UNIVERSITY OF CAPE COAST

CROP DIVERSIFICATION AND FARM OPTIMIZATION AMONG SMALLHOLDER FARMERS IN THE WASSA EAST DISTRICT OF GHANA

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BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: ………………………... Date: ………………

Name: Isaac Eshun

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised with the guidelines on supervision of the thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: …………………….. Date: ……………

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ABSTRACT

Crop diversification is critical for smallholder farmers as far as farm optimization is concerned. This study examined crop diversification activities and farm optimization of smallholder farmers in the Wassa East District of Ghana's Western Region. A structured interview schedule was used to collect data using a cross-sectional survey design. The multistage sampling technique was employed to select 398 smallholder farmers, and Linear Programming (LP) model, crop diversification index, and Tobit model were used as analytical tools to analyze the data. The LP model was used to determine the optimal food crop combination that farmers should diversify to maximize income while at the same time satisfying their food subsistence and food security issues. Farmers in the study area identified cassava, plantain, maize, and sweet potato as the main crops. The results indicated that access to credit, land size owned, farming experience, off-farm activities, farm base organization, and optimum income statistically influence the extent of crop diversification. To achieve an optimum income of GH¢12927.9, farmer should cultivate 2.47 acres of maize, 0.22 acres of plantain, and 3.31 acres of cassava without growing any other crop. However, because the framers' goal extends beyond profit maximizing, the LP model introduces non-basic activities and offers farmers alternate crop combinations to address their problem of food subsistence. According to the LP model analysis, capital followed by land and labour were the most limiting constraints. The sensitivity study also showed that the LP model withstood up well to changes in labour, capital, and land. The study suggested that farmers should adopt appropriate optimum farm plan system to ensure income stability and food subsistence. Finally, credit opportunities from financial institutions should be made available to farmers to increase their productivity and income.

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DEDICATION

To my parents, siblings and the Christian Divine Church Campus Ministry

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LIST OF ABBREVIATIONS

CD	Crop Diversification
CDI	Crop Diversification Index
DP	Dynamic Programming
DEA	Data Envelopment Analysis
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Corporate Statistical Database
FBO	Farmer-Based Organization
GA	Genetic Algorithms
GDP	Gross Domestic Product
GM	Gross Margin
GSS	Ghana Statistical Service
HI	Herfindahl Index
LP	Linear Programming
LR	Log-Likelihood Ration
OLS	Ordinary Least Square
MoFA	Ministry of Food and Agriculture
SA	Sensitivity Analysis
SHFs	Smallholder Farmers
SRID	Statistics Research and Information Director
SFA	Stochastic Frontier Analysis

CHAPTER ONE

INTRODUCTION

Overview

The chapter provides an overview of the study. It includes the study's background, problem statement, purpose, specific objectives, research questions, and significance. Other issues related to delimitations and limitations of the study, and operational definition of key concepts to put the study into perspective.

Background to the Study

Agriculture is a significant sector of the global economy. The global value-added generated by agriculture, forestry, and fishing increased by 73% between 2000 and 2019, reaching $3.5 trillion in 2019 (FAO, 2021). Agriculture supports nations' economies, which in turn affects their gross domestic product (GDP). It contributed to 3% of the global GDP in 2018 and grew to 4% in 2019 (FAOSTAT, 2021). The agriculture sector continues to play vital role in global economies and provides main sources of food, income, and employment especially to rural populations (Dethier & Effenberger, 2011).

According to Kiss and Benita (2020), 67% of the world's population is engaged in agriculture, and agriculture remains important as it also provides essential nutrients for humans and raw materials for industries. However, agriculture is not resistant to climate change effects, and crop diversification (CD) is one important strategy that can be used to protect against production and marketing risks, as well as threats to farm revenue and food security

(Larkai, 2019). Crop diversification can be used to increase farm income, create jobs, lower poverty, and safeguard soil and water resources.

Crop diversification involves the cultivation of a variety of crops on a piece of land. The greater the number of crop combinations, the greater will be the degree of profit (Reckling et al., 2016). Moreover, CD is one possible approach to support agricultural productivity. According to Rehima, Dawit, Belay, and Rashid (2013), CD is a stage in the shifting process from subsistence to commercial agriculture. This is important as it minimizes uncertainty about smallholder farmers' (SHF) income, agricultural productivity, production stability and marketing risk (Feliciano, 2019).

In China, Li et al. (2009) reported that farmers in the Yunnan province achieved higher yields from 33.2% to 84.7% when they used a diverse cropping system. Mango, Makate, Mapemba, and Sopo (2018) noted that farmers who used diversified agricultural systems had a higher chance of having high incomes and food security. Similarly, some studies done in different countries have highlighted that CD maximizes crop yields, optimizes resource utilization, and improves land utilization efficiency (Kemboi, Muendo, & Kiprotic, 2015; Kazakova & Radeva, 2020).

Ghana, a middle-income nation in West Africa, undoubtedly depends heavily on agriculture (Jaffee et al., 2018). The agriculture sector largely employs SHFs who cultivate cash crops and food, and remain the major driver of the economy (Kamara et al., 2019). Despite this, Ghana continues to import around 15% and 70% of its maize and rice, respectively (Darfour & Rosentrater, 2016), and vegetables like tomatoes, onions, and garden eggs from faraway and neighboring countries, despite its agricultural accomplishments (Gamor, Akoto, Karg, & Chagomoka, 2015). This is because, the production of food crops is low, and are met with resource allocation challenges. However, as SMFs make up the majority of Ghana's agricultural sector, these problems must be addressed.

The Wassa East District is located in the Western Region of Ghana, and it is well-known for growing food crops like maize, cassava, plantains, yam, sweet potatoes, cowpea, and cocoyam as well as vegetables like pepper, okro, and garden eggs (Larkai, 2019; MoFA, 2020). However, farmers in this district face resource allocation problems coupled with low productivity (Odoom & Annor-Frempong, 2023). As a result, SMFs in this area, like many other farmers, sometimes rely on their intuition, experience, or status quo in the area, which does not always produce the best results and frequently leads to losses (Sibiko, 2016). This reduces their output, prevents them from gaining income, and has a detrimental effect on the nation's growth rate (Ibrahim, Mensah, Alhassan, & Adzawla, 2019). Therefore, CD and farm planning activities become necessary to explore to see how these farmers can navigate through the challenges they face.

Statement of the Problem

In Ghana, smallholder farmers (SMFs) are faced with low incomes, which translate to poor savings, and low investments, in their activities and themselves, which lead to a low level of productivity (Ankrah, Kwapong, Eghan, Adarkwah, & Boateng-Gyambiby, 2021). The farmers mostly rely on rainfall and the natural fertility of the land for production. Despite the noted significant challenges, crop diversification (CD) or crop combination has been identified to increase the efficiency and resilience of the food supply (FAO, 2017). According to Larkai (2019), CD is one of the main ways to protect against production risk.

Many studies have shown that CD benefits most SMFs and ecosystem function by reducing agricultural losses while at the same time enhancing soil fertility (Tscharntke et al., 2005; Tiemann et al., 2015), increasing biodiversity, and resulting in yield stability and nutrient diversity (Schulte et al., 2017). To achieve food security, diversifying crops on the same piece of land plays a significant role (Acharya et al., 2011). Similar to how crop rotation and nitrogen fixation improve soil health, CD plays key role in economic growth by increasing production, household incomes, and intensifying sustainable agriculture (Mussema et al., 2015).

According to Michler and Josephson (2017), CD serves as a means of reducing production risk and poverty as it can boost overall yields and yield stability for several crops, which increase household income. In northern Ghana, Osman (2023) reported that 88% of households struggle with poverty despite rearing livestock and growing a variety of crops like millet, maize, yam, rice, corn, soybeans, and groundnuts for subsistence. With this finding, there is the need to practice crop combination and CD, and also know the optimum crop combination to diversify to maximize production, income, and at the same time, food subsistence.

To attain this, Adewumi (2017); Adekanmbi and Olugbara (2018); and Koufie (2020), suggested the need for farmers to have an optimal cropping plan in place to efficiently utilize their available resources. In analyzing the efficient use of these resources, most studies used the data envelopment analysis and stochastic frontier analysis approach (Sakouvogui, 2020).

However, the limitation of these approaches is that they consider one outcome variable at a time - resource efficiency or profit (Ray, 2004). The inability of these models to predict multiple outcomes has led to the introduction of the linear programming (LP) model (Gade & Jindas, 2016).

Many studies have examined the LP model's role in addressing losses due to poor input combinations and challenges faced by SHFs (Majeke, 2013; Asante, 2018; Larkia, 2019; Koufie, 2020; Luckman, 2021). However, these studies were limited to finding the maximum profit and ignored the other potential goals of the farmer, like food security and basic survival problems. Western Region is one major producer of food crops like cassava, plantains, cocoyam, maize, and sweet potatoes, which account for approximately 74% of the total agricultural output in the region in Ghana (Aidoo et al., 2019). Specifically, the Wassa East District serves as one of the region's most important food crop production areas, with a population of 74,818 small-scale food crop farmers (Agriculture Department, Wassa East District, 2020).

However, farmers in the Wassa East District face crop mix problems, in terms of the best crop combination that will lead to optimal profit as well as boost their households' livelihoods (Ashante, 2017; Larkai, 2019). By utilizing the LP model, the best crop combinations that they can need to diversify to maximize profit, while also satisfying their subsistence needs can be determined (Mellaku et al., 2018). There are instances where the LP model was employed to determine the perfect crop combinations that farmers could diversify for profit, but crops that support the subsistence of the farmers were cut off. Such crop(s) are known as non-basic activities, which the LP model does not encourage farmers to add to their optimal crop combination list. Yet, there is a tendency that such non-basic activity (non-selected crops) by the LP model could influence a farmer's profit. Therefore, it becomes important to analyze if truly such non-basic activities (crops) influence the profit of farmers or otherwise. This study fills the knowledge and literature gaps in this regard.

Additionally, the study performs sensitivity analysis (SA) to see how resilient the LP model is to changes in other resources, using the activities of SHFs with the Wassa East District as a case. Performing SA helps identify the key resource constraints faced by SHFs in this area, and gives an understanding of which resources (such as land, labour, capital, fertilizer, or water) have the most significant impact on agricultural productivity and profitability. By identifying and addressing these constraints, farmers in this area can optimize the allocation and utilization of resources, leading to more efficient and sustainable farming practices, such as crop diversification.

Purpose of the Study

The study examines the optimal crops to diversify by smallholder farmers (SHFs) in the Wassa East District, and how best these farmers can allocate their resources for optimum income.

Research Objectives

Six (6) specific objectives guided the study:

1. To identify the diverse crop enterprise patterns operated by SHFs in the Wassa East District.
2. To analyze the extent of CD among SHFs in the district.
3. To find the optimal crop enterprise combination that yielded the highest profit for SHFs in the district.

4. To perform a sensitivity analysis on the resource constraints (optimal allocation of resources for the enterprises) faced by the SHFs in the area.
5. To analyze the non-basic activities and their profit to the SHFs in the area.
6. To analyze the effect of optimum income on the extent of CD for the SHFs in the district.

Research Questions

1. What diverse crop enterprise patterns are operated by SHFs in the district?
2. What is the extent of CD among SHFs in the district?
3. Which crop enterprise combination yielded the highest profit for SHFs in the district?
4. How will an increase or decrease in resources affect the optimum profit?
5. What are the non-basic activity and their profit to the farmer?
6. What is the effect of optimum income on the extent of CD for the SHFs in the district?

Significance of the Study

The LP model is an effective technique for predicting crops that will yield maximum profit given the farmers' restricted resources (Akpan, & Iwok, 2016). This makes the study important as it aids in the solution of crop mix issues and gives SHFs the greatest planting strategy to enable them to maximize revenues while using available resources effectively. All other things being equal, with this strategy, farmers' output will rise, boosting their capacity to generate reasonable income.

Also, sensitivity analysis (SA) provides evidence-based information for designing targeted interventions and support services for SHFs (Ojo et al., 2023). Therefore, by identifying the specific resource constraints, policymakers, development organizations, and extension service providers can tailor their interventions to address the specific needs of farmers. For instance, the analysis showed that access to capital is a critical constraint: hence, interventions that can improve farmers' access to financial services were recommended.

This study can also assist crop experts and extension service providers in designing a flow scheme for climate-sensitive farm decision-making for optimal profit. Finally, the study fills some empirical gaps and brings to light the peculiar aspects the previous studies missed while utilizing the LP model to make predictions. These serve as good sources of information for researchers and students in this field and future research work.

Delimitation of the Study

The research focused on CD and optimization analysis for SHFs in Wassa East District of Ghana. The study addressed specific goals like the various crop enterprise patterns operated by SHFs, extent of CD among the farmers, optimum crop combination considering the farmers' resources that would maximize their gross margin (GM) of crop enterprises, and the optimum resource allocation for maximum returns in the research area. The selection of the district was based on the fact that the district is the highest producer of food crops in the region, and with the highest number of registered SHFs in the region (MOFA, 2020). Also, the selection of the district was based on convenience, as the researcher's familiarity with the area, and some of the farmers prompted my choice of the district.

Cross-sectional survey design, and analytical tools (like Crop Diversification Index (CDI), the Tobit model, descriptive statistics, and the LP model) were used. Land, labour, capital, fertilizer, food crops, and farmers' production decisions were also considered as variables.

Limitations of the Study

Several issues served as challenges to the work. First, maintaining accurate reports of production was not done by most SHFs, which impacted their income computation. Secondly, the dispersed nature of the various communities in the district made the data collection quite difficult, but some strategies were developed with the help of the extension officers to reach out to the farmers with ease. Finally, the data collection came with a huge time and financial cost and that affected the progress of the study.

Definition of Terms

Crop diversification (CD): It is used interchangeably with crop combination. It is a sustainable agriculture practice of growing several crops on the same land in a given growing season or across multiple growing seasons.

Optimization. It means the action of making most effective use of resource. That is, smallholder farmers' ability to make use of available resources like land, capital, etc. for reasonable income through crop diversification.

Smallholder farmer (SHFs): a producer who farms on a small scale, rearing livestock and crops. In other words, they are small-scale farmers that cultivate one or two cash crops in addition to some subsistence crops on land they own that ranges in size from one hectare to ten hectares.

Linear programming (LP): this is a mathematical method used to optimize a linear objective function, subject to a set of linear constraints. The goal is to either maximize or minimize the objective function while adhering to the given constraints.

Sensitivity analysis (SA): this involves adjusting the values or relationships within a problem to assess how the optimal solution reacts to these changes. This process evaluates the resilience of an LP model by examining the impact of variations on the solution.

Non-Basic Activities: these are crops which the LP model does not encourage farmers to add to their optimal crop combination list.

Farm Optimization: the process of enhancing agricultural practices to maximize productivity, efficiency, and sustainability. It involves using various techniques and technologies to improve crop yields, resource management, and overall farm operations.

Organization of the Study

The study is divided into five chapters. Chapter 1 includes the study's background, problem statement, objective, research questions, significance, limitations, delimitations, and definitions of terms. The second chapter reviews literature, primarily emphasizing findings from studies carried out by different researchers that are related to the issues in the study. It also highlighted some theoretical bases that are related to the study. A description of the study area and the study's methodology are covered in Chapter 3. The results and discussions with the existing literature and theories are presented in Chapter 4. The final chapter gives a summary, conclusions, recommendations, and some suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter provides review of relevant and related literature and theories. It begins with conceptual reviews of some basic issues related to crop diversification (CD) and crop combination patterns, followed by the concept of sensitivity analysis and theoretical review, an analytical framework, and some empirical reviews. Finally, the conceptual framework and the idea of LP, a method for selecting the best crop mix and resource distribution that has been used in recent studies was interrogated to lay the groundwork for using this estimating method in this study.

Concept of Crop Diversification

Crop diversification can be considered as a way to help farmers include risk aversion into their decision-making process, as crop specialization can result in extremely unstable income due to variations in the crop's output, production, or price. There are two primary attributes associated with CD. First, it increases a farmer's production possibility set, which raises the likelihood of producing revenue and creating jobs. Secondly, it lessens the chance of farmers going with one crop, or a small number of crops that have a high covariance risk (Sichoongwe, 2014).

Diversification in agriculture refers to the reallocation of farms productive resources, such as land, capital, labour, and farm equipment, into new agricultural activities (Boncinelli et al., 2018). The general perception of CD is that it involves switching from historically farmed, less profitable crops to more recent, profitable crops. Moreover, it is a strategy meant to optimize the utilization of land, water, and other resources for a nation's overall agricultural development. It gives farmers practical choices for cultivating a variety of crops on their piece of land. Consequently, the choice to diversify made by a farmer is seen as a major economic decision that significantly affects the farmer’s level of income and food security (Essandoh, 2021).

Globally, CD is rising in favor of more valuable and competitive crops (Storkey et al., 2019). Due to this, farmers’ sensitivity to weather or market shocks has decreased as a result of their ability to distribute output and income risk (FAO, 2018; Mango et al., 2018). Michler and Josephson (2017) described CD as the practice of growing several crops on a specific plot of land each year to lower biological instability, revenue, marketing risks, and vulnerability. The authors emphasized that CD is the best approach for households as a source of income, risk mitigation, and poverty alleviation. According to Makate et al. (2016), CD can be an addition or development of new crops into the current farming system. Thus, adding more crops to the current cropping system - also known as "horizontal diversification" - is the primary and most well-understood part of CD.

In addition, Larkai (2019) defined CD as a risk-reduction method to increase the use of production inputs like land and water for higher crop productivity. In this case, farmers can grow a range of crops on their property. In essence, it involves making sure that time and season do not affect a farmer's income and food security. A study, published in the Field Crop Research journal (2020), found that CD can increase crop yields and reduce crop losses due to pests, diseases, and weather events (Reckling et al., 2016).

The study further reported that CD also led to more efficient use of resources and reduced the need for synthetic fertilizers and pesticides.

Tscharnke et al. (2021) also indicated that CD helps to promote biodiversity and protect ecosystems by reducing the use of pesticides and herbicides; while at the same time mitigating the negative impacts of climate change by increasing the resilience of agroecosystems. According to Abdul-Rahaman (2016), blending crop varieties on a piece of land mitigates the negative consequences of monoculture. That is to say, farmers can use all of their resources - human and financial - to produce a significant quantity of food, regardless of the season; while at the same time providing the soil with a range of essential nutrients needed for better soil conditions. Therefore, by growing multiple crops on the same field, farmers can improve soil health, increase yields, reduce risk, and protect ecosystems (Roos et al., 2018).

Determinants of Extent of Crop Diversification

Many studies have examined CD in countries like Malawi, Ghana, Nigeria, and India. For instance, Jangid (2023) studied the nature and extent of agricultural diversity in Karnataka, India found that CD was influenced by several technology and infrastructure factors affected production. Given that most of these factors were found to have an impact on the nature and extent of CD, results of the study indicated that supporting agricultural development and CD required developing basic infrastructural facilities, such as consistent supply of irrigation, markets, fertilizer, and good roads and transport.

According to Asante et al. (2017), demand-side and supply-side factors that affect farmers' decision to use CD can be separated into two. On the supply side, variables at the household level, agricultural variables, risk factors, institutional, environmental, biophysical factors, resource endowments, and technology have been discovered. On the demand side, variables like per capita income, industrialization, and increased population have also been identified as the factors that determine the extent of CD.

According to Loevinsohn et al. (2013), a farmer's decision to adopt new technology is influenced by the dynamic interaction between the technology's features and a variety of situations. Lavison (2013) grouped the factors that influence farmers’ decision to diversify into institutional factors, financial and economic factors, household’s specific factors, and agriculture farm variables.

1. ***Institutional Factors***

Farmers’ decisions to engage in CD are influenced by institutional factors like membership in farmer-based organizations (FBOs), extension services, credit availability, access to markets, and government policies and subsidies (Branca et al., 2022). Peer groups of farmers can learn from one another about the benefits and uses of new technology. Moreover, CD is significantly influenced by the demand for different crops in local, regional, and international markets. Thus, if farmers believe there is a significant market for a variety of crops and that they can sell them for a higher price, they are more likely to diversify their crop production. A study by Sagemuller (2023) found that market-oriented smallholders in developing countries tend to diversify their crops more than subsistence-oriented farmers. In Zimbabwe, Dube et al. (2016) analyzed the factors that determine the extent of diversification and found access to agricultural markets to be positively significant.

2. Economic Factors

Access to credit is an important determinant of CD, particularly for smallholder farmers in developing countries (Adjimoti & Kwadzo, 2018). Farmers need credit to purchase inputs like seeds, fertilizers, and pesticides, which can increase crop yields and diversify their crops. In addition, credit can also enable farmers to invest in new crops or livestock that can provide a diversified income stream. A study by Debnath et al. (2018) in India found that farmers who had access to credit were more likely to diversify their crops. The study further reported that farmers who had access to credit were more likely to use new technologies and practices, which further increased CD. In Ghana, Aneani et al. (2011) noted a link between access to credit and cocoa farmers diversifying into three or more crops.

In many developing countries, off-farm income is an essential means by which rural residents overcome credit restrictions (Davis et al., 2010). According to Larkai (2019), off-farm income gives funds to farmers to buy inputs that boost output, like better seeds and fertilizers. Asante et al. (2017) added that while greater off-farm incomes may conflict with farmers' goals and cause resource diversion away from agriculture, they may also give them extra money to sustain their agricultural activities.

3. Household-specific Factors

Farmers’ decision to employ technology in CD activities is greatly influenced by his or her human capital. Education improves a farmer's capacity to take in, process, and apply crucial information to adopt new technology (Lavison, 2013). For instance, in a study on the determinants of agricultural diversification at the household level, Aheibam et al. (2017)

discovered that education had a favorable and significant impact on a household's decision to diversify. A high level of education has an impact on farmers' beliefs and perceptions, making them more open to and rational in judging the advantages of technology (Mwangi et al., 2015).

Age is also seen as a significant factor affecting the likelihood of crop diversification being adopted, as it is deemed a main latent feature in adoption choices (Singh & Kovid, 2020). Older farmers see farming as a way of life, while younger farmers may be more inclined to see it as an economic opportunity (Lundberg & Persson, 2018). In an earlier study by Mignouna et al. (2011), it was discovered that younger farmers diversified their agricultural activities, while elderly farmers did not. As a result, CD negatively correlated with age. However, age has been found as either negatively connected to adoption or unimportant in farmer adoption decisions.

Crop diversification is known to be significantly influenced by gender, as the household head is the main decision-maker (Asante et al., 2017). Usually, men have control over many resources than women owing to sociocultural standards and beliefs. This makes gender dynamics in CD decisions becomes relevant (Mignouna et al., 2011). For instance, male family heads are predominated in Northern Ghana because of their patriarchal system of practice, and they have a positive impact on decisions on diversification (Asante et al., 2017). Usually, household head's gender has a large and favourable impact on agricultural production and decisions.

Lastly, the size of a farming family is predicted to influence the decision to diversify cropping operations beneficially. This is because; large households tend to diversify more into crop enterprises which tend to increase their levels of production (Melketo & Sieber, 2020).

4. Farm Variables

Farm-specific factors such as farm size, fertilizer quantity usage, tractor ownership or farm implement usage, or source of animal power, as well as the location of the farm. Dube et al. (2016) state that one of the key factors influencing the extent of CD is farm size. Koufie (2020) also found that farmers with vast farmland typically undertake CD to secure a steady income. A study by Asante et al. (2017) which analysed CD behaviour of integrated farming households in Ghana found that using ploughing equipment and fertilizer influenced CD decisions.

Dembele et al. (2018) evaluated ox ownership, an animal power source, as a factor influencing smallholder farmers' diversification into diverse crop production systems in Southern Mali. The authors discovered that ox ownership significantly and positively affected the likelihood of diversification.

Aneani et al. (2011) earlier identified the location of a farm to influence the extent of diversification. That is, farmers who lived on or closer to their farms were motivated to diversify some crops to support their subsistence. Makate et al. (2016) added that location positively affected decisions to diversify crop. They claimed that, compared to farmers in Zimbabwe's Guruve area, farming households in Mudzi had a 97% higher probability of adopting CD because of their location at their farm site.

Concept of Crop Combination Pattern

Crop pattern refers to the arrangement or sequence of crops planted in a given area over a specific period (Begue et al., 2018). It is a crucial aspect of agricultural planning as it helps to optimize yields, minimize pests and diseases, and conserve soil fertility (Shah & Wu, 2019). Singh et al. (2021) defines cropping patterns as the amount of arable land that can be used for various agricultural operations. Social-cultural, geo-climatic, technological, and agronomic criteria are the various factors that come into play when dealing with crop patterns.

Crop patterns are also location-specific depending on several factors such as climate, soil type, crop rotation, and market demand. It also takes various forms, including monoculture, intercropping, and crop rotation. In monoculture, farmers grow only one crop in a field or region, whereas intercropping involves growing two or more crops in the same field at the same time. Crop rotation also involves growing diverse crops in a specific sequence in the same field over several years.

Murugesan, Gangai, and Selvam (2018) stated that a region's agricultural pattern is typically determined by the strength of its crops. Owing to that, Shah et al. (2021) evaluated the effect of crop patterns on soil health and found that crop rotation had significant benefits over monoculture as each specific has its benefits to the soil.

Concept of Sensitivity Analysis

Sensitivity analysis (SA) helps in understanding how variation in mathematical model output can be apportioned to different sources of variation in the input parameters. The SA, or "what if” analysis, is used to analyze how changes in one or more input parameters can affect the output of a model system (Pianosi et al., 2016). This analysis was employed in the study to identify which input parameters have the greatest impact on the output.

Also, the SA was carried out to verify the model's stability and robustness against alterations or shocks. Therefore, some production variables and fixed inputs, including labour, capital, and land, were changed and observed to verify the stability of the model. Based on the LP model results, these production variables were selected because the farmer's access to these resources was most limited. To see the impact on the model, labour, land, and capital were all increased following the conclusions of certain research studies (including Majeke, 2013; Igwe & Onyenweaku, 2015; Koufie, 2020) to see the effects/changes that might occur.

Types of Sensitivity Analysis

There are several types of SA, each serving a specific purpose and providing valuable insights into the behaviour of the model under different scenarios. For the purpose of the study, the research concentrated on one-way and multi-way SA.

One-Way Sensitivity Analysis

One-way SA is used to evaluate how certain variables or factors affect a given model or result. The method helps to understand the behaviour of the model under various scenarios by changing one input variable at a time while keeping the others constant. The primary purpose of one-way SA is to examine the effect of uncertainty or variability in input parameters on the results of a model or analysis (Borgonovo & Plischke, 2016). By systematically altering one parameter and observing its impact on the output, decision-makers can gain insights into which factors have the most significant influence on the results.

Multi-Way Sensitivity Analysis

Multi-way SA varies several input factors at once to see how they all affect the result (Cevik et al., 2022). This type of analysis is valuable when there are interactions or dependencies among different input variables that need to be considered together. Multi-way SA helps to make more robust decisions. It gives decision-makers an understanding of how various variables interact and impact the final result, enabling them to pinpoint crucial variables that have a big impact on the outcomes.

Theoretical Framework of the Study

Three theories were employed to help explain and understand the issues in the study - the rational theory, the theory of constraints, and the optimization theory.

The Rational Choice Theory

The roots of rational choice theory (RCT) can be traced to the 18th century when intellectuals like David Hume and Adam Smith developed ideas about human behavior based on rationality and self-interest. The RCT aims to explain how individuals make decisions based on rational calculations of costs and benefits. According to this theory, individuals are rational and will always make decisions that maximize their utility or well-being (Schwartz, 2015). That is, people make decisions based on their preferences for many outcomes or options and select the one that maximizes their utility or profit.

Relating it to this study, farmers make decisions on first, whether to engage in CD or not, and secondly, in choosing the enterprises to combine considering their limited available resources. Alternatively, farmers can decide to rely on the LP model to determine the best way to allocate resources and combine crop enterprise. This will increase crop yields and provide additional income (Koufie, 2020).

According to the theory, individuals are self-interested and will always act in their own best interests (Ogu, 2013). Thus, this does not mean that individuals are purely selfish, but rather that they will consider the impact of their actions on their well-being. In the context of agriculture, CD refers to a farmer growing two or more crops on a single plot of land. Farmers' decisions to diversify are influenced by a variety of variables, including reducing the chance of crop failure, adapting to shifting customer needs, modifying governmental regulations, and, more recently, the effects of climate change.

Optimization Theory

Optimization refers to a statistical and methodical process of finding the best solution or approach to a particular problem, given a set of constraints or objectives (Mirjalili, 2015). In other words, it involves maximizing or minimizing a particular function, subject to certain conditions. The earliest form of optimization can be found in calculus, where the maximum or minimum of a function with one variable is represented by a point on the function where the first derivative is equal to zero (Kiranyaz et al., 2014). Pierre de Fermat and Joseph-Louis Lagrange made the initial contributions to the development of calculus-based equations for locating the optimal, and Isaac Newton and Johann C.F. Gauss also introduced iterative methods to obtain the optimal.

One of the first widely used optimization methodologies was the LP which was developed by Kantorovich in 1939 (Dantzig, 2002). In 1947, George Dantzig released the Simplex Method, which is considered to be the first well-known technique. Since then, several different optimization techniques have been developed. The Karusah-Kuhn-Tucker (KKT) condition was developed by two separate groups in 1939 and 1951 to assess the prerequisite for a restricted optimum. The 1940s through the 1970s saw the rapid development of the classic optimization approaches, which peaked in that decade. Other names for optimization include mathematical programming or mathematical optimization. According to Bazaraa, Sherali, and Shetty (2013), optimization is a rapidly growing field that encompasses many different areas: multi-objective optimization, single-objective, unconstrained constrained, dynamic programming, and goal programming.

The Simplex approach was adopted in this study, and concentrated on linear optimization problem. The farmer's goal is largely to determine the best mix of food crops to maximize gross margin (GM) and resources while at the same time, adhering to a set of constraints. For instance, a farmer may want to maximize the total revenue from a given piece of land while minimizing the usage of chemical inputs, such as pesticides and fertilizers. An optimization model can be used to determine the best combination of crops that a farmer should diversify, which is one of the objectives of this study. In this way, optimization can help farmers make informed decisions about crop diversification that balance economic, social, and environmental considerations and contribute to sustainable agriculture (van Zonneveld et al., 2020).

Theory of Constraints

The theory of constraints is based on the idea that any organization or system is limited in achieving its goals by one or more constraints, which are often referred to as bottlenecks (Goldratt, 1990). In other words, the theory presupposes that decision-makers must deal with constraints of some kind that make it difficult for them to attain their goals, whether they are utility maximization, profit maximization, or loss minimization (Ang et al., 2018).

Functional and non-negative constraints are a few different types of constraints. We also have constraints related to land, labour, capital, and other factors, in addition to the functional constraints. A diverse range of strategies for reaching a goal are provided by the concept of constraints. The theory of constraints has developed and changed over time, and it is now used in many fields, including economics. In the framework of this research, the farmer faces a variety of restrictions, including those related to labour, land, capital, and fertilizer.

Analytical Framework

Crop Diversification Index

The extent and nature of food CD by SHFs were determined using the Crop Diversification Index (CDI), otherwise known as the Transformed Herfindahl Index (THI). The CDI is calculated by subtracting the Herfindahl Index (HI) from one. The HI is calculated by taking the sum of squares of the acreage proportion of each crop in the total cropped area (Ojo et al., 2014). Mathematically, the index is given as follows;

$$\text{HI} = \sum_{i=0}^{n} (p_i^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This concentration indicator has a direct correlation between specialization and diversification, with a zero-value indicating specialization and a movement towards one indicating increasing levels of diversification. The CDI is therefore indicated mathematically as;

$$CDI = 1 - \sum_{i=0}^{n} (p_i^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,

n = the total number of crops, (unknown)

Pi = area proportion of the ith crop in the total cropped area

CDI = Crop Diversification Index

HI = Herfindahl Index

Tobit Model

The Tobit model is any of a class of regression models where the dependent variables observed range is in some way censored. The most popular censored regression model, the Tobit model, aids in translating the observed level into a latent variable. Since the ordinary least square (OLS) method will result in skewed and inconsistent parameter estimations (Tobin, 1958), using the Tobit model makes sense. As more observations have a value of 0, the bias will likewise become more pronounced. The general formula for the Tobit model;

$$Y_i^* = (y_i^* \text{ if } y_i^* > 0 \quad \text{or} \quad 0 \text{ if } y_i^* \leq 0)$$

Where

$Y_i^* = \beta X_i + e_i$ ……………………………… (3)

Y_i^* = dependent variable

X_i = independent variable

B= the vector of unknown parameters

e_i = the error term

Empirical Review on the Analytical Framework and Crop Diversification

Crop diversification studies can be used to determine the factors that influence a household's decision to diversify as well as the extent of diversification. According to Rajasekharan and Veeraputhran (2002), a Tobit regression model is an excellent tool for determining the choice and extent of CD, in contrast to the Probit and Logit models. OLS regression is applicable if all farmers cultivate all types of crops or practice CD, but in reality, not all households or farmers cultivate all types of crops. As a result, it was anticipated that employing OLS regression would result in a sample selectivity bias because the model would have removed the non-participants.

Several studies have made use of the Heckman Two-Stage Model, which is based on the finding that not all families diversify their crops even when they have the opportunity to. In 2011, Aneani, Anchirinah, Owusu-Ansah, and Asamoah looked at the factors that affect Ghanaian cocoa farmers' CD. The Simpson's Index and a multinomial regression model were used by the researchers to estimate the extent and factors that influence agricultural diversification. The study's findings demonstrate that cocoa farmers had increased their sources of income by growing additional crops in addition to cocoa, such as oil palm, citrus, cassava, and cocoyam. From the analysis, the Simpson Diversification Index is 0.9, and in addition to growing cocoa, a total of 36.3% of the farmers cultivated just one crop, 16.7% grew two other crops, 6.0% grew three or more crops, and 11.0% grew only cocoa. Again, from the results of the multinomial regression analysis, the age of the cocoa farmer, the accessibility of financing, and the cocoa-producing regions (Western, Brong-

Ahafo, and Central) were all statistically significant (P 0.05) predictors of the diversification of cocoa farming.

The logit model was used by Akudugu et al. (2012) to identify the variables that affect farm households' decisions to adopt new agricultural production techniques. The logit model is often used to determine if changes in the measurement variables would cause a change in the nominal variable when there is just one nominal variable and one or more measurement variables. Dembele et al. (2018) looked into what motivates SHFs in Mali's cotton-growing region to expand their CD efforts. In the study, the multinomial logit model was employed. When the dependent variable has more than two options and no inherent order, the multinomial logit model can be used.

Another study conducted by Rehima, Belay, Dawit and Rashid (2013) investigated the variables that impact CD. Their study used the Heckman two-stage model to assess farmers' decisions on CD independently. A Probit model was used to identify the determinant of CD, and the study showed that factors such as gender, education, trade experience, resource ownership, extension contract, as well as cooperative involvement, influenced CD.

Shahbaz, Boz, and Haq (2017) investigated the factors influencing CD in the Punjab mixed cropping zone of Pakistan, and they employed the HI and the Tobit model to estimate the level of farmer diversity and analyze the factors influencing the agricultural diversification index, respectively. Cluster analysis was used to divide the selected farmers into low- and high-diverse farms based on the HI. The results of the Tobit model demonstrate that crop diversity is positively and significantly influenced by education and farm size.

On the other side, having a farm tractor boosts the diversity of crops grown there.

Aheibam et al. (2017) also determined the factors influencing CD using the Heckman two-stage model. The first step determines the probability of achieving a positive outcome, while the second stage specifies the level of involvement that is dependent on seeing a positive outcome. The model suggests that several combinations of variables can be used in the two-step estimation, and it is important to note that at least one of the explanatory variables in the first equation is not included in the second step for identification.

Asante et al. (2017) state that the decision to diversify may be preliminary to the decision on the extent of farmers' diversification. Thus, the authors examined whether the two decisions were joint or separate. The Cragg two-step approach was employed to analyze the factors influencing diversification among integrated agricultural households, and the first step involved applying the Probit model to analyze discrete decisions on diversification. A truncated regression model was then used for analysis of the extent of diversification among the diversified subsample.

Lastly, a study on CD was carried out by Baba and Abdulai in 2021. The HI and the conditional mixed process model were used in the study to measure and analyze CD. The HI showed that the average CD in the study area was 0.55 and that 61% of the farmers were found to have values above the average, which indicates significant CD. Job, labour, and extension service were all significant determinants, according to the conditional mixed process model.

History of the Linear Programming Model

The technique for explaining a system of linear inequalities was introduced in 1827 by Jean-Baptiste Joseph Fourier, a French mathematician, and physicist who was born in Auxerre and is best known for starting the study of the Fourier series. Linear programming (LP) is a technique for maximizing a linear objective function subject to linear inequality and linear equality constraints. The first LP formulation of a problem that is equivalent to the general LP problem was given by the Soviet mathematician and economist Leonid Kantorovich in 1939, who also proposed a method for solving it. He developed it during World War II as a way to plan expenditures and returns to reduce costs to the army and increase losses incurred by the enemy. Alongside this, American economists Frank Lauren Hitchcock and T. C. Koopmans also developed linear programs to solve transport and classical economic problems, respectively.

George Bernard, an American mathematical scientist independently developed a general LP formulation to use for planning problems in the US Air Force. In 1947, Dantzig invented an efficient method, the simplex algorithm, for solving LP problems. Since the development of the simplex algorithm, LP has been used to solve optimization problems in industries as diverse as agriculture, banking, education, forestry, petroleum, and trucking. In optimization, the cost of production is either minimized or the profit is maximum under the minimum resource utilization of a production process (Sofie et al., 2015).

The LP approach, according to Arsham, Adlakha, and Lev (2009), has been applied to solve issues. The objective function and constraints are both in linear form in an LP model because they only use linear functions. A mathematical optimization model consists of an objective function and a set of constraints that are expressed as an equation or inequality system. By integrating the choice factors, the objective function is a mathematical expression that conveys the decision-maker's intention or goal. The objective function can be a measure of cost or profit. Mathematically, it can be expressed as:

$$\boldsymbol{Max\ z = CX\ or\ Min} \newline \boldsymbol{= CX} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (4)$$

Where X is a matrix of decision variables and C is the objective function's coefficient matrix. The choice variables are represented algebraically with the help of alphabetic letters. For instance, $x_{1,}\ x_{2,}\ x_{3,}\ldots x_n$. The constraints are the restrictions or limitations imposed on the values that may be assumed by the decision variables. They are also expressed in the form as;

$$\boldsymbol{AX \leq B\ or\ AX \geq B} \ldots\ldots\ldots\ldots (5)$$

Where A is the activity coefficient vector of the decision variables and B is a matrix of the maximum limit of the constraints. The LP models can be solved manually by using graphical and simple methods. The corner point method, the isocost method, and the isoprofit are all graphical methods. Some examples of computer programs that can be utilized are Excel Solver, LINDO, and R. (Acquah, 2018).

Applying LP to a real-world scenario involves five steps: identifying the issue, developing a matrix, solving the issue, interpreting the results, and testing the model. The following steps must be taken to explicitly identify the decision variables, objective function, restrictions, and sign limitations when creating an LP problem:

1. Select the appropriate decision variables.
2. Specify the objects that the activities require as inputs or produce as outputs, as well as the measurement units.
3. Specify the goal function, where the problem's aim is determined.
4. Set the boundaries given by the original problem.

Conditions Associated with the LP Model

Six basic conditions underlie the LP model (Igwe & Onyenweaku, 2013). First is the proportionality assumption, which states that any LP problem's objective function and constraints must both be linear. According to the additive assumption, the objective function and constraints must also be additive, which means that each variable's contribution to the overall function or constraint is independent of the other variables. The divisibility assumption proposes that variables can take on any non-negative real value, meaning that fractional values are allowed. Moreover, the finiteness assumption asserts that the amount of resources and activities that can be programmed is limited.

There are more presumptions in addition to the six fundamental assumptions of the LP. For example, optimization appropriateness presupposes that an acceptable objective function is either minimized or maximized. The appropriate formulation of LP problems is also addressed by the assumptions of the objective function, decision variable, and restriction adequacy.

Strength of the Linear Programming Model

The capacity to analyze a large range of potential decisions has made the LP model a standard planning tool for farm management for the past 40 years (Winterboer & Beneke, 1973). Below is a more detailed discussion of the additional benefits that the LP approach offers:

- Under predetermined parameters of resource limitations, the LP model aids in maximizing net revenue from a combination of enterprises. This is accomplished through the computational process, which ensures that once the issue has been accurately formulated in the language of LP, neither the farm planner nor the researcher will have an impact on the result, which makes the LP solution more accurate.
- The LP model facilitates the evaluation of all viable alternatives, hence, increasing objectivity in decision-making. Since all conditions and assumptions are spelled out, the mathematical model is objective.
- The LP model makes parametric or sensitivity analysis easier. Parametric or sensitivity analysis asks how sensitive the LP model's optimal solution is to variations in its parameters. It is also called "what if" analysis.

The LP is characterized by several advantages; however, it is also associated with some disadvantages. Some of the disadvantages of the application of LP are as follows:

- The LP model assumes that there is a linear relationship between decision variables as well as the objective function; however, this is not always the case in real-life situations. LP models are purely based on the linear relationship between different decision variables as well as the objective function.

- Lastly, the issue of modeling - the actual formulation or construction of the model - is the most crucial step in mathematical modeling. To use LP, a researcher must convert the research problem into a mathematical model. To do this, the researcher needs an objective, such as maximizing profit or minimizing cost, which must also include decision variables that affect those objectives and constraints that limit what the researcher can do. Since the problems tend to be very complex, it is possible to wrongly model the real problem; thus, important decision variables may be omitted or the model may be inappropriate for the situation.

Crop Calendar in Building the LP Model

Crop calendar contains information on planting, sowing, labour, and harvesting periods of locally adopted crops in specific agroecological zones. It provides data on seed sowing rates and planting material and the main agricultural practices. To build an LP model efficiently, a crop calendar must be followed as a reference (Filippi, Mansini, & Stevanato, 2017). This is prepared to determine the needed labour and time required to prepare land, plant, fertilize, weed, and harvest crops. Usually, information used to prepare crop calendars is obtained from the district department of Agriculture under the Ministry of Food and Agriculture (MoFA).

Basis for Selecting the LP Approach

Using the LP model for this study is supported by its extensive application for agriculture-related studies. The research employed the LP model to attain its main objectives, which were to determine the optimal crops to diversify and the optimum resource allocation. This is because other models - aside from the LP model - examined single-crop enterprise analyses. For instance, the econometric models have solely addressed a single farm's production output, leaving crop composition decisions to chance (Singh & Janakiram, 1986). Also, the estimated elasticity produced by econometric models is misleading when creating various corrective techniques (Tibaijuka, 1994). The econometric method has also been used to assess the supply response and the impact of structural changes on rural households and agriculture. Still, it could not account for the issues caused by inadequate knowledge and accountability systems.

According to Ghaffar et al. (2022), farmers cannot reach their full profit potential without implementing optimal crop patterns that maximize utilizing available resources. Certain farm planning issues are too complex to use GMA, whole-farm budgeting, or partial budgeting to establish the optimal level of farm activities (Hansen & Naerland, 2017). These approaches do not provide systematic methods for selecting the best combination of crop farm enterprises, exhaustive searches for all activity level combinations, or possible combinations of crop farm activity. The policy analysis matrix cannot be employed as a methodology in this study because the objective is not to measure the inter-regional relationship between production and product transportation (Elsedig et al., 2015).

Other programming techniques, such as the recursive programming model, have also been used in some research in addition to the mathematical programming technique. This method gathers data over time or from year to year and then uses it to compare results since SHFs do not keep accurate farm records. The finding's validity is diminished as a result of its many presumptions.

Empirical Review on Resource Allocation and Optimization Using the LP

The most crucial component of agricultural planning is cropping planning, which considers soil characteristics, crop patterns, crop intensities, terrain, climate, irrigation methods, and several other factors. Crop planning is influenced by limited resources such as land, water, labour, fertilizer, and capital. Using optimization techniques to combine the best crops for the most profit has long been a crucial part of agricultural planning. There are many optimization techniques available, including LP, dynamic programming (DP), and genetic algorithms (GA).

The LP technique is important for resource allocation optimization and achieving efficient production planning, particularly, for increasing agricultural productivity (Igwe et al., 2011). Agriculture and non-agricultural settings can both be analyzed using the LP model. Some of these applications are discussed below, along with their results, which are then compared to the study's objectives.

The LP model was employed by Ahmed et al. (2011) to assess how resources were distributed across the competing field crops in the dominant crop combination. The research findings revealed that increasing the number of resources used to grow food legume crops like peas, soybeans, and peanuts would increase tenants' returns. In Haq's et al. (2020) study on cropping pattern optimization in India, it was found that a 10.18% improvement was achieved using the LP model when compared to farmer’s existing plan, and it showed an increase in annual net revenue.

Using the LP model, Lone et al. (2014) showed how a farmer with fewer resources can still achieve the optimum results. According to the LP model, to achieve maximum production, the farmer should plant 33.70 ha of rice and 8.15 ha of maize. Bumbescu (2015) also used the LP model to demonstrate how Nigerian food crop farmers may profit from more effective resource allocation methods. The study's results showed that the most productive crop patterns were maize/yam and maize/vegetable. The farmers' current plans showed a projected return that was less favorable than the optimal farming pattern. The farmers’ plans’ net returns were N31,959.81, while the LP model’s net returns were N98,861.24, meeting the study’s objective.

Ogunbo (2015) employed the LP model to examine resource efficiency and the most effective farm plan during the 2010 pepper planting or production season in Nigeria. The results of the LP model suggest that a farmer with a typical farm size of 0.25 ha or 0.66 ha should be able to produce an enterprise of pepper/tomato and pepper/maize/cassava, respectively. The optimal strategy led to a 115.47% increase in the GM of the pepper/tomato enterprise and a 31.62% increase in the GM of the pepper/maize/cassava enterprise, which was higher.

Patel, Tharker, and Chaudhari (2017) used the LP model to predict how agricultural land will be distributed among the key crops in India. The study's primary objective was to establish the highest productivity and income. The study's findings demonstrate that the LP model generated the greatest output and profit. It was discovered that the optimal crop combinations to be planted were rabi, kharifmung, summer bajra, potato, and udad. The LP model determined that the most limiting factor was land.

Lastly, the LP model was employed in a different study by Adewumi et al. (2020) to identify the ideal farm plan that increased the revenue of SHFs in cassava production in Nigeria. From the LP model results, farmers were advised to plant combinations of cassava and groundnuts, cassava and soybeans, and cassava and maize on 0.4379 ha, 1.0886 ha, and 0.6435 ha, respectively, to boost their revenue by 69.82%. Additionally, the least likely crops to reduce farmers' income if forced into the plan were melon, groundnuts, and cassava. They created LP models for four farms, one for each agricultural system.

Conceptual Framework of the Study

Crop diversification has long been recognized as a means to reduce the risk of crop failure. A farmer's decision to adopt CD is influenced by a variety of factors, including the need to respond to changes in consumer demands, address the effects of climate change, and change in government policy (Ojo, & Baiyeyunhi, 2020). Farmers are exposed to environmental shocks and stress, such as temperature rises and changes in rainfall patterns, which force them to diversify their crop yield to maintain economic stability (Birthal & Hazrana, 2019). Farmers who specialize in growing a particular crop must contend with the effects of climate change as well as the risks associated with crop production, such as pests and diseases, which can lead to economic insecurity (Tito et al., 2018).

Farmers practicing CD often rely on their intuition, experiences, and sometimes advice from their neighbors, which mostly do not guarantee optimum results. This usually leads to incurring losses (Koufie, 2020). However, the alternative, which is the application of LP, helps the farmer obtain an optimum crop pattern, which increases yield, thereby, increasing income (Hakeem, 2021). In this study, the LP model also addressed the issue of resource constraints and the subsistence issue of the farmer and still gave the farmer a moderate income, which is still higher than the farmer's income. This is backed by the rational choice theory, optimization theory, and the theory of constraint.

Thus, farmers who choose to vary their cropping operations get the agronomic and economic benefits of CD by making the most use of their limited production resources. Increased soil fertility, reduced weed, insect, and disease infestations, increased yield, and hence income levels, are some of the related advantages. Farmers may spread production and revenue risk over a variety of agricultural operations through CD, lowering their susceptibility to climatic shocks. A farming household's selection of crop combinations to plant is based on a conventional method that does not always yield optimal outcomes. To maximize farm revenue, LP is appropriate to determine the best mix of agricultural enterprises and the optimal resource allocation.

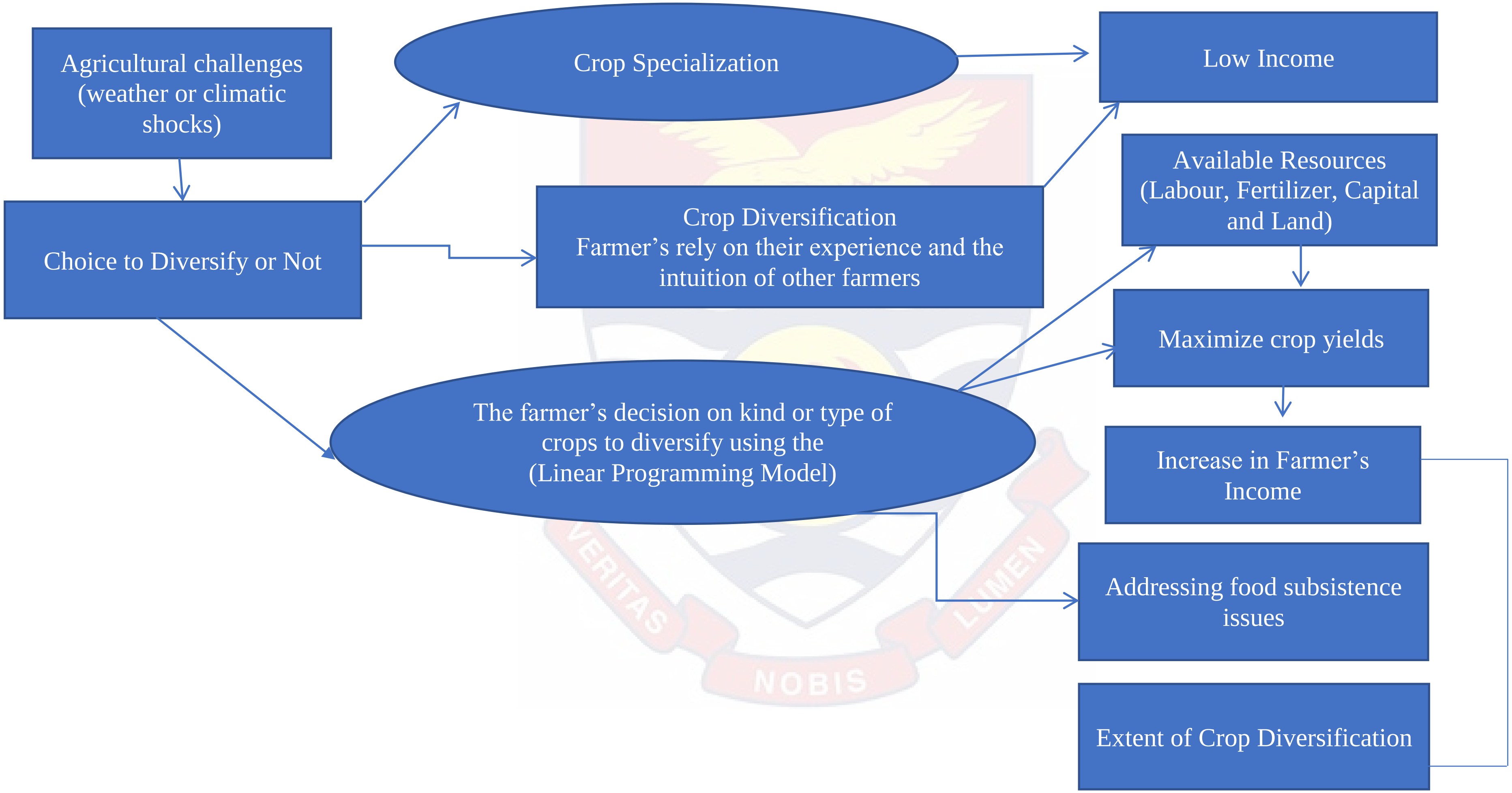

Figure 1: Conceptual Framework, Source: Eshun, (2023)

Chapter Summary

The study was supported by theories such as rational choice, optimization, and constraints theories, which were discussed in this chapter along with some relevant concepts including CD, crop combination pattern, crop calendar, and crop budget. This chapter also reviewed literature on the various estimation techniques such as the LP, the CDI, and the Tobit model used in this study.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter highlights the methods used to conduct the study. It is organized into some sections: research philosophy, study design, study area, study population, sample size and sampling procedure, data collection instrument, and data collection process. Other issues related to data processing and analysis, ethics, and empirical model estimations were also detailed.

Research Philosophy

Research philosophy is a set of beliefs about how data on a phenomenon should be collected, analyzed, and utilized (Collis & Hussey, 2014). The three major philosophies used in research are positivism, interpretivism, and pragmatism. Under positivism, the phenomenon is explained and predicted based on theories. The explanations establish relationships between variables by evaluating their influence on the outcomes and linking them to a deductive theory (Park, Konge, & Artino, 2020). Positivists posit that an assertion should be justifiable and that knowledge is derived from 'positive' information that can be verified scientifically (Collis & Hussey, 2014). In other words, providing mathematical or logical proof for every rationally justifiable assertion is possible. Therefore, positivists employ logical reasoning to ensure accuracy. Rigor and objectivity underpin positivists' approach rather than subjectivity and intuitive understanding (Collis & Hussey, 2014). They believe that reality exists independently of people and that investigating social reality has no effect on it (Creswell, 2014). Hence, they use statistical methods of analysis for quantitative research data.

For interpretivists to gain interpretive understanding, they explore the complexity of social phenomena. Interpretivists believe that society is not objective but highly subjective, as people's perceptions shape it. The line between the researcher's perspective and the social environment is distorted because of the researcher's interactions with the study subjects (Creswell, 2014). Interpretivists use several methods to describe, interpret, and explain a phenomenon rather than statistical analysis of quantitative data like positivists. Therefore, the research under interpretivism uses an inductive approach.

Pragmatism is about concepts only being relevant if they support action (Kelemen & Rumens, 2016). It was developed in the USA during the late Nineties and early Twenties by John Dewey, Charles Pierce, and William James. It aims to reconcile various perspectives on subjectivism and objectivism, as well as facts and values, with rigorous and accurate knowledge. This philosophy considers the various ideas, theories, and research findings not only in abstract form, but also in terms of how they can be used as instruments of action and thought, and how they can be beneficial in certain contexts. Pragmatism advocates value knowledge for how it can help facilitate successful actions. Pragmatism advocates for the development of practical solutions to problems. Pragmatism advocates favor practical solutions to problems, and their research may differ in terms of how subjects and objects are perceived. In this case, if the research problem does not explicitly call for the use of a particular type of method or knowledge, the pragmatist believes that it is possible to work with any approach that will best produce a quality outcome.

For this study, the positivist philosophy was utilized. This was important considering the variables and constructs that needed to be established to ensure optimal benefits to the smallholder farmers in the study and the study area. This philosophy was employed to dissociate from and acquire knowledge unrelated to personal values, existing perceptions, and moral contents. More intrinsically, the study is purely quantitative, which largely lends itself to positivism.

Research Design

A research design is a plan used by a researcher to generate answers to questions that guide a study (Kasonde-Ng'andu, 2013). It is a framework comprising the methods and strategies to be used to solve a research problem. Considering the philosophical basis of the study, cross-sectional survey design, which is a quantitative research approach and design, was employed. According to Farooq (2018), this design entails gathering data from a sample that accurately represents the entire population. The cross-sectional survey design is a one-shot approach to sampling and makes data collection relatively quick and simple to perform, meaning it does not require lengthy periods of follow-up. The design was chosen because it helps in planning resources (needs assessments) meant for the study. This was important considering the limited resources (time, money, and personnel) at my disposal. Despite the strength of the chosen design, and how it helped me make judicious use of available resources, Marcus et al. (2017) mentioned that it is inclined to low response rates, and tends to encourage some bias in the sampling and data collection processes.

Study Area

The study was conducted in Wassa East District, which is located in the Western Region of Ghana. The district is bordered on the northeast and southeast by the Twifo Hemang Lower Denkyira District, Twifo Ati Morkwa District, and Komenda-Edina-Eguafo-Abrem Municipality, all in the Central Region. The district is again bordered on the west by the Prestea Huni-Valley district, and on the south by the Shama district. It also shares boundaries on the east with the Mpohor district. The district has a total land area of 1,651.992 square kilometers (Manteaw, Steve, & Adamtey, 2018).

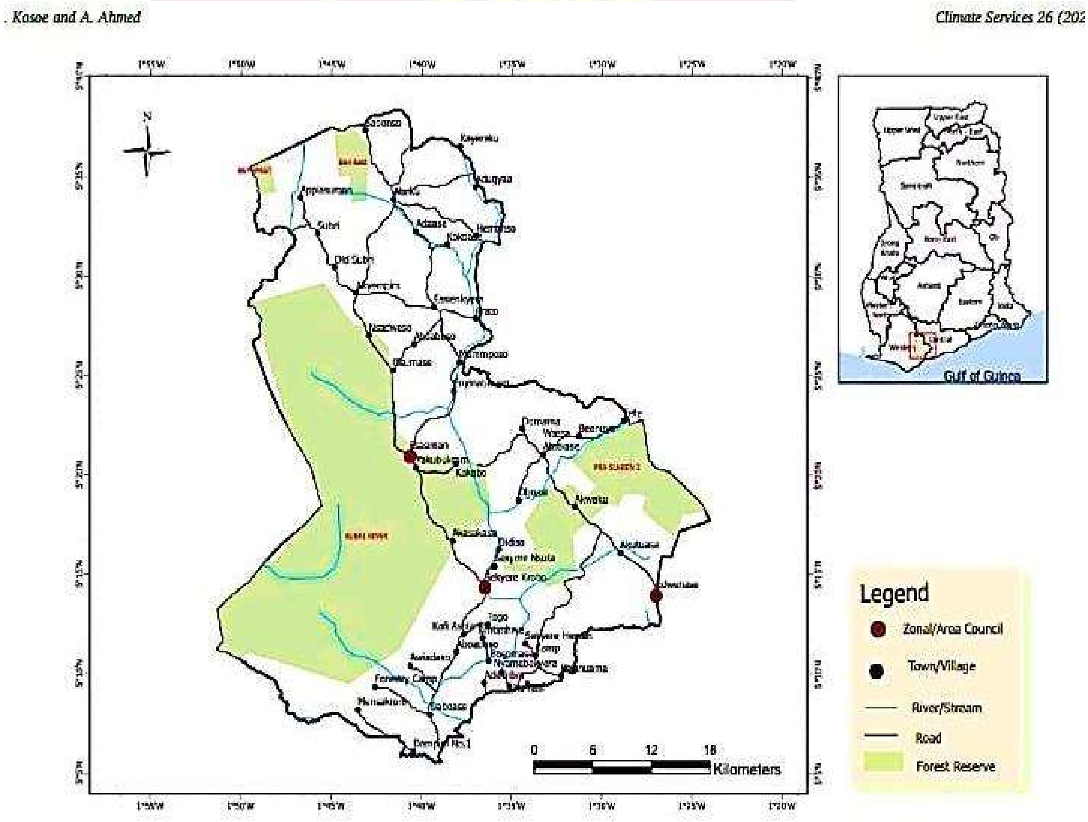

Fig. 1. Study area map.

Figure 1: Map of Wassa East District of Ghana

Source: (GSS, 2020)

Daboase is the capital of the district, which is about 6.7km from the Cape Coast-Takoradi main road (Ghana Statistical Service [GSS], 2021). The district falls within the tropical climate zone, and the mean annual rainfall is 1500mm and ranges from 1300mm to 2000mm, with an average annual temperature of 30°C. The wet period in the district is between March and July, which are known as business months for the farmers, while November to February are relatively dry months (MOFA, 2020).

The district has a total population of 99,641, with 51,200 males representing 51.38% and 48,441 females representing 48.62% (GSS, 2020). Agriculture remains the major economic activity of the inhabitants of the district and continues to be the greatest single contribution to the local economy, employing over 70% of the working population (GSS, 2020). The major staple food crops produced in the district include cassava, plantains, maize, yams, cocoyam, sweet potatoes, cowpeas, rice, and vegetables such as pepper, garden eggs, okro, tomatoes, and cabbage (MOFA, 2020). From the recognizance survey, it was observed that all these farmers engaged in crop diversification that is, combined several of these crops on their farms. The purpose was both for commercial and subsistence purposes. Additionally, some of these farmers were into cash crop plantations like cocoa, oil palm, and coffee production.

Traditionally, the Wassa East district is clustered into 4 councils (Daboase, Wassa Ekutuase, Ateiku, and Enyinabrem) with 20 operational farming areas. These four councils and their operational areas are captured in Table 1. The district was purposefully selected for the study because of its dominance in food crop production in the region (MOFA, 2020).

Table 1: Councils and Operational Areas in the Wassa East District

Councils	Daboase	Wassa Ekutuase	Ateiku Area	Enyinabrem
Operational Areas	Daboase North	Wassa Edwenase	Ateiku	Wassa Senchem
	Daboase South	Wassa Atobiase	Akyempim	Wassa Essamang
	Dompim No. 1	Nyamebekyere	Saponso	
	Krofofrom	Domama	Osenso	
		Amponsaso	Appeasumang	
		Sekyere Adiembra	Asratoase	
		Sekyere Abroadzewuram		
		Ebukrom		

Source: Department of Agriculture, Wassa East District Assembly (2023)

Population

The study's population consists all smallholder farmers (SHFs) residing in the Wassa East District. Specifically, the study targeted only smallholder food crop farmers within the district. They numbered 74,818 people from diverse demographic backgrounds (like genders, age, marital status, and ethnic and religious backgrounds) (Wassa East District Agriculture Department, 2023).

A breakdown of the SHFs within the councils, along with their respective populations, is captured in Table 2. These are numbers that the researcher retrieved from the Agric Department as smallholder food crop farmers that had registered their activities with the department and benefited from some of their services.

Table 2: Councils and Respective Farmers' Population in the Wassa East District

No.	Councils	No. of smallholder farmers
1	Daboase Area	14,964
2	Wassa Ekutuase Area	29,927
3	Ateiku Area	22,446
4	Enyinabrem Area	7,481
	Total	**74,818**

Source: Agric Department of Wassa East District, (2023)

Sample Size and Sample Procedure

There are generally two types of sampling techniques, namely, probability and non-probability (Kanaki & Kalogiannakis, 2023). Probability sampling is used in quantitative research, and it denotes that every element in the sampling frame has an equal chance of being selected (Rahi, 2017). The non-probability, on the other hand, is used in qualitative research works and also denotes that some members of the population are selected based on some incidences, like their knowledge, availability, and willingness for the study. Consequently, the Yamane's statistical sample estimator was used to determine a representative sample for the study. Yamane's (1967) sample estimation method is given as:

$$k = \frac{z}{1+z(y)^2} \quad \text{………............} \quad (6)$$

Where; z is size of Population

k = size of the sample

y = the margin error or level of precision (5% error or 0.05)

Given k = 74818 (source = Agric Department, Wassa East District)

$$k = \frac{74818}{1+74818(0.05)^2} = 397.87\text{~}398 \text{ ……………} \quad (7)$$

Multi-stage sampling method was employed to draw the sample, and it involves employing several techniques in an attempt to draw parts of the population to a study (Senator, 2005). Specifically, the study employed cluster, proportionate, and the simple random sampling techniques. The cluster sampling technique was used at the first stage, where the researcher relied on the four (4) existing councils (Daboase, Wassa Ekutuase, Ateiku, and Enyinabrem) as clusters from which the communities (operational areas and zones) were sampled. In the second stage, communities (operational areas or zones) that are predominant in the production of food crops were selected from each of the four clusters (councils). A proportion was used to determine the number of communities per council (cluster) to ensure equal representation (summary is presented in Table 3).

After the communities were determined, the number of farmers to be sampled for each community was determined proportionately. Then, the simple random sampling technique was employed to select the smallholder food crop farmers from the various selected communities. This was done with Microsoft Excel, which helped to save time, and ensured efficiency in the selection process. Here, the software was fed with the names of all the farmers in the selected communities, and the software randomly selected the required number for each case (community). So, for Daboase Area Council which Daboase North and Krofofrom were selected as predominant farming communities, the software helped in the selection of 30 and 50 farmers, respectively, within 2 seconds after the command was issued. This was done for the other three (3) councils and helped to eliminate any form of possible bias in the selection process.

The sample size of the food crop farmers through the multistage sampling techniques (cluster, proportionate, and simple random) is summarized and presented in Table 3. It should be noted that considering the numbers of farmers in the communities, the selected numbers are sound for any rigorous analysis that is generalizable for the broader community and district.

Table 3: Sample size per Operational Area

No.	Councils	Selected Operational Area	Sample
1	Daboase Area	Daboase North	30
		Krofofrom	50
2	Wassa Ekutuase Area	Wassa Atobiase	40
		Nyamebekyere	20
		Domama	50
		Amponsaso	49
3	Ateiku Area	Ateiku	45
		Saponso	34
		Appeasumang	40
4	Enyinabrem Area	Wassa Senchem	40
Total			398

Source: Field survey, Eshun (2023)

Instrument for Data Collection

A structured interview schedule was used to collect the data. It was formed from the objectives that guided the study, and the literature reviewed. It consisted four (4) sections of mainly closed-ended questions, with a few open-ended questions. Section (A) gathered information on the background characteristics of the smallholder food crop farmers, covering age, sex, marital status, household size, educational level, etc. Section (B) solicited information about farm characteristics such as the current land holding status, the types of crops they diversify, and the size of land cultivated for each crop selected. Section (C) also asked questions on the farmer's source of labour and the fixed input used. Whether family labour, hired labour, or both and labours used, the share of labour, number of hired labour, hours per day for hired labour, the number, and the cost of labour. The fixed inputs include land, cutlass, hoe, knapsack sprayer, watering cane, and others.

Finally, section (D) asked questions on the type of food crop production pattern, the quantity of each crop harvested, the quantity consumed, the quantity sold, the prices of the various food crop combinations, the reasons behind those combinations, the amount of capital invested in each food crop production, and the amount and quantity of fertilizer used in the production of each crop. This section also captured the resource constraints to the farmer.

Validity and Reliability

For validity purposes, I forwarded the instrument to my supervisors for review, where the content was scrutinized for appropriateness. From there, a pre-test was done before the actual data collection. Twenty (20) smallholder food crop farmers were selected from two sub-communities in Jukwa (Nyameani and Watreso), in the Twifo Herman Lower Denkyire district. This exercise ensured that the items were sufficiently clear for the participants to respond without encountering any difficulties and sharp enough to measure the appropriate items.

Cronbach’s alpha was used to verify the internal consistency, which ensured the reliability of the instrument. To put it briefly, it evaluated the degree to which scale items evaluated the items (Tavakol & Dennick, 2011). Cronbach's alpha was more than 0.70, indicating that the instrument was reliable. In the instance of determining the extent of CD, the average number of each crop per acre yield was calculated based on the total number of acres in the combination. The possible GM was also ascertained using the current market pricing.

Data Collection Process

I dispensed the structured interview schedule directly to the farmers; some at their homes, farms, and most of them at the community centers. Two (2) extension officers from the district and Agric department helped enormously by first making community entries through the chiefs and information centers in the communities, and secondly, reaching out to the farmers to identify conducive times to meet them in the respective communities. The study's intent was explained to the chiefs as well as the community members, and the researchers together with two (2) field assistants were well-received with warm greetings. This was important and served as insurance or security for our presence in those communities.

The two (2) field assistants were employed to fast-track the data collection exercise. The enumerators helped SHF-respondents who could not read or write to them fill it out by explaining the issues in their local language (wassa or fante) through interviews. The exercise took the whole month of June 2023.

Source of Data

Both primary and secondary data were used. The primary data was generated through the fieldwork/data which was retrieved from SHFs in the Wassa East District with the use of the structured interview schedule. The district's extension officers also provided the data on smallholder food crop growers, and crop calendars and crop budgets collected from the Statistics

Research and Information Directorate (SRID) of MoFA, Ghana, served as the secondary data.

Data Processing and Analysis

The R statistical software package version 4.0.0 and IBM-SPSS software version 25.0 were used to process the collected data, and the data was analyzed based on the study's objectives. The data was analyzed using descriptive statistics, the Crop diversification index, LP, and the Tobit models. Objective 1: the identification of the various crop combinations or crop mixes on the farm was analyzed using descriptive statistics such as frequencies and percentages. Thus, in identifying the crop combinations and patterns, each of the farmers was asked to mention the various crop enterprises they engaged in. The numbers of farmers belonging to a particular crop mix or crop combination category were presented in frequencies and percentages. To determine the extent of CD, the CDI was used to analyze this objective. Objectives 3 to 5 were analyzed using the LP model, and objective 6, which is the effect of optimum income on the extent of CD, was analyzed using the Tobit regression model.

Empirical Model Specification

Estimating the Extent of Crop Diversification

Following other researchers, particularly Larkai (2019) and Kujawska, Strzelecka, and Zawadzka (2021), the study, in an attempt to achieve objective 2, which is the extent of CD, was measured using CDI, otherwise known as the Transformed Herfindahl Index (THI). The CDI is calculated by subtracting the Herfindahl index from one; while the Herfindahl index is also calculated by taking the sum of squares of the acreage of each crop in the total cropped area.

Mathematically, the index is given as follows;

$$HI = \sum_{i=0}^{n} (p_i^2) \text{ .... (8)}$$

This is an index of concentration with a direct relationship to diversification, where a value of zero shows specialization while a movement toward one indicates a rising level of diversification. The CDI is therefore indicated mathematically as;

$$CDI = 1 - \sum_{i=0}^{n} (p_i^2) \text{ .... (9)}$$

Where:

n = the total number of crops,

Pi = area proportion of the ith crop in the total cropped area;

CDI= Crop Diversification Index

HI= Herfindahl Index

Determination of the Optimal Crop Combination and Resource Allocation for Maximum Profit

Every farmer aims to maximize profit under optimum resource allocation, and this requires the use of the LP technique as an appropriate decision-making tool in the analysis (Larkai, 2019). Based on an earlier study by Majeke (2013), a few adjustments were made in the present model to cover the minimum food combination required. Usually, farmers do not aim to make only a profit but to secure some food for the family as well. To address these issues, minimum food crop combination was added to the model. This was done to address the issue stated above by introducing non-basic activity into the LP model.

The LP model used by Majeke (2013) was adopted and slightly modified to include fertilizer constraints and capital constraints; this is mathematically elabourated below:

max Z

$$= \sum_{j=1}^{n} c_j x_j \quad \ldots\ldots\ldots\ldots (\boldsymbol{Objective\ function}) \ldots\ldots\ldots\ldots\ldots (10)$$

Subject to:

$$\sum_{j=1}^{m} a_{ij} x_j \leq b_i \quad \forall_i = 1, \ldots m \quad \ldots\ldots\ldots (\boldsymbol{Resources\ constraint}) \ldots. (11)$$

Where Z = the value of total profit. , x_j: level of activity j (j=1…, n): c_j: performance measure coefficient for activity j , b_i : Quantity of resource i at disposal (i=1…, m) , a_{ij} : quantity of resources i used by a particular unit of activity j. The decision variables are x_j and the parameters are c_j, b_j, a_{ij}. To formulate the actual LP problem, we defined the decision variable as acres of land to be allocated to the various crop enterprises (x_j) , j= 1, 2………7 where x_1=cassava (tones), x_2= plantain (bounces), x_3= cocoyam (bags), x_4= maize (bags), x_5= sweet potatoes (bags), x_6= garden-eggs (bags), x_7= okro (basket). We then set up the objective function as maximize $\pi(\text{GHC}) = \mathrm{c_1 x_1 + c_2 x_2 + \cdots + c_7 x_7}$, where $\mathrm{c_j}$ are the contributions to the total profit per of each crop enterprise. Later, we set up the constraints imposed and their limits, $\mathrm{b_i}$ where $\mathrm{b_1}$ (land), $\mathrm{b_2}$ (Labour), $\mathrm{b_3}$ (Capital),$\mathrm{b_4}$(Fertilizer), constraint. The LP model was then formulated as:

$$\textbf{Maximize Z} = \mathrm{c_1 x_1 + c_2 x_2 + \ldots + c_7 x_7} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Subject to the constraints:

(Resources constraints)

$x_1 + x_2 + x_3 + \cdots + x_7 \leq b_1$ (Land constraint) ……………….. (13)

$a_2x_1 + a_2x_2 + \cdots + a_2x_7 \leq b_2$ (Labour constraint) ………….. (14)

$a_3x_1 + a_3x_2 + \cdots + a_3x_7 \leq b_3$ (Capital constraint) …………….. (15)

$a_4x_1 + a_4x_2 + \cdots + a_4x_7 \leq b_4$ (Fertilizer Constraint) ……………. (16)

$x_1, x_2, x_3, \ \ldots \geq 0$ (Non –negativity constraint) ……………………. (17)

Minimum Requirement:

$\sum_{j=1}^{n} k_{ij}x_j \ \geq \ w_i \quad \ldots \ldots \ (Min.\ food\ crop\ combination)$ ……… (18)

$\forall_i = 1, \ldots n$

k_{ij} = the food crop coefficient that was not chosen in the optimal crop pattern. That is, since it is not in the researcher's best interest, the coefficient of other food crops was set to zero (0) based on the combinations.

w_i = the farmer's total minimum food crop produced to address subsistence farming and food security.

The average value of resources, such as land, labour, fertilizer, and capital holdings of sampled farmers was determined and the LP model was executed for the SHFs.

Systematic Modelling the LP Model for this Study

I first established the inequalities that describe the issue and then determined the coefficients of the objective function (*cj*). To determine the crops' per-unit profit margin, the average profit was calculated from the total profit of each crop enterprise.

Then, in order to determine the coefficient of each constraint (a_{ij}) for each food enterprise, averages of the total values of each constraint like the average number of labour-man days, amount of capital (GH¢), amount of land size (acres), and the amount of fertilizer (kg/acre) were computed. Following that, the average total value of all the various constraints (b_i) were determined. I numerically input known values in the model, and then ran the model using the R statistical program. This is the initial analysis from which the ideal crop combination and maximum profit margin values were derived.

After that, I updated the model to include the minimum food combination. To do this, a combination of food crops that did not make it into the optimal solution—the non-basic activity—were entered into the model to examine how it affected maximum profit as well as challenges related to subsistence and food security.

After that, I used the SA to verify the model's robustness. This was to make sure the model can withstand variations in the farming season and other potential shocks. Thus, in order to examine its effect on the model, the values of the two most limiting constraints were doubled or increased.

Gross Margin (GM)

The GM per acre of each farm enterprise was the first thing the researcher computed while creating the LP matrix for the study. According to Dent et al. (1986), an activity's GM is equal to its revenue less the variable costs incurred in generating that income. This was defined in terms of per acre. The GM is expressed mathematically as:

$\pi = \sum_{i=1}^{n} py - C$ ………………… (19)

I = 1, 2……n, where n is the number of crops per acre

Another name for GM is net agricultural returns. The cash cost (or total variable cost) in Ghana Cedi per acre, the yield in units per acre, and the price per unit are represented by the variables P, Y, and C, respectively. There are two approaches to handling GM in the context of the LP matrix: either it is directly inserted into the matrix or it is divided into its parts (cost and returns).

Measuring the Effect of Optimum Income on the Extent of CD

Tobit model was used to determine the statistical relationship between dependent and independent variables to show the effect of optimum income on CD extent. The extent of CD was the dependent variable, and it was measured using the CDI, which is censored between 0 and 1, and CID above 0 signifies the extent of CD. The Tobit model allows censoring of the dependent variable from below and above, also called left and right censoring, and is mainly appropriate for regression analysis of the CDI. Tobit model was appropriate to use because the sample consisted of observations both above and below the limit. According to Mesfin et al. (2011), this model is the most appropriate because standard linear regression models like ordinary least squares (OLS) assessments give biased and inconsistent results. The formula of the Tobit model used by Larkai (2019) is expressed below.

$$CID = \beta_0 + \beta_i X_i + \ldots + \beta X_n + e_i \text{ .... } (20)$$

CDI= Crop Diversification Index

β_0 = Constant or intercept

β_i = Probability of crop diversification due to X_i or coefficient

X_i = Factor affecting crop diversification (Independent variable or explanatory variable)

e_i = Error term

The CID is the dependent variable and will be censored at zero. The choice of the Tobit model was supported by previous research that utilized the same model to qualify the influence of socioeconomic and institutional variables on farmers' diversification behavior (Wondimagen *et al.*, 2011; Dube *et al*., 2016; Shahbaz *et al.*, 2017). In this study, the model is given as;

Extent of Crop Diversification = $\beta_0 + \beta_1\, Age + \beta_2 Education + \beta_3 Experience + \beta_4 OffarmActivities + \beta_5 Land + \beta_6 Optimum\ Income + \beta_7 Extension\ services + \beta_8 Credit + \beta_9 HHSize + \beta_{10} member\ assc. + e_i$…………… (21)

Age, gender, education, farming experience, household size, access to credit, membership association, and non-farm activities are the explanatory variables.

Validation of Hypothesis Testing

Hypothesis testing is a test that measures whether a certain variable is significant in explaining the decisions of farmers to diversify their crop production or not. The test assumes a null hypothesis, which is the status quo and generally accepted unless contradicted by the alternate hypothesis. The hypothesis test for this particular study is stated below:

H_0 : The independent variables have no significant effect on the decision of the farmer to diversify his/her crops.

H_1 : One or more of the independent variables has a significant effect on the dependent variable (CDI- decision of the farmer to diversify his crop diversification). The Likelihood ratio (LR) test statistics is stated below;

$$LR = 2ln[L(M_1) - L(M_2)]$$ ……................. (22)

Where $L(M_1)$ is known as the Log Likelihood of the more restricted model and $L(M_2)$ is the Log Likelihood of the less restricted model. If the LR statistic is greater than the critical value at 10%, 1%, and 5% then we reject the null hypothesis and accept the alternative hypothesis.

A breakdown of the Tobit model's different explanatory factors and their respective a-priori expectation is given in Table 4:

Table 4: Explanatory variables for the Tobit model

Variables	Description	Measurement	A-priori Expectation
Gender	Sex of the farmer	Male=1, Female=0	±
Age	Age of Farmer	Years	−
Fertilizer	Qty of fert used	kg/hectare	+
Membership of Association	Being a member of a farmer-based organization	Yes=1, Otherwise =0	+
Access to credit	Access to credit	Yes =1, Otherwise = 0	+
Extension Services	Access to Ext. Service	Yes =1, Otherwise = 0	+
Household Size	No. of persons in the household	Number	±
Education	Level of educ. attained	Years	+
Land Size owned	Available land size	Hectare	+
Experience	No. of years in farming	Years	+
Off-farm Activities	Engage in off-farm activities	Yes=1, Otherwise =0	−

Source: Eshun, (2023)

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents the results on the respective objectives of the study. There are four major sections in this chapter, and it includes descriptive statistics of socioeconomic variables, crop diversification, analysis of the LP model, and the Tobit model analysis.

Background the Respondents

The respondents' socioeconomic characteristics as shown in Table 5, highlighted issues like their gender, age, education, farming experience, and engagement in off-farm activities. It revealed that 74.9% of the total respondents were male and 25.1% were female. Thus, it can be concluded that more men are into food crop production in this district. This is so as the cultural system in the area gives men easier access to land acquisition and production inputs, thereby giving them a competitive advantage over women in farming.

Table 5: Background Characteristics of Respondents

Variables	Frequency	Percentage
Sex		
Males	298	74.9
Females	98	25.1
Total	398	100
Age		
<36 years	76	19.1
≥ 36 years	322	80.9
Total	398	100
Education Level		
No Formal Education	55	13.8
Primary	208	52.3
JHS	70	17.6
SHS	65	16.3
Total	398	100
Access to Extension Service		
Yes	300	75.4
No	98	24.6
Total	398	100
Engagement in Off-Farm		
Activities	260	65.3
Yes	138	34.7
No		
Total	398	100
Member of an FBO		
Yes	139	34.9
No	259	65.1
Total	398	100

Source: Field Survey, Eshun (2023)

Age affects a farmer's ability to manage risk and his capacity for innovation. This is because, as a farmer becomes older, his or her capacity to conduct manual labour declines. From Table 5, 80.9% of the respondents were above 36 years. In terms of education, most of the farmers (52.3%) in the study area had completed primary school, while 13.8% had received no formal education. The rest had received some form of formal education ranging from junior to senior secondary levels (33.9%). This suggests that the majority of farmers will be able to obtain knowledge and embrace and use new technologies, such as the LP model. These findings confirm Koufie's (2020) study on the optimal combination of food crop enterprises in the Assin North District of Ghana, which claimed that farmers with basic education were more inclined to adopt and use new technologies in their farming operations. However, this finding was contradicted by studies like Owusu-Amankwah (2018) and Larkia (2019), which found the majority of their farmer respondents were without any form of formal education.

Further, 75.4% of the farmers had access to extension services in the area. This shows how a large number of farmers in the research area benefited from using extension services and initiatives. More so, farmers can get finance for their agricultural operations and enhance their household farm income by engaging in some off-farm activities. From Table 5, 65.3% of farmers were engaged in some off-farm activities such as motor riding (Keke), mining, etc, for which they earned additional income in addition to their agricultural income. This additional income is then used to augment the household budget on the farm.

Among the surveyed farmers, 65.1% indicated that they were not affiliated with any FBO, while the remaining percentage expressed their membership in such organizations. This implies that when faced with difficulties in their agricultural activities, these farmers relied on their instincts. The outcomes of this investigation align with the findings made by Tagoe (2023), who, when examining food CD and the economic efficiency of SHFs in the Okere District in Ghana’s Eastern Region, noted that 66.7% of the farmers do not belong to any FBO, and that served as a challenge in their attempt to acquire new knowledge or information about their farming activities.

Summary Statistics of Food Crop Farmers' Socio-Economic Characteristics

Table 6 shows that the average age of the respondents in the study area is 51.47 years, which suggests that the younger generation is not engaged in crop farming. This is probably because most of the youth attend school or participate in activities other than farming. The study area has an average household size of approximately 5 (4.8) persons, exceeding both the Western Region's average of approximately 3 persons and the national average of approximately 4 persons in a household found in the 2021 Population and Housing Census Report (GSS, 2021). This suggests that the farmers' labour costs will likely be lowered as a result of the increased family size. This is consistent with research like Koufie (2020) and Igwe and Onyenweaku (2013), which discovered that having a large family lowers labour expenses related to agricultural production by increasing family labour.

Table 6: Summary Statistics of food crop farmers' characteristics

Variable	Minimum	Maximum	Mean	Standard Deviation
Age	30	70	51.47	9.615
Household Size	1	12	4.86	1.810
Farming Experience	8	20	17.48	4.016
Land size Owned	3	8	5.51	1.476

Source: Field Survey, Eshun (2023)

From Table 6, average land size owned by the farmers in the study area was 5.51 acres, which is equivalent to 2.23 hectares. This is consistent with research conducted by Koufie (2020) in the Ghanaian district of Assin North as well as a study from MoFA, which supports that smallholder farming accounts for the majority of all landholdings in Ghana, with 90% of them being smaller than two hectares (MOFA, 2017). This finding is in opposition to that of Makate et al. (2016), Ashante et al. (2017), and Larkai (2019), who found that SHFs often possessed more than two hectares of land.

Identification of Different Crop Patterns in the Study Area

Food crops like cassava, plantains, maize, cocoyam, sweet potatoes, and vegetables are mostly grown by farmers in the Western Region (Adjei-Nsiah et al., 2019). According to MoFA (2021), the Western Region's contribution to the nation's food basket in terms of food crops cannot be understated, and the Wassa East District significantly contributes to the region's output levels. According to the field survey, cassava, maize, plantains, sweet potatoes, and vegetables such as okro and garden eggs were the primary food combinations produced in the study area. This outcome is in line with the data provided by MoFA (2021). The various food crop combinations used by the farmers in the research district are shown in Figure 3, along with the matching number of respondents for each combination.

The findings from Figure 3 shows that 153 (38.4%) of farmers engaged in four crop combinations, 84 (21.1%) of the farmers grow three crop combinations, 52 (13.1%) of the farmers grow two crop combinations, 46 (11.6%) of the farmers grow five crop combinations and 30 (7.5%) are engaged in six crop combinations, while only a few farmers, 23 (5.8%) engaged in seven crop combinations. The results of the survey move further to show that 10 (2.5%) of the farmers grow only one crop.

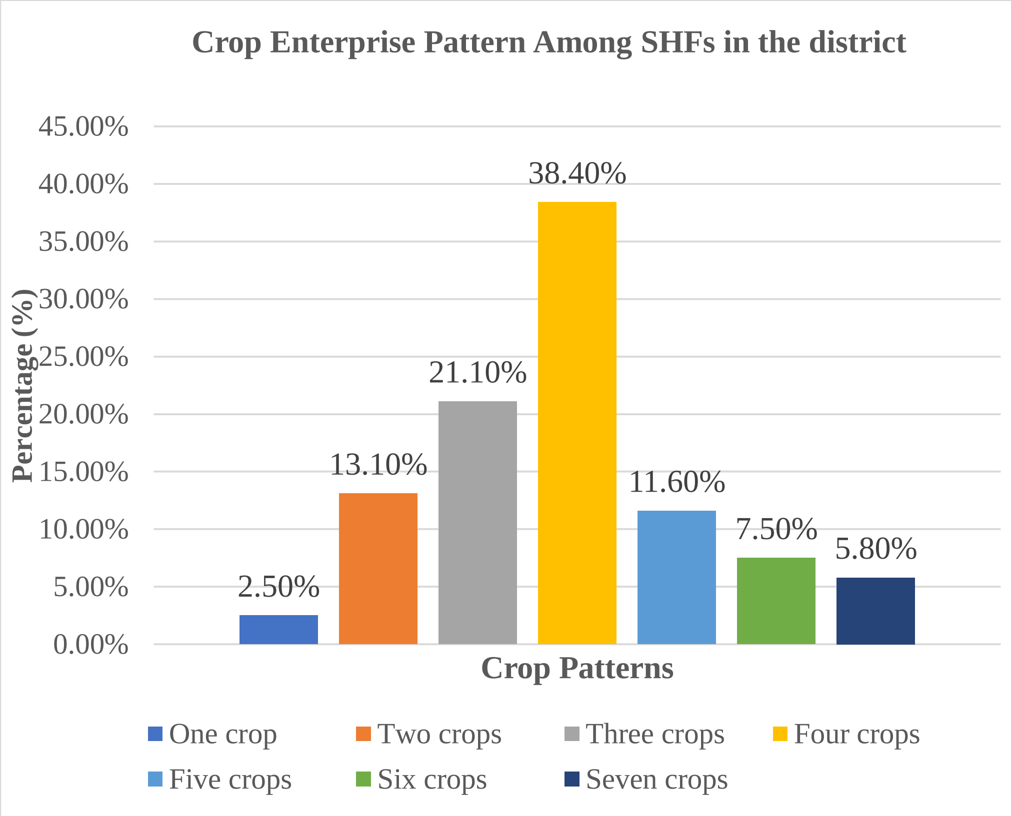

Figure 2: Crop Enterprise Pattern

Source: Filed Survey, Eshun, (2023)

Figure 3 shows four crop combinations with the highest number of farmers (153 representing 38.4%). This outcome is consistent with a study by Dembele et al. (2018) found that four crop combinations were at the highest level employed by farmers in Mali. However, the outcome from this study contradicts the findings of Larkia (2019), who identified 2 crop combinations as the highest level of crop combinations with 124 farmers (representing 41%). These variations or differences can be attributed to several different reasons, including crop strengths in various places, level of soil fertility, climatic conditions, agronomic concerns, culture, preference of farmers, and their financial capacity (Koufie, 2020).

The Extent and Nature of Crop Diversification

The extent of CD among farmers was measured using the CDI. This index is scaled from zero (0) to one (1), where values greater than zero indicate the extent and nature of CD, while zero represents the specialization of a single crop. In this study, the average value of the extent of CDI was 0.77, indicating a high level of CD.

Table 7: Relative Crops Diversification Indices for various crop combinations

Diversification Indices	Relative Crop Diversification Index
Mono cropping	0.019
Two crop combination	0.099
Three crop combination	0.160
Four crop combination	0.292
Five crop combination	0.087
Six crop combination	0.072
Seven crop combination	0.058

Source: Filed Survey, Eshun (2023)

The results further showed that 97.5% of the 398 respondents engaged in CD in the study area. A total of 10 farmers, accounting for 2.5% of the overall farmer population, opted not to engage in CD in their production. These were farmers who specialized in producing only one crop. This might be explained by the difficulty in obtaining land for farming purposes due to mining activities in the district (Tetteh et al., 2015). The results from Majeke (2018) and Ashante et al. (2017), who reported a value of 0.9 and 0.47, respectively, are consistent with the average value of the CDI.

Figure 4 displays the distribution of the extent of CDI, which is very symmetrical. The majority of farmers exhibit a diversified approach to their food cropping activities, as the values for most of them were greater than 0.55. About 2.5% of the farmer respondents had specifically produced a single crop. Limited lands in the study area and other resources for producing these crops or high returns from the crops could account for this result. These results are in line with Ogundari's (2013) study on CD among some farmers in Nigeria.

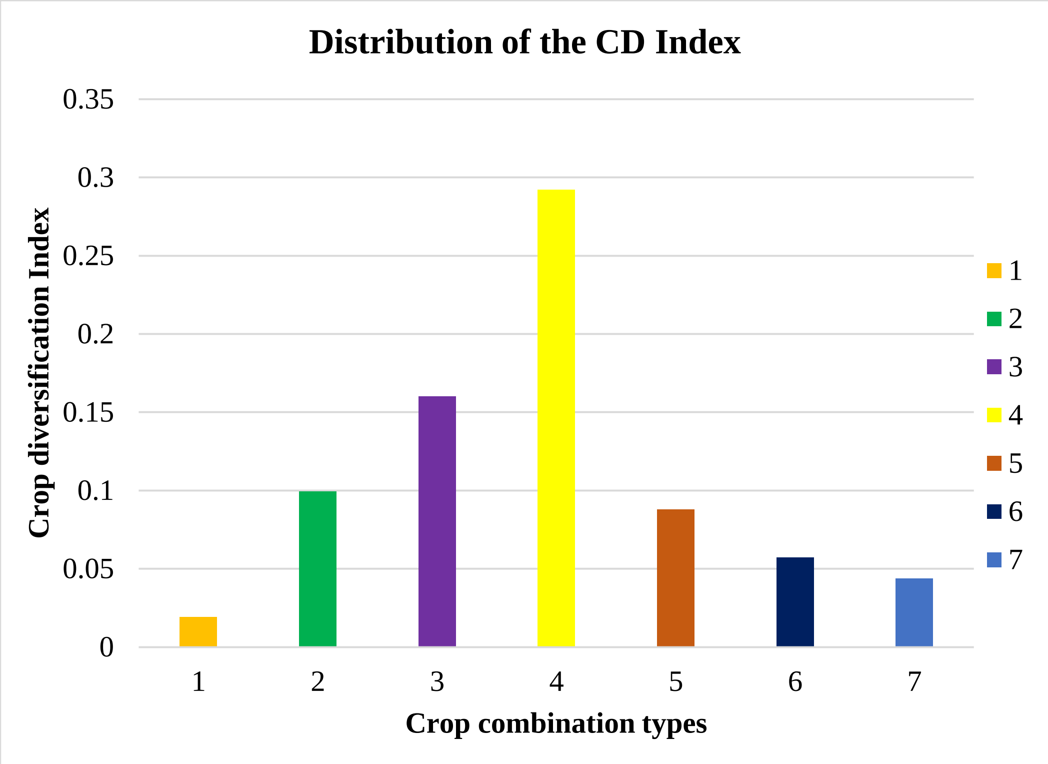

Figure 3: Crop Diversification Index

Source: Field Survey, Eshun (2023)

Optimal Crop Combination and Resource Allocation

A comparison between existing crop combination plans of the smallholder food crop farmers and the optimal crop combination plans (using the LP model) with the available resources such as land, labour, capital, and fertilizer and the level of utilization is highlighted in Table 8. For the farmers' existing plan, as shown in Table 8, they cultivated cassava on 0.70 acres, plantains on 0.80 acres, maize on 2.00 acres, cocoyam on 0.50 acres, sweet potatoes on 0.50 acres, garden eggs on 1.00acres, and okro on 0.50 acres from an average of 6.00-acre land size to obtain an average GM of GH¢6,567.

The result varies from earlier studies by Antwi (2016) and Koufie (2020) in Ghana. According to Antwi (2016), farmers' existing plan is to produce maize in 1.1acre, rice in 1.2acre, soybean in 0.6acres, cowpeas in 0.4acre, peanuts in 0.5acre, pepper in 0.4acre on an average land size of 5.00acres to obtain an average GM of GH¢2,300. Koufie's (2020) study also showed that the farmers had existing ideas to cultivate 0.60acres, 0.40acres, 0.50acres, 0.10acres, 0.20acres, and 0.20acres of maize, cassava, plantains, cocoyam, garden eggs, and rice, respectively, from an average land size of 7.00 acres to obtain a GM of GH¢7,688. The reason for the variations in crop patterns is that crop patterns are influenced by the farmers' cultural background, geographic location, and the individual crops' strengths.

In the optimum crop plan from the initial LP scenario as indicated in Table 8, the SHFs have to cultivate about 3.31 acres of cassava, 0.22 acres of plantains, and 2.47 acres of maize and do not recommend the production of cocoyam, sweet potatoes, garden eggs, and okro, respectively, to attain a maximum income of GH¢12,927.9 with the same average land size of 6.00 acres, "all other things being equal." By this optimum plan from the LP model, the SHF earns more income of GH¢12,927.9, which is higher than the existing plan income of GH¢6,567 (which is an increase of GH¢6,360.9).

Furthermore, for a farmer to make a maximum income of GH¢12,927.9, the farmer should diversify into these three crops. These show that farmers can gain more when the LP model is used in their diversified system of farming. It will also enable smallholders to spread risk in case one of the crop enterprises fails, considering the rainfall patterns in Ghana. The result's is in line with the studies of Darfor's (2000) which reported that farmers in Central Region of Ghana should focus on cultivating maize on a 2.1acres, garden eggs on a 3acre, and combine maize, cassava, plantains, and cocoyam on an acre of land. This recommendation is based on the LP initial analysis, which suggested that planting these crops together will be more profitable for farmers compared to planting them as single crops.

Table 8 presents the second scenario of the LP optimal plan, which is the subsistence requirement. It shows that an acre of sweet potato was introduced into the model due to the other objectives of the farmer. The objectives were solely for subsistence and food security. The results show that farmers should cultivate 1.00 acres of sweet potato, 3.00 acres of cassava, 2.00 acres of maize, and 0.06 acres of plantains to realize an income of GH¢12,583.6.

Additionally, the result indicates a decrease in land size allocated to maize, cassava, and plantains respectively. This resulted in a GH¢344.3 drop in the optimal income from GH¢12,927.9 to GH¢12,583.6. The implication is that to achieve food subsistence, there will be a trade-off of income; however, comparing this with the profit of the farmer's existing plan (GH¢6,567), the farmer is better off with the subsistence requirement of the LP model than his plan in terms of income and food availability. These findings are in line with earlier studies by Patel et al. (2017); Antwi (2016) and Majeke et al. (2013).

The third scenario of the LP analysis is the SA, which ensured that the model remained stable in the event of modifications or shock. From Table 8, land, labour, and capital were increased (with other parameters constant) while satisfying the subsistence requirement for sweet potato production. These resources were increased because the LP's initial requirement identified them as the most limiting resources for the farmer. The researcher then decided to make it available to the farmer by increasing the amount of capital and labour by 10% and increasing the size of the land by an acre, following studies such as Koufie (2020), Larkia (2019), and Antwi (2016) as a benchmark to observe how it affects the LP model.

From the results, the optimum crops that farmers should diversify under this scenario were 3.40 acres of cassava, 2.60 acres of maize, and 1.00 acres of sweet potato to realize GH¢14,180.9 income. “All other things being equal,” this makes economic sense as the farmer can sell cassava and maize to attain this high income of GH¢14,180.9 while at the same time satisfying his food subsistence needs through the production of sweet potatoes. This increase in income is a result of a capital increase, which is the main constraint in the study area, followed by labour and land. Making it available to the farmer-led to the increase, and this is backed by the optimization theory.

This finding is consistent with research by Darfor (2000), which found that when hired labour was increased from 30% to 60%, the LP model did not change. Since labour was abundant, adding more would have no impact on the model if it did not increase land, which is the most restrictive constraint. This is because labour was not the restrictive constraint in the model, but land. Therefore, adding more labour will not change the model if there is no land to cultivate.

On the other hand, for food subsistence, where an acre of sweet potato was added to the model, some capital was left unused (GH¢2,689) and the land was fully used. This also makes economic sense since cassava, maize, and plantains, which were all part of the optimal crops for farmers to diversify, have been reduced in terms of the acres of land allocated to them. Although all three optimal crops have been reduced, sweet potatoes not being capital-intensive led to capital not being fully used. After the sweet potato crop was added to the optimal crops that the farmer should diversify, the optimum income dropped to GH¢12,583.9. This decrease in income was brought on by the shadow cost of this addition. This is in contrast to research by Larkai (2019), who fully used all of the capital while introducing maize as a subsistence requirement into the optimum crop plan.

Increasing capital, labour, and land, which were the most restrictive resource constraints in the study area, led to an increase in the output of the optimal crops while at the same time satisfying the issue of food subsistence. From Table 9, the result again shows that after the increase, labour, and fertilizer were fully utilized while GH¢2,689.9 of capital was left unused. The reason is that, since sweet potatoes are more labour-intensive than capital-intensive, they tend to use the availability of labour for their production. The fertilizer was fully used because of the production of cassava and maize, which is the highest production in this study, and its yields are mostly based on fertilizer application.

Also, it can be seen from Table 8 that as capital, labour, and land were increased, the farmer now gets more income (GH¢14,180.9) than both the subsistence requirement (GH¢12,583.9), the LP initial requirement (GH¢12,927.9) is even higher than the farmer's existing plan (GH¢6,567). This analysis makes the farmer better off in terms of income, food subsistence, and resource availability, and this is backed by the rational and constraint theories.

Table 8: Farmer's Plan and the Optimal Crop Combination and Resource Allocation of the LP

Farmer's Plan/LP Scenarios	Optimal values of Decision Variables (Acres)							
Crops	Cassava	Plantain	Maize	Cocoyam	Sweet Potatoes	Garden-Eggs	Okro	Gross Margin (GH¢)
Farmer's Plan	0.70	0.80	2.00	0.50	0.50	1.00	0.50	6,567
Initial Analysis	3.31	0.22	2.47	0.00	0.00	0.00	0.00	12,927.9
Subsistence Requirement	3.00	0.06	2.00	0.00	1.00	0.00	0.00	12,583.9
Sensitivity Analysis	3.40	0.00	2.60	0.00	1.00	0.00	0.00	14,180.9

Source: Field Survey, 2023

Table 9: Resource Utilization under the Optimal Solution for SHFs from LP Model

Resource	Initial Analysis			Subsistence Requirement			Sensitivity Analysis		
	Available	Usage	Left Over	Available	Usage	Left Over	Available	Usage	Left Over
Land (Acres)	6.00	6.00	0.00	6.00	6.00	0.00	7.00	7.00	0.00
Labour (man-days)	288	288	0.00	288	288	0.00	317	317	0.00
Capital (GH¢)	6,566	6,566	0.00	6,566	6,566	0.00	7,223	4,534.0	2,689
Fertilizer (Kg)	100	59.06	40.99	100	56.86	43.13	100	100	0.00

Source: Field Survey, Eshun (2023)

From Table 9, the preliminary analysis on resource use, the resources available for crop production were 6.00 acres of land, 288 labour man-days, GH¢6,566 in capital, and 100kg of fertilizer. With these, the 6.00 acres of land were fully utilized, as were the capital and labour at their disposal. However, only 59.06 kg of fertilizer was used, which means 40.99 kg was unutilized. This is contrary to studies by Onyenweaku and Nwaru (2017) and Abdelaziz et al. (2019) where capital was the only restrictive resource, while resources like labour, land, and fertilizer were underutilized.

Furthermore, Kaur et al. (2010) pointed out that while land had no marginal value product, labour was the only resource that was limited. Mohamad and Said (2011) mention capital as the only factor that restricted farmers in Nigeria's Abia State from growing the best, most optimal crops for diversification. The reason for this disparity in restricting resource limits is that they are based on region, area, farmer group, and culture. For instance, a resource that is most limiting for one set of farmers may not be for another group of farmers or a different place.

From Table 10, the optimum income obtained by the LP initial analysis was GH¢12,927.9, which is 96.9% above the farmer's income. This confirms the findings of Koufie's (2020) study, which used the LP model to ensure an effective resource allocation pattern for crop producers in Ghana's Central Region's Assin North. Igwe and Onyenweaku (2013) applied the LP technique to farm data obtained from thirty arable crop farmers during the 2010 farming season to maximize GMs from various combinations of arable crops and livestock enterprises. The results of their LP model were significantly different from the existing plan of the farmer. The optimum income obtained was 61.35% higher than the existing plan of the farmer.

Table 10: Comparison of farmers' existing plan and LP model's GM levels

Farmer's Plan/ LP Scenarios	Gross Margin (GH¢)	% Increases in Farmer's Plan
Farmer's Plan	6,567	-
Initial Analysis	12,927.9	96.9
Subsistence Requirement	12,583.9	91.6
Sensitivity Analysis	14,180.9	115

Source: Field Survey, Eshun (2023).

When the sweet potato was introduced into the model, the optimum income was reduced to GH¢12,583.9, compared to the initial LP model requirement result, but it was 91.6% higher than the farmer's existing plan from Table 10. Majeke et al. (2013) developed an LP model to determine the optimal crop patterns and the optimal number of breeding sows. The researchers compared the LP results with the existing plans of the farmers. The LP techniques yielded more income than the farmer's plan. Majeke (2013) developed an LP model for farmers in Marondera, Zimbabwe, to maximize their net incomes through optimal enterprise combinations that were subject to resource constraints. In this study, the LP model's recommendations that the researcher generated were more acceptable than the farmer's existing plan.

In terms of the SA, increasing the number of labour man-days, capital, and land resulted in an increase in optimum income to GH¢14,180.9, which is more than the farmer's plan from Table 10. This confirms the study by Nordin and Fatimah (2010), which found that a unit increase in labour-man days results in a 10% increase in the optimum income relative to the achieved optimum income. In contrast, Darfor (2000) found that optimizing the maize-based agricultural system in Ghana's Central Region by increasing labour days alone did not influence the optimum income. The rationale is that labour was not a constraint in that study, and labour in real terms cannot function in isolation.

Sensitivity Analysis's Effect on the LP Model by Increasing Capital

Capital as a production variable was increased to meet the initial requirement. The data presented in Table 11 indicates that the ideal land area was approximately 6.00 acres. This indicates that the land was fully utilized and that 54.69kg of fertilizer was used, leaving 45.30kg unused out of 100kg. Also, around GH¢3,770 of the GH¢7,223 in capital that was available were not used, which is about 50% of the total capital increase. Comparing this to the farmers' current plan or the basic model, the optimum income increased by 88.34%, and this is in line with the study by Koufie (2020).

Table 11: Sensitivity Analysis's Effect on the LP Model by Increasing Capital

Resources	Land (Acres)	Labour (Man-days)	Capital (GH¢)	Fertilizer (Kg)	Optimum Income
Available	6.00	288	7223	100	
Usage	6.00	288	3770	54.69	
% Usage	100	100	48	45.31	
Left Over	0.00	0.00	3453	45.30	
% Left Over	0.00	0.00	52	54.7	
% Increase of Farmer's Plan					88.3%

Source: Field Survey, Eshun (2023)

Sensitivity Analysis's Effect on the LP Model by Increasing Labour

To meet the initial requirement, labour as a production variable was increased (as seen in Table 12). The (labour-man) days made available in the SA was an adjustment of the former 288 (labour-man) days upward by 10%, resulting in a total of 317 (labour-man) days. The result of the SA indicated that optimality is achieved according to the LP model with the adjustment by total utilization of the land available to the farmer. Therefore, the total land available to the farmer, which was 6 acres, was fully utilized. Subject to the adjustment, the results indicate that 292 (labour-man) days out of the 317 (labour-man) days were used, representing a 92.11% usage of (labour-man) days made available because of the adjustment. The left-over (labour-man) days according to the LP model and, by extension, the SA is 25 (labour-man) days.

The results also indicate that the adjustment results in a 65% utilization of capital (GH¢ 4,311.86) and a left-over of 35% of available capital (GH¢ 2,255.13). The results revealed that the usage of fertilizer to achieve optimality is 37.56%. This sensitivity analysis is a one-way SA. The overall impact of the model is to determine the effect of the adjustment on the farmer's plan. The results indicated that the overall impact of the adjustment will result in a 100% increase in the optimum income.

Table 12: Sensitivity Analysis's Effect on Increasing Labour

Resources	Land (Acres)	Labour (Man-days)	Capital (GH¢)	Fertilizer (Kg)	Optimum Income
Available	6.00	317	6566	100	
Usage	6.00	292	4311.86	62.44	
% Usage	100	92.11	65	37.56	
Left Over	0.00	25	2255.13	35.55	
% Left Over	0.00	7.88	34.34	62.45	
% Increase of Farmer's Plan					100%

Source: Field Survey, Eshun (2023)

Sensitivity Analysis's Effect on the LP Model by Increasing Land

The SA results from the LP model, with a particular focus on the effects of increased land on different resources and the overall plan, are presented in Table 13. The Table's most important finding is the increase in the optimum income, which stands at 99.69%. This suggests that the optimum income can be increased by 99.69% by increasing the amount of land accessible for farming.

When conducting SA in LP, increasing the amount of a particular resource, in this case, land, allows for an examination of how changes in that resource affect the optimal solution and other related variables. In this context, it appears that as the land increases, there is a significant increase in the optimum income. This suggests that land is a critical resource, and its availability directly impacts the overall plan and output of the farmer. Therefore, SA on the LP model by increasing land in Table 13 has shown that an increase in land has a substantial impact on the optimum income and resource allocation, leading to a more efficient utilization of resources and an increase in overall output.

Table 13: Sensitivity Analysis's Effect on Increasing Land

Resources	Land (Acres)	Labour (man-days)	Capital (GH¢)	Fertilizer (Kg)	Optimum Income
Available	7.00	288	6566	100	
Usage	7.00	288	4069.49	68.22	
% Usage	100	100	61.96	31.77	
Left Over	0.00	0.00	2497.51	31.77	
% Left Over	0.00	0.00	37.57	68.23	
% Increase from farmers' existing plan					99.69%

Source: Field Survey, Eshun (2023)

The Non-Basic Activity and their Profit to the Farmer

According to Mujuru and Obi (2020), SHFs aim to maximise profit, food security, subsistence, and accumulate wealth. The problem of subsistence farming and food security, along with other farmer goals, makes it challenging for SHFs to allocate all of their resources to growing the best combination of food crops to maximize income. Therefore, there is a need for different crop food combinations. These different crop food combinations relate to the crop combination that was left out of the optimal solution. They are also referred to as excluded activities or non-basic activities.

If these food crops are forced into the model, their marginal opportunity cost will lower the optimum income. Table 14 shows that the non-basic activity (different food crop combinations) that yielded the highest optimum income aside from the LP optimal were okro/cassava/plantain/maize with a reduced optimum income of GH¢12,672.1, and the activity that recorded the lowest level of optimum income was cocoyam/sweet potatoes/garden eggs/okro/ cassava/maize with an optimum income of GH¢11,149.6. Moreover, from Table 14, the farmer can decide which combinations he or she wants to diversify into while at the same time satisfying his or her food subsistence needs.

Table 14: Non-Basic Activity Requirement for Different Food Crop Combinations and their Optimum Income

Different Combinations of Food Crop for Subsistence and Diversification	**Optimum Income (GH¢)**	**% Trade-off in Optimum Income**
Cassava/Plantain/Maize (LP- OPTIMUM)	12927.9	-
Cocoyam/Cassava/Plantain/Maize	12506.1	3.26
Sweet Potatoes/Cassava/Plantain/Maize	12583.6	2.66
Garden-eggs/Cassava/Plantain/Maize	12171.4	5.85
Okro/Cassava/Plantain/Maize	12672.1	1.97
Cocoyam/Sweet Potatoes/Cassava/Plantain/Maize	12161.9	5.92
Cocoyam/Okro/Cassava/Plantain/Maize	12250.4	5.24
Sweet Potatoes/Garden-eggs/cassava/Plantain/Maize	11827.2	8.51
Garden-eggs/Okro/Cassava/Plantain/Maize	11915.7	7.82
Okro/Cocoyam/Cassava/Plantain/Maize	12250.4	5.24
Cocoyam/Sweet Potatoes/Garden-eggs/Cassava/Plantain/Maize	11405.4	11.77
Cocoyam/Sweet Potatoes/Garden-eggs/Okro/Cassava/Plantain/Maize	11149.6	13.75

Source: Field Survey, Eshun (2023)

Effect of Optimum Income on Extent of Crop Diversification

Table 15 shows that the Tobit model's estimated Wald statistic is 269.2, which is highly significant with a p-value of less than 2.22e-16 (<2.22e-16). This shows that the choice of the farmer to engage in the extent of CD is explained by some variables, including optimum income, in the Tobit model. From the results in Table 15, the size of land is statistically significant at 1% and has a positive relationship with the extent of CD. This implies that farmers with large farm sizes practice more CD than farmers with small farm sizes. The coefficient derived from the result indicated that a farmer's probability of engaging in CD will increase by approximately 0.0672 units with an increase in the size of the land they own. This finding concurs with the findings of Wongnaa et al. (2018), who found that the more farmers have access to additional land, the higher the probability that they will engage in multiple crop combinations.

The results are also consistent with the research of Sisay et al. (2016) and Asante et al. (2018), who noted that households with larger farmlands have the capacity and chance to cultivate a wider range of crops than those with smaller farmlands. Similarly, Rehima et al. (2013) revealed that large land size is a strong determinant of the extent of CD.

Access to credit was also found to be statistically significant at less than 1% and positively related to the likelihood that a farmer will engage in the extent of CD. The outcomes show that a unit increase in the amount of credit will increase the likelihood for a farmer to engage in the extent of crop diversification by 0.1415 units. Farmers who have access to credit can invest and diversify into multiple crops. Access to credit may have the effect of reducing the financial strain that comes with purchasing agricultural production inputs like cutlass, hoes, and seedlings, allowing farmers to raise the number of crops they maintain.

Farmers' involvement in off-farm activities is statistically significant at 1% and has a negative relationship with the extent of CD. The coefficient of off-farm activities being -0.2150 indicates that an increase in the number of off-farm activities will lead to a lower likelihood of farmers practicing crop diversification by 0.2150 units. This implies that farmers who participate in off-farm activities are less likely to practice e multiple crop combinations. It was also observed by the researcher that aside from farming being the main economic activity in the study area, some of the farmers also engage in other off-farm activities such as petty trading, driving Keke, and mining activities. This finding aligns with the research conducted by Mussema et al. (2015), which found that crop farming is negatively and significantly impacted by off-farm activities. Additionally, this outcome supports the findings of Omiti and Mccullough (2009), who argued that higher income from non-farm activities discourages farmers from farming.

Farming experience is statistically significant at 10% and has a positive relationship with the extent of CD. The coefficient of farming experience being 0.0082 indicates that an increase in the number of years of farming experience increases the likelihood of farmers engaging in CD by 0.0082 units. Thus, farmers with more experience in farming are more likely to diversify their crops. The research aligns with the results of Ashraf et al. (2014), who establish that farmers with more experience frequently diversify their farming practices.

Furthermore, from Table 15, the findings show that the relationship between extension services and the extent of CD is statistically significant at the 1% level. The coefficient of extension services, which is -0.3671, suggests that an increase in the number of extension services leads to a decrease in the probability of farmers engaging in CD by 0.3671 units. This negative relationship implies that as the availability of extension services increases, farmers are less likely to diversify their crops. This negative association may be attributed to the point that extension services primarily focus on improving farmers' productivity and agronomic practices while overlooking the importance of CD in minimizing risks.

Extension services often concentrate on enhancing traditional farming methods and promoting specific crops, which may discourage farmers from exploring diverse crop options. The results are consistent with the assertion made by Mesfin et al. (2011) that extension services discourage farmers from engaging in multiple crop combinations. In contrast to the aforementioned findings, Rehima et al. (2013) argued that extension services have a positive and significant impact on the extent of CD.

Similarly, Baba and Abdulai (2021) also found that extension contacts led to an increase in the extent of CD among farmers. This could be attributed to the fact that extension agencies often consider market demand and profitability when providing recommendations to farmers. Consequently, if there is a substantial market demand for a particular crop, extension services may prioritize promoting its cultivation to assist farmers in meeting the demand and achieving financial stability. In light of this current study, it was observed that many farmers were involved in cassava, plantains, and maize production due to the demand for these crops and the advice received from extension agents.

Optimum income was found to be statistically significant at less than 1% and negatively related to the likelihood of food crop farmers engaging in CD. The results show that an increase in optimum income will lead to a lower likelihood of food crop farmers engaging in crop diversification by 0.0106. One reason why high-income farmers may not diversify their crops is that they have achieved financial stability. This result is in line with a study by Mubhoff (2020), who found that farmers with high income levels tend not to diversify their crops. Again, Sarwosri (2020) also found that high-income farmers may have secured long-term contracts or agreements with buyers for their existing crops. These contracts may provide stable and lucrative markets for their produce, making it less appealing for them to explore other crop options.

Lastly, Kankwamba et al.'s, (2018) study on patterns, determinants, and policy implications of CD in Malawi found that government subsidies and support programs can influence high-income farmers' decisions regarding the extent of crop diversification. They found that crops like maize, sorghum, and rice were heavily subsidized by the government, and this made about 60% of the farmers focus on these crops rather than exploring diversification options.

FBOs were found to be statistically significant at 1% but negatively associated with the probability of food crop farmers engaging in CD. The findings demonstrate that for every unit increase in FBO, a farmer's likelihood of determining the extent of CD decreases by 0.1930. This shows that these farmers relied on their intuition when faced with any form of challenge on their farms. The findings of the study agree with the study of Twumasi (2021), who pointed out that FBO is negatively related to the extent of CD when examining the optimization analysis of crop farm enterprises in the northern region of Ghana. Other variables, such as age, years of education, and household, are all statistically insignificant. This finding is consistent with previous studies such as Kassie et al. (2012), Meraner et al. (2015), and Larkai (2019).

Table 15: Tobit Regression Results on the Effect of Optimum Income on Crop Diversification

Variables	Coefficients	dy/dx	Std. Error	P. Values
Age	-0.0003	-0.0003	0.0007	0.7017
Extension Service	-0.3671	-0.3671	0.1108	0.0009***
FBO	-0.1930	-0.1930	0.0556	0.0005***
Land Size owned	0.0672	0.0672	0.0161	3.11e-05***
Years of Education	0.0003	0.0003	0.0008	0.7369
Household Size	-0.00031	-0.00031	0.0024	0.8954
Off-Farm Activities	-0.2150	-0.2150	0.0704	0.0023***
Access Credit	0.1415	0.1415	0.0159	< 2e-16***
Farming Experience	0.0082	0.0082	0.0047	0.0815*
Optimum Income	-0.0106	-0.0106	0.0028	0.0002***
Constant	0.9614	0.9614	0.0917	2e-16***
Model Summary				
Observation			398	
Wald – Statistics			269.2	
P – Value			< 2.22e-16	
Left - Censored			10	
Uncensored			388	
Right - Censored			0	
Log - Likelihood			398.1	
AIC			-772.1427	
BIC			-724.3657	
Pro > Chi2			0.000	

*** 1% Significance, ** 5% Significance, * 10% Significance

Source: Field Survey, Eshun (2023)

Chapter Summary

This chapter presented a detailed analysis of CD and farm optimization. The analyses started with the descriptive statistics of the farmers, which included their socio-demographic characteristics. The study further looked at the various crop enterprise patterns, the extent of CD, the results of optimal crop enterprise combinations, SA on resource constraints, and non-basic activity and its profit to the farmer. The last part of this chapter also looked at the effect of optimum income on the extent of CD among farmers.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This is the final chapter of the study. It presents the summary of the results and makes conclusions from its main findings. In addition, some recommendations were captured to relevant stakeholders to improve CD among smallholder food crop farmers for optimization analysis.

Summary

This study was guided by five (5) specific objectives to; find the various crop enterprise patterns operated by smallholder farmers (SHFs), analyse the extent of CD among SHFs, determine the optimal crop enterprise combination, perform SA on the resource constraints, analyse the non-basic activity and their profit to the farmer, and lastly, analyse the effect of optimum income on the extent of CD among SHFs in the Wassa East District in the Western Region of Ghana. The district is divided into four area councils: Wassa Ekutuase, Ateiku, Daboase, and Enyinabrem area councils, with 20 operational areas (farming communities). The different food crops grown among the farmers in the study area were cassava, plantains, maize, cocoyam, sweet potatoes, garden eggs, okro, and others. The study employed a quantitative research approach and a cross-sectional survey design. The target population of the study was all smallholder crop food farmers in the study area. The researcher sampled 398 crop food farmers in the district out of 74,818 farmers using the multi-stage sampling technique. The study used a structured interview schedule for data collection to address the objectives of the study. The collected data was analysed to address the objectives using descriptive statistics, the LP model, the CDI, and the Tobit regression model. The key findings of the study are outlined below.

Four crop combinations were largely practiced among the farmers in the study area. Food crops like cassava, plantains, maize, and sweet potato dominated the other food crops in the study area. The mean value of the extent of CD from CDI implies that multiple food crop combinations are practiced among the SHFs in the study area. The CDI was employed to find the extent and nature of crop diversification among the farmers in the study area, and the mean index value of 0.77 indicates that more of the smallholders in the research area participate in CD.

The existing plan for the farmer was to diversify into various crops, including 0.70 acreages of cassava, 0.80 acreages of plantains, 2.00 acreages of maize, 0.50 acreages of cocoyam, 0.50 acreages of sweet potatoes, 1.00 acreages of garden-eggs, and 0.50 acreages of okro, to realize an income of GH¢ 6567. According to the LP model results, the farmers were to diversify 3.31 acreages of cassava, 0.22 acreages of plantains, and 2.47 acreages of maize to achieve a maximum profit of GH¢12,927.9, which is significantly greater than the existing plan's projected profit of GH¢6567 of the farmer.

In the farmer's plan, the utilization of farm resources was maximized, as indicated by their levels of resource. The LP model was employed to rank resource limitations such as land, labour, capital, and fertilizer. This ranking aimed to identify the most limiting constraints faced by the farmer. The analysis showed that labour and land were the next most limiting factors, after capital. Again, comparing the GM of the three LP set-ups, including the first analysis, subsistence requirement, and sensitivity analysis, to that of the farmer's plan, it is evident that the LP model yields a greater GM than the smallholder's idea.

The SA was conducted to assess the stability of the model when subjected to shocks. The study focused on the three (3) limiting constraints: capital, land, and labour. These constraints were increased to observe their impact on the model. The results showed that when capital, land, and labour were increased, the optimum income also increased significantly from GH¢12,927.9 to GH¢14,180.9. This increase was higher compared to the farmer's initial plan.

The model provided alternative food crop combinations for farmers who may not want to diversify their optimal crops, which included cassava, plantains, and maize. These alternative combinations were found to reduce the farmer's optimum income or GM compared to the base model. However, they still satisfied the farmer's purpose of food subsistence and security, as well as other objectives of the farmer.

Using the Tobit model, the study found that land size, off-farm activities, access to credit, farming experience, FBO, extension service, and optimum income statistically influence the extent CD. The log-likelihood ratio of 398.1 was found to be statistically significant at 1%. The result further showed that an increase in optimum income leads to a decrease in the extent of CD. Moreover, variables such as household size, years of education, and age were found to be statistically insignificant to the extent of CD.

Conclusions

Based on the findings presented, it is concluded that farmers were faced with limited resources like capital, land, labour, and fertilizer, among other constraints, which made it difficult for them to know the correct combination to diversify to attain the goal of maximizing GM while at the same time satisfying their food subsistence and food security issues. The farmers mostly relied on their instinct, compared with their neighbours, or sometimes relied on previous experience, which does not guarantee optimum results and frequently leads to uncertainty when they resort to this traditional approach.

The study findings indicate that a significant number of farmers in the research area commonly practiced a four-crop combination. Specifically, crops like cassava, plantains, maize, and sweet potato were predominantly combined and cultivated by the farmers. The extent of CD was notably high at 0.77 among those focusing on food crops. The primary motivation behind this practice was to mitigate household food insecurity. By diversifying their crops, farmers aimed to ensure consistent food availability regardless of the prevailing weather conditions throughout the production season.

Comparing the farmer's existing plan and the cropping plan suggested by the LP model, the farmer should use the LP model's results, rather than using his instincts and consulting friends when making farm decisions. The LP model was found to be more efficient than the farmer's plan based on the GM realized; hence, by using the LP model, the farmer would earn more profit (GH¢12,927.9). According to the LP finding, the most limiting constraints in the study area were labour, land, and capital.

As a result of the SA, the study demonstrated that the model was resilient to variations in labour, capital, and land. Diversifying different food crops combinations such as sweet potatoes, cocoyam, okro, and garden eggs together with the optimal crops, that is, cassava, plantains, and maize will allow farmers to attain other purposes such as subsistence as well as food security issues.

Again, the estimated Tobit regression model revealed that land size owned, off-farm activities, extension service, FBO, access to credit, farming experience, and optimum income influenced the extent of crop diversification or otherwise. Thus, farmers can take advantage of large farm sizes to increase the number of crops grown and expand production to enjoy economies of scale. Moreover, through access to finance, more crops, farm inputs, and farm labour can be hired to expand the area of cultivation.

Recommendations

To guarantee stable income and food subsistence, farmers are advised to implement a CD system based on the study's findings and conclusions. To maximize profits, farmers should follow the optimum crop plan, which the LP model determined to be cassava, plantains, and maize. However, since farmers do not only produce to maximize profit and the results show a negative relationship between optimum income and the extent of CD, farmers should execute lower crop combinations that will cater to subsistence and income stability. The four crop combinations determined by the LP will be appropriate and should be encouraged among the farmers since it caters to both subsistence and income beyond the farmer’s plan.

Again, MOFA should educate farmers on CD strategies and practices to guarantee a steady supply of food in order to prevent food insecurity during the off-season. This can include planting a variety of crops, using conservation agriculture techniques, and implementing integrated pest management strategies. By adopting these measures, farmers can ensure a stable food supply throughout the year, even during the off-season.

The Agriculture Department of the local government, in collaboration with MoFA, should provide training to extension agents on how to use the LP model to assist farmers in solving resource allocation and CD challenges in the study area. This will enable extension officers to have access to important data such as input prices, output prices, and market prices, which are essential for farmers to maximize their income.

According to the study, the restricting constraint in the research area was capital, which was followed by land and labour. The SA conducted in the study demonstrated that a capital increase led to a corresponding increase in the optimum income of the farmers. Consequently, it is recommended that the government, along with other organizations and financial institutions such as microfinance and credit unions in the study area should provide credit in the form of capital to enable farmers to enhance their output and revenue, given that capital was identified as the most limiting constraint.

Finally, there is a need to increase the number of agricultural development banks and credit organizations in rural areas. This expansion will facilitate greater access to credit facilities for farmers, enabling them to purchase necessary farm equipment essential for improving efficiency and accelerating their work processes also the Department of Agriculture and NGOs in the area should implement programs that will ensure land reclamation among farmers to increase farmlands.

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APPENDIX

QUESTIONNAIRE

Introduction

This study is on crop diversification and farm optimization among smallholder farmers in Ghana. It is for partial fulfillment of an MPhil. Agric Economics Programmed. Therefore, any information given will only be used for educational purposes.

Consent Information: Please do you want to proceed in answering these questions?

Yes [ ] No [ ]

Community……………………..

Section A: Background of Respondents

1. Age at last birthday ……. in years

2. Sex of the respondent a. Male. [ ] b. Female [ ]

3. Education a. No school [ ] b. MSLC/JHS [ ] c. Primary school [ ] d. SHS/Technical/Vocational [ ] e. Tertiary [ ] f. others (specify) ……

4. Years of farming experiences……………………………

5. Marital status a. Married [ ] b. Widowed [ ] c. Single [ ] d. Separated [ ]

6. Religion a. Christianity [ ] b. Islam [ ] c. Traditionalist [ ] d. others (specify)………………………

7. Ethnicity a. Wassa [ ] b. Ahanta [ ] c. Fante [ ] d. other, specify………

8. Do you have access to credit? a. Yes [ ] b. No [ ]

9. If yes, where from the source?
a. Banks [ ] b. Family [ ] c. Friends [ ] d. others (specify) -------------

10. How many members are in your household?

Household size	**Male**	**Female**
Under 6 years		
Between 6-18 years		
Above 18 years		
Adult Males		
Adult Females		

11. Do you participate in any other activities aside farming?

    a. Yes [ ] b. No [ ]

12. If yes to Q11, how much income comes from this activity S? GHS………
13. Aside from farming, what other economic activity do you engage in?.........
14. What is your main economic activity?..
15. Do extension officers visit you on your farm in a production year?

    a. Yes [ ] b. No [ ]

16. if yes, how often do they visit in a production year?.......................... times
17. Are you a member of farmer-based group in the area? A. Yes [ ] B. No [ ]

SECTION B: PRODUCTION INFORMATION (Extent of Crop Diversification)

19. Land Ownership: What type of land ownership do you have?

    a. Own [ ]……… (Acres) b. Lease [ ]…... (Acres)

    c. Share Production [ ]…(Acres) d. Rented [ ]……(Acres)

20. Land size owned ……….. (Acre(s))
21. Land size Cultivated ………………… (Acre(s))
22. Land size rented----------------------------(Acres)
23. Amount paid for using rented land for production (GHS) ……………
24. Indicate in the table below crops you cultivate and farmland size used.

Crops Produced by the Farmer	**Response**		**Land Area Under Cultivation**
	Yes	**No**	**Acres**
Cassava			
Plantain			
Cocoyam			
Maize			
Sweet potatoes			
Garden-eggs			
Okro			
Others……..			

SECTION C: SOURCE of LABOUR and LABOUR REQUIREMENT

25. What is the primary labour source you use for your farming operations? Please specify……………………………………

Labour requirement for family labour

Crops Produced by the farmer	Number of labour		Hours per day	days per week	Cost per day	Amt per month
	family	rented				
Cassava						
Plantain						
Cocoyam						
Maize						
Sweet Potatoes						
Garden-eggs						
Okro						
Others						

26. Please indicate if you own or rent the following farming equipment and the costs incurred for ownership or renting.

Inputs	Owned		Rented		Qty Used	Cost	Date	Duration(year)	Scrape value (GHS)
Tractor	Yes	No	Yes	No					
Hand hoe	Yes	No	Yes	No					
Cutlass	Yes	No	Yes	No					
Knapsack Sprayer	Yes	No	Yes	No					
Watering Cane	Yes	No	Yes	No					
Others (Specify)									

SECTION D: TYPE of CROP COMBINATION PATTERN

27. What crop combinations and patterns do you mostly cultivate? Please tell us why.

Crop Mix Produced by the farmer	Justification (Reason)
1	
2	
3	
4	
5	
6	
Others(specify)	

28. Do you have farm records? A. Yes [ ] B. No [ ]
29. Why do you produce crops? a. Subsistence [ ] b. Commercial [ ]
    c. Both [ ] d. others(specify)……………………………………
30. Whom do you sell your produce to? a. Individuals [ ] b. Retailers [ ]
    c. Aggregate [ ] d. Processors [ ] e. others (specify) ………………
31. Where do you sell your produce? a. Farm gate [ ] b. Local Market [ ] c. District [ ] d. Others (specify) ………………...
32. What is the distance from your farm to the marketplace? ……………km
33. Is fertilizer applied to your farm? a. Yes [ ] b. No [ ]
34. Which varieties of fertilizer do you use?
    a. ………………………………………………..
    b. ………………………………………………..
    c. ………………………………………………..

35. How much did you spend during the most recent major season on fertilizer purchases and applications?

a. Quantity bought of each variety
    a. ………………………………………………..
    b. ………………………………………………..
    c. ………………………………………………..

b. Unit price of each type
    a. ………………………………………………..
    b. ………………………………………………..
    c. ………………………………………………..

c. Application cost …………………………………...cedi

36. Fertilizer needs for the production seasons and crop farming activities.

Crop Mix Produced	Quantity of Fertilizer Applied
Cassava	
Maize	
Plantain	
Sweet potatoes	
Cocoyam	
Garden-eggs	
Okro	
Other (Specify)	

37. What is your total capital available for your farming GHc ………………

38. Complete the table below by indicating the capital input to its production

Crops Produced	Amount of Capital (GHS)
Cassava	
Plantain	
Maize	
Cocoyam	
Sweet potatoes	
Garden-eggs	
Okro	
Others…….	

39. What were the profits and benefits for the previous production year?

Crops Produced	Amount Harvested (Bags/kg)	Amount Sold (Bags/Kg)	Amount Consumed (Bags/Kg)	Unit Price
Cassava				
Plantain				
Maize				
Cocoyam				
Sweet potatoes				
Garden-eggs				
Okro				
Others………..				

40. Please rank the numerous constraints for you as the farmer on a scale of (1-4), with 1 being the most pressing and 4 being the least pressing.

a. Land [ ] b. Fertilizer [ ] c. Labour [ ] d. Capital [ ]