistical Service, 2019). Cocoa provides livelihoods to farmers, cocoa extension agents, researchers, and workers across sectors and industries such as buying companies, input dealers, and processing companies (COCOBOD, 2019; Kolavalli & Vigneri, 2017). In addition, revenue from cocoa production is used for road construction in Ghana (COCOBOD, 2019; Kolavalli & Vigneri, 2017).

Cocoa as a major source of foreign exchange for Ghana (Kolavalli & Vigneri, 2017), is managed and controlled by Ghana Cocoa Board (COCOBOD) [2], a public sector institution. COCOBOD has subsidiaries that provide various services to the cocoa sector in Ghana. For example, Cocoa Research Institute of Ghana (CRIG) conducts research on pests, diseases and plant breeding in order to provide seeds for multiplication by the Seed Production Division (SPD) which supplies improved planting materials to the Cocoa Health and Extension Division (CHED) to distribute to farmers as part of the Free Seedlings Programme (FSP) (COCOBOD, 2019). CHED is also mandated to identify and rehabilitate diseased farms, and to provide artificial pollination and extension services as well as to distribute fertilisers and agrochemicals to farmers through Cocoa Disease and Pest Control (CODAPEC) as well as Hi-Tech fertiliser programs (COCOBOD, 2019).

The many activities and interventions of COCOBOD can be considered a sort of value chain finance for which reason COCOBOD tries as much as possible to control the purchase and sale of cocoa beans in Ghana. COCOBOD uses its subsidiary, Cocoa Marketing Company (GH) Ltd (CMC) to control buying and selling of cocoa beans through a competitive sub-

[2] https://cocobod.gh

sector of over 40 Licensed Buying Companies (LBCs) (COCOBOD, 2019) spread throughout cocoa producing areas in Ghana. Using this system, COCOBOD is able to control the producer price paid to farmers in order to be able to pay for international syndicated loans and local credit contracted to support cocoa production and allied services (COCOBOD, 2019; Kolavalli & Vigneri, 2017). The increased participation of and competition among several LBCs (Adu-Appiah et al., 2013) has led to an increase in farmer agency since farmers have the choice to sell to any of the several Purchasing Clerks (PCs) in the communities who work for the LBCs. This has forced LBCs to adopt value chain finance strategy to build relationships with farmers and increase loyalty. LBCs therefore offer credit and other input incentives to farmers who supply cocoa beans on a regular basis (Kolavalli & Vigneri, 2017).

There are several inefficiences and operational challenges in the cocoa sector in Ghana (AFD, 2019) which contribute to low productivity of cocoa farms. The previously identified challenges of high incidence of pests, diseases, epiphytes, low producer price, high cost of and scarcity of farm labour (Dormon et al., 2004) still exist in the sector. Adverse climatic conditions will even make cocoa farming to become more risky since cocoa farming in Ghana is largely dependent on rainfall, uses low amounts of inputs and which result in lower than possible average yields (Asante et al., 2022). Low producer price is also a concern to international actors such as Rainforest Alliance (Diakite, 2020). Though COCOBOD offers a stable producer price to cocoa farmers, it puts farmers at a disadvantage because these prices do not change quickly enough in response to foreign exchange rates, rising costs of fertiliser, fungicides, insecticides, labour and other inputs required. In response, farmers commit less resources to farm management in terms of fertiliser application, pest and disease control.

The slow response of producer prices to market conditions contributes to smuggling of cocoa beans into Togo and Cote d'Ivoire for foreign exchange which results in higher income to cocoa farmers in border communities (Kolavalli & Vigneri, 2017).

Due to global warming and climate change, temperatures are rising in all ecological zones in Ghana which is accompanied by low volumes of rainfall and less predictable rainfall (Ozyurt, 2019) as well as increased duration of the dry season (Nyabor, 2022). The changing climate and the inefficient use of pesticides (Kolavalli & Vigneri, 2017) are a major threat to productivity of cocoa farms (COCOBOD, 2019). Though spraying gangs are established in various cocoa production communities and supported by COCOBOD with agrochemicals and motorised sprayers (COCOBOD, 2019), there are complaints from farmers of poor service delivery and inadequate supply and inaccessibility of the fungicides and pesticides required for spraying (Kolavalli & Vigneri, 2017).

The challenge of PCs adjusting the weighing scales (Adu-Appiah et al., 2013) to account for losses that arise from sorting, drying and bulking of beans purchased (Kolavalli & Vigneri, 2017) is now being addressed through the introduction of electronic weighing scales (Awumah, 2021; Hayford, 2021).

Low producer prices make it difficult for farmers to commit resources into farm improvement. Most tree crop farmers therefore rely on the existing capacity of the land to generate yield through what is termed 'forest rent' (Schroth & Ruf, 2014). When farmers do not invest incomes in farm improvement, it negatively influences farm productivity. For example, shade management and pruning of branches are key disease management practices (CHED & WCF, 2016; Guest, 2007; Luseni & Kroma, 2015) for controlling the activity of the pathogen that causes black pod disease of cocoa, *Phytophthora* (Guest, 2007). Shade management and pruning requires labour which comes at a cost. Improper management of black pod disease, forces the farmer to frequently spray fungicides (Bymolt et al., 2018) which also increases labour and fungicide cost. When farmers avoid any of these disease management costs, the results are lower yields due to black pod destroying about 20-30% of pods and killing some of the cocoa trees (Guest, 2007). The labour intensive nature and low producer prices of cocoa farming makes the youth to feel that incomes from farming are not worth the effort (Anyidoho et al., 2012).

In terms of low producer prices, value addition activities at the farmgate can provide extra income to cocoa farmers. For example, Koa Impact Ghana Limited [3] has implemented an innovative project in Assin Akrofuom to extract fresh juice from the pulp around cocoa beans. The value proposition of Koa includes extra income that is verifiable through a transparent process to buyers such as Lindt, Valrhona, Felchlin, Sprüngli and consumers in general (Koa, 2023).

While it is believed that farmers will be better off if they diversify their farms away from cocoa (Odijie, 2018), the strict control of the cocoa sector by COCOBOD is not promoting diversification of cocoa farms in terms of agroforestry (Ozyurt, 2019). A more conciliatory approach is possible through the inclusion of other crops in cocoa production systems. Research reports from CRIG show that this is possible through the inclusion of fruit trees and this can increase farm income (COCOBOD, 2019) and improve food security of farm

[3] https://koa-impact.com/

households. Cocoa farmers are mostly adults who cannot be described as youths. The youth are less interested in farming in general because of the low value placed on farm workers in the social structure (Anyidoho et al., 2012). Providing higher producer prices and a more competitive service delivery or value chain is the only way cocoa production can become sustainable and resilient to climate and market risks.

2.3.3 Oil palm production

Though only 11.3% of tree crop farmers are engaged in oil palm production in Ghana, it accounts for 35.2% (1,517,327 metric tonnes) of output of all tree crops produced in Ghana (Ghana Statistical Service, 2019). Data from UN Statistics Division (UN Comtrade, 2020) shows that Ghana's palm oil exports increased from 108,154.5 tonnes in 2015 to 135,935.34 tonnes in 2019, representing an increase of about twenty five percent (25%). Globally, the palm oil industry is growing and has been valued to be worth more than US$ 50 billion per annum (Paterson & Lima, 2017). Oil palm is a multi-functional crop (Khatun et al., 2020) with many uses. The oils extracted can be used for cooking oil, margarine, biofuels and cosmetic products (Corley & Tinker, 2016; Khatun et al., 2020; MASDAR, 2011).

Empty Fruit Bunches (EFBs) and other waste can be used as media for mushroom production (Marlina et al., 2015; Sudirman et al., 2011; Triyono et al., 2019). Palm trees can be felled and used for palm wine production (Manley & Leynseele, 2019) when palm trees grow too tall or for socio-economic reasons. Oil palm production provides livelihoods for several people along the value chain including sections of the society who are considered marginalised and vulnerable in other sectors. For example, women participate in the oil palm value chain as farm owners and or farmers or as labourers engaged in gathering loose fruits, carrying FFBs, or as processors of crude palm oil and palm kernel oil in the formal and informal sectors of the oil palm value chain (Etuah et al., 2020).

The oil palm varieties typically planted by farmers include the dura type (with thick shell and thin flesh) and the tenera type (with thick flesh and a thinner shell) (Corley & Tinker, 2016). Research by the Oil Palm Research Institute (OPRI) under the Council for Scientific and Industrial Research (CSIR) has resulted in a hybrid that gives higher yields (Agyei-Dwarko, 2021) when compared with the type originally planted by smallscale farmers (MASDAR, 2011). It is reported that the use of improved hybrids results in yields being thrice higher on company-owned plantations when compared to yield from smallholder farms due to better planting material and management practices (NEPCon, 2017). The Presidential Special Initiative (PSI) on oil palm, which was functonal between 2003 and 2008, has enabled lots of farmers to get access to improved seedlings from OPRI for cultivation (MASDAR, 2011).

Rainfall deficit is another source of yield gap in oil palm production in Ghana (MASDAR, 2011). Oil palm requires lots of rainfall and its production in West Africa, including Ghana, is limited by rainfall (Corley & Tinker, 2016). It is therefore recommended that oil palm farms should be sited on low-lying lands to take advantage of higher soil moisture levels in such places (Bonneau et al., 2018). The weather requirements for oil palm production viewed from the perspective of climate change (Murphy et al., 2020) means that there will be a drop in the aggregate value of farm output since most plantations are currently the most profitable farm type (Etwire, 2020) and the most common type of tree crop farms in Ghana (Ghana Statistical Service, 2019).

Apart from poor rainfall, research by the International Plant Nutrition Institute (IPNI) identified insufficient labour (for weed control, for pruning of palm fronds, harvesting and fruit collection), inadequate knowledge of farmers and poor soil fertility (IPNI, 2015). Yield gap can therefore be reduced by increasing use of labour, cover crops, weeded circles, pruning and the implementation of three harvest cycles per month (i.e., harvesting intervals of <10 days), especially in the peak season (Rhebergen et al., 2018). Even though weeds can be controlled by weeding and the use of herbicides, the use of cover crops is possible (Corley & Tinker, 2016) and can present lower farm management costs in the long term. The use of cover crops is viable considering cost and scarcity of labour and the difficulty of smallholders to access credit for farm management (MASDAR, 2011; Rhebergen et al., 2020). It is interesting to note that, cover cropping is widely used to control weeds in the estates of the large companies that produce oil palm (MASDAR, 2011).

Cover crops identified to be used include leguminous cover crops such as *Mucuna bracteata*, *Pueraria phaseloides* (MASDAR, 2011). In addition, the integration of sweet potato into oil palm plantations (Renier et al., 2021) can also play the role of organic weed control considering its allelopathic effects on considering the allelopathic effects of sweet potato on *Imperata cylindrica*, *Bidens pilosa* and *Ageratum conyzoides* (Xuan et al., 2016), *Cyperus esculentus* (Harrison & Peterson, 1986), *Galinsoga parviflora*, *Lolium multiflorum* and *Phalaris minor* (Shen et al., 2022). The use of cover crops to control weeds can also reduce the hazards of weedicide application such as lower reproductive rates and hence lower levels of fertility as reported in other countries (Mason & McDowell, 2021; Pye et al., 2016). As an intervention to reduce the poor farm management practices and the challenges of limited farmer know-how, Solidaridad Network has successfully piloted the establishment of Rural Service Centres to provide skilled services to ensure that farmers are adopting Best Management Practices (BMPs) for oil palm production (Solidaridad, 2021).

In order to produce palm oil that will be internationally acceptable, medium to large scale millers in Ghana such as AVNASH Industries Ghana Limited, Norpalm Ghana Limited, Ghana Oil Palm Development Company (GOPDC), Juabeng Oil Mills Limited, Twifo Oil Palm Plantations Limited, Volta Red Limited have all become members of the RSPO [4]. The Certified Sustainable Palm Oil (CSPO) by the Roundtable on Sustainable Palm Oil (RSPO, 2016) enable registered members to be monitored and audited according to standards. One of the RSPO members, GOPDC, is located in the Kwaebibirem municipality. Other medium to large scale firms in the municipality include Birim Oil Mills (FW Africa, 2018) and Serendipalm. GOPDC, established in 1975, has its mill and primary oil palm estate at Kwae in the Kwaebibirem Municipality. The company is wholly owned by the Société d'Investissement pour l'Agriculture Tropicale (SIAT) Group (GOPDC, 2021; SIAT Group, 2021). GOPDC has about 8,000 hectares of oil palm plantation and access to FFBs from about 7,000 farmers, cultivating about 13,700 hectares of oil palm (SIAT Group, 2021). At the mill, GOPDC extracts Crude Palm Oil (CPO) and Palm Kernel Oil (PKO) and further refines and packages the oils into various products (GOPDC, 2021; SIAT Group, 2021). Operations at the mill are highly mechanised, right from loading FFBs into sterilisers up to packaging of refined vegetable oil (GOPDC, 2020).

[4] https://rspo.org/members/all

Serendipalm, on the other hand, is intentionally designed to use manual labour for striping of fruitlets from FFBs, removal of fruits, splitting of firewood, loading of drums for steaming and milling of steamed fruits into press liquor so as to create employment for the people in and around Asuom township (Serendipalm, 2021a). The firm was started in 2007 as a project by Dr. Bronner's to produce organic and fair trade palm oil from FFBs sourced from smallholder organic farmers (Serendipalm, 2021). The oil produced is exported to Dr. Bronner's. Serendipalm also exports oil to Rapunzel (Rapunzel, 2021b, 2021a). Farmers who work with Serendipalm are fair trade certified to the "Fair for Life" standard organic certification in line with EU Organic Regulation (EC) No. 834/2007, the National Organic Program (NOP) of the U.S. Department of Agriculture (USDA) and the Naturland organic standard (Serendipalm, 2021b).

In Ghana and especially in Kwaebibirem municipality, milling companies buy fruits from contract farmers as well as non-contract farmers (Manley & Leynseele, 2019). There are, however, several small scale and artisanal processors in the municipality (Osei-Amponsah, 2018) who also compete with the millers for fruits. This competition has increased farmer agency but has also amplified claims of adverse inclusion by contract farmers which has led to or increased side selling. Adverse inclusion, a situation whereby people believe their participation in a project, program or policy is based on unfavourable terms (World Bank, 2013) is reported in various forms in the oil palm sector (Castellanos-Navarrete et al., 2018; Gyapong, 2020; Mohd Noor et al., 2017; Pye et al., 2016; Sinaga, 2021). Side-selling is one of the likely outcomes of adverse inclusion when farmers are not happy with contractural terms. Side-selling makes it difficult for farmers to access credit for production (Sahara et al., 2017). Due to side-selling, GOPDC has reduced value chain financial service provision to contract farmers (Manley & Leynseele, 2019). Previously, GOPDC used to pre-finance the supply of seedlings, fertilisers and weedicides supplied to contract farmers. Secondly, the difficulty of holding farmers to contract terms has made GOPDC to be disinterested in financing the establishment of new outgrower and smallholder schemes for farmers (Manley & Leynseele, 2019).

In the long term, climate change will lead to a change in the favourable ecology required for oil palm production and that will lead to farm diversification (Etwire, 2020). Some studies, outside Ghana, suggest the intercropping of oil palm with yams and vanilla (ETA & TBI, 2021), cocoa (ETA & TBI, 2021; Khasanah et al., 2020; Stomph, 2017) and groundnuts (Stomph, 2017). While the ecology in Ghana may not make vanilla production to be commercially viable, cocoa, yams, and groundnuts are already produced in Ghana (Ghana Statistical Service, 2019). Since the Tree Crops Development Authority (TCDA[5]) is mandated to develop and regulate oil palm, rubber, cashew, shea, mango and coconut value chains (Tree Crops Development Authority Act, 2019), they can explore diversification options for sustainable oil palm production. Already, the TCDA has identified ginger, tumeric and yam as crops that can be considered for crop production diversification (TCDA, 2021).

[5] https://tcda.org.gh/functions-of-tcda-summary

2.3.4 Rubber production

Rubber has contributed significant foreign exchange to Ghana's economy over the years as shown in Figure 2.1. The rubber value chain is important to the development of Ghana and has therefore been identified for support using revenue from the oil and gas sector (NDPC, 2014). As such, it is one of the tree crops included in the Planting for Export and Rural Development (PERD) project. The PERD project is designed to provide raw materials for local industrial processing as part of government's drive to build industries across all districts in Ghana (Graphic.com.gh, n.d.; Lartey, 2019). PERD is currently implemented by MOFA through the TCDA (NDPC, 2021; TCDA, 2021). With financial support from the Agricultural Development Bank (ADB) in Ghana, the Anglican Church is one of the institutions that has taken advantage of PERD project to cultivate rubber (ADB, 2021; GNA, 2021) on a 330.4 hectare plantation Assin Nsuta in the Central Region of Ghana (Communications Bureau, 2022; Conger, 2022).

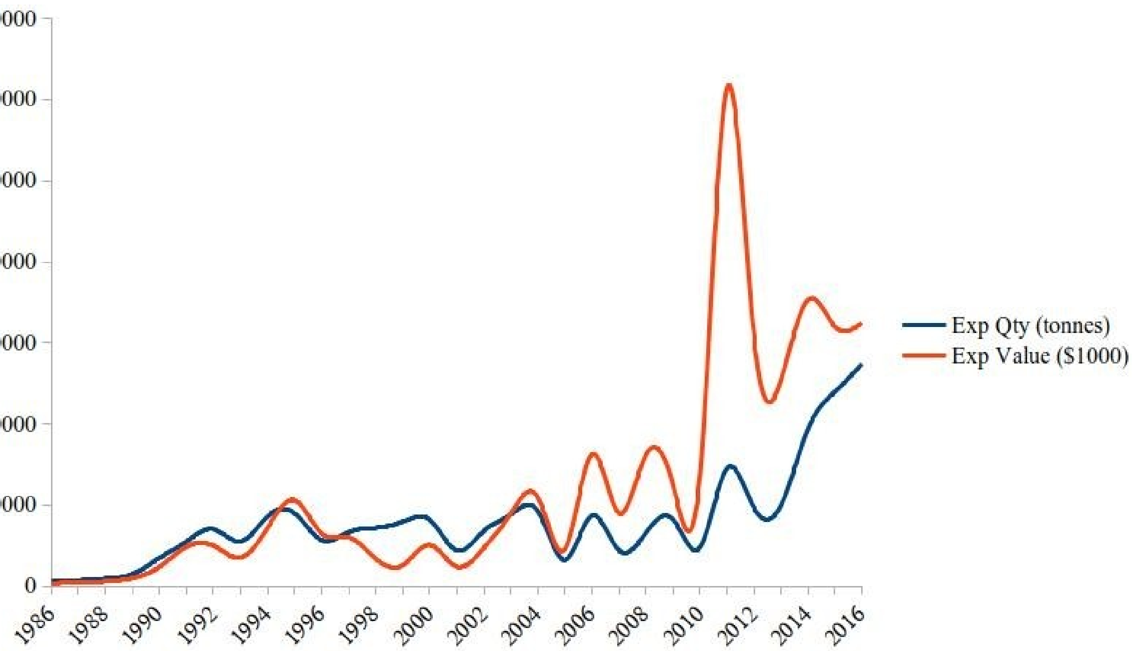

Figure 2.1: Ghana Rubber Exports (1986-2016)
Data source: FAOSTAT

Due to the significant investments required in establishing rubber plantations (Delarue, 2009), the outgrower model has been used succesfuly to create plantations with several farmers producing and supplying cup lumps of rubber latex to processing companies. With development funding and support from French Development Agency (AFD), Reconstruction Credit Institute (KfW) and the World Bank, the first outgrower scheme was established with agreement between the Ghana Rubber Estate Limited (GREL), the Rubber Outgrowers Agents Association (ROOA) ADB Bank (FAO, 2018) and the National Investment Bank (NIB) of Ghana (Delarue, 2009).

Similar funded outgrower schemes for rubber plantation establishment were carried out in Cambodia and Vietnam (Delarue, 2009). Key lessons learned from these schemes include:

- Loan terms offered by partner banks in Ghana were less favourable to farmers when compared with the terms offered to farmers in Cambodia and Vietnam.

- The triangular arrangement (MOFA, 2012) between banks, offtaker and farmers is only sustainable in a monopolised market. Competition from other offtakers can amplify risks of moral hazard, adverse inclusion and farmer agency.
- Young rubber plantations are intercropped with arable crops for the first three years of farm establishment.
- The long gestation period of rubber (7 to 8 years) compared to that of oil palm, coconut, cashew and coffee provide the opportunity for a diversified tree crop farm; however farmers were not interested because price for rubber was high at the time.
- In order for farmers to get fair prices, there should be a transparent process to determine and agree on the Dry Rubber Equivalent (DRE) rate of fresh products.
- Motorable road access to farms influence land selection.
- Spontaneous development of smallholder rubber farms is possible if rubber seedlings are readily available and accessible to farmers outside outgrower schemes.

In Guinea, diversified tree crop farming of oil palm and rubber as part of an outgrower scheme was carried out by SOGUIPAH from 1989 to 2002. An impact assessment of this project revealed that revenue from the oil palm plantation supported farmers to earn income to help manage the rubber farm until tapping began. However, the scheme's success depended on the supply of quality planting material and farm establishment support (Delarue & Cochet, 2013).

2.3.5 General issues of tree crop production

Traditionally, most smallholder farmers do not think or know much about the effect of genetics on the productivity of the cultivar they plant. This leads to farmers doing local selection of seeds and seedlings from existing farms (Molnar et al., 2013). Local selection by farmers leads to lower yields and relatively poor crop performance. This was seen in independent plantations developed in Guinea as a spillover of outgrower scheme establishment (Delarue, 2009) and in traditional oil palm plantations in Ghana (MASDAR, 2011).

The development of multi-crop and mixed perennial farm systems has not been rapid because of the relatively longer gestation periods and the wide timescales over which tree crops interact with the environment (Luedeling et al., 2016). Lack of capital, inadequate technical knowledge of agroforestry systems as well as fragmentented and insecure land tenure systems were identified as factors that make sustainable tree crop farming a challenge in Indonesia and Bangladesh (Rahman et al., 2017). Without secure rights to the land, it is difficult for a farmer to use the land as collateral to access credit. Even if a farmer has secured rights to the land, the size of the land could influence how much credit the farmer can access (Rahman et al., 2017). Insecure land tenure also discourages farmers from long term investment on rented farm plots (Rahman et al., 2017). Most rural farmers do not save money and as such do not have financial liquidity required to adopt new farming technologies (Delarue, 2009; Rahman et al., 2017) or buy land. Outgrower schemes or contract farming arrangements can however be used to support farmers to secure and properly document land for tree crop farming as well as buy inputs and establish farms (Delarue, 2009; Delarue & Cochet, 2013).

An outgrower scheme is an interesting value chain financing model that supports farmers to access credit for investment into tree crop production. Since 2011, the Outgrower and Value Chain Fund (OVCF) in Ghana has been providing funding to farmers (outgrowers), processing/marketing companies (technical operators who provide inputs, services and technical advice to farmers and buy produce from farmers) and financial service providers in certain agricultural value chains with medium to long-term credit (MOFA, 2020). The OVCF has been successful because it is backed by government and KfW (Government of Ghana, 2019) and it provides credit to value chain actors at rates lower than the conventional financial market rate (Government of Ghana, 2019; MOFA, 2020). The OVCF has previously supported oil palm, rubber, cocoa, maize-poultry, cassava-gari, soya-sorghum-maize, pineapple and rice value chains. The fund is also evaluating proposals to support new schemes involving rice, soya, Orange-Fleshed Sweet Potato (OFSP), cassava, ginger, pineapple, avocado and cocoa value chains (MOFA, 2020). The Rubber Plantations Ghana Limited (RPGL) at Topease near Asamankese in the Eastern Region of Ghana is one of the beneficiaries of OVCF credit. RPGL has been able to set up an outgrower scheme in Kwaebibirem and Atiwa West, made up of about one thousand two hundred and sixteen (1216) farmers using credit from the first round of funding of the OVCF (Government of Ghana, 2019). The OVCF, with its funding model for food and tree crop value chains, provides an opportunity to support farmers to practice a mixed farming system that can provide food and cash for the farm household. Essentially, the OVCF reduces the risk for farmers and other stakeholders in Ghana to participate in market-oriented agricultural value chains.

Underdeveloped markets create a challenge for cash crop farmers (MOFA, 2012). If farmers percieve market information to be poor (unreliable or not current), market infrastructure to be poor and or prices to be unstable (Rahman et al., 2017), they will switch to the production of crops which have more developed markets (Rahman et al., 2017). Such change in production has been observed in Cote d'Ivoire (Delarue, 2009). Diversified farming systems are becoming popular as a strategy to minimise risk. Profitability of the diversified farms may, however, not be better than the best performing specialized farms (Delarue & Cochet, 2013; Mosnier et al., 2021). Diversified farms however present development benefits that are beyond financial profitability (Delarue & Cochet, 2013).

Tree crop production enable the farmer to earn income and fruits which help the farm household to be income and food secure (Molnar et al., 2013). Tree crop production under a monocrop system, as is common in oil palm and rubber production, is however challenged for its negative effects on biodiversity especially in large monocrop estates. In a study involving the Kwaebibirem area for example, it has been reported that though farm sizes appear to be small and fragmented, they are composed of similar mono tree crop farms which creates a landscape similar to what exists among large-scale institutional plantations (Asubonteng et al., 2020). These large contiguous stretches of monocrops compromises reliance on nature's ability to use a diverse biosystem to pollinate crops such as cocoa and oil palm and to control pests and diseases (Asubonteng et al., 2020). However these criticisms as catalysts, provide justification for the research and development of multi-crop and mixed perennial farm systems (Molnar et al., 2013). Tree crop farms can be diversified at the plot level as agroforestry systems with sub classifications such as agrosilvicultural (a mix of trees and crops), silvopastoral (a mix of trees, pasture and animals), and agrosilvopastoral (a mix of trees, crops and animals) systems (Maponya et al., 2022). If properly designed, such agroforestry systems will provide food, fibre, energy and cash to the farm household while also providing ecological services to the environment (Sibale et al., 2013). In Malawi, for example, the integration of Jatropha, Moringa and Neem into existing crop systems has successfully provided over 4000 farmers with additional livelihood options (Sibale et al., 2013).

While tree crop farmers perform better on food security assessment with respect to perceptions of hunger and coping behaviors, they also perform worse in terms of food diversity (Balde et al., 2019). However, a well-designed agroforestry system can improve household food diversity. For example, through participatory action research in South Africa, a successful system made up of food crops such as maize, sweet potatoes, groundnuts, bambara nuts, vegetables and Eucalyptus trees was created (Maponya et al., 2022). Essentially, such a system is possible if researchers, policy makers and farmers can work collaboratively in developing it. Ghana Rubber Estates Limited recognised the importance of farm diversification for food security and has therefore supported farmers in its outgrower scheme to be trained food crop and animal farming (GREL, 2011). The company even included farm diversification in its farmer selection requirements for outgrower schemes. GREL made it compulsory for at least 0.4 hectares of food crop in order to be selected into its Phase V outgrower project (GREL, 2013). Apart from food security benefits, farmers use agroforestry as a risk management strategy when crops fail and when the health of the farmer deteriorates (Rahman et al., 2017). Farmers also use the integration of tree crops into existing farming systems as a way to increase their rights to the land (Rahman et al., 2017).

2.4 Food Security

2.4.1 Definition of food security and food insecurity

Food security is a complex issue of public policy importance. As such, the definition of food security has evolved over the years as several actors attempt to operationalise it (Clay, 2003). In Ghana, the Ministry of Food and Agriculture (MOFA) defines food security as "the availability and physical access to food by the population, irrespective of whether or not it is produced within the country" (MOFA, 2017). This definition is a recognition of the fact that Ghana imports some of its food and is therefore not self-sufficient in food production to meet domestic demand. Food security is internationally defined as the situation where all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (Clay, 2003; IFPRI, 2021; World Vision, 2021).

Sustainability concepts have been used to expand the definition of food security as a situation where "all people at all times have physical and economic access to adequate amounts of nutritious, safe, and culturally appropriate foods, which are produced in an environmentally sustainable and socially just manner, and that people are able to make informed decisions about their food choices" (Resilience, 2015).

On the other hand, food insecurity can occur when the country does not produce enough food (Sasson, 2012) or when the household does not have enough income to buy food (Ecker

& Breisinger, 2012). Food insecurity can therefore be described as a situation where the country is unable to produce or import enough food that will be available and accessible to the population. Food insecurity is defined as a situation where people have the limited or uncertain availability of nutritionally adequate and safe foods, or limited or uncertain ability to acquire acceptable foods in socially acceptable ways (Bickel et al., 2000).

Due to the many actors involved in food value chains, food security has many facets and these can be organised around three main pillars. The pillar of availability deals with production, distribution and exchange; while the pillar on access deals with affordability, allocation, and preference; and the utilisation pillar considers nutritional value, social value and food safety (Linderhof et al., 2019; Wocatpedia, 2016). Logically, the pillars can be arranged sequentially such that without food being available, there can be no access even if the household can afford it; in continuation, a household can have access to food but may not be food secure depending on how they use the food they have access to. The pillars of food security can also be expanded to include a pillar on stability (Ecker & Breisinger, 2012). Which means that the food security status of a person is not static, it can vary over time based on several factors.

Over the years, the state of food insecurity has become worse in several countries, even before COVID-19 occurred, due to worsening socio-economic conditions contributing to chronic and acute hunger (World Bank, 2021). A joint statement by ILO, FAO, IFAD and WHO reports that COVID-19 is a threat to the survival of millions of enterprises, such that people are unable to feed their households or have reduced the quality and or quantity of food they eat (ILO et al., 2020). The increased state of food insecurity is expected to continue beyond the year 2022 (UN DESA, 2021; WFP, 2021b; World Bank, 2021).

Similarly, according to the High Level Panel of Experts (HLPE) on Food Security and Nutrition of the UN's Food and Agriculture Organisation (FAO), COVID-19 has resulted in lower incomes while some food prices continue to increase; thereby making it difficult for several people to access food (HLPE, 2020). As such, the state of food insecurity worldwide, especially in Africa, makes the zero hunger goal of the SDGs very difficult to achieve (HLPE, 2020) but therefore more important to achieve.

2.4.2 Dimensions of food security

The four dimensions of food security are simple to extract from the WFS concept and are equally effective for food security analysis when used together. These include:

Availability dimension

The availability of food is the first factor to consider. It refers to the term "sufficient" as defined by the WFS. According to the World Food Programme, "the amount of food present in a country or territory through all types of domestic production, imports, food stocks, and food aid" (World Food Programme, 2022). The definition clearly refers to net commercial imports after deducting commercial and other exports, and it also applies to villages and households, not only countries or territories. Despite the fact that the FAO Founding Conference's final resolution stated that "poverty is the first cause of malnutrition and hunger," food security has long been associated with food availability (Shaw et al., 2014). Most of the work done by researchers, practitioners, and educators over the last three decades has focused on proving and persuading people that food security is more than just a matter of food supply (Ahmad et al., 2021). The belief that food security is determined by the availability of food commodities leads to the assumption that increasing food production will improve food security. Again, over the last fifty years or so, agricultural production has consistently outpaced population growth, and the amount of food commodities available on Earth (at least in terms of macronutrients) is largely sufficient to feed more than today's global population, despite the fact that some people lack access to food.

Accessibility dimension

The accessibility of food is the second aspect of food security (Minnesoto, 2021). Despite the fact that Amartya Sen proposed the concept of food access in the early 1980s, it is still not widely recognized as an important component of food security. Furthermore, many people have been tempted to reduce the access dimension of food security to its economic or financial character after the Niger food crisis in 2005 and the world food price crisis in 2008 (Ahmad et al., 2021).Food access is defined by the World Food Programme as "a household's ability to obtain adequate amounts of food on a regular basis through a combination of purchases, barter, borrowings, food aid, or gifts." (WFP, 2017). In fact, physical, financial, and socio-cultural factors all have a role in food access. In fact, the physical part resembles a logistical dimension. An example is a situation in which food is produced in one country or region but consumed in another, with limited or no transportation between the two places and a lack of information. Food is available where people (households, etc.) truly need it in a state of food security. As WFP defines it, the economic side of food access can be defined. In a scenario of food security, food commodities are available where people need them, and households have the financial means to purchase sufficient amounts of food on a regular basis to meet their needs. According to the WFS definition, "social" or “socio-cultural” access to food is the last factor of food access (WFS, 2016). This refers to the reality that food commodities may be available physically close to the consumer with the necessary resources to obtain them, but that socio-cultural barriers may limit access to food, particularly for some sectors of the population for gender or societal reasons. However, more research is needed in this area, which has proven to be less popular than other aspects of food security.

Utilization dimension

Food use is the third dimension of food security. According to the WFS criteria, "safe and nutritious food that fits their nutritional needs" To ensure that individuals eat a "safe and nutritious" diet, it is not enough for food to be available and accessible to homes. A lot of factors come into play here, including food commodity selection, preservation, and preparation, as well as nutritional absorption. Food must be of good quality and safe to consume. It should not be assumed that everyone, even in so-called traditional communities, understands how to best use food commodities, especially given the fact that dietary patterns are rapidly changing, even in so-called traditional societies (Ahmad et al., 2021). This is especially true for displaced people, refugees, and people who have been affected by a shock that has altered commodity value networks. It may be necessary to provide training to assist people in making the most use of the food that is available and to which they have access. In fact, a number of observations have been made, particularly by the World Food Programme (WFP), of people living in areas where food is plentiful but who are still malnourished due to improper food usage (Conte & Colleagues, 2019). Clean water, sanitation, and health care are all linked to food consumption (World Food Programme, 2022). It does, however, demonstrate how intimately nutrition is tied to food security, demonstrating that talking about food security and nutrition is pointless because there can be no food security without good nutrition.

Stability dimension

Stability is the fourth dimension of food security. At all times, according to the WFS definition, this stability applies first and foremost to the three characteristics of food security described above. Food security is "a circumstance" that does not have to occur for a single moment, day, or season but rather on a long-term, sustainable basis (Nguyen, 2020). Chronic and transitory food insecurity are defined by the stability dimension of food security:

1. A long-term or continuous failure to achieve minimum food requirements is known as chronic food insecurity.
2. A momentary or short-term food shortage is known as "transitory food insecurity." There are cyclical food insecurity issues as well, such as seasonality (Szabo, 2016).

2.4.3 Factors that influence food insecurity of agricultural households

Food insecurity is very common in countries that depend a lot on agriculture (ICDD, 2019). Even in the USA, a study of farm workers in Salinas Valley, in California, reported that more than half (66%) of farm workers in the study were reportedly food insecure (Kresge, 2011). Another study involving migrant farmworkers in the state of Georgia in the USA, reported that more than half (62.83%) of the respondents did not have enough food, while undocumented migrant and seasonal workers had a three (3) times higher risk of food insecurity compared to documented migrant and seasonal workers (Hill et al., 2011). A study from Malaysia reported that agrarian women with significantly higher mean years of education and lower mean number of children were more food-secure than other females that were in food-insecure groups. The study further identified mean diet diversity, mean household income and income per capita as significant factors that determined the food insecurity status of the women (Mohamadpour et al., 2012).

It is reported that rainfall-dependent farming is one of the causes of food insecurity in rural areas of Ghana (Darfour & Rosentrater, 2016) because the rains are not reliable and dry seasons are becoming prolonged. Erratic and inadequate rainfall is therefore having negative effects on the production of crops (Hirons et al., 2018) and as such can lead to food insecurity among farmer households (Asare-Nuamah, 2021). These negative effects of climate change threaten food systems sustainability (Hoegh-Guldberg et al., 2018) thereby creating food insecurity across the food system as whole (WFP, 2021b; Yaro, 2013). Farmers who practice rain-fed agriculture are better off, if they can earn off-farm income to to procure food when the weather does not help agricultural production. In a study in Northern Ghana, it was observed that off-farm income helps in ensuring household food security (Owusu et al., 2011). Another study in Ghana also reported that income from agricultural activities, non-farm activities, remittances and wage activities had positive significant effect on per capita food consumption expenditure of households (Adzawla & Kudadze, 2017). While in Pakistan, it was reported that food security status of the household improves when household heads are in paid employment (Muhammad et al., 2021). In a study involving eighteen (18) African countries, off-farm employment opportunities were also identified as influential factors in achieving food security (Waha et al., 2018). In all, income from off-farm activities will enable households to buy food items that they cannot produce in sufficient quantities.

Partly due to the negative effects of climate change, farm diversification is identified as an appropriate livelihood improvement strategy to help farm households to become food secure (Makate et al., 2016; Mekuria & Mekonnen, 2018) since households that are diversified in crop production are more likely to include food crops in their farming mix and can therefore be food secure (Adjimoti & Kwadzo, 2018). Essentially, diversification of production enables the household to spread the risk among multiple enterprises while providing a wider range of food items for households (Asante et al., 2018; Dessie et al., 2019).

Household size can also affect food security of the household, if several members of the household are not engaged in income generation activities from which they can support household expenditure. Pei *et al.* (2018) observed that smaller sized households with significantly fewer children were food secure but larger sized households with more children were not food secure. The factors that were significant in influencing the food insecurity status of the respondents were mean household income, income size in relation to household size, and food expenditure (Pei et al., 2018). The study of Pei *et al.* (2018) means that a household can be large and still be food secure if several members of the household earn income or if the household income is large enough for a high per capita income of household members. As such, work must provide decent income since adequately paid jobs determine purchasing power and this further determines a household's access to food (Scherrer & Saha, 2013).

Land size and market orientation are also identified as key drivers for food security (Douxchamps et al., 2016). A farm manager who is interested in selling produce and products from the farm may do so with the mindset that revenue from the produce and product can be used to purchase food. This is common among monocrop tree crop farmers. For such farm managers, increasing acreage of production means generating more revenue from which the household can procure food. The risk with targeting food security through market orientation is that, if the markets do not function properly, then the farm household that specialises in production will be vulnerable to food insecurity (Roest et al., 2018).

2.4.4 Measurement of food security and food insecurity

There are several indicators used to measure food security. The U.S. Household Food Security Survey Module (US HFSSM) is used to estimate the prevalence of food insecurity in the United States on an annual basis (Coates et al., 2007). The International Dietary Data Expansion (INDDEX) Project also identified the Household Food Insecurity Access Scale (HFIAS) (Coates et al., 2007), Household Hunger Scale (HHS) (Ballard et al., 2011), Food Consumption Score (FCS) (Maxwell et al., 2014) and the Food Insecurity Experience Scale (FIES) (Ballard et al., 2013; Cafiero et al., 2018). The Coping Strategies Index (CSI), Reduced Coping Strategies Index (rCSI), the Household Dietary Diversity Scale (HDDS) and a self-assessed measure of food security (SAFS) were also identified by Maxwell *et al.* (2014). There are several other indicators available; but the choice of indicator to use depends on the research objectives that a researcher may be interested in (INDDEX Project, 2018).

Recall period of measurement

The HFIAS is made up of nine questions covering a recall period of thirty days (Coates et al., 2007) while the FIES is made up of eight questions covering a recall period of twelve months (Ballard et al., 2013) and the HHS is made up of six questions covering a thirty day recall period. As such, if the research objective is sensitive to how easy it will be for respondents to recall their state of food insecurity, thirty days will be more suitable than twelve months. The Food Consumption Score (FCS), on the other hand, limits recall to the past seven days, while Household Dietary Diversity Score (HDDS) considers the past twenty four hours as the suitable recall period (INDDEX Project, 2018).

Dimension of measurement

The FCS and HDDS with their shorter recall periods can provide detailed information if repeated over time; this is important and it makes FCS and HDDS suitable for measures in the stability domain of food security. On the other hand, the FCS and HDDS are used to assess caloric intake which is relevant for the quality pillar of food security. The HHS, HFIAS and FIES have similar questions and they are used to measure the access domain of food security.

The Household Food Insecurity Access Scale (HFIAS)

The HFIAS is adapted from the US HFSSM. The HFIAS is made up of nine occurrence and nine frequency questions to measure feelings of uncertainty or anxiety over food, perceptions of insufficient food quantity, perceptions of insufficient food quality, reduction in food intake, consequences of reduced food intake and feelings of shame for resorting to socially unacceptable means to obtain food resources (Coates et al., 2007). The food quality related questions in the HFIAS are not direct measures of food nutritional quality; these questions are designed to assess the household's perception of diet quality change without considering the objective nutritional composition of diets. The HFIAS cannot be used to determine if one household needs more help than another.

Food insecurity is a complex, multidimensional concept (Coates et al., 2007), The different instruments are however, designed to measure specific (different) dimensions of food security. A comprehensive study on food security will therefore require the use of a mix of different measures in order to cater for various dimensions of food security and insecurity (Maxwell et al., 2014).

2.5 Review of Previous Empirical Studies

The Herfindahl index (HI) was used to compute a Diversification Index to measure production diversity among 500 farmers in Zimbabwe (Makate et al., 2016). It was also used in other studies involving 271 smallholder farmers in central Malawi (Mango et al., 2018), 608 smallholder farmers in Ghana (Asante et al., 2018), 385 smallholder farmers in Ethiopia (Dessie et al., 2019) and 420 rural households in Benin (Adjimoti & Kwadzo, 2018). From their study, Makate *et al*. (2016) applied probit regression to identify land size, farming experience, asset wealth, access to extension services, information on output prices, low transportation costs and general information access as factors associated with adoption of diversification.

However, tobit regression model was used by Dessie *et al*. (2019) to identify farmland size, sex, age, land fragmentation, distance to development center, market distance, and off-farm income as the factors that affected farmers decision and extent of crop diversification. On the other hand, Asante *et al*. (2018) applied Cragg two-step regression model to identify access to tillage equipment, fertilizers, credit and market information as factors that encourage farmers to diversify. Adjimoti and Kwadzo (2018) noted that the Crop Diversification Index (CDI) derived from the Herfindahl index is also called the Simpson Diversity Index (SDI) by ecologists or the Herfindahl–Hirschman Index (HHI) by economists (Adjimoti & Kwadzo, 2018).

Mekuria and Mekonnen (2018) used a different measure of diversification called the Margalef index to measure production diversity among 211 farmers in Ethiopia. Results from the analysis of data, using a tobit model, showed that livestock holding, access to extension service and irrigated land positively and significantly influenced the extent of crop-livestock diversification. However, the use of improved seed and higher soil fertility status negatively and significantly influenced crop–livestock diversification among respondents (Mekuria & Mekonnen, 2018).

To identify factors that influence crop diversification, Feliciano (2019) applied scoping review methodology to 49 publications that were systematically identified out of 2,426 publications retrieved from the Web of Science. Across the publications studied, the scoping review identified access to roads and markets, access to irrigation, land size, land and water rights, chronic poverty, and policy interventions as the main factors that influence crop diversification.

Adjimoti and Kwadzo (2018) studied the effect of crop diversification on household food security in Benin. They measured household food security by developing a composite food security index derived from indicators for food accessibility, food affordability, food utilization and food stability using Principal Component Analysis (PCA). After analysing the data with a linear regression model, the study reported that crop diversification positively affected household food security status. They realised that when the household depends mostly on their farm for food, crop diversification enables the household to produce the different crops that they cannot access either because of cost or because of poor physical infrastructure constraints. The study also identified access to storage facilities and extension services as factors that affect household food security in the study area (Adjimoti & Kwadzo, 2018).

While Adjimoti and Kwadzo (2018) combined various measures/indicators of food security to develop a composite index for food security, Makate *et al*. (2016) used the Food Consumption Score (FCS), Household Food Insecurity Access Score (HFIAS) and Household Dietary Diversity Score (HDDS) separately as measures of household food security status in order to determine the influence of crop diversification on household food security using a probit regression model. They reported a positive and statistically significant effect of crop diversification on household food security of farmers (Makate et al., 2016).

Mango *et al*. (2014) also used HFIAS and HDDS separately to measure food security of farmers in their study of factors that affect food security among smallholder farmers in Zimbabwe. After application of linear regression to analyse the data, they identified age and education level of the household head, availability of household labour, household labour size, livestock ownership, access to market information and remittances as factors that influence HDDS among respondents. A separate linear regression analysis also identified labour, education of the household head, household size, remittances, livestock ownership and access to market information as factors that affected HFIAS of households in the study (Mango et al., 2014).

In a study to determine the effect of diversification on food security of farmers in Malawi, Mango *et al*. (2018) also used HFIAS and FCS separately as measures of food security. After applying Ordinary Least Squares (OLS) regression, they reported that crop diversification significantly affected farmers' food security status with respect to FCS and HFIAS (Mango et al., 2018).

While Adjimoti and Kwadzo (2018), Mango *et al*. (2018) as well as Mango *et al*. (2014) used HFIAS as well as other indicators to measure food security, Poczta-Wajda *et al.* (2020) used only the HFIAS to measure food security among 710 smallholder farmers in Poland. Since a large proportion of the respondents were food secure (HFIAS = 0), a zero-inflated Poisson (ZIP) regression model was applied in the study to identify factors that could influence the food security status of the respondents. From the analysis, higher age and secondary or higher education of the farm manager, having children in the household and higher land productivity had significantly positive influence on the food security status of farmers' households. However, production of tree crops, dairy cow production and having family size above four were identified as factors that reduces the food security of smallholder farm households (Poczta-Wajda et al., 2020).

Though Makate *et al*. (2016) and Mango *et al*. (2014) used the HDDS and other measures of food security in their studies, Antwi *et al*. (2018) used only the HDDS to assess the food security status of 320 cocoa farmers in the Wassa Amenfi West District of Ghana. They used a logit model to identify gender of household heads, age of households' heads, household size, years of schooling, annual cocoa output, and household non-agricultural income as factors that significantly influence food security status among cocoa farming households in the study area (Antwi et al., 2018).

Nkegbe *et al*. (2017) used the Household Hunger Scale (HHS) to measure food security status of farmers in northern Ghana. After analysing the data with an ordered probit model, they identified education, means of transport, ownership and use of mechanized farm equipment, yield, agricultural crop production and commercialization, cultivation of multiple crops, ownership of poultry, small livestock, large livestock, food consumption expenditure, locality and region of residence as factors that affect the food security status of farm households (Nkegbe et al., 2017).

Akukwe (2020), on the other hand, generated Household Food Security Index (FSI) as a measure of household food security based on household monthly per capita food expenditure in relation to the mean food expenditure of all households sampled. This approach is essentially a measure of food accessibility. After data analysis with a logistic regression model, the study identified monthly income, dependency ratio, level of education, marital status and distance to market as the statistically significant variables that determined farm household food security status in the study area (Akukwe, 2020).

Abu and Soom (2016) also generated a Food Security Index based on a recommended daily calorie intake to measure food security of 180 rural and urban farming households in Benue State, Nigeria. They identified income of households head, rural household size and farm size as factors that positively affected household food security; while age of household head and urban household size negatively affected household food security after data analysis with a probit model. They also used PCA to identify factors that constrained achievement of household food security among the respondents. Constraints identified include lack of access to credit, inadequate land availability, and poverty, infertility of the soil, lack of non-farm income generation activities, storage and processing problems (Abu & Soom, 2016).

Dompreh *et al.* (2021) used the FCS and HFIAS in a study to determine whether adoption of tree crop certification schemes influenced food security of farm households. Data was collected from 608 tree crop farmer households and analysed with propensity score matching. The study reported that cocoa/oil palm farmers who were certified were more food secure compared to uncertified tree crop farmers and food crop farmers. Significant differences were, however, only observed when HFIAS was used (Dompreh et al., 2021).

Jahan *et al*. (2022) used SWOT analysis to identify the strengths, weaknesses, opportunities, and threats of agroforestry practices among 240 farmers in Bangladesh (Jahan et al., 2022). They identified good soil, receptive and hard working nature of farmers, regular income and increased provision of environmental services as strengths while lack of knowledge on agroforestry practices, relatively high investment costs, limited extension advisory and promotional services as well as long gestation period of the trees were identified as weaknesses. Threats identified include climate variability, frequency and duration of natural hazards, increasing labour costs, and land acquisition from farmers for for government projects. Parra-López *et al*. (2021) used AHP/SWOT/PESTLE model to determine importance of the conditioning factors of digital transformation in the olive sector in Spain (Parra-López et al., 2021). They then went further to design policies that can strengthen digital transformation through TOWS analysis.

Falcone *et al*. (2020) applied SWOT analysis to identify strategies that can be used to effectively develop a sustainable forest-based bioeconomy in Italy. They identified improving environmental and forest planning tools by defining viable methods of circular management, promoting investment in forest infrastructure, supporting entrepreneurship programs for forest professionals and enhancing innovative forest-based value chains as the most effective strategies (Falcone et al., 2020).

In their study of how crop diversification affects soil aggregation and associated carbon and nitrogen in olive groves, González-Rosado *et al*. (2022) employed one-way ANOVA to compare means of the various treatments and Tukey's HSD for post hoc tests, to compare soil properties data among the treatments (significance level of $p < 0.05$). They then applied Two-way ANOVA to compare changes in soil properties in factors depth and time, and Dunnett's for comparisons between diversifications and the control system. Their study showed that crop system diversification has a high potential in increasing soil stability and organic carbon sequestration into the soil (González-Rosado et al., 2022).

Dai *et al*. (2017) used propensity score matching method to assess the effect on smallholder incomes when fruit grain and cotton farms are diversified with fruit trees in rural Xinjiang, China. Their study, involving a survey of 352 households, revealed that incomes on and off-farm were negatively affected largely due to land tenure insecurity.

Using data on 51,770 households, Birthal *et al*. (2015) applied generalized propensity score matching and reported that crop diversification into high value crops improves farmers livelihood. Using data from a nationally representative survey, we establish that households diversifying toward HVCs are less likely to be poor, the biggest impact being for smallholders. They also applied continuous treatment matching to show that farmers need to allocate at least 50% of farm land to high value crops in order to escape poverty. Their research also revealed that the positive effects of diversification peaks at a cut off point because of constraints which make it difficult for farmers to diversify further (Birthal et al., 2015).

2.6 Conclusion

The literature reviewed suggests that each diversification strategy has its pros and cons. As such, the farmer will utilise the strategy they believe can better help them to achieve their objectives. The extent of diversification also has an influence on food security and farm income of farm households. The extent of diversification is largely influenced by factors such as livestock holding, size of farmland, gender and age of farmer, land fragmentation, market accessibility (distance and cost to markets), access to off-farm income, farming experience, asset wealth, access to extension and information services. The literature also identified various challenges and opportunities available that can be used to support and provide a favourable environment to drive diversification of tree crop production.

The literature identified age, level of education and gender of household head, household size, size of farmland, poverty, recurrent drought, inadequate rainfall, yield, monthly income, distance and transportation cost to market, food prices, energy security, access to credit, remittances, unemployment, assets, off-farm income, availability of household labour, livestock ownership, access to market information, access to farm inputs, preference to consume what is produced, market orientation of the farming system, extension services and storage facilities as factors that affect household food security status.

The literature also shows that lack of knowledge on agroforestry practices, relative high investment costs, limited extension services as well as a lengthy maturity period are weaknesses that can affect farmers adoption of agroforestry practices. While climate variability, frequency and duration of natural hazards, increasing labour costs, and loss of land to government projects are threats to farmers engaged in agroforestry.

The estimation approaches, explanatory variables and functional forms used in the study are guided by the findings from the literature reviewed.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology applied in this study is presented in this chapter. The basic theories adopted and how they guide the formulation of a conceptual framework are discussed. Other sections also discuss the study area, types of data collected and the methods of data analysis applied to achieve the study objectives.

3.2 Conceptual Framework

Considering the gestation period, productive lifespan of the tree crops and the use of produce from the tree crops, it is conceptualised that medium-term (10-year) aspirations will have an effect on the extent to which farmers practice diversification.The objectives of tree crop farmers (as is evident among cocoa, oil palm and rubber farmers) are not centred on producing crops and harvesting the produce for domestic food consumption. It is argued that tree crop farmers will use the income from the tree crops to buy (access) food. It is therefore conceptualised that farmers who want a higher proportion of their income from the farm will diversify less compared to others. Secondly, farmers who have a future farm outlook centred on food crop production will diversify more compared more compared to others.

Due to the cash earned from tree crops, farmers will only use diversification to reduce household food insecurity and increase or stabilise household income if markets become more unreliable and the climate becomes less favourable. At the local level, however, several bio-physical characteristics of the farm site and socio-economic factors present strengths, weaknesses, opportunities and threats that can influence the extent of crop diversification among farmers. Such factors include topography of the plot site, land tenure and availability of household labour.

Based on this framework, it is conceptualised that gender, age and educational level of the farm manager (household head) coupled with adult (> 14yrs) sex ratio, dependency ratio, literacy ratio, access to off-farm income, household labour available, and access to information will influence the level of diversification practiced by the farmer.

Furthermore, topography of the farm plot site, land tenure arrangement, structure-conduct-performance of the market, government policies, labour constraints, availability of investment capital and access to planting material will influence the level of crop diversification the household can practice.

The conceptual framework for this study is graphically presented as Figure 3.1

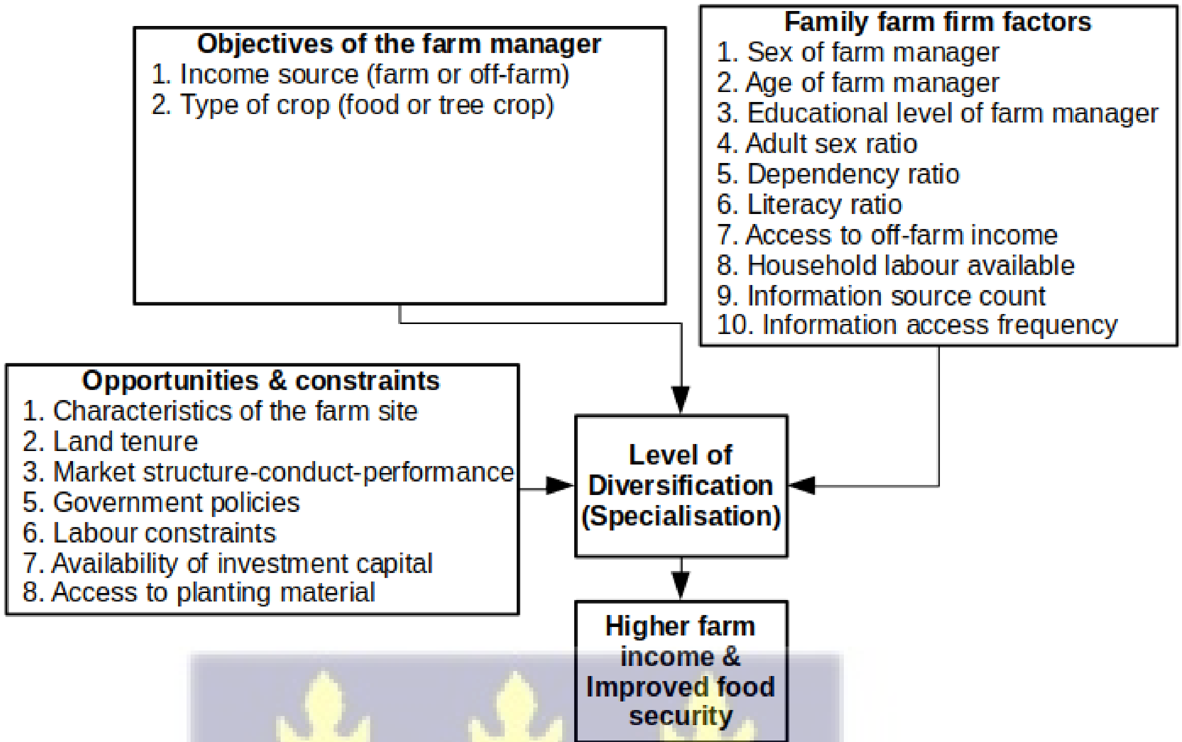

Figure 3.1: Conceptual framework based on Schroth and Ruf (2014)

3.3 Theoretical Framework of the Study

The theoretical framework is based on factors and approaches identified in the literature. The influence of independent factors on diversification of farmers can be expressed as:

$$D_j = \beta_j X_i + \varepsilon_j \qquad (3.1)$$

Where D_j is the state of diversification of farmer j ; X_i is the vector of independent factors that influence farm diversification; β_k represents parameters to be estimated and ε_j is an independent error term.

Since farmers produce tree crops for cash instead of food for the household, it is hypothesised that this objective will drive farmers to practice less crop farm diversification.

3.4 Method of Data Analysis

Descriptive statistics were used to analyse demographic characteristics of respondents. Gross profit, Household Food Insecurity Access Scale (HFIAS) Score and Crop Diversity Index were computed and used to describe enterprise profitability, household food insecurity (access domain) status and level of crop diversification respectively. Tobit regression was used to determine factors that influenced crop diversification of farmers.

Finally, SWOT-TOWS analysis was used to describe the strengths, weaknesses, opportunities and threats of the bio-physical and socio-economic environment observed in the study area in order to propose strategies to improve or increase diversification.

In this study, common and major tree crops in the study area such as cocoa, oil palm and rubber as well as food crops were the types of crops considered. It is important to note that the CDI does not indicate mixed cropping on the same plot of land. Essentially, the CDI is mostly an indication of the extent to which farm land is shared among crop enterprises in the farm business portfolio of the household. In this study, tree farm manag

3.4.1 Factors that influence extent of crop diversification among farmers

The extent of crop diversification among farmers was estimated using a Crop Diversity Index (CDI) based on the Herfindahl Index (HI). Crop diversification is computed as an index of concentration (minimum = 0, maximum = 1) such that a CDI score of zero means the farmer uses all farm plots for the cultivation of only one type of crop and hence there is no diversification. However, any value above zero indicates an extent of diversification such that diversity increases as the value/score of the index increases from 0 towards 1. The crop diversification index is empericaly computed from the Herfindahl Index (Hirschman, 1964) as:

$$CDI = 1\text{-}HI \tag{3.2}$$

Where $HI = \sum_{i=1}^{n} P_i^2$ (3.3)

Where P_i is the proportion of cropped area (land) occupied by the i^{th} crop relative to total land (ha) under production by the farm household.

$$P_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{3.4}$$

Where A_i is land (ha) occupied by the i^{th} crop.

The CDI has the advantage of not requiring the farmer to produce all type of crops (Adjimoti & Kwadzo, 2018). In this study, common and major tree crops in the study area such as cocoa, oil palm and rubber as well as food crops were the types of crops considered. It is important to note that the CDI does not indicate mixed cropping on the same plot of land. Essentially, the CDI is mostly an indication of the extent to which farm land is shared among crop enterprises in the farm business portfolio of the household. In this study, tree farmers were asked to indicate the major land use of each farm plot. It is important to note that the CDI as constructed in this study is based on what the farmer considers to be their crop(s) on the farm plot.

Based on the classification used by Makate *et. al* (2016), farmers who had CDI score greater than 0.5 were considered to be highly diversified in their production. In addition, a new classification was also developed in order to determine farm households that are completely specialised since the classification used by Makate *et. al* (2016) does not give a finer detail of the extent of diversification. This new classification is as follows:

- Not diversified (CDI = 0), Slightly diversified (CDI > 0; CDI < 0.25), Moderately diversified (CDI > 0.25; CDI < 0.5), Diversified (CDI > 0.5; CDI < 0.75) and Highly diversified (CDI > 0.75).

Tobit regression was used to estimate the influence of the independent variables on the dependent variable. The dependent variable (crop diversity score) has an upper limit of 1 as the highest possible score; as such the scores are considered to be left censored. The Tobit model was therefore used because it is an appropriate model for a censored dependent variable (Cunillera, 2014; Mekuria & Mekonnen, 2018). The Tobit model is expressed as:

$$Y_i = \beta X_i + u_i \quad (3.5)$$

Where Y_i is the observed dependent variable of crop diversity (CDI_i); X is the set of independent variables affecting the dependent variable; the subscript i represents 1 to n, which is an index of the number of observations in the study; β represents the coefficients of the independent variables, and u are residuals that are independently and normally distributed with a mean of zero and a common variance. Common variance is the variance of the unexplained error term in a regression model. The set of variables used in the model are presented in Table 3.1.

Table 3.1: Variables to assess factors that influence crop diversification among farmers

Variables	Description	Measurement Unit	*A priori* Expectations
Dependent Variable			
Crop diversity	Crop Diversity Index (CDI)	Scale (decimals)	
Independent Variables			
Income mix	Future income composition	Ranks (only farming = 1,	-

Variables	Description	Measurement Unit	*A priori* Expectations
	(FINC)	mostly farming = 2, a little over half from farming = 3,half from farming = 4, a little over half from non-farm = 5, mostly non-farm = 6, only non-farm = 7	
Crop mix	Future crop portfolio composition (FCROP)	Ranks (only food crops = 1, mostly food crops and some tree crops = 2, a little more food crops than tree crops = 3, half food & half tree crops = 4, a little more tree crops than food crops = 5, mostly tree crops and some food crops = 6, only tree crops = 7)	+
Farm plot count	Number of farms (FCOUNT)	Count	+
Distance to farm	Average time spent to move from the house to the farm (FDIST)	Continuous (minutes)	+/-
Land tenure	A measure of ownership (TENURE)	Continuous	+
Information access frequency	How frequently the farmer accesses information (INFOFREQ)	Continuous (decimals)	+
Sex	Sex of farmer (SEX)	Dummy (F = 1, M = 0)	+
Age	Age of farmer (AGE)	Years	+
Education	Educational level of farmer (FEDU)	Ranks (NONE = 0, Primary = 1, JSS = 2, SHS = 3, Tertiary = 4)	+
Dependency ratio	Ratio of dependents to those employed (DR)	Continuous	+
Livestock count	A count of the number of livestock the farmer keeps (LSTOCK)	Continuous	+/-
Off-farm	Access to off-farm income	Dummy (Yes = 1, No = 0)	+

Variables	Description	Measurement Unit	*A priori* Expectations
income	(OFFINC)		
Household labour	Count of household labour (HLABOUR)	Count	+

Description of variables used for tobit regression

Cropping diversity: is the dependent variable. It is the Crop Diversity Index (CDI) based on the Herfindahl Index (HI) of crop production.

Income mix: based on data taken on how farmers want their income composition to look like in the medium-term (10-year). Farmers had a range of options from only farm income on one end to only off-farm income on the extreme opposite end of the income composition range. It is expected that farmers who want to continue tree crop production will more likely have farm income in their income mix; such farmers will practice less crop diversification (Anyidoho et al., 2012; Dessie et al., 2019; Schroth & Ruf, 2014).

Crop mix: based on data taken on how farmers envisage their farm to be like in the medium-term (10-year). It is expected that farmers who are interested in crop diversification will be in interested in a crop mix that includes food crops (Anyidoho et al., 2012).

Farm plot count: If farmland is fragmented, then plots may be at different sites with different typographical and ecological features that may be suitable for different crops. As such it is expected that the more parcels of farmland a household has access to, the higher the possibility that they will be diversified in crop production (Schroth & Ruf, 2014).

Distance to farm: is measured in terms of how long it takes the farmer to move from the house to the farm. The average time (minutes) spent in travelling to the farm is computed to represent distance to farm; computation of average time is used in order to take care of situations where farmers have multiple parcels of land. It is theorised that the longer time it takes to visit different farms, the higher the possibility that the farms have different site-specific characteristics which can increase diversification of the crops cultivated by the household (Schroth & Ruf, 2014). However, it is also theorised that if the farmer has to spend a long time in travelling to the farm, they would want to concentrate labour on producing one crop of high value instead of sharing resources between several crops.

Land tenure: it is based on the tenure of each parcel of land available to the household, a score was created using the following steps:

i. All lands that are inheritted , bought outright or gifts were classified as 'owned_land' and given a score of 3.
ii. A classification was created for long-term leased lands ('long_term') and given a score of 2.
iii. All other lands were classified as 'not_owned' and given a score of 1.
iv. Then a composite score was created for strength of land ownership as:

$$Tenure = \frac{\sum Land\ score_i}{n} \quad (3.6)$$

Where

Tenure: Mean strength of ownership of all lands within the household's land portfolio.

Land $score_i$: The strength of ownership of each parcel of land.

n: A count of all lands within the household's land portfolio.

Based on the structure of this score, tenure is within a range of 1 and 3. Secondly, tenure increases if the farmer owns most of the land in the land portfolio of the family. In addition, the number of land parcels or the size of land parcels does not influence the score. It is expected that as there is increase in control over land use decision making, diversification will increase and vice versa (Adjei-Nsiah, 2006; Alufah, 2015; Mandal & Maity, 2022; Schroth & Ruf, 2014; Dai et al., 2017).

Information access frequency: In this study, a score is computed based on the frequency with which farmers receive information from each of the sources listed such as agents of the Ministry of Food and Agriculture (MOFA), COCOBOD, input suppliers, produce buyers, for working on other farms, farmer groups/cooperatives, other individual farmers, NGOs, certification bodies (such as Utz/RA, Fairtrade, RSPO), the internet, books/brochures/newspapers, radio, and other sources of information. Frequency of information access is coded as weekly = 4, monthly = 3, every 2-3 months = 2, once or twice a year = 1. Therefore the highest information access score for a farmer who very frequently receives information from all the thirteen sources is fifty two (52) and the lowest score for a farmer who does not receive any information is zero (0) from the thirteen sources of information access (Adjimoti & Kwadzo, 2018; Mekuria & Mekonnen, 2018; Schroth & Ruf, 2014).

Sex: female farmers are coded as 1 while male farmers are coded as 0. It is theorised that female farmers will want to have access to foodstuffs in order to cook their own food at home. It has been reported that when females are engaged in the decision-making process, it leads to higher diversity in terms of production and consumption (Sariyev et al., 2021). It is therefore expected that female farmers will be more diversified in crop production compared to male farmers.

Age: it is expected that as age of the farmer increases, diversification of crop production will also increase (Schroth & Ruf, 2014).

Education: as the educational level of the farmer rises, the farmer will be exposed to more information and will be in a better position to make informed decisions as to diversification. It is expected that as educational level of the farmer increases, diversification of the farmer will increase (Schroth & Ruf, 2014).

Dependency ratio: traditionally, it is the ratio of household members between the ages of 0 to 14 years and above 65 years to those who are 15 to 64 years. It is based on the assumption that people within the dependent age group are not actively earning income from any work. However, lots of farmers actively engage in farming and other income generation activities beyond age 65. This study therefore measured dependency ratio in terms of number of household members who do not work (do not contribute to household income) compared to number of household members who work (generate income for the household). It is expected that as dependency ratio reduces, there will be an increase in crop diversification since farmers will have more income at their disposal which can be invested in the production of other crops (Schroth & Ruf, 2014).

Livestock count: the expected effect of livestock count on crop diversication is indertiminate. If livestock count has a positive effect on diversification, then it means farmers are interested in having multiple farm income sources and are therefore interested in crop diversification (Mekuria & Mekonnen, 2018). On the other hand, if livestock count has a negative effect on diversification, then it means that the farmer is not interested in crop diversification irrespective of livestock production .

Off-farm income: farmers who have access to off-farm income will be able to invest into crop production diversification. It is expected that off-farm income will lead to an increase in crop diversification (Mango et al., 2014).

Household labour: most rural households rely on family labour for farm activities. Therefore as household labour increases, the farm household will be in a better position to diversify production (Schroth & Ruf, 2014). Household labour is expected to have a positive effect on crop production diversification.

Tobit regression was modelled in R statistical software using the censReg function (Henningsen, 2017).

3.4.2 Differences in food insecurity status based on level of crop diversification

Based on the HFIAS guide, the Household Food Insecurity Access Scale (HFIAS) Score was computed for each farm household as a measure of the access dimension of food security of farm households. The lowest score per question is zero (0) and the highest score per question is three (3) which means that the highest total score per household for the nine (9) questions from the HFIAS guide is between 0 and 27.

$$HFIAS\ Score = \left(\sum_{i=1}^{9} Q_i \right) \quad (3.7)$$

Where Q_i is the the household's score of the *i*th question out of the nine (9) questions in the HFIAS. As HFIAS score increases, the household's perception of food insecurity also increases. On the other hand, as the HFIAS score decreases, the household's perception of food insecurity (access) decreases.

Test of statistical differences in mean HFIAS scores

Based on the classification used by Makate *et. al* (2016), farmers who had CDI score greater than 0.5 were considered to be highly diversified in their production. Based on the sample size of farmers that fall into each diversification class, differences in mean HFIAS scores were tested using the Z-test because the sample sizes for each group were greater than 30. The Z-test is estimated as:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{S_{\bar{x}_1 - \bar{x}_1}} \quad (3.8)$$

Where:

$\bar{x}_1$ Is the mean HFIAS score of highly diversified farmers.

$\bar{x}_2$ Is the mean HFIAS score of lowly diversified farmers.

$S_{\bar{x}_1 - \bar{x}_1}$ Refers to the standard error of the difference between the two means.

With

$$S_{\bar{x}_1 - \bar{x}_1} = \sqrt{\frac{S_1^2}{n_1} - \frac{S_1^2}{n_2}} \qquad (3.9)$$

Where:

S_1^2 is the unbiased estimate of the variance of each diversification class.

n_1 and n_2 are sample sizes for the highly and lowly diversified class, respectively.

Statement of hypothesis:

The null hypothesis (H_0) was tested against the alternative hypothesis (H_1) at 5% significance as follows:

H_0 is: there is no statistically significant difference in the mean HFIAS scores of farmers in each diversification class.

H_1 is: there is a statistically significant difference in the mean HFIAS scores of farmers in each diversification class.

The decision rule is stated as: if the calculated test statistic is greater than or equal to the tabulated (critical) statistic, then the null hypothesis is rejected.

3.4.3 Differences in farming gross profit based on level of crop diversification

Gross profit: is estimated from crop revenues and expressed in Ghana Cedis (GHS) per hectare. Cost of hired labour, herbicides, insecticides, fungicides, organic fertiliser and inorganic fertilser as well as yields, prices and revenues were determined from plot surveys (358 cocoa plots, 333 oil palm plots and 49 rubber plots) in order to determine the average variable costs and gross profit per hectare of cocoa, oil palm and rubber farms.

Subsequently, the average variable costs and gross profit per hectare of the sampled plots were used to compute gross profit for each crop in the portfolio of the farm household as:

$$GP_i = R_i - VC_i \tag{3.10}$$

where GP $_i$ represents gross profit of the ith crop, R is revenue from the crop and VC is variable cost incurred in producing the crop.

For each household, Total Gross Profit (TGP) per hectare is computed as:

$$TGP = \left(\sum_{i=1}^{n} GP_i \right) / a \tag{3.11}$$

Where GP_i is the gross profit of the ith crop enterprise in the household's farm portfolio and a is the total farm acreage managed by the household. Variable costs and revenue from other crops, if any, were also included to determine the total gross profit for each farm household.

Test of statistical differences in mean gross profits

Based on the classification used by Makate *et. al* (2016), farmers who had CDI score greater than 0.5 were considered to be highly diversified in their production. Based on the sample size of farmers that fall into each diversification class, differences in mean gross profits were tested using the Z-test because the sample sizes for each group were greater than 30. The Z-test is estimated as:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{S_{\bar{x}_1 - \bar{x}_1}} \tag{3.12}$$

Where:

$\bar{x}_1$ Is the mean gross profit of highly diversified farmers.

$\bar{x}_2$ Is the mean gross profit of lowly diversified farmers.

$S_{\bar{x}_1 - \bar{x}_1}$ Refers to the standard error of the difference between the two means.

With

$$S_{\bar{x}_1 - \bar{x}_1} = \sqrt{\frac{S_1^2}{n_1} - \frac{S_1^2}{n_2}} \tag{3.13}$$

Where:

S_1^2 is the unbiased estimate of the variance of each diversification class.

n_1 and n_2 are sample sizes for the highly and lowly diversified class, respectively.

Statement of hypothesis:

The null hypothesis (H_0) was tested against the alternative hypothesis (H_1) at 5% significance as follows:

H_0 is: there is no statistically significant difference between the mean gross profit of farmers in each diversification class.

H_1 is: there is a statistically significant difference between the mean gross profit of farmers in each diversification class.

The decision rule is stated as: if the calculated test statistic is greater than or equal to the tabulated (critical) statistic, then the null hypothesis is rejected.

3.4.4 SWOT-TOWS analysis of diversification strategies

Strengths, Opportunities, Weaknesses, Opportunities and Threats (SWOT) analysis was done to understand the structure, conduct and performance of cocoa, oil palm and rubber farm enterprises in the study area. Subsequently, the Threats, Opportunities, Weaknesses and Strengths (TOWS) framework was used to analyse and develop strategies to guide farmers interested in tree crop diversification in the study area. The SWOT-TOWS framework is indicated in Table 3.2.

SWOT analysis is used by analysts for planning and to provide a clearer insight of the business environment (Helms & Nixon, 2010). While TOWS analysis is used to clearly produce linkages between factors from a SWOT analysis in order to generate strategies for the enterprise (Proctor, 2000). TOWS as a strategy development framework helps managers to manage business risks (Dandage et al., 2019) by maximising strengths and opportunities while minimising weaknesses and threats related to the enterprise and its environment.

Table 3.2: SWOT-TOWS matrix

	Strengths (S)	Weaknesses (W)
Opportunities (O)	S-O Strategy: Maxi-Maxi	W-O Strategy: Mini-Maxi
Threats (T)	S-T Strategy: Maxi-Mini	W-T Strategy: Mini-Mini

Variables assessed in terms of strengths and weaknesses include:

- Age of tree crops, age and educational level of farmers, investment costs, gestation period of crop, household labour available, access to off-farm income, gross profit from crops, household food security, farm size, farm plot count, product nature and quality and farm management practices.

Variables assessed in terms of opportunities and threats among respondents include:

- Climate, producer price, availability of buyers, government policies, non-household labour, agricultural finance, planting material, land tenure, extension service, input supply, farmer groups, variable costs, gross profit, research and development.

3.5 Method of Data Collection

3.5.1 Sources of data

This study used data collected between September 2020 and March 2021 from farmers by the use of structured questionnaires as part of the Governing Multifunctional Landscapes (GML) project of the Centre for International Forestry Research (CIFOR) executed in collaboration with the Forest and Horticultural Crops Research Centre (FOHCREC) of the University of Ghana.

Subsequently, data was collected from focus group discussions from six (6) community platforms established by the GML project at Kwabeng, Abomosu, Tumfa, Takyimang, Asuom and Kade as well as separate in-depth interviews with twenty one (21) farmers in Abodom (2), Asuom (1), Akinkaase (2), Pramkese (2), Awenare (1), Tumfa (3), Ekorso (3), Kwabeng (1), Takyimang (2), Ademan (1) and Nkwantanang (3) as well the District Director and staff of the Department of Agriculture in Kwabeng.

3.5.2 Sampling techniques and sampling size

A multi-stage sampling technique was applied in the study. Kwaebibirem and Atiwa West were purposely selected for the GML project due to the presence of oil palm, cocoa and rubber production in addition to the Atiwa Forest in the area. Subsequently, the Department of Agriculture as well as FOHCREC were consulted to identify suitable communities for data collection. Purposive sampling was then carried out in each community to interview farmers who had at least one tree crop farm that is matured and being harvested regularly. After data cleaning, data from 740 farm households were found to be suitable and hence used for this study.

3.5.3 The study area

This study targeted cocoa, oil palm and rubber farmers in Atiwa West district and Kwaebibirem municipality of the Eastern Region of Ghana as shown in Figure 3.2. According to the Eastern Regional Coordinating Council (ERCC), agriculture provides jobs for 47.8% of the people in the Kwaebibirem municipality (ERCC, 2016). The Kwaebibirem municipality is in the south-western part of the Eastern Region (Ghana Districts, n.d.). The municipality shares boundaries with Atiwa West District to the north, Denkyembour District to the south, East Akim Municipal to the east and Birim North to the west (Ghana Districts, n.d.).

About 66.7% of the population in Atiwa West lives in rural areas with about 60% of the population engaged in agriculture. The major crops produced in the district are cocoa, maize, cassava, plantain, oil palm and vegetables. Cocoa and oil palm are identified as the major cash crops in the district (ERCC, 2018).

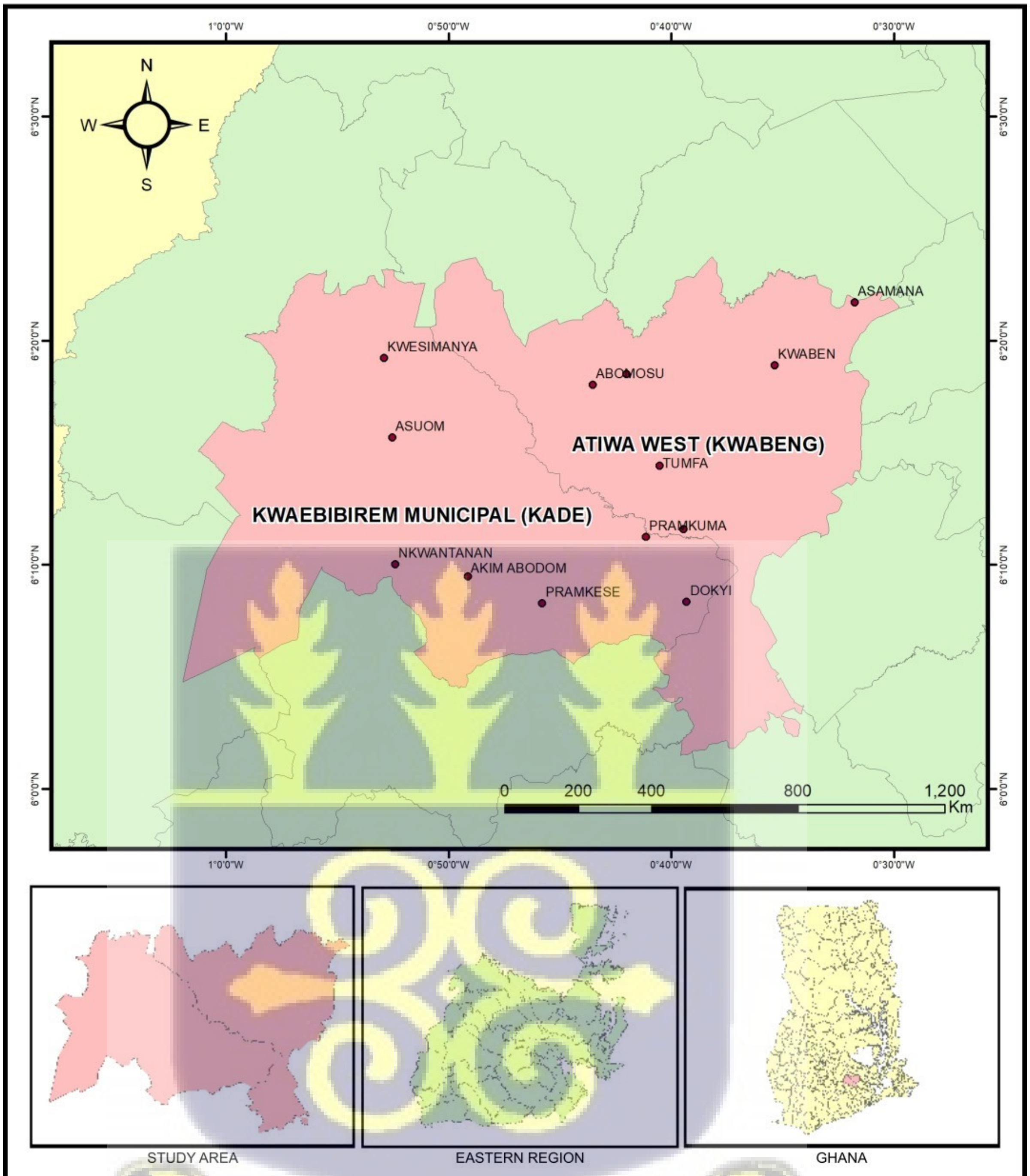

Figure 3.2: Map of the study area
Source: Geography Department, University of Ghana

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses results presented in the form of tables and graphs. Farmer demographics and farm characteristics are presented in section 4.2. Next, crop diversification is disscussed in section 4.3, while factors affecting crop diversification are presented and discussed in section 4.4. This is followed by the discussion of differences in farm household insecurity in section 4.5. The next section presents and discusses results on the differences in farm profits based on diversification in section 4.6. Subsequently, results on the SWOT/TOWS analysis of crop diversification is presented in section 4.7 and section 4.8.

4.2 Description of Farm Households

Characteristics of respondents and their households are presented and discussed in the sections that follow.

4.2.1 Age distribution among farm household heads

The mean age among heads of farm households is about 55 years; with majority (92.70%) of farmers being over forty five (45) years in age (Table 4.1). The age distribution of household heads shows that a lot of the youth are not engaged in farming. This finding is similar to what was reported in the 2017/2018 agricultural census in Ghana. The census results revealed that more than 84.1% of all tree crop holders were above 36 years of age (Ghana Statistical Service, 2019).

4.2.2 Sex of households heads

Most (78.92%) of the households are headed by men (Table 4.1). The household head, most of the time, leads the decision making process on what to cultivate and how to manage the farm.

4.2.3 Educational characteristics of households

From Table 4.1, it is observed that majority of the respondents had primary or junior high school education. The mean household literacy ratio of 0.49 (Table 4.1) also shows that on average, about half of each household is literate and hence, have basic literacy and numeracy skills. As such, farm households are likely to be better informed in decision making about what to produce and how to allocate farm plots. The agricultural census revealed that about 44% of farmers have attained basic education with more than half of farmers being able to read and write with understanding in at least one language (Ghana Statistical Service, 2019).

Table 4.1: Household characteristics

Variable	%	Mean	Median	Min	Max	S.D
Age		54.57	55.00	19.00	90.00	12.28
Age (≤ 35)	6.49	30.62	31.00	19.00	35.00	3.22
Age (36 - 45)	0.81	41.1	41.00	36.00	45.00	2.64
Age (> 45)	92.70	59.94	60.00	46.00	90.00.	8.69
Sex						
Female	21.08					
Male	78.92					
Education						
Primary	22.3					
J.H.S.	60.27					
S.H.S. / Vocational	10.54					
Tertiary	6.89					
Other household characteristics						
Household size		5.98	6.0	1.00	64	3.41
Literacy ratio		0.49	0.50	0.00	1.00	0.29
Off-farm jobs	11.89					
Livestock	53.11					
Farm size (Ha)		5.64	4.40	0.40	58.40	5.05
Farm plot count		3.33	3.00	1.00	19.00	1.90

Source: Author's computation

4.2.4 Farm acreage of households

As a whole, households cultivated an average of 5.64 hectares of farm land (Table 4.1). However these lands are mostly not one contiguous parcel of land; farmers had access to an average of 3.33 different plots of farm land (Table 4.1). The results also show that only a few farmers (< 5%) had farm land above 20 hectares (Figure 4.1). Based on the Ghana national interpretation of RSPO principles (RSPO, 2020), farmers in the study are classified as smallholders with land sizes below the 40 Ha threshold used for classifying smallholders.

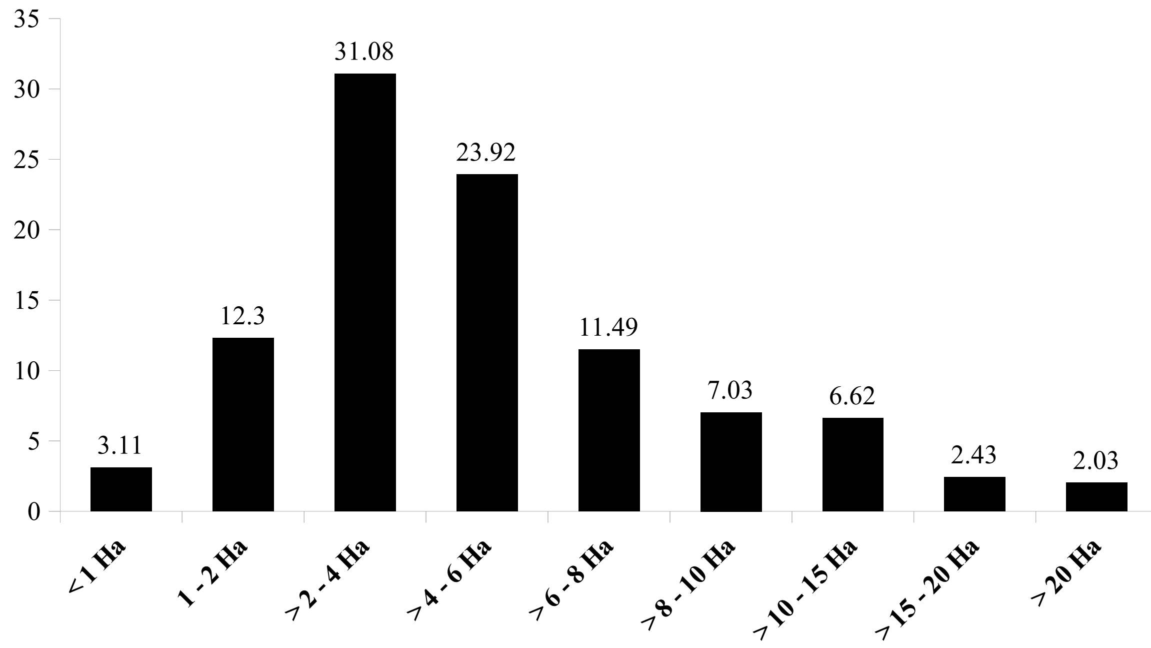

Figure 4.1: Farm size distribution (%) among households
Source: Field Survey, March 2021.

4.3 Crop Diversification

4.3.1 Extent of crop diversification

The results revealed that farmers in this study are not highly diversified as observed from the average Crop Diversification Index (CDI) of 0.23. Majority (96.89%) of the households belong to the low diversification group with more than 95% of lands allocated for the production of tree crops (Table 4.2).

Results in this study are in contrast with what Makate *et al*. (2016) observed, with 81% of farmers being diversified in their study. The results are also different from what Dessie *et al*. (2019) reported with a high mean diversification of 0.769 to indicate that 92.46% of farm households were diversified above CDI of 0.5.

Table 4.2: Extent of crop diversification among farm households

	%	Mean	Median	S. D.	Min	Max
Total		0.23	0.24	0.23	0.00	0.73
Land allocated for tree crops		95.00%	100.00%	11.49		
Diversification intensity						
Low diversification	96.89	0.22	0.20	0.22	0.00	0.60
High diversification	3.11	0.64	0.64	0.03	0.60	0.73

Source: Author's computation

On average, farmers who commit majority (50% or more) of their lands to cocoa farming were least diversified (0.197) in land use (Figure 4.2), followed by oil palm farmers (0.243). One respondent committed more land to citrus production but with a low CDI score of 0.444, while five farmers committed majority of their land to food crops (0.512) belonging to the highly diversified group. From these two isolated cases alone, it is seen that a farmer who majors in food crops is more diversified than the average tree crop farmer.

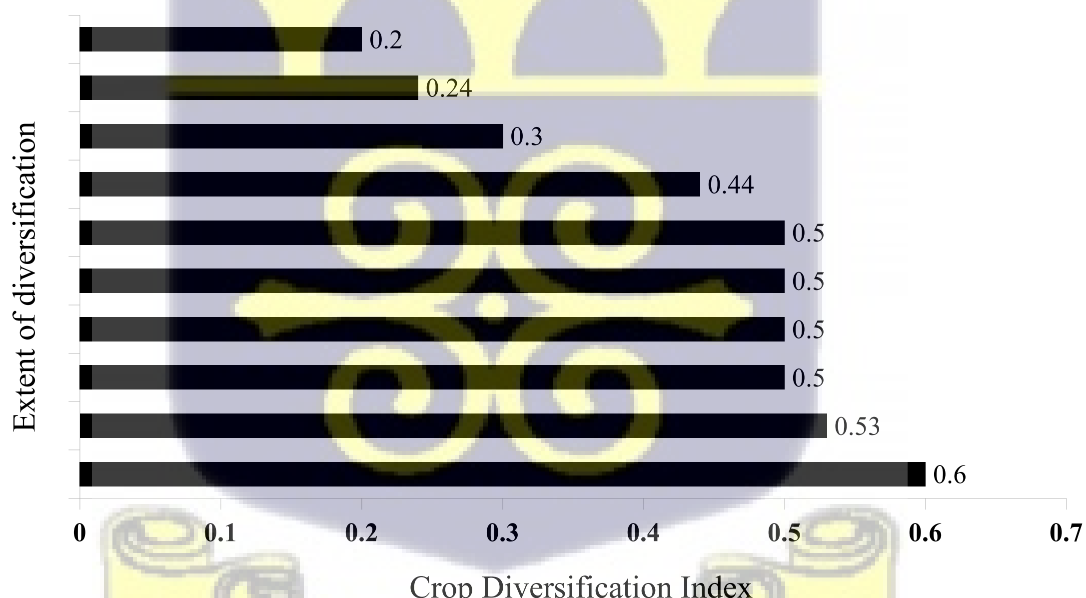

Figure 4.2: Average CDI of farmers per main crop
Source: Field Survey, March 2021.

The results from this study (carried out in southern Ghana) contrasts observations made in northern Ghana where farm households maintain high levels of crop diversity of up to eight (8) crops (Bellon et al., 2020). Contrasting the two studies in terms of agro-ecological zones, it seems that cash crop farmers in the Forest Zone of Ghana are less likely to diversify crop cultivation compared to what is observed among arable crop farmers in the Northern Savannah zone. This is because crops are more likely to fail due to poor and erratic rainfall as well as other climatic shocks in the Northern Savannah zone than what farmers experience in the Forest Zone of southern Ghana where the amount and distribution of rainfall is better (Bellon et al., 2020).

4.3.2 Diversification classes

No household was highly diversified in their crop production activities and hence, not present in Figure 4.3. Households that specialised in the production of only one crop (44.87%) were in the majority which was a bit more than those that were slightly diversified (41.62%).

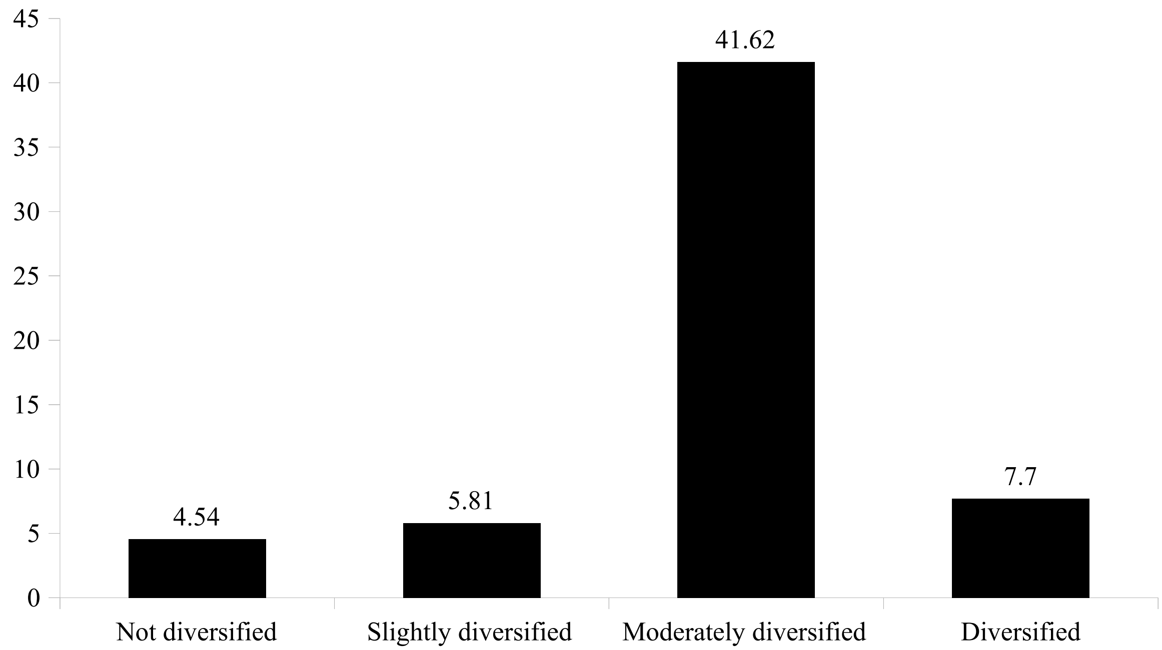

Figure 4.3: Household distribution (%) per diversification class
Source: Field Survey, March 2021.

Apart from households that produced only one crop, households that were in other diversification classes allocated between 33.33% and 99.82% to the major crop in the portfolio of the household (Table 4.3). The differences between medians and means of farm land allocation show that majority of farmers allocate more than 50% of farm land to one major crop even if they do not specialise on one crop. For farmers who were slightly diversified, 100% was the maximum registered because the household allocated all farm land to tree crops but shared equally, 50% each to two tree crops (Table 4.3).

The preference of farmers to allocate more than half their farm lands to tree crops means that tree crop farmers in the study are market-oriented in their production. This is because, though palm nut soup and Crude Palm Oil (CPO) are widely consumed by farm households, the quantities consumed domestically will not merit specialising on oil palm as a major crop unless the farm manager intends to sell produce and products. For cocoa farmers, cocoa butter and chocolate are not produced domestically and they are not staple foods in Ghana. Similarly, Palm Kernel Oil (PKO) is not commonly produced at home from oil palm.

Table 4.3: Share of major crops to farm land in each diversification class

	Not diversified	Slightly diversified	Moderately diversified	Diversified
Minimum (%)	100	85.71	33.33	35.9
Median (%)	100	90	66.67	55.6
Mean (%)	100	90.13	68.89	56.35
Standard deviation (%)	0	3.27	11.62	12.38
Maximum (%)	100	99.82	100	97.56

Source: Author's computation

It was observed from plot surveys that almost every farm plot had at least a fruit tree or food crop plant but farmers did not consider them in discussing what they produce on the plot. Farmers discuss diversification within the context of crops that they directly spend money on in order to control weeds, pests and diseases. While farmers harvest produce from such plants for domestic consumption and sometimes for sale, they do not consider such plants to be "the crop(s)" they cultivate. For example, farmers who were moderately specialised did not indicate any food crop as part of their farms (Table 4.4). Essentially, farmers reported on crop diversification within the context of what they (the farmer) deliberately spent resources on to cultivate. Subjective as this perception of farmers may be, it also shows that tree crop farmers are more interested in the "major or main" crop on the farm.

Table 4.4: Details of farm land (%) allocated to major crops

	Specialised	Moderately specialised	Slightly specialised	Slightly diversified
Cocoa	100.00	90.54	68.03	52.00
Oil Palm	100.00	89.81	69.42	54.60
Rubber	100.00	86.67	65.79	50.69
Cocoa & Oil Palm	-	-	90.53	78.28
Cocoa & Rubber	-	-	100.00	-
Oil Palm & Rubber	-	-	-	87.27
Cocoa & Food Crops	-	-	50.00	-
Rubber & Food Crops	-	-	50.00	-
Food crops	-	-	39.39	55.00
Citrus	-	-	66.67	-

Source: Author's computation

Though the data shows that farmers prefer tree crops to food crops, an interesting reality was observed from plot visits, focus group discussions and in-depth interviews with farmers. Every farmer cultivates food crops during the establishment phase (3-4 years) of tree crops. Some farmers intercrop the food crops themselves or they allow other farmers to do so. This intercropping of food crops with tree crops motivates farmers to regularly control weeds, get produce to feed the household and or earn income from the food crops.

Due to the benefit of this strategy, farmers who give out their young tree crop farms to other farmers to intercrop with food crops do not take any fee for renting their farm. So there is a mutually beneficial arrangement whereby the tree crop farm owner gets weed control and the food crop farmer gets land, at least till the tree crop canopy makes it difficult to keep food crops. So it can be said that every tree crop farm plot in the study is temporarily diversified. As such, some farmers who at the time of this study had food crop farms are only temporarily diversified and will not have food crops in the household's portfolio in subsequent years, all other things being equal. It was further observed that farmers who were not diversified had the highest gross profit on average per hectare of farmland (Figure 4.4). Average gross profit per hectare decreased as diversification increased (Figure 4.4). What it means is that, a cash crop farmer with income as the main objective for farming is more likely to specialise than diversify the household's farm portfolio.

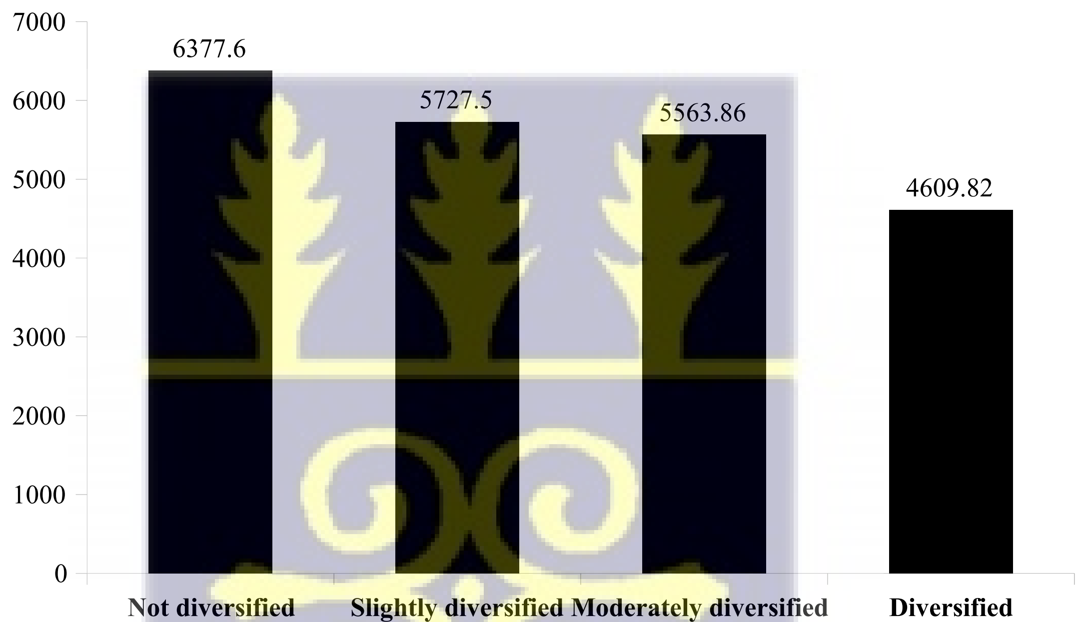

Figure 4.4: Average gross profit (GHS) per hectare per diversification class

Source: Field Survey, March 2021.

4.4 Factors Influencing Diversification

Comparing the tobit regression model to a null model with a constant term shows that all of the regression coefficients are simultaneously not equal to zero ($p < 2.2$ $^{-16}$). The results (Table 4.5) based on the tobit model is therefore considered to be statistically significant compared to the null model.

Number of farm plots is significant ($p < 0$) and positively related to farm diversification (Table 4.5). It is likely that different plots have different characteristics which will make them suitable for different crops. It has been reported that, farmers plant different tree crops based on the topography of the land (Schroth & Ruf, 2014). It is also likely that different plots were acquired through different land tenure arrangements. Interactions with farmers revealed that, sharecroppers "have no option than to plant what the landowner dictates".

It is observed that distance to the farm is significantly ($p < 0.01$) and positively related to diversification (Table 4.5). For a farmer with multiple farms, an increase in distance means that the farms are not close to each other. Such farms are likely to have different characteristics and were probably acquired under different arrangements. These can lead to different crops being planted on different lands.

From Table 4.5, it is also observed that the frequency with which a farmer receives information about agriculture is positively and significantly ($p = 1.62e^{-5}$) related to diversification. This is in agreement with the findings of Mekuria and Mekonnen (2018). They observed that extension contact had a positive and significant influence on the extent of diversification.

In terms of sex, men were more likely to diversify their farms compared to females (Table 4.5). It might be the case that men have more decision making power in deciding what to do with their lands than what women can do. Interestingly households with higher dependency ratio and households with access to off-farm income have positive and significant relationship with diversification at the 5% and 10% levels respectively. The higher the dependency ratio, the more income and food the farm manager needs to meet household objectives. Such a farm manager is therefore likely to diversify to increase food security of the household. Access to off-farm income can provide farmers with the leverage and financial space required to invest into tree crop cultivation. However, Dessie *et al*. (2019) observed that access to off-farm income can negatively influence diversification.

Though land tenure did not have a significant effect on crop diversification, its effect was negative. Which means that the more farmers have control over the land, the less diversification they practice. This strengthens the view that farmers are using income from the tree crops to support their livelihoods.

Table 4.5: Determinants of diversification

Independent variables	Estimate	Std. error	t value	Pr (> t)
Future income mix	0.0000236	0.0000682	0.3470000	0.7289420
Future crop portfolio mix	0.0000743	0.0000823	0.9030000	0.3666160
Number of farm plots	0.0593500	0.0074800	7.9340000	0.0000000 ***
Average distance to farms (minutes)	0.0018280	0.0006310	2.8960000	0.0037790 ***
Land tenure (ownership) strength	-0.0024490	0.0192100	-0.1270000	0.8985860
Frequency of information access	0.0275200	0.0063810	4.3120000	0.0000162 ***
Sex of farmer (Male)	0.0946700	0.0376300	2.5160000	0.0118650 **
Age	0.0023640	0.0011890	1.9890000	0.0466920 **
Level of education of the farmer	0.0000614	0.0000801	0.7670000	0.4432380
Dependency ratio	0.0265200	0.0078780	3.3660000	0.0007630 ***
Livestock count	-0.0009722	0.0012880	-0.7550000	0.4504830
Access to off-farm income	0.0865700	0.0417800	2.0720000	0.0382730 **
Household labour count	-0.0226900	0.0123200	-1.8420000	0.0655120 *
(Intercept)	-0.5335000	0.1110000	-4.8060000	0.0000015 ***
logSigma	-1.0750000	0.0394600	-27.2320000	0.0000000 ***

Likelihood ratio test: p < 2.2e-16
Wald test: p < 2.2e-16

NB: *, ** and *** denotes 10%, 5% and 1% significant levels respectively
Source: Author's computation.

4.5 Differences in Household Food Insecurity Status

Test of differences between the means shows that there is no significant difference in mean household food insecurity access scale score of farm households grouped by diversification (Table 4.6). Therefore, we cannot reject the null hypothesis. In other words, there is insufficient evidence to suggest that diversification among tree crop farmers leads to differences in food insecurity status of the farmers.

The characteristics of the tree crops planted in the study area shows that farmers are not relying on their tree crop farms for food produce. In other words, income from the tree crop farms are used to access food from the market. This contrasts observations made by Adjimoti and Kwadzo (2018) that diversification improves household food security.

Table 4.6: Difference in mean household food insecurity (access) status based on crop diversification

	Mean	Std. Deviation	D. f.	T-Cal	P value	95% C. I.	Decison Rule
Low diversification	3.94	4.10	67.19	0.75	0.46	-0.66 – 1.46	H_o not rejected
High diversification	3.54	3.83					

Source: Author's computation

On average, a mean Household Food Insecurity Access Scale (HFIAS) Score of 3.91 was observed in the study (Table 4.7). The mean HFIAS Score based on the crop with the biggest land use per farmer reveals that, farm households that commit majority (> 50%) of farm land to either cocoa, oil palm or rubber production had mean HFIAS scores below 4 (Table 4.7). If we ignore the single cases (constituting 0.135% each) of farmers commiting more land to food crops or citrus, it can be said that farmers who commit more land to cocoa, oil palm or rubber had average HFIAS scores below 7 out of a possible HFIAS score between 0 – 27.

The results in Table 4.7 shows that the mean HFIAS score (3.97) for those who commit majority of their lands into cocoa production is higher than what Dompreh *et al*. (2021) observed for certified cocoa farmers (2.76) but lower than what they observed for uncertified cocoa farmers (4.39) in their study. Secondly, the HFIAS score for oil palm farmers (3.58) in this study shows that perception of food insecurity is higher than what Dompreh *et al*. (2021) reported in their study for certified oil palm farmers (1.74), uncertified oil palm farmers (3.16) and food crop farmers (3.31).

Table 4.7: HFIAS score distribution among farm households

	Mean HFIAS Score	S. D.	Count	%
Total	3.91	4.08	740	100
Not diversified				
Cocoa only	4.30	4.07	210	28.38
Oil Palm only	4.44	4.55	112	15.14
Rubber only	2.9	6.05	10	1.35
Dominant land use				
Food crops	6	2.92	5	0.676
Rubber	3.54	4.49	26	3.510
Oil Palm	3.58	4.13	277	37.430
Cocoa	3.97	3.98	407	55
Cocoa & Oil Palm	6.67	4.09	18	2.43
Cocoa & Food Crops	5.33	4.62	3	0.405
Cocoa & Rubber	8	NA	1	0.135
Oil Palm & Rubber	2	NA	1	0.135
Rubber & Food Crops	11	NA	1	0.135
Citrus	9	NA	1	0.135

Source: Author's computation

However, Table 4.7 shows that farmers who mostly produce oil palm have a lower average HFIAS score (3.58) compared to cocoa farmers (3.97); this was similarly observed by Dompreh *et al*. (2021) who reported that certified oil palm farmers had a lower score (1.74) than that of certified cocoa farmers (2.76) and similarly, uncertified oil palm farmers had a lower score (3.16) compared to that of uncertified cocoa farmers (4.39). In this study, less than 20% of respondents are certified for organic oil palm or cocoa production.

From Figure 4.5, it is observed that more than a third (39.86%) of the households could be classified as food secure in terms of the access dimension. This proportion of food secure households is higher than what Mango *et al*. (2018) reported (22.9%) in their study from Malawi and also higher than the 22% reported by Makate *et al*. (2016) from Zimbabwe. In addition, only 38.25% of the households were mild to moderately food insecure, compared to a higher percentage (70.5%) as reported by Mango *et al*. (2018). The lower levels of food insecurity in this study compared to other studies are in line with the findings of Wiggins *et al*. (2015) and Hashmiu *et al*. (2022) that, tree crop production provides income that helps to improve household food security of farmers.

Combining farmers who are mildly, moderately and severely food insecure in Figure 4.5 reveals that at least half (51.08%) of the farm households experience various levels of food insecurity. This is more than the global average of about 33.33% but lower than the sub-Saharan Africa average (66.2%) for the year 2020 as reported by UN DESA (2021).

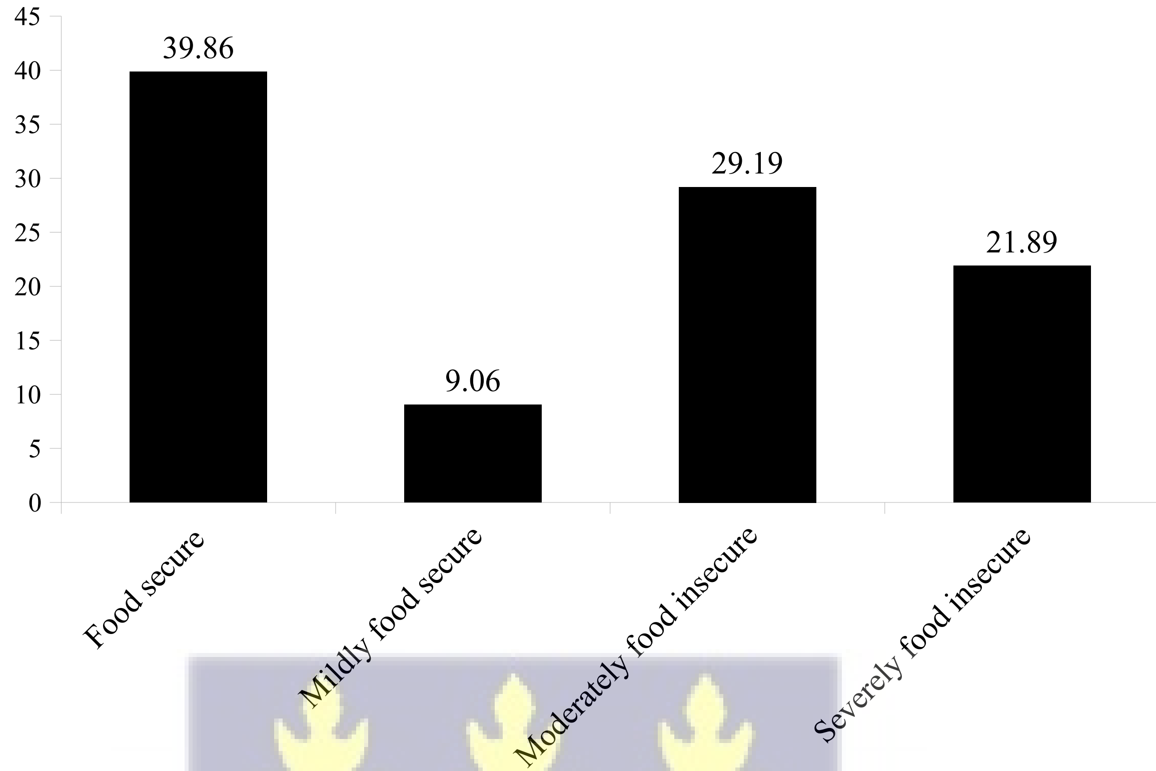

Figure 4.5: Distribution of households according to food insecurity categories
Source: Field Survey, March 2021.

In terms of diversification, farm households that were not diversified in crop production had a higher perception of food insecurity (access) than those in other diversification classes (Figure 4.6). It means that cash from tree crop production alone may not necessarily be enough to improve household food security. This is inline with the observations of Ecker (2018) that relying on income from non-food crop production is a risky food security strategy for most farmers in Ghana. It was expected that food insecurity will reduce as diversification increases, however, those who were slightly diversified did not have the lowest perception of food insecurity (Figure 4.6). It means that a balancing act is required to reduce household food insecurity (Figure 4.6) while improving farm income at the same time as seen in Figure 4.4, if farm diversification is the strategy to be pursued.

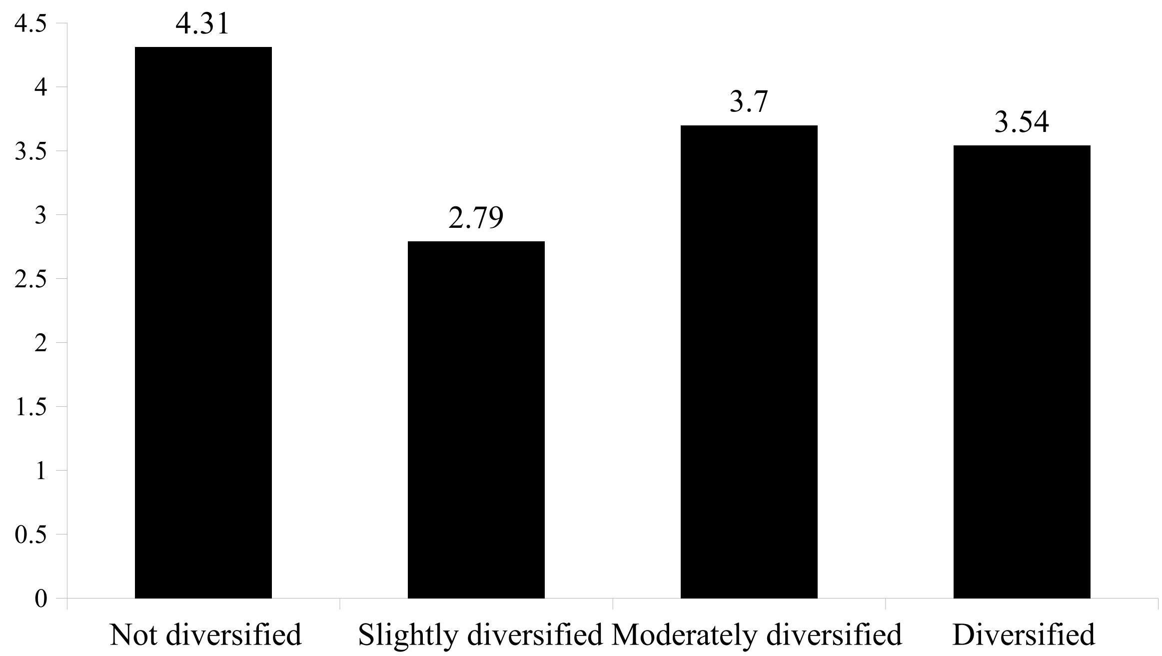

Figure 4.6: Household distribution (%) per diversification class

Source: Field Survey, March 2021.

4.6 Differences in Gross Profits based on Extent of Crop Diversification

Test of differences shows that highly diversified farmers had significantly higher gross profits compared to lowly diversified farmers (Table 4.8). Therefore, we reject the null hypothesis. In other words, there is sufficient evidence to suggest that diversification among tree crop farmers leads to differences in gross profits.

Schroth and Ruf (2014) report that diversification reduces economies of scale and leads to higher transaction costs in poorly developed markets. It can therefore be argued from the profit maximisation perspective that, farmers should only practice diversification if the commodities they will sell have well developed markets. In other words, diversification will not bring cost advantages to tree crop farmers if they will find it difficult to access inputs, difficult to get inputs at competitive prices and or incur higher transaction costs in bringing the produce to market and or get comparatively low prices for the produce in a market that is not competitive.

Table 4.8: Difference in mean gross profit based on level of crop diversification

	Mean	Std. Deviation	D. f.	T Calc	P-value	95% C. I.	Decison Rule
Low CDI	5969.71	1565.99	85.63	9.98	$5.33e^{-16}$	1088.88 – 1630.90	H_o rejected
High CDI	4609.82	924.44					

Source: Author's computation

4.7 SWOT Analysis of Diversification Strategies

Outcomes from the survey, in-depth interviews and community platform meetings in the GML project are used for discussions in the sections that follow.

4.7.1 Strengths of cocoa, oil palm and rubber farming in the study area

Mature and productive farms: on average, tree crop ages observed in the study were between eight (8) and seventeen (17) years (Table 4.9). This gives assurance that farmers can have a minimum of 10 years of continuous harvest from their tree crop farms, all other things being equal. Such farms can be collateralised to access capital to establish new plantations or for some other household expenditure. It was learnt from the field visits and in-depth interviews that some of the farms 'owned' by farmers are in reality a form of payment for loans given to the original owners. When the agreed period of harvesting is due, the farm is given back to the original owners. The relatively younger age of rubber farms observed (Table 4.9) is due to the fact that these farms were established between 2011 and 2012 as part of RPGL's outgrower scheme with funding from the first round of the OVCF (Government of Ghana, 2019).

Table 4.9: Average age of tree crops in the study

	Cocoa	Oil Palm	Rubber
Mean	16.42	13.67	8.2
Median	14	12	7
SD	11.06	7.76	3.31

Source: Author's computation

From the field survey, it was observed that some cocoa farms are young because they have been rehabilitated and replanted. In addition, most cocoa farmers plant new seedlings in existing farms or allow young cocoa shoots to take over when old trees die. This ensures that cocoa farmers continuosly get fruits to harvest from their farms unless a major disaster wipes out the whole farm. From focus group discussions and in-depth interviews, it was learnt that in most of the tenancy agreements used for cocoa farming, "the tenant farmer can continue cultivating the farm until there is no cocoa tree on the farm plot again". So in the absence of a major disaster, tenant cocoa farmers have their farms secured in perpetuity.

Market-oriented farmers: it was observed that majority (70.54) of farmers do not want to specialise on only tree crops (Table 4.10); farmers want to produce more cash crops than food crops. This reinforces the market oriented nature of farmers in the study area. It means farmers may want to diversify their farms and integrate food crops if the right market structures are provided for food crops.

Table 4.10: Future farm outlook based on aspirations

Outlook	% (n = 740)
Predominantly cash crops & some food crops	70.54
A little more cash crops than food crops	11.22
Exclusively cash crops	10.95
50/50 food crops & cash crops	3.64
Predominantly food crops & some cash crops	2.29
A little more food crops than cash crops	0.68
Exclusively food crops	0.27
No farm	0.41

Source: Author's computation

Out of the 740 respondents, almost half (47.84%) have income security as their primary objective (Table 4.11). This is reflected again in the secondary choice of respondents. Cash is still required to achieve the second highest (40.54%) objective of helping children get good jobs in the city (Table 4.11). During in-depth interviews, farmers explained that "they can buy food if they get income from the tree crops". Food security is therefore embedded in the objective for income security. It means any farm diversification strategy must have a value proposition of being market-oriented in order to generate income (cash) for the farmer.

Table 4.11: Objectives of farmers for farming

Future aim	1st choice	2nd choice	3rd choice
Become more income secure	47.84	38.24	8.92
Become more food secure	3.24	29.32	30.54
Help children get good job in the city	40.54	19.46	11.76
Become more respected	1.22	1.76	13.65
Create more free time for family	1.89	4.05	7.16
Improve family health	4.86	5.41	19.73
Become city dwellers	0.41	1.76	8.24

Source: Author's computation

Rational reasons for diversification: The gross profit of the various diversification classes (Figure 4.4) shows that specialisation is the best strategy for higher farm incomes. Based on prices at the time of the field survey, gross profit analysis of the farm enterprises reveals that cocoa offered the highest gross profit per hectare (Figure 4.7). However, oil palm and rubber present the farmer with regular income streams all-year round, unlike cocoa (Kolavalli & Vigneri, 2017). As such, farmers who diversify cocoa production to include oil palm and or rubber, may do so for "regular income stream and not just a big windfall", as reported by the farmers. Therefore diversification with a mix of cocoa and oil palm and or rubber helps farmers to get relatively regular revenues spread throughout the year. However, as discussed in other sections, there are other factors that influence the extent of diversification.

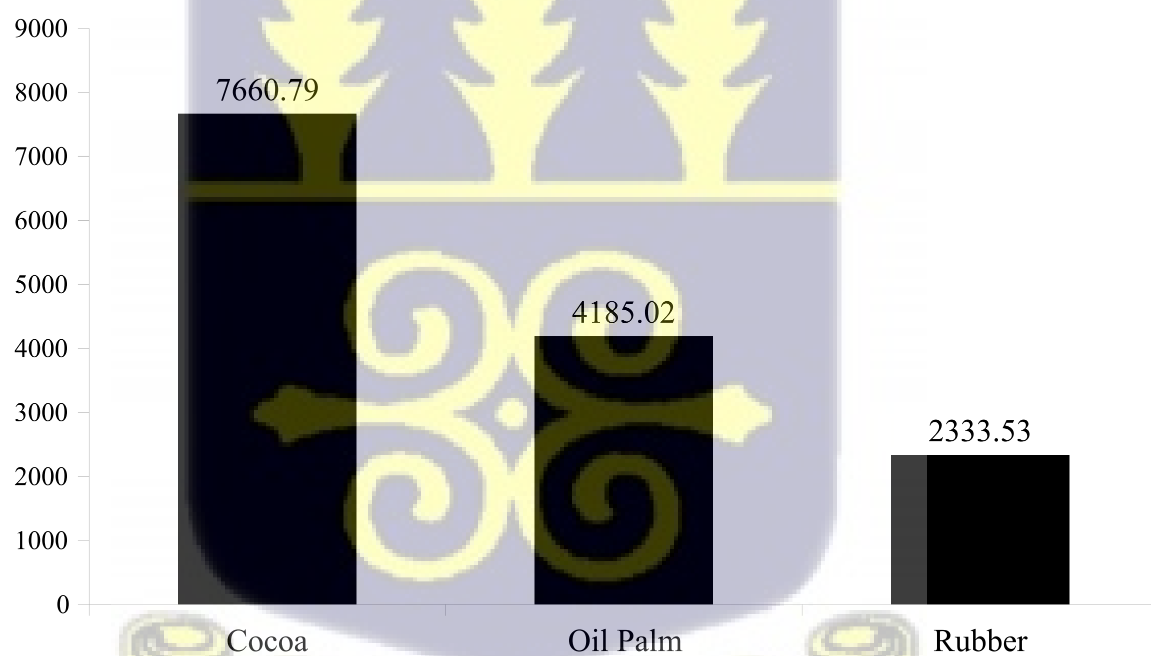

Figure 4.7: Gross profit per hectare (GHS)
Source: Field Survey, March 2021.

Food crop intercropping in young plantations: farmers intercrop new farms with food crops for income and food. It shows that farmers are not opposed to food crop cultivation.

Low levels of food insecurity: results from the study (Table 4.7 & Figure 4.5) show that farmers experience relatively low levels of food insecurity when compared to farmers from other studies. This is mostly achieved through relatively high levels of specialisation with slightly diversified farmers expressing the lowest levels of food insecurity (Figure 4.6). The relatively low levels of food insecurity among farmers in the study has an influence on their diversification strategies. It reinforces the perception that income from tree crops helps farmers to buy food even if they do not produce their own food crops. It might be the case that tastes and preferences of farmers are changing and they are relying more on processed food products than on traditional food crops from the farm for food.

High gross profit relative to variable costs: an analysis of variable costs and revenues show that there is high gross profit per hectare compared to variable costs (Figure 4.8). It means tree crop farming is profitable. The low variable costs compared to gross profits also mean that farm productivity is currently largely dependent on the 'forest rent' rather than farm improvement. However, farming objectives (Table 4.11) of farmers may drive spending farm revenue on non-farm expenses more than investing into farm improvement.

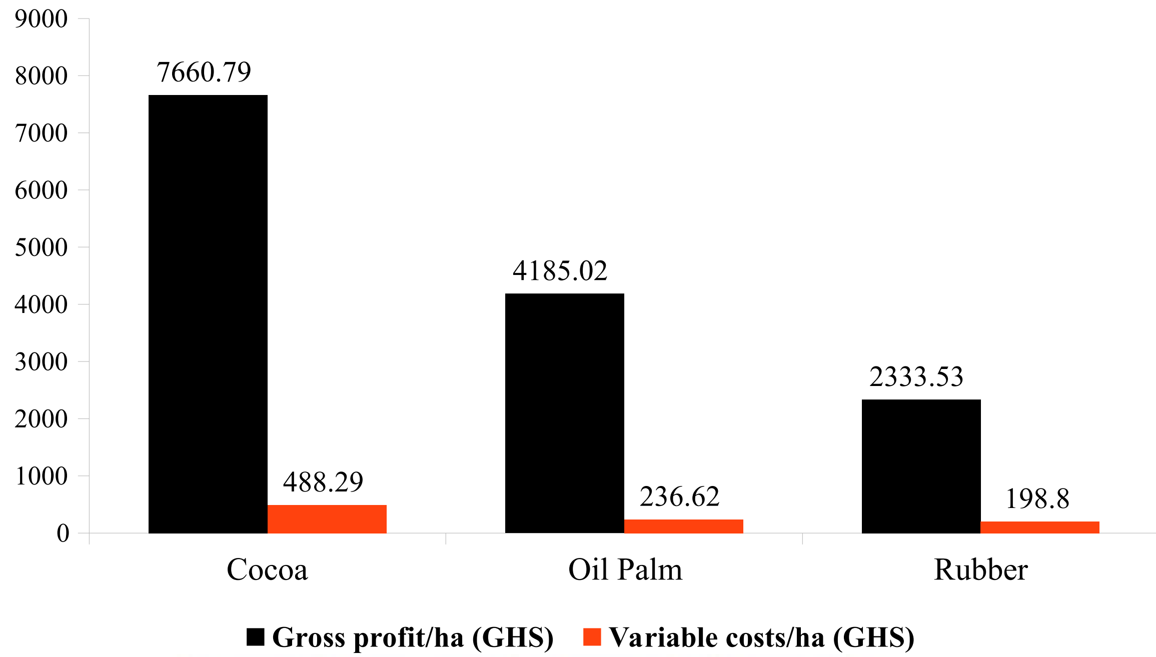

Figure 4.8: Gross profits compared to variable costs
Source: Field Survey, March 2021.

Farm plots with varied characteristics: average number (3.33) of plots per household as indicated in Table 4.1, means that most farmers have more than one plot and that these plots are not at the same location. In pursuit of a landscape mosaic of cocoa, oil palm, rubber and food crops with ecological and environmental benefits, farmers can dedicate each plot to a separate tree crop in combination with food crops. Farmers can only be convinced to see value in the ecological and environmental benefits of diversified cropping systems if it does not negatively affect income generated from the farms.

In-depth interviews, interactions at community platform meetings and field visits reveal that farmers "consider the nature of the farm plot to decide on what to cultivate", as reported by the farmers. For example, even farmers wish to cultivate only cocoa, this desire will be modified if the land is not suitable for cocoa. It was realised in the landscape that, oil palm is more likely to be found on low-lying flood prone lands because oil palm tolerates and does better on such lands than cocoa. This variation of land use based on nature of the farm plot accounts for the landscape mosaic observed in the Eastern region (Michel-Dounias et al., 2013). Essentially, farmers have the ability of being rational about reasons why they will use different plots for different tree crops.

Farm management know-how: farmers know that timely pruning, weeding, pest and disease control is required to improve output from the farms. Farmers indicated that cocoa requires more labour, agrochemicals and management than oil palm and rubber. Some farmers said they switched or diversified into oil palm production because they do not have time or the cash liquidity required for carrying out cocoa management practices in order to get optimal yields. So the more tasking it is to manage a particular tree crop, the higher the likelihood that farmers will switch or diversify if there are favourable market opportunities for other crops.

Interest in additional enterprises: farmers expressed interest in having additional enterprises, provided market structures will be created for them to earn income from these additional enterprises. In Abomosu, community platform members revealed that they were ever trained on snail production and there was a buyer who regularly came to buy snails but when the buyer went out of business, their businesses collapsed because they did not have market for the snails and the it was more than what the household can consume.
Similarly, farmers in Asuom said that they expressed interested in rabbit production when a firm from Tema came to the community to discuss the possibility of rabbit production with

the farmers. The firm did not carry through with its intentions but the farmers are still interested, provided there will be assurance of market to sell the rabbits.

Relatively durable produce: makes post-harvest losses less of an issue. Cocoa beans require fermentation and drying in order to be sold, while oil from palm fruits does not evaporate when kept for long. In fact, it was realised during in-depth interviews that artisanal processers claim a higher oil extraction rate when palm fruits are kept for a period to start rotting. For cocoa, beans need to be fermented and dried before they are sold. Rubber cup lumps actually need to harden up and be air dried to remove excess moisture.

As such cocoa, oil palm, and rubber farmers did not have post-harvest losses as some of their challenges when compared to what pertains in the vegetable and arable crop sectors. This means that prices at the farmer level are not negatively affected based on glut in the local market.

4.7.2 Weaknesses of cocoa, oil palm and rubber farmers in the study area

Poor pest and disease control: cocoa farmers in the study were not controlling pests and diseases properly. Farmers rely mostly on the spraying of agrochemicals to control pests and diseases. The use of these agro chemicals also kill beneficial organisms and natural enemies of pests in the farms. Integrated pest and disease management principles are poorly implemented. For example, black pod control requires integrated disease management which includes phytosanitary processes (CHED & WCF, 2016; Guest, 2007). However interactions with farmers reveal that, farmers do not dedicate time to remove only diseased pods or do pruning; as farmers control weeds and do pruning, they also remove diseased pods. Secondly, farmers do not burn or bury diseased pods far away from the farm. It means that farmers end up spreading fungal spores which will subsequently cause black pod disease. Farmers practice these poor control measures out of ignorance or due to the costs that will be incurred if extra labour must be commited to remove only black pods. In addition, farmers do not properly manage tree shade or conduct pruning due to cost and access to labour. This creates a suitable environment required for pest and disease incidence. It was however observed on rubber and oil palm farms that, pests and diseases are not much of a problem compared to what pertains in cocoa farms.

Inadequate artificial pollination: most farms do not get visits from the artificial (manual) pollination gangs of CHED of Cocobod. It was learnt from plot visits and in-depth interviews that farmers have the perception that the improved varieties do not fruit properly without artificial pollination. Some farmers are therefore reluctant to plant improved varieties. This weakness, however, was not reported in the study for oil palm or rubber production.

Inadequate knowledge on diversification of tree crops at the plot level: it was observed that farmers practice what extension officers teach them. Currently, all tree crop production extension advice is designed towards optimised plant population for monocultures. Therefore farmers do not have knowledge on how to intercrop different tree crops on the same plot and the benefits of intercropping on matured farms. As such, when the canopy of the optimised monoculture closes, they are unable to intercrop with food crops again.

These large stretches of monocrops also have negative influence on natural pollination, pest and disease control because the biosystem is not diverse (Asubonteng et al., 2020).

High investment costs: it takes a longer time for tree crops to establish and start producing fruits for harvest. During this period, regular maintenance of the farm is required. Without good capital base, it is difficult for farmers to establish new farms.

Relatively longer gestation period: cocoa, oil palm and rubber farmers need to wait for a few years before they start harvesting. This, coupled with investment costs, makes it difficult for farmers to do field trials without external support. Farmers are therefore reluctant to conduct trials on diversification in tree crop farms. They do not want to risk it.

Absence of cover crops and inadequate knowledge on cover cropping: most farmers use weedicides or slashing to control weeds in oil palm farms. However, GOPDC uses Mucuna as a leguminous cover crop and occasional brushing (slashing) to ensure that the cover crop does not climb the palm trees. It means farmers in the study area are incurring higher costs of weed control through the use of slashing or weedicides. Apart from the costs and environmental effects, farmers are losing the opportunity to fix nitrogen into the soil.

It was observed in the study that no cocoa or rubber farmer used cover crops to manage weeds in their farms. Cocoa farmers claimed that using cover crops will increase the presence of snakes and insect pests. Patches of leguminous cover plants were observed in some of the cocoa, oil palm and rubber farms, but the frequent spraying with weedicides and brushing has made it impossible for these cover plants to spread and cover whole farms.

In-depth interviews with farmers in different communities reveal that farmers know the benefit of leguminous cover crops but they do not make any deliberate attempt in establishing cover crops in the farms. Farmers claim that they do not know where to get the seeds and they do not have the expertise to establish and manage cover crops. Farmers interviewed are willing to pay about GHS 1875 per hectare for establishment of leguminous cover crops into oil palm and rubber farms.

Aging farmers: It was observed in Table 4.1 that majority (92.7%) of farmers are over 45 years of age. This may be due to the fact that majority of the youth are not interested in farming. It is possible that most of the youth prefer off-farm job opportunities. In fact, interactions with the community platforms reveal that the youth prefer work on mining sites in the study area than in farms.

It is also likely that there is no enabling environment to support the youth in terms of land, input, credit, knowledge and skills acquisition to start their own farms. It could also be that the youth will only have access to farmland as inheritance. Since tree crops are regular sources of income for farmers, the youth may only inherit farmland when the current primary user or owner of the land is no more in good health to cultivate the land or has passed on. If this system persists, the youth of every generation will not be able to engage in farming when they are youths; they will only become farmers when they inherit land later in life when they are no more youthful.

Inadequate household labour: on average, households do not have enough labour to carry out all farm management practices. Even when there are youthful household members who can provide farm labour, they may be in school most of the time or not interested in farm work. Therefore a household that does not have income to pay for hired labour at a particular time will struggle with farm management activities even if they have knowledge of what must be done.

Inadequate off-farm income: in the face of inadequate household labour, the farm manager needs income to pay for hired labour and to buy agro chemicals. It was observed that only 50 respondents had household members with regular off-farm income (Table 4.12). It means most farmers are highly reliant on income from their farms. If farm income does not come regularly, it will be difficult for the farmer to carry out farm management practices.

Table 4.12: Household labour and off-farm income

Household (hh) size	n	Income earners (average)	Off-farm income % (n = 50)	Average household labour count
< 6 members	342	1.77	60	1.46
6 to 10 members	362	2.47	20	1.98
11 to 15 members	31	4	20	4
16 to 20 members	4	5.5	0	3.5
> 20 members	1	5	2	1

Source: Author's computation

High labour and fertiliser cost: it can be seen from the total variables costs for each crop that, the variable cost of producing a hectare of cocoa is double (2.06) the variable cost of maintaining a hectare of oil palm and more than double (2.46 times) the variable cost of maintaining a hectare of rubber farm (Figure 4.8). It means that a cocoa farmer needs a high level of liquidity in order to carry out farm management regularly compared to an oil palm and rubber farmer. From Table 4.13, it is observed that labour constitutes the major cost of an oil palm or rubber farm while mineral fertiliser is the highest cost item for a cocoa farm.

The cost of mineral fertiliser in absolute terms (GHS 220.53) is higher than the labour costs of oil palm (GHS 204.12) and rubber farmers (GHS 167.29). While the cost of labour is largely driven by local socio-economic conditions such as labour pull towards gold mining activities in the study area, mineral fertilisers are imported and hence their prices are affected by events in the international market. COCOBOD offers a stable price for cocoa beans bought from farmers, it might also be hurting farmers if these prices do not change early enough in response to rising costs of fertilisers and other inputs required. This ultimately means that farmers will apply less fertiliser and will spend less on pest and disease control.

Table 4.13: Variable cost structure per hectare of farm

		Percentage (%) share of total variable cost					
	Total variable cost (GHS)	**Hired labour**	**Herbicide**	**Organic fertiliser**	**Mineral fertiliser**	**Insecticide**	**Fungicide**
Cocoa	488.29	23.74	1.7	0.67	45.16	19.28	9.45
Oil palm	236.62	86.26	11.1	0.48	2.01	0.15	-
Rubber	198.8	84.15	4.47	-	11	0.39	-

Source: Author's computation

It seems farmers do not spend a lot on other production costs. However, these costs could rise if the 'forest rent' is finished, leading to lower productivity and increase in pest and disease prevalence. Secondly, the cost share of fertiliser (45.16%) for cocoa means that if cocoa producer prices paid farmers are not responsive enough, farmers will not want to use fertiliser and in the long term, farmers might switch to oil palm and rubber where farmers use less fertiliser.

Difficulty to adhere to contracts: the largest oil palm processor in the study area, Ghana Oil Palm Development Company (GOPDC) is not interested in establishing new outgrower and smallholder schemes because a lot of beneficiary farmers from the existing scheme are no more supplying FFBs to GOPDC.

Cocoa farmers are likely to default in supplying cocoa beans to Purchasing Clerks (PCs) who offer them credit for farm operations. Some cocoa farmers also end up selling to several PCs depending on whether they are trying to avoid paying off all their loan at a go or whether they had received credit from several PCs. This makes it difficult for PCs to trust farmers when they request for credit and promise to supply cocoa beans.

Currently, rubber farmers were found to be compliant with the contract terms agreed on with the offtaker, Rubber Plantations Ghana Limited (RPGL), who established the outgrower scheme with funding from OVCF I. This is so because there is, currently, no other buyer or processor in the study area. This is however likely to change when other buyers of rubber start visiting the study area. Competition from other buyers will increase risks of farmers defaulting on the terms of their contracts as was observed in other outgrower schemes (Delarue, 2009; Manley & Leynseele, 2019).

Use of uncertified planting materials: rubber farmers interviewed in the study all indicated that they got their planting material from RPGL, as part of the outgrower scheme. It was however observed that some cocoa and oil palm farmers plant uncertified planting materials (Table 4.14). Some cocoa farmers also did not know the type of variety planted due to various reasons. Some of the farms were inheritted or bought from other farmers, while other farms were established using seeds from other farms.

Planting material of low quality may be susceptible to pests and diseases and less tolerant to adverse climate. This will ultimately result in lower yield.

Table 4.14:Varieties of cocoa and oil palm planted by farmers

Cocoa varieties planted						
Amazonia	Trinitario	Amelonado	Forastero	Criollo	Hybrid	Unknown
354	0	19	1	0	1108	16

Oil palm varieties planted			
Dura	Pisifera	Tenera	Unknown
69	11	839	0

Source: Author's computation

4.7.3 Opportunities of cocoa, oil palm and rubber farming in the study area

Diverse buyers and processors: for oil palm, there are several artisanal mills which provide milling services at a fee to anyone who brings fruits for processing. Meanwhile Birim Oil Mills and Serendipalm, all in the study area, do not have their own plantations; they depend on individual farmers to supply FFBs for processing. In additon, Juabeng Oil Mills from the Ashanti region has established weighing centers in the study area to buy FFBs for their Mill. These market dynamics have provided a vibrant market and increased the agency of oil palm farmers to be able to choose who they sell FFBs to and be able to bargain for credit and favourable payment terms.

Cocoa farmers can sell to any PC or any LBC of their choice. It is common for LBCs and PCs to poach farmers through informal credit arrangements in order to get cocoa beans to buy. Serendipalm has an organic cocoa program with farmers in the study area. This provides organic cocoa farmers with a price differential compared to the conventional cocoa farmers. Rubber farmers, on the other hand, have only one offtaker, RPGL. According to members of the rubber outgrowers scheme, “this is not much of an issue because we are under contract to supply the offtaker with cup lumps to defray the farm establishment investments made on our behalf”.

Available value chain finance: it was learnt from the study that farmers use various value chain financing strategies to get credit for farm management. The oil palm sector is competitive to the extent that artisanal processors provide credit for pruning, harvesting and transportation of FFBs from farms to processing centers. Oil palm farmers even give their established mature farms out for harvesting in return for credit for an agreed period of time. Serendipalm, an organic oil palm processing company in the study area, also provides extension services and transportation services for carrying fruits from farms to the mill. GOPDC previously established outgrower and smallholder schemes by supplying farmers with seedlings, fertilisers and extension service and other forms of support. This is also a form of value chain finance.

RPGL accessed funds from the OVCF to establish an outgrower scheme and also provides transport services to pick up cup lumps of latex at designated pick up points from farmers. They also provide extension service and training on tapping to farmers. There is an agreed formula to deduct the cost of credit provided farmers when they are paid for the produce supplied. Farmers are paid through a bank who is part of the credit arrangement for establishing the outgrower scheme. However, individuals can establish their own rubber farms without being part of the outgrower scheme.

For cocoa, if a PC trusts a cocoa farmer, they are likely to offer credit which is paid in kind through the supply of cocoa beans. Some PCs also supply agro chemicals to farmers if they sell cocoa beans to them. Cocobod as the government-mandated manager of the cocoa sector, conducts research, provides seedlings, agrochemicals and extension support to farmers. Cocobod even has spraying gangs in various communities who provide spraying services to farmers. These are all forms of value chain finance, for which reason Cocobod controls the buying and selling of cocoa beans in Ghana. Serendipalm also provides extension and input support to organic cocoa farmers.

Land tenure arrangements whereby the tenant farmer establishes the farm and pays for the land rent with half of the tree crop farm to the landowner is also an interesting agricultural value chain finance approach to enable landowners who may not have the resources to establish their own farms to do so using land rent.

Favourable climate: Compared to northern Ghana, the rainfall in the study area is suitable and reliable for cocoa, oil palm and rubber production. This gives farmers assurance that their investments into tree crops will not be wasted. Secondly, the micro climate in cocoa and rubber plantations present the opportunity for ecotourism.

Additional enterprise potential of the farms: farmers can add additional farm enterprises based on tree crops and the general farm ecology; provided additional enterprises are not labour intensive but are market-oriented. This is possible since farmers have access to more than one farm plot (an average of 3.33 plots) as seen in Table 4.1. The varied characteristics of each farm plots present the opportunity for varied farm enterprises.

Suitable soils for leguminous cover crops: some leguminous cover plants growing in the wild in the study area include *Pueraria phaseoloides*, *Calopogonium mucunoides* and *Centrosema pubescens*. These can be planted in the farms to fix nitrogen into the soil.

Active research and development: COCOBOD conducts research for the cocoa sector through the Cocoa Research Institute of Ghana (CRIG), whiles the Oil Palm Research Institute (OPRI) under the Council for Scientific and Industrial Research (CSIR) provides research to support the oil palm sector.

Rubber, on the other hand, does not have a specific government agency mandated for its research and development. However, Forest and Horticultural Crops Research Center (FOHCREC) of the University of Ghana provides research and development support to farmers in the study area. The Tree Crops Development Authority (TCDA) is also actively working to develop other tree crops in the country apart from cocoa.

Through their research activities, OPRI has an improved oil palm variety which is sold as pre-germinated nuts by Ghana Sumatra, a subsidiary of CSIR. Meanwhile, GOPDC also has their own improved variety for planting. The major difference reported by farmers is that the GOPDC variety gives bumper harvest over a defined period in the year whiles the OPRI variety spreads the yields throughout the year.

CHED of Cocobod supplies farmers with improved planting materials at a fee. However, if farmers have an old or diseased farm, CHED may provide free cocoa and forest tree seedlings.

Extension services available: Crop Health and Extenision Division (CHED) of Cocobod provides extension service to cocoa farmers and Serendipalm provides additional extension service to organic cocoa farmers. The Department of Agriculture at the District and Municipal levels provides extension to rubber and oil palm farmers. Serendipalm also provides extension to organic oil palm farmers who they work with while RPGL provides extension service to farmers in their outgrower scheme.

Presence of farm service enterprises: some private enterprises, called Rural Service Centers, were found in the study area. These service providers were established by Solidaredad to provide farm management services to oil palm farmers. They provide agro inputs, equipment, tools and trained or skilled labour for farm management. These private enterpreneurs know that farmers are not obliged to patronise their services. As such their credibility and reputation for high quality service is what they use to attract clients in order stay in business.

Presence of agri-related non-profits: Solidaridad is active in the study area and has helped farmers to come together as groups to establish Village Savings and Loan Associations (VSLAs) as well as private Rural Service Centre (RSC) operators.

The Center for Internation Forestry Research (CIFOR) is also active in the study area through the Governing Multi-functional Landscapes (GML) project which involves cocoa, oil palm, and rubber farmers. The GML project has established commodity working groups for cocoa, oil palm, rubber and a working group for mining degraded land reclamation. The capacity of these working groups has been built to formulate development strategies for their domains as far as Kwaebibirem and Atiwa West is concerned.

Favourable government policies: the establishment of the TCDA is to provide policy and operational support for other tree crops not managed by Cocobod. As part of the government's Planting for Export and Rural Development (PERD) program, TCDA and the Department of Agriculture have supplied oil palm and rubber seedlings to farmers. Similarly, the Minerals Commission also supplied oil palm seedlings to farmers through the Department of Agriculture as part of their alternative livelihood project for artisanal and illegal miners in the study area.

Apart from improved planting material, CHED of Cocobod supplies farmers with free insecticides, fungicides and spraying gangs under Cocoa Diseases and Pest Control Program (CODAPEC), as well as subsidised fertilisers. They also provide free farm establishment and maintenance for 3 years on old and diseased farms under a cocoa rehabilitation program.

4.7.4 Threats of cocoa, oil palm and rubber farming in the study area

Inadequate access to planting material: though OPRI, GOPDC and CHED of Cocobod provide improved seedlings, it is common to find farmers using seeds from their farms or farms of neighbours with the assumption that they are from the improved stock of CHED for cocoa or that from OPRI or GOPDC for oil palm.

The use of farmers' own seeds, as products of sexual propagation (Table 4.12), leads to cocoa and oil palm farms being cropped with genetically segregated planting material that do not have the expected hybrid vigour required for optimal crop growth and output. Since these are tree crops, it takes about 3 to 5 years when fruiting begins for farmers to realise their expensive mistakes. Reasons why farmers use their own seeds include inadequate knowledge of genetic principles, cost of seedlings, untimely availability or delivery of seedlings, distance to seedling distribution centers and inadequate supply of seedlings.

From field visits and community platform discussions, it was realised that rubber farmers only use rubber clones supplied by FOHCREC, RPGL or Department of Agriculture.

Input and service supply challenges: the free insecticides and fungicides as well as the subsidised fertilisers supplied by CHED of Cocobod is not enough for farmers. Meanwhile, some farmer groups do not distribute these inputs in a transparent and equitable manner to their members. Farmers complain of being cheated during in-depth interviews. Farmers also complained of these inputs not arriving on time for farmers to apply, based on the crop production calendar. Some farmers showed us inorganic fertiliser that came late when there was no rainfall and as such were not applied but kept for the next season.

It was also realised from visits to the shops of agro-input dealerships that, they have on display agro-chemicals from CHED which have been labelled "Not for sale". It means agro-chemicals meant for free distribution to farmers are being diverted and sold back to unsuspecting farmers. In one interesting encounter during in-depth interviews, a farmer said that "I recently bought an agro-chemical and when my children drew my attention to the 'Not for sale' label, I returned it to the shop and they gave me a different one". The farmer assumed that the label meant the agrochemical was of poor quality.

Farmers also complained about the quality of spraying services from the spraying gangs established by Cocobod. It is reported that most spraying gangs do not take their time to spray the farms properly and their time table is such that they do not visit farms at the right time. Most farmers at community platform meetings and through in-depth interviews therefore wish that they own their own motorised sprayers.

The supply of these "free" or subsidised inputs and services are considered as costs that affect how much farmers receive as producer prices for cocoa. These interventions make farmers to practice cocoa production as a form of traditional subsistence instead of as a profitable business (Laven & Boomsma, 2012).

Another challenge was the presence of sub standard agro chemicals in the open market. Unsuspecting farmers buy these agro chemicals and they end up wasting their resources and sometimes these affects their behaviour and they decide not to control pests and diseases because the chemicals do not work.

For oil palm and rubber farmers, they did not complain about inputs received as part of their various outgrower schemes. However, these inputs were only supplied during establishment phases of the various schemes. A major challenge of rubber and oil palm farmers is that, there are no customised fertilisers for these crops in the open market. In the absence of strong producer associations, it is difficult for individual farmers to negotiate with a fertiliser company to formulate fertilisers targeted for these crops.

Contentious produce weights: cocoa is weighed by the Purchasing Clerks (PCs) of the various Produce Buying Companies (PBCs). However, farmers complained about adherence of PCs to weighing standards. Farmers believe that some of the weighing scales are tempered with and as such, they get cheated. It was observed that some farmers do not ferment their beans properly and some of the beans are not properly dried when they are sent to the PC. As such, some PCs use the adjustment in weighing scales to account for losses that arise from sorting, drying and bulking of beans purchased. The challenges with weighing of cocoa are not peculiar to the study area, they are reported and documented all over cocoa producing areas in Ghana (Kolavalli & Vigneri, 2017).

Oil palm farmers who sell to weighing centers and the mills did not complain about weights. However, artisanal processors count the number of FFBs and translate it into tonnage. Some communities consider 60 FFBs while others count 80 FFBs as a ton. Some also use the age of the crop to determine the number of FFBs that make a ton. Some farmers do not supply artisanal processors because they feel counting of FFBs is not an objective measure of weight. Some farmers also supply small fruits to artisanal processors and send large fruits to weighing centers. It can be said that oil palm farmers did not have to worry about weights because FFBs are processed as soon as they get to the mills and there is no loss in oil through evaporation. It also means that the longer the value chain and the more intermediaries exist between the farmer and the processor, the higher the probability that there will be challenges with having a reliable and acceptable weighing regime.

During the oil palm working group meeting, farmers from the outgrower and smallholder schemes of GOPDC indicated that they are part of the pricing committee of the company; this gives them assurance of transparency and fairness in the prices that are announced. They also indicated that prices are responsive to price changes in the local oil palm and the international palm oil markets.

For rubber, it came out during working group meetings that farmers lose almost half of potential revenue because about 40% of cup lump weight is deducted from the weight of produce supplied to the offtaker before farmers are paid. This deduction is carried out as part of a formula to determine the Dry Rubber Equivalent (DRE) rate of rubber. Farmers feel that the deduction is not fair but they do not have any alternative because there are no other buyers of rubber in the study area and farmers are tied to a contract as part of the outgrower scheme. This contention over an opaque formula to determine DRE rate was also identified in GREL's outgrower scheme (Delarue, 2009). This is a source of market failure that may amplify adverse inclusion and moral hazard tendencies among contract farmers if their agency increases due to competition among buyers.

Unfavourable land tenure terms: It was learnt from in-depth interviews that, the terms or conditions for hiring or renting land also affect crop diversification decision. Some landowners dictate the type of crop that can be planted on the land in order to give land owners the opportunity to renegotiate the terms of hiring the land after some years have elapsed. For example, lands hired/rented for cocoa farming are relatively given out in perpetuity but land given out for oil palm are for 25 to 28 years. The challenge is that a tenant farmer may not increase investment on the land if there is no assurance of the rent being renewed at favourable terms.

Cost and scarcity of hired labour: interactions from community platforms and in-depth interviews revealed that hired labour is becoming scarce and expensive because of mining activities in the landscape. It is deemed more lucrative to work at a mining site than to work in a farm. In other studies, it is reported that most youth rank work involving manual or casual labour lower than formal or salaried work (Anyidoho et al., 2012). Therefore, the youth who are ready to do manual work will always choose the highest recruiter available; in this case, mining contractors. Hired labour's share of variable cost (Table 4.13) shows that hired labour is a significant cost item in cocoa, oil palm and rubber farming. Total cost of labour will even be higher if farmers put cost to how much household labour is used in the farms.

Adverse climatic conditions: there are seasons with dry spells and the heat within such periods makes cocoa flowers to drop and young cocoa fruits to dry or get 'burnt'. Adverse climatic conditions are considered a threat for cocoa production (COCOBOD, 2019). The rainfall pattern is changing and farmers express worry about the uneven spread of rainfall compared to the situation a few years back. The changing climate is negativly affecting the succesful establishment of new farms because seedlings are more likely to die even when food crops and trees are planted to provide shade.

Delayed payment of producer prices to farmers: cocoa farmers complained about delay in payment of producer prices. Though not frequent, most farmers believe that it affects their ability to maintain their farms. They believe, the fact that oil palm and rubber farmers are promptly paid by processors and offtakers is an incentive that pushes farmers to diversify into oil palm or rubber production. It is believed that Cocobod's centralised control of the cocoa sector also makes the sector vulnerable to widespread shocks since their decision and policies affect all cocoa farmers.

4.8 TOWS Strategy Analysis

4.8.1 Introduction

It was realised in previous sections that farmers who produced only one type of crop (non-diversified farmers) had the highest average gross profit per hectare (Figure 4.4) but moderately specialised farmers expressed the lowest average levels of food insecurity (Figure 4.6). Basic matrix scoring of the strategies shows that moderately specialised farmers will get the best benefit in terms of improving gross profit and reducing food insecurity (Table 4.15).

Table 4.15: Matrix score of diversification strategies

	Gross profit	Food Insecurity	Total
Not diversified	4	1	**5**
Slightly diversified	3	4	**7**
Moderately diversified	2	2	**4**
Diversified	1	3	**4**

Source: Author's computation

In terms of profit (Figure 4.4), farmers are more likely to pursue cash crop production and the objective of income security (Table 4.11), this section attempts to propose strategies that will be market-oriented to decrease costs and increase incomes while reducing food insecurity in the process.

4.8.2 Weakness and threat minimisation (WT: mini-mini) strategies

Farmers should use cover crops to reduce need for labour and agro-chemicals. Usage of leguminous cover crops will reduce variable costs, increase nitrogen fixation in soils, improve soil structure and reduce soil erosion.

4.8.3 Weakness minimisation and opportunity maximisation (WO: mini-maxi) strategies

Extension service providers should train farmers on artificial pollination and integrated pest and disease management for cocoa. Farmers should be given targeted training on proper removal and disposal of black pods and general farm sanitation as part of an integrated pest and disease management system. In the long term, it will reduce disease burden on the farm, and increase the presence of beneficial organisms and natural enemies of pests. This will reduce variable costs since the need to buy fungicides and insecticides will go down.

Extension service providers should train farmers to establish leguminous cover crops. Farm service enterprises can be contracted to establish cover crops and supply high quality agro inputs which farmers will pay for, using value chain finance. One model of farm service centers can be a situation where buyers, processors and off-takers establish the farm service centers and provide skilled labour support to farmers. The service centers will take part in harvesting in order to secure and weigh the produce, price it and make deductions for services rendered. The farm service centers can also provide spraying and transportation services. If service centers provide agro chemicals and spraying services, it will be easier for quality assurance and control processes to be instituted to ensure that these private and commercial service centers are providing value for money, compared to the current arrangement of using volunteer spraying gangs from CHED. The service provider can used the number of farmers who have registered for the service to determine how many motorised spraying machines are needed and establish a spraying time table in consultation with the farmers.

Motorised weed slashers and pruners can be provided to farmers through value chain finance. This will help farmers to reduce their dependence on hired labour and this can reduce labour cost in the long term. The farm service centers can sell these motorised equipment to farmers and also provide spare parts and servicing services to ensure that the equipment are maintained for use in the long term.

Establish ecotourism to attract the youth into becoming tour guides, farm owners and farm hands to assist tourists in experiencing the culture and ecology in the study area. This will bring off-farm income to households and will also serve as an incentive for farmers to manage their farms properly and adopt ecologically friendly practices in order to be included in farm tours. Since most farmers have an average of three plots, farmers should consider mixed cropping trials of cocoa, oil palm and or rubber on one plot to compare the outcomes.

To increase yields and optimise farm performance, farmers should only use certified planting materials. Institutional buyers of tree crop produce should consider accessing funding such as the OVCF to help farmers acquire certified planting material for farm establishment.

4.8.4 Strength maximisation and threat minimisation (ST: Maxi-mini) strategies

In Ghana, sweet potato integration with oil palm has been suggested (Renier et al., 2021). Sweet potato can make a good cover crop, considering the allelopathic effects of sweet potato on *Imperata cylindrica*, *Bidens pilosa* and *Ageratum conyzoides* (Xuan et al., 2016), *Cyperus esculentus* (Harrison & Peterson, 1986), *Galinsoga parviflora*, *Lolium multiflorum* and *Phalaris minor* (Shen et al., 2022). If this option is feasible, the farmer can use sweet potato leaves as food for the household or as feed for livestock. In the process, the farmer can also get sweet potato tubers for home consumption and sale. The use of sweet potato as cover crop may also reduce the cost and need for hired labour.

Due to increasing agency of farmers, weighing of produce and formulae for determining producer prices should be determined and agreed upon more transparently to ensure that farmers adhere to contracts and reduce moral hazards.

4.8.5 Strength and opportunity maximisation (SO: Maxi-maxi) strategies

Processors and LBCs should consider provision of price differential for farmers who will diversify their farms, use cover crops and or practice IPM. The higher income potential will attract farmers and hopefully lead to wider adoption when farmers see the other benefits of diversification and environmentally friendly production systems.

Farmers should be supported to modify monocrop plant density and canopy size for diversification. Research institutions and extension service providers should share modified plant density options and canopy management strategies for diversification at the plot level.

State and non-state actors should establish youth-oriented tree crop farming schemes. Secured lands and value chain finance should be used to support agricultural graduates to go into tree crop farming. A pilot of such a scheme can propose a diversified portfolio of crops the young farmer can cultivate. Extension services should be provided to support such young farmers to learn on the farm.

Actors in the study area (government agencies, buyers, off-takers, non-profits) should support farmers to integrate additional market-oriented farm enterprises for additional income. Enterprises that will not be labour or time intensive should be considered. For example, *Aframomum melegueta* (fom wisa) farming and honey production can be integrated into tree crop farms. Some studies, outside Ghana, suggest the intercropping of oil palm with yams (ETA & TBI, 2021), cocoa (ETA & TBI, 2021; Khasanah et al., 2020; Stomph, 2017) and groundnuts (Stomph, 2017).

Similarly, the production of grasscutter, rabbits, snails and mushrooms can be added as enterprises for the household. While farm households can consume products from these additional farm enterprises as food, they will also be able to sell some for income. Farmers will also be able to harvest leguminous cover crops from the tree crop farms as feed for the animals that will be reared. For these to work properly, robust market linkages need to be created to ensure that farmers are able to sell the produce from these additional farm enterprises. If there is a sustainable market structure created for these additional farm-related income sources, farmers will adopt them.

Considering the presence of organic cocoa farmers in the study area, Serendipalm and other partners can establish fresh juice extraction from cocoa pulp by learning from the model that Koa[6] is using in Assin Akrofuom. The extra income and the additional enterprise activity will provide opportunities for the youth to get more involved in cocoa production and related service provision.

Cocobod should consider payment of higher producer prices to cocoa farmers in order to enable farmers to buy inputs at market price on their own. This will reduce the challenges of input diversion by input supply chain intermediaries. When farmers are paid higher prices,

[6] https://koa-impact.com

their agency increases, their valuation of cocoa farming will increase and they will invest in farm improvement in order to increase harvests and subsequently incomes. It is suggested that since farmers still incur input costs due to the challenges with Cocobod's input supply programs, Cocobod and government should consider the option of paying farmers higher producer prices so that farmers will be financially positioned and incentivised to buy and use their own inputs (Kolavalli & Vigneri, 2017).

In Table 4.16, a summary of the strengths, weaknesses, opportunities and threats of tree crop production as well as the strategies discussed for improving and diversifying tree crop production is presented as a composite SWOT-TOWS table.

Table 4.16: SWOT-TOWS analysis for farm diversification

	Weaknesses (W) poor pest and disease control, inadequate artificial pollination, absence of cover crops, inadequate knowledge, aging farmers, inadequate household labour, inadequate off-farm income, high labour cost, dificulty to adhere to contracts, inadequate knowledge on tree crop diversification, high investment costs, lengthy gestation period.	**Strengths (S)** Farm size is not a barr productive farms, market- levels of food insecurity, hig with varied characteristics diversification, farm mana intercrop in young plantation enterprises, relatively durabl
Threats (T) Inadequate access to planting material, inputs and services, contentious produce weights, unfavourable land tenure terms, cost and scarcity of hired labour, adverse climate, delayed payment	**WT: mini-mini strategies** - Use cover crops to reduce labour and agro-chemicals usage and costs.	**ST: maxi-mini strategies** - Use groundnut and swe and for food. - Use only certified plan - Conduct mixed croppi palm and rubber.
Opportunities (O) Diverse buyers and processors, available value chain finance such as OVCF, favourable climate, active research and development, extension services available, activity of farm service enterprises, additional enterprise potential, cover crops grow in the wild, presence of agri-related non-profits, favourable policies.	**WO: mini-maxi strategies** - Access OVCF and other funds for farm establishment and training of farmers on plot level diversification of mature. - Train farmers on artificial pollination, cover cropping and integrated pest and disease management. - Contract farm service enterprises to provide technical support through value chain finance. - Start ecotourism to attract the youth and generate foreign exchange. - Provide motorised slashers through value chain finance.	**SO: maxi-maxi strategies** - Support farmers to es market-oriented farm - Support farmers to m density and canopies - Provide price differe will diversify their fa and or practice IPM. - Invest in youth-orien farming schemes. - Pay cocoa farmers hi let them buy their ow - Support farmers to p

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the study, the conclusions and major finding as well as policy recommendations for various actors.

5.2 Summary of the Study

Lots of studies have been conducted on arable crop diversification but little work exists on diversification among tree crop farmers and its effects on farmer welfare. In the study area of Kwaebibirem and Atiwa West in the Eastern region of Ghana, for example, not much literature exists on tree crop diversification and its effects on household food insecurity and farm incomes. This study therefore assessed the factors that influence crop diversification among farmers and the state of food insecurity, gross profits and diversification levels among cocoa, oil palm and rubber farmers in Kwaebibirem Municipal and Atiwa West. Furthermore, the study assessed strategies that can increase diversification among these farmers.

Data for the study was taken from the Governing Multifunctional Landscapes (GML) project of CIFOR. Tobit regression was conducted using R Studio Server Version 2023.06.1 running R version 4.3.1 to understand factors that influence diversification among farmers, differences in household food insecurity access status and farm gross profits of the respondents. Libre Office Calc was used for gross profit analysis of tree crop production.

It was observed that farmers are more specialised than diversified. Number of farm plots, average distance to farms, frequency of access to information, sex and age of the farmer, dependency ratio, access to off-farm income and household labour had positive significant effects on the level of diversification observed in the study. However, farmers only practice higher levels of diversification in young farms where tree crop canopy allow intercropping with food crops. In addition, there is no significant difference in the household food insecurity status of farmers who are lowly diversified compared to farmers who are highly diversified. However, there was a significant difference in the gross profits of farmers who practice low diversification compared to those who practice high diversification. The study also revealed that extension service and market-oriented strategies can influence farmers' decision to diversify.

5.3 Conclusions

Based on the findings from the study, it is concluded that:

- Farmers are less diversified in crop production. Farmers prefer tree crop production to food crop production. Farmers, however, practice temporal diversification using food crops in immature tree crop farms. Farmers practice tree crop production due to relatively organised market structures for these crops. Market-oriented diversification with food crops is not practiced in matured farmers due to closed canopies.
- Household food insecurity (access domain) is not perceived as a problem by most tree crop farmers in the study. Farmers depend on income from tree crop production for household food security. Cocoa, oil palm and rubber as cash crops provide

opportunity to lower food insecurity among farmers. However, crop production diversification among tree crop farmers can further reduce food insecurity.

- The study also revealed that number of farm plots, distance to farms, frequency of information access, sex (male), and dependency ratio had significant positive influence on the extent of crop diversification among farm households.
- In addition, the study revealed that tree crop production for cash and better market structures have made farmers to be market-oriented in decision making about farm diversification. Farmers may therefore consider crop diversification if the options provided are market-oriented and do not negatively affect profitability of the farm.

5.4 Recommendations

Based on the findings of the study, the following recommendations are made to guide policy formulation and implementation to increase diversification among tree crop farmers.

- Researchers and policy makers should study and develop more efficient markets for food crops, if they want tree crop farmers to practice diversification with a long term outlook.
- The OVCF should design their funding portfolio to include market-oriented crop diversification.
- Extension service should provide more information and training to farmers on mixed cropping of cocoa, oil palm and rubber. Such extension advice should be based on what will increase farm incomes without negatively affecting household food security.

- Additional market-oriented farm enterprises such as groundnuts, sweet potato, *Aframomum melegueta* (fom wisa), rabbit and snail production should be introduced to farmers.
- Diversification can start with the inclusion of edible and leguminous cover crops to improve household food security, fix organic nitrogen and reduce costs and labour for weed control and inorganic fertiliser application.
- OPRI, CRIG, FOHCREC and non-profit actors in the study area should conduct participatory research trials and training with farmers on cocoa, oil palm and rubber mixed cropping systems.

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APPENDICES

Appendix A: Data Collection Instruments

The questions below were extracted from the Open Data Kit (ODK) data collection instrument used for the GML project by CIFOR.

Household Food Insecurity Access Scale (HFIAS) Questions

GG1.1	Over the last four weeks (month), how often did you worry that your household would not have enough food?
GG1.2	Over the last four weeks (month), how often did you were or any household members not able to eat the kinds of foods you preferred because of a lack of resources?
GG1.3	Over the last four weeks (month), how often did you or any household member eat just a few kinds of food day after day because of a lack of resources?
GG1.4	Over the last four weeks (month), how often did you or any household member eat food that you did not want to eat instead of other foods because of a lack of resources?
GG1.5	Over the last four weeks (month), how often did you or any household member eat a smaller meal than you felt you needed because there was not enough food?
GG1.6	Over the last four weeks (month), how often did you or any household member eat fewer meals in a day because there was not enough food?
GG1.7	Over the last four weeks (month), how often was there ever no food at all in your household because there were no resources?
GG1.8	Over the last four weeks (month), how often did you or any household member go to sleep at night hungry because there was not enough food?
GG1.9	Over the last four weeks (month), how often did you or any household member go a whole day without eating anything because there was not enough food?

Response options to the questions
No, never
Rarely (one or twice in 4 weeks)
Sometimes (3-10 times in 4 weeks)
Often (more than 10 times in 4 weeks)

Plot level questions

C4. How long does it take to reach the plot from the primary residence using ${transport_mode}?

C6. What is the size of the plot?

C6a1. Units for measuring plot size

C7. What is the size of the area currently under cultivation?

C8. How did your household gain access to this plot?

C8.1. If leased, how many years has this plot been leased?

C9. In which year did your household gain access to this plot?

C12.1. What is the arrangement for using this plot?

C13. What was the dominant land use on this plot in this last planting season?

C13.1. Which horticultural garden crops did you grow in this last planting season?

C14. When was ${tree_crop} first established on this plot (including land preparation)?

C14.1. If you are not sure of the exact date, give an approximate range

C14.2. Why did you start growing ${tree_crop}?

C15. What were the other land uses on this plot in this last planting season?

C15.2. Specify other tree crops

C15other. Specify other land uses on this plot in this last planting season?

C15.3. How is the Oil palm planted in relation to ${tree_crop}?

C16. When was Oil palm first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Oil palm?

C16.2other. Specify other reason for growing Oil palm

C15.3. How is the Cocoa planted in relation to ${tree_crop}?

C16. When was Cocoa first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Cocoa?

C16.2other. Specify other reason for growing Cocoa

C15.3. How is the Rubber planted in relation to ${tree_crop}?

C16. When was Rubber first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Rubber?

C16.2other. Specify other reason for growing Rubber

C15.3. How is the Citrus planted in relation to ${tree_crop}?

C16. When was Citrus first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Citrus?

C16.2other. Specify other reason for growing Citrus

C15.3. How is the Rice planted in relation to ${tree_crop}?

C16. When was Rice first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Rice?

C16.2other. Specify other reason for growing Rice

C15.3. How is the Cocoyam planted in relation to ${tree_crop}?

C16. When was Cocoyam first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Cocoyam?

C16.2other. Specify other reason for growing Cocoyam

C15.3. How is the Yam planted in relation to ${tree_crop}?

C16. When was Yam first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Yam?

C16.2other. Specify other reason for growing Yam

C15.3. How is the Maize planted in relation to ${tree_crop}?

C16. When was Maize first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Maize?

C16.2other. Specify other reason for growing Maize

C15.3. How is the Cassava planted in relation to ${tree_crop}?

C16. When was Cassava first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Cassava?

C16.2other. Specify other reason for growing Cassava

C15.3. How is the Plantain planted in relation to ${tree_crop}?

C16. When was Plantain first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Plantain?

C16.2other. Specify other reason for growing Plantain

C15.3. How is the Wood lots planted in relation to ${tree_crop}?

C16. When was Wood lots first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing Wood lots?

C16.2other. Specify other reason for growing Wood lots

C15.3. How is the ${C15.c} planted in relation to ${tree_crop}?

C16. When was ${C15.c} first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing ${C15.c}?

C16.2other. Specify other reason for growing ${C15.c}

C15.3. How is the ${C15other} planted in relation to ${tree_crop}?

C16. When was ${C15other} first established on this plot (including land preparation)?

C16.1. If you are not sure of the exact date, give an approximate range

C16.2. Why did you start growing ${C15other}?

C16.2other. Specify other reason for growing ${C15other}

C15.1. Which horticultural garden crops?

C15.1Other. Which horticultural garden crops?

C15.3a. How is the Taro planted in relation to ${tree_crop}?

C16a. When was Taro first established on this plot (including land preparation)?

C16.1a. If you are not sure of the exact date, give an approximate range

C16.2a. Why did you start growing Taro?

C16.2othera. Why did you start growing Taro?

C15.3b. How is the Garden eggs planted in relation to ${tree_crop}?

C16b. When was Garden eggs first established on this plot (including land preparation)?

C16.1b. If you are not sure of the exact date, give an approximate range

C16.2b. Why did you start growing Garden eggs?

C16.2otherb. Why did you start growing Garden eggs?

C15.3c. How is the Pepper planted in relation to ${tree_crop}?

C16c. When was Pepper first established on this plot (including land preparation)?

C16.1c. If you are not sure of the exact date, give an approximate range

C16.2c. Why did you start growing Pepper?

C16.2otherc. Why did you start growing Pepper?

C15.3d. How is the Forest pepper planted in relation to ${tree_crop}?

C16d. When was Forest pepper first established on this plot (including land preparation)?

C16.1d. If you are not sure of the exact date, give an approximate range

C16.2d. Why did you start growing Forest pepper?

C16.2otherd. Why did you start growing Forest pepper?

C15.3e. How is the Okra planted in relation to ${tree_crop}?

C16e. When was Okra first established on this plot (including land preparation)?

C16.1e. If you are not sure of the exact date, give an approximate range

C16.2e. Why did you start growing Okra?

C16.2othere. Why did you start growing Okra?

C15.3f. How is the Tomatoes planted in relation to ${tree_crop}?

C16f. When was Tomatoes first established on this plot (including land preparation)?

C16.1f. If you are not sure of the exact date, give an approximate range

C16.2f. Why did you start growing Tomatoes?

C16.2otherf. Why did you start growing Tomatoes?

C15.3g. How is the Bananas planted in relation to ${tree_crop}?

C16g. When was Bananas first established on this plot (including land preparation)?

C16.1g. If you are not sure of the exact date, give an approximate range

C16.2g. Why did you start growing Bananas?

C16.2otherg. Why did you start growing Bananas?

C15.3h. How is the ${C15.1Other} planted in relation to ${tree_crop}?

C16h. When was ${C15.1Other} first established on this plot (including land preparation)?

C16.1h. If you are not sure of the exact date, give an approximate range

C16.2h. Why did you start growing ${C15.1Other}?

C16.2otherh. Why did you start growing ${C15.1Other}?

C16m. When was Wood lots first established on this plot (including land preparation)?

C16.1m. If you are not sure of the exact date, give an approximate range

C16.2m. Why did you start growing Wood lots?

C16.2otherm. Why did you start growing Wood lots? Specify other

C15.3n. How is the Forest planted in relation to ${tree_crop}

C16p. When was ${C15.c} first established on this plot (including land preparation)?

C16.1p. If you are not sure of the exact date, give an approximate range

C16.2p. Why did you start growing ${C15.c}?

C16.2otherp. Why did you start growing${C15.c}? Specify other

C15.3q. How is the ${C15other} planted in relation to ${tree_crop}

C16q. When was ${C15other} first established on this plot (including land preparation)?

C16.1q. If you are not sure of the exact date, give an approximate range

C16.2q. Why did you start growing ${C15other}?

C16.2otherq. Why did you start growing ${C15other}? Specify other

C17. Prior to ${tree_crop}, what was the main land use on this plot?

C17other. Specify other

C17.1. Specify other tree crop(s)

C18. How was the land cleared to establish ${tree_crop} on this plot?

C18other. Specify other how the land cleared to establish ${tree_crop} on this plot?

C19. Which household members participate in cultivating this plot?

C20. Which household members provide harvest labor on this plot?

Aspirations related questions

In this story, how will your livelihood composition look like in terms of income source: farming vs. other income generating activities

1. All of the households' income from farming
2. Most of the households' income from farming
3. A little over half of the households' income from farming
4. Half of the households' income from farming and half from other income generating activities
5. A little over half of the households' income from other income generating activities
6. Most of the households' income from other income generating activities
7. All of the households' income from other income generating activities

In this story, how will your farm look like in terms of type of crops: mainly food crops vs. mainly cash crops.

1. Produce exclusively food crops
2. Produce predominantly food crops and some cash crops
3. Produce a little more food crops than cash crops
4. Produce 50/50 food crops and cash crops

5. Produce a little more cash crops than food crops

6. Produce predominantly cash crops and some food crops

7. Produce exclusively cash crops

** *The full questionnaire in XLS Form format can be provided if requested. for*

Appendix B: Results from analysis in R

```
> summary(tb)

Call:
censReg(formula = CDI ~ finc + fcrop + plot_count + avg_dist_farm_in_mins +
    tenure + info_access_freq + sex + age + ed_rank + dep_ratio +
    livestock_sum + off_farm_inc + hh_labour, right = 1, data = gml)

Observations:
       Total  Left-censored     Uncensored Right-censored
         740           332           408              0

Coefficients:
                      Estimate Std. error t value  Pr(> t)
(Intercept)          -5.335e-01  1.110e-01  -4.806 1.54e-06 ***
finc                  2.361e-05  6.815e-05   0.347 0.728942
fcrop                 7.429e-05  8.229e-05   0.903 0.366616
plot_count            5.935e-02  7.480e-03   7.934 2.13e-15 ***
avg_dist_farm_in_mins 1.828e-03  6.310e-04   2.896 0.003779 **
tenure               -2.449e-03  1.921e-02  -0.127 0.898586
info_access_freq      2.752e-02  6.381e-03   4.312 1.62e-05 ***
sexMale               9.467e-02  3.763e-02   2.516 0.011865 *
age                   2.364e-03  1.189e-03   1.989 0.046692 *
ed_rank               6.143e-05  8.012e-05   0.767 0.443238
dep_ratio             2.652e-02  7.878e-03   3.366 0.000763 ***
livestock_sum        -9.722e-04  1.288e-03  -0.755 0.450483
off_farm_inc          8.657e-02  4.178e-02   2.072 0.038273 *
hh_labour            -2.269e-02  1.232e-02  -1.842 0.065512 .
logSigma             -1.075e+00  3.946e-02 -27.232  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Newton-Raphson maximisation, 8 iterations
Return code 8: successive function values within relative tolerance limit (reltol)
Log-likelihood: -382.3935 on 15 Df
```

```
> lrtest(tb)
Likelihood ratio test

Model 1: CDI ~ finc + fcrop + plot_count + avg_dist_farm_in_mins + tenure +
    info_access_freq + sex + age + ed_rank + dep_ratio + livestock_sum +
    off_farm_inc + hh_labour
Model 2: CDI ~ 1
  #Df  LogLik  Df  Chisq Pr(>Chisq)
1  15 -382.39
2   2 -451.91 -13 139.04  < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Wald test

Model 1: CDI ~ finc + fcrop + plot_count + avg_dist_farm_in_mins + tenure +
    info_access_freq + sex + age + ed_rank + dep_ratio + livestock_sum +
    off_farm_inc + hh_labour
Model 2: CDI ~ 1
  Res.Df  Df Chisq Pr(>Chisq)
1    725
2    738 -13 133.9  < 2.2e-16 ***
---
Signif. Codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

To determine whether there is a difference in the food insecurity status of various diversification classes of farmers.

```
> t.test(lowf,highf)

        Welch Two Sample t-test

data:  lowf and highf
t = 0.74652, df = 67.192, p-value = 0.458
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.6629381  1.4551603
sample estimates:
mean of x mean of y
 3.939971  3.543860

> sd(lowf)
[1] 4.100021
> sd(highf)
[1] 3.826926
```

To determine whether there is a difference in the gross profits of various diversification classes of farmers.

```
> t.test(lowgross, highgross)

        Welch Two Sample t-test

data:  lowgross and highgross
t = 9.9757, df = 85.63, p-value = 5.333e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 1088.876 1630.904
sample estimates:
mean of x mean of y
 5969.713  4609.822
```

Hired labour’s share of variable cost (Table 4.11)

```
> sd(lowgross)
[1] 1565.986
> sd(highgross)
[1] 924.443

> # Mean age of tree crops
> mean(recombined_data[recombined_data$cocoa_num > 0, 'cocoa_age'])
[1] 16.42078
> mean(recombined_data[recombined_data$op_num > 0, 'op_age'])
[1] 13.67198
> mean(recombined_data[recombined_data$rubber_num > 0, 'rubber_age'])
[1] 8.20339
> # Median age of tree crops
> median(recombined_data[recombined_data$cocoa_num > 0, 'cocoa_age'])
[1] 14
> median(recombined_data[recombined_data$op_num > 0, 'op_age'])
[1] 12
> median(recombined_data[recombined_data$rubber_num > 0, 'rubber_age'])
[1] 7
> # SD age of tree crops
> sd(recombined_data[recombined_data$cocoa_num > 0, 'cocoa_age'])
[1] 11.05564
> sd(recombined_data[recombined_data$op_num > 0, 'op_age'])
[1] 7.7558
> sd(recombined_data[recombined_data$rubber_num > 0, 'rubber_age'])
[1] 3.305062

> # Mean HFIAS score of tree crop only households
> mean(recombined_data[recombined_data$major_crop == 'Cocoa' &
recombined_data$major_crop_percent == 100, 'hfias_score'])
[1] 4.304762
```

```
> sd(recombined_data[recombined_data$major_crop == 'Cocoa' &
recombined_data$major_crop_percent == 100, 'hfias_score'])
[1] 4.071429
> mean(recombined_data[recombined_data$major_crop == 'Oil Palm' &
recombined_data$major_crop_percent == 100, 'hfias_score'])
[1] 4.4375
> sd(recombined_data[recombined_data$major_crop == 'Oil Palm' &
recombined_data$major_crop_percent == 100, 'hfias_score'])
[1] 4.549589
> mean(recombined_data[recombined_data$major_crop == 'Rubber' &
recombined_data$major_crop_percent == 100, 'hfias_score'])
[1] 2.9
> sd(recombined_data[recombined_data$major_crop == 'Rubber' &
recombined_data$major_crop_percent == 100, 'hfias_score'])
[1] 6.0452
```

Appendix C: Plagiarism Report

Turnitin Originality Report

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