UNIVERSITY OF CAPE COAST

FOOD CROP DIVERSIFICATION AND ECONOMIC EFFICIENCY OF SMALLHOLDER FARMERS: IMPLICATIONS FOR IMPROVING FOOD SECURITY IN OKERE DISTRICT IN THE EASTERN REGION, GHANA.

JACOB ADAM TAGOE

2022

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BY

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A thesis submitted to the Department of Agricultural Economics and Extension of the School of Agriculture, College of Agriculture and Natural Science, University of Cape Coast, in partial fulfillment of the requirements for the award of a Master of Philosophy Degree in Agricultural Economics

NOVEMBER 2022

DECLARATION

Candidate's Declaration

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

Candidate's Signature……………………………Date…………………

Name: Jacob Adam Tagoe

Supervisors' Declaration

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

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

Name: Prof. Henry De-Graft Acquah

Co-supervisor's Signature: ……….…………….. Date………………………

Name: Dr. Selorm Akaba

ABSTRACT

The purpose of the study was to analyse food crop diversification and economic efficiency, and their influences on household food security in the Okere District of the Eastern Region of Ghana. Primary data were collected from 330 food crop farming households using a structured interview schedule. The multistage sampling technique was employed to select 9 communities for the study. Several analytical tools including the Tobit model, binary logistic regression, Herfindahl index, data envelopment analyses, and endogenous treatment effect model were used. The findings revealed that plantain, cassava, and maize dominate in the study area more than the other crops. The mean value based on the extent of food crop diversification was 0.55. Again, the determinant of food crop diversification and economic efficiency showed that age, household size, extension service, access to credit, off-farm activities, land size owned, and experience of the farmer significantly influence food crop diversification and economic efficiency. Furthermore, the results from the household food insecurity scale pointed out that just a little over a quarter of the farmers were food secure whiles 74% were food insecure. Finally, the results revealed that food crop diversification and economic efficiency as well as socio-demographic factors influence household food security status. The study recommends that policies to promote food crop diversification should focus on encouraging farmers to increase the size of land cultivated. Mono-food crop farmers should be encouraged to engage in food crop diversification since this reduces household food insecurity. Finally, credit opportunities from banks should be made available for farmers to acquire inputs that will help them to save time and be more efficient in their food crop production.

KEYWORDS

Crop Diversification Index

Household Food Insecurity Access Scale

Food insecurity Prevalence

Allocative

Technical

Economic Efficiency

ACKNOWLEDGEMENTS

I am grateful to my supervisors, Prof. Henry De-Graft Acquah and Dr. Selorm Akaba. Again, I appreciate Dr. Dickson Emeriku, Mr. Augustine Koufie, and Mr. Selorm Omega for their guidance and their contributions that helped to put the work on track.

Prof. Samuel K.N. Dadzie and Dr. Emmanuel Wisgtos Inkoom of the Department of Agricultural Economics and Extension deserve my deepest gratitude for their expert counsel, suggestions, encouragement, and goodwill that helped me to complete this study.

Also, I would like to express my profound gratitude to the Ministry of Food and Agriculture, Eastern Region, specifically the Department of Food and Agriculture, Okere District for their support during my field work exercise.

Furthermore, my thanks also go to the farmers in the various communities who provided valuable data during the field work. Again, I am grateful to University Inter-denomination Church for their spiritual support.

I am extremely grateful to Carnegie Cooperation of New York through the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for funding me through Dr. Frank Kumi's Post-Doc Fellowship Award Project (RU/2020/Post Doc/06). I am also grateful to Samuel and Emelia Brew-Butler’s foundation for their immense financial support which enabled me to complete this work within the stipulated period.

DEDICATION

To my Parents, and University Inter-denomination Church.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

FS	Food Security
CD	Crop Diversification
EE	Economic Efficiency
TE	Technical Efficiency
AE	Allocative Efficiency
DEA	Data envelopment Analyse
HFIAS	Household Food Insecurity Access Score
FAO	Food and Agriculture Organization
WFP	World Food Program
SRID	Statistics Research and Information Directorate

CHAPTER ONE

INTRODUCTION

Overview

The chapter explains the backdrop of the study, its problem statement, its goal, its general and specific objectives, its research questions, and its significance. For the clarification of the scope of the research and any potential limits, the research's delimitations and restrictions are reiterated. The final section of the chapter provides an explanation of the key terms.

Background of the study

When attempting to fight poverty and encourage economic growth, the agriculture and food industry is essential to the Ghanaian economy. According to Badu-Gyan (2015), Agriculture promotes economic growth and the decrease of poverty in a nation by increasing the GDP and increasing the quality of life for a sizeable section of the population within the country. Over 60 percent of Ghana's working population can find employment and earn a living in this sector, especially in the country's rural areas. (World Bank, 2017). Undoubtedly, the agriculture sector of Ghana has now become a major contributor to the growth of the economy.

The agricultural sector employs 54.2 percent of the entire population, (GSS, 2013). This suggests that Ghana's agriculture sector contributes significantly to the country's economy. The majority of African countries are still far from meeting these conditions for a successful agricultural revolution, despite the fact that agriculture-led growth significantly reduced food and nutrition insecurity and transformed the economies of many African nations (Babatunde & Qaim, 2009). The primary features of agricultural production in

Ghana are risk and unpredictability (Ibrahim, Mensah, Alhassan, Adzawla & Adjei-Mensah, 2019). Smallholder farmers face numerous difficulties, such as climate change, poor soil fertility, water scarcity, a dysfunctional input-output market, inadequate extension services, and bad policies (Thierfelder, Cheesman & Rusinamhodzi, 2013). Consequently, numerous rural households are facing financial hardships caused by dwindling agricultural output, insecurity regarding food and nutrition, and fluctuations in income. The biggest factor affecting the livelihoods of smallholder farmers is food and nutrition insecurity. To avert these challenges, the majority of smallholder farmers often partake in a variety of income-generating activities., including food crop diversification,

A study conducted by Thornton and Herrero (2015) noted that the crop diversification pattern happens to be a crucial component in farming activities since it promotes livelihood and food security opportunities for millions of individuals. The research by Herrero et al. (2009) also shows that crop diversification account for nearly 50 percent of world food. Precisely, in terms of cereals, about 74 percent of millet, 66 percent of sorghum, 86 percent of rice, and 41 percent of maize production are consumed globally. With the increasing population and reduction of farmland, crop diversification is central to ensuring food security (Herrero et al., 2010).

The Eastern part of Ghana has been driven by agricultural growth and predominantly small-scale farmers who grow both food and commercial crops (MoFA, 2015). The Region is the second top producer of maize and a top producer of cassava. Both crops are stapled food in Ghana and are mostly cultivated by smallholder farmers. Despite its gains in this sector, the country still records low productivity which results in food insecurity (Nkegbe & Issahaku, 2017).

The Okere District is known for cultivating food crops in the Eastern Region of Ghana where the majority of the food crop production is done by smallholder farmers. Again, the production of these farmers continues to face a lot of challenges such as low soil fertility, climate change, resource allocation, and others which hamper agricultural production as well as lead to underproduction (Al-Hassan, et al., 2019). Consequently, numerous rural households are facing financial hardships caused by dwindling agricultural output, insecurity regarding food and nutrition, and fluctuations in income. When faced with these challenges, these farmers occasionally depend upon their intuition or evaluate themselves against their neighbours, which does not guarantee the best outcome and frequently results in losses and inefficiency in production (Ibrahim et al., 2019). This reduces their productivity, hinders them from making the most profit, and harms their growth rate (Sibiko, 2016). As a result, crop diversity and economic efficiency can help farmers avoid food insecurity. As a result, it is regarded as an essential approach for dealing with the majority of crises that agricultural households in developing nations encounter.

Statement of the problem

Smallholder farmers in Ghana who cultivate at least one hectare of food and cash crops predominate the agricultural sector (MoFA, 2015). The majority of these farmers relied on small-scale farming systems as the primary source of their livelihoods. This farmers' production is reliant on rainfall and the natural soil's intrinsic fertility, resulting in low productivity which becomes a challenge to these farmers (FAO, 2011). In Ghana, the majority of smallholder farmers plant food crops for their own consumption, with a focus on staple foods (Baba & Abdulai, 2021).

The Eastern Region of Ghana plays a substantial role in supplying the nation's food requirements, primarily driven by small-scale farmers. Their efforts not only support urban areas with food but also contribute to the country's overall food balance sheet, reducing the need for food imports. According to Tinonin et al. (2016), despite the fact that smallholder farmers account for the majority of agricultural output, they also have high rates of poverty, nutritional deficiency, and food insecurity all of which continue to impede human development (World Food Programme, 2012).

According to the World Food Programme (2012), Ghana has made significant progress in terms of food security in recent years. However, there remains a significant disparity in development issues among smallholder farmers across the country. Most of this farmer leaves in rural areas confirming the widely held belief that farmers who leave in the rural area are resource-poor people and are vulnerable to food insecurity and malnutrition from time to time (Moyo & Masika, 2009; Pannell et al., 2019). Due to an ongoing intensification in the production of uniform staple foods that lack nutritional value and a reduction in crop diversity among rural farmers, there is a prevalent issue of high malnutrition rates and food insecurity. (Pritchard, Ortiz & Shekar, 2016; Khoury et al., 2014). Despite rural farmers' commitment to staple food production, the majority of households continue to be net purchasers of staple foods, when farmers are disadvantaged by unfavorable market and commercialized exchange systems and forced to sell farm products at a loss while they are in abundance, and buying it at a higher price when it is scarce or the harvest is over.

According to the World Food Programme (2012), smallholders purchased roughly 65 percent of the food they consumed in 2012 with cash. Why are the people who produce the majority of the nation's food also at the forefront of conversations about finding solutions for food security? Hence, there exists a baffling dichotomy between crop production and food insecurity among smallholder food crop farmers. Thus, the farmers who are responsible for producing larger quantities of the nation's food are also the same ones facing significant food security challenges (Baba & Abdulai, 2021). However, crop diversification, as part of climate-smart agriculture, has been suggested to smallholder farmers in an attempt to hedge against food insecurity.

According to Asante, Rene, George, and Lan (2017), Most smallholder farmers employ crop diversification as a means of ensuring household food security since it spreads the risk of a specific crop failing. As a result, weather conditions that are viewed as unfavourable for one crop and have a negative impact on that crop's output may be ideal for other crops that will produce effectively (Baba & Abdulai, 2021). Additionally, Koufi (2017) claimed that although there are significant obstacles to implementing agricultural methods, crop diversity and crop combination surge the efficiency of food crop production. Hence, smallholder farmers can obtain some yields that would provide food security by mixing a diversity of crops on a specific plot of land with the aid of economic efficiency.

However, considering food crop production, the Okere district’s contribution towards the national food basket (example plantain, yam, maize and vegetables) cannot be underestimated. According to MoFA (2015), the district is recognized as one of the predominant areas when it comes to food crop production with smallholder farmers spearheading production activities. These farmers frequently find themselves trapped in a cycle of insufficient savings, minimal investments, and meagre earnings. Consequently, their levels of production and productivity remain low, rendering these farmers susceptible to periodic episodes of food insecurity. According to Djangmah (2016), inefficient agricultural practices and drought have been the main causes of these farmers' poor productivity. Due to the unstable nature of agricultural production, this makes the farmers vulnerable to economic shocks, natural disasters, and food insecurity from time to time.

Crop diversification is one of the climatic agriculture approaches that attempt to increase output and enhance soil fertility, according to Baba and Abdulai (2021). Crop diversity increases farmers' resilience to weather volatility in the present climate of climate change. Furthermore, Larkai, (2019) also pointed crop diversification is noted to be a key strategy to hedge against production risk and with economic efficiency ensuring efficient use of available resources which make enough food available

Despite a large body of literature reviewed on crop diversification, limited study has been conducted in the Eastern Region. Most of the research conducted such as Aneani et al. (2011); Asante et al. (2017); Zakaria et al. (2019); Nyamekye, (2016); Ntrie, (2016) and Baba et al. (2021) only focused on the determinants of farm diversification in integrated crop-livestock farming systems. Akrasi al et. (2020) also focused on strategies for income diversification and household food security among Ghanaian farmers.

However, Baba and Abdulai (2021) studied crop diversification and its effects on household food security without looking at crop diversification and economic efficiency of smallholder farmers: implication for improving household food security in the Okere District of the Eastern Region.

Purpose of the study

The purpose of the study is to analyse the effects of food crop diversification and economic efficiency of smallholder farmers on household food security in the Okere District of the Eastern Region of Ghana

Objective of the study

1. To evaluate the determinants of food crop diversification among smallholder farmers.
2. To evaluate the determinants of economic efficiency among smallholder farmers in the district.
3. To determine the prevalence of food insecurity among smallholder farmers.
4. To examine the effect of crop diversification and economic efficiency on food security.

Research questions

1. What are the determinants of crop diversification among smallholder farmers?
2. How efficient are the smallholder farmers in the Okere District?
3. What is the prevalence of food insecurity among smallholder farmers in the area of study?
4. What is the effect of crop diversification and economic efficiency on food security among the farmers in the study area?

Significance of the study

Despite potential risks from low soil fertility and climate change, crop diversity is a potent strategy that will provide farmers with the productivity they need. This research is significant because it will help the farmers to cope with other crop failures whiles maintaining the harvest of other crops at the same time. This will allow farmers to maximize profits irrespective of climate variability, seasonality of some crops, and failures of other crops.

The findings of this research are relevant to guide smallholder farmers on how to farm to increase their income level despite the risk and uncertainty associated with agricultural activities. This is also in line with the sustainable development goals that deal with the eradication of extreme poverty and hunger, which is of fundamental importance to achieving the other goals.

Furthermore, the result from this study may be useful in decision-making and policy planning purposes by the Ministry of Food and Agriculture, and other relevant departments and stakeholder organizations in the country. Research institutions and Universities among others may also get valuable information from the study. This study will also provide information upon which the existing agricultural policies could be reviewed.

Finally, this study provides important value by investigating the variables that affect farmers' decisions to vary their food crop production. It also complements other studies on crop diversification. Therefore, because it complements earlier research, conducting this study is worthwhile.

Delimitation

The study focused on food crop diversification, economic efficiency, and food security in the Okere District of the Eastern Region of Ghana. The study addressed specific objectives such as the extent of crop diversification, prevalence of food security, economic efficiency, and determinants of household food security. In this research, a cross-sectional method was employed. Additional analytical methods, descriptive statistics, data envelope analysis, logistic models, and Tobit models were used. Furthermore, to ensure a targeted sample for the study, the district's food crop growers and had registered formally with the Department of Agriculture were the only participants in the study.

Limitations of the study

A sizable portion of farmers did not keep track of their farming activities, which made it difficult to calculate the output for the previous producing season. Additionally, the study ignored the issue of mobility, particularly the researcher's and their team's use of motorbikes to go to other areas. Additionally, the vast scope of data collection, together with the related financial considerations and time constraints, significantly increased how long the researcher and their team had to collect the data.

Operational definition of terms

Crop diversification: utilizing the same plot of land or space for more than one food crop. For example, growing cassava, maize, plantain, and other food crop on the same area or land.

Economic efficiency: An environment where all resources are effectively managed to best benefit each individual or institution while minimizing waste and inefficiency is referred to as being economically efficient.

Food security: The term exists when people have reliable physical and financial accessibility to an adequate source of safe and nutritious food that satisfies their dietary requirements and preferences, empowering them to lead active and healthy lives.

Smallholder Farmers: These are those farmers who mostly cultivate food crops on a limited scale of land. Thus, less than 5 ha.

Food crops: These are subsistence crops that are meant for human consumption**.** An example is cassava, yam, maize plantain, and vegetable cocoyam among others

Organization of the study

This study has five sections that made up its structure. The study's background, problem statement, goals, and questions, as well as its significance, delimitations, and limitations, as well as its organization, were all covered in Chapter one.

The importance of performing a literature review was highlighted in Chapter two of the study, providing additional insight into the research findings of other writers that were pertinent to the subject at hand. In Chapter three, the study methodologies were examined, including the research design, sample techniques, target farmers, data collection tools and techniques.

Chapter Four of the study was dedicated to presenting the results and facilitating a comprehensive discussion of the findings. The concluding chapter encompassed the summary, conclusions, and recommendations derived from the study's outcomes.

CHAPTER TWO

LITERATURE REVIEW

THE GENERAL OVERVIEW

The literature review of this chapter first starts by looking at the theory and conceptual framework in relation to the study. It also focused on existing work in relation to crop diversification, economic efficiency and household food security.

THE THEORETICAL STRUCTURE OF THE STUDY

Theory of Choice

The choice theory is relevant to this research. It is a part of economics' decision theory, which is concerned with determining the values, uncertainties, and other factors that are pertinent to a particular decision, its rationality, and the ensuing best course of action. Wanyama et al. (2010) stated that choice can be formed within frameworks that explain distinctive choice behaviour. The decision to select a particular business is a behavioural reaction brought on by a variety of options and limitations the decision maker must consider. Most decisions in choice theory are either normative or prescriptive, meaning they aim to govern the optimum course of action under the assumption of a perfect decision Originally developed for use in finance, the MPT is currently used to agricultural sciences to select the best crop combinations for a portfolio under uncertain conditions (Markowitz, 2010, 1952). the essential premise of this theory is that if the yields of two crops are not fully connected, mixing them in a portfolio, which corresponds to the same land use, reduces the risk of agricultural production.

Given the risks and uncertainties involved in agricultural output, this theory is quite useful. When selecting a choice, a person considers the usefulness of two options, thus is the one that will yield the higher satisfaction, in this case, diversification or otherwise and selects the best alternative that results in the highest level of satisfaction. Thus, a farmer will be willing to diversify if the level of utility he can obtain with diversification is higher than otherwise.

Agricultural performance in Ghana

Ghana's GDP from agriculture decreased from 10264.10 million Ghana cedi in the first quarter of 2022 to 8366.50 GHS million in the second quarter (GSS, 2021). According to Chamberlin (2008), about half contribution in term of providing livelihood for the country's poorest households cannot be underrated. Low yields for both cash and staple crops define the industry. The main crops are divided into industrial and cash crops (kola, oil palm, cotton, soya bean, coconut, cocoa, rubber, cashew, shea, and coffee) and starchy staples encompassing cereals and legumes (yam, plantain, yam, cocoyam, cassava, groundnut, rice, cowpea, sorghum, millet, and maize).

Ghana's economy has always been dominated by its agricultural sector. However, the contribution of agriculture to GDP has fluctuated recently. Between 2008 and 2015, the country's average annual agricultural growth rate was roughly 4.3%, which is less than the anticipated growth rate and the Maputo target of 7% (MoFA, 2015). Azumah, Donkoh, and Awuni (2018) estimate that agriculture's contribution to GDP in 2017 was 19.8

percent, up from the 19.4 percent reported in 2016. Agriculture was the most significant economic sector in the nation from 2008 to 2018.

Despite the forward tendency in the sector's performance, low productivity is a result of both internal and external issues. For instance, governmental spending on agriculture has been decreasing and is below the Maputo Declaration's 10 percent target. Due to the low productivity of the industry, Ghana now imports a net number of staple items like rice, chicken, sugar, and vegetable oils. The country's anticipated 2 billion dollars in yearly cocoa export revenue is now exceeded by the cost of food imports (MoFA, 2015). The country's employment, income, and security of food and nutrition are seriously impacted by the ongoing decline in agricultural productivity, particularly in the majority of rural communities that are dominated by smallholder farmers.

Policy on crop diversification

The government has long identified agricultural diversification in the form of non-traditional export crops as a key strategy to boost and stabilize export revenues for long-term economic growth. The risk associated with the over-concentration of conventional export commodities like cocoa and forestry was intended to be avoided. This risk included global price swings, weather, crop pests, and illnesses. Established in 1969 by the Ghanaian government focuses on developing and promoting exports in the country.

Ghana Cocoa Board (COCOBOD) expressed the need for cocoa farmers to expand their domestic income funds considering the government's agricultural diversification policy. The study drew on data from the baseline survey on cocoa farmers' production techniques from the Ghana Cocoa Farmers' Newspaper Project, which was authorized by the Cocoa Research Institute of Ghana in partnership with Cadbury & Fry Ltd.

Smallholder farming in Ghana

On small plots of land, smallholder farmers frequently cultivate one or two cash crops in addition to one or two crops for subsistence, employing almost entirely family labour. Smallholder farmers' production systems typically feature primitive, outmoded technologies, severe periodic labour variation, low returns, and a substantial role for women in production. Personal characteristics, land size cultivated, smallholder farmers can be distinguished by various factors such as their resource allocation choices among food and cash crops, animals, and off-farm investments, utilization of hired labour and inputs, the proportion of food crops sold, and patterns of household expenses.

Why diversification by Household

Diversification serves a variety of purposes for households. According to Ellis, (1998) agriculture's seasonality, diversified workforce markets, risk tactics, coping behaviour, lack of credit opportunities, and intertemporal investment and savings policies are some of the main determinants. All these are incentives that motivate households to diversify. In the literature, pull and push factors are widely investigated in conjunction with incentive variables.

In rural non-farm activities, higher payoffs, or lower risk (given risk preferences) are examples of pull variables (Reardon, Berdeque, Barrett & 2007). Farm households may be able to save money with higher returns from a non-farm activity which they can then reinvest in farming (tools and equipment, as well as modern technology), so increasing farm earnings even more. As a result of synergy between agricultural and non-farm operations, pull factors may emerge.

Reardon et al. (2007) reported that households engage in "risk management measures," which include selecting income diversification options that allow for income smoothing across time. In addition, poorer farmers are frequently forced to diversify into events with a low positive correlation with agricultural returns, reflecting a preference for low-risk activities even if they pay less. Permanent (or inter-year) drop or chronic inefficiency of farming income due to physical (such as environmental degradation, chronic rainfall deficits, and disease) or market/policy reasons, credit, or insurance market failures, are among the push factors. Seasonal drops in farming income to levels insufficient for off-season survival, and permanent (or inter-year) drops in, or chronic insufficiency of, farming income are other push factors (Reardon et al., 2007).

Concept of food crop diversification

According to Ojo and Anitsal (2015), the concept of crop diversification can be expressed in a diverse way to diverse individuals at diverse stages. Anderzen et al. (2020) define diversification as an activity whereby rural homes build up a variety of occupations and several assets to exist and improve their living standards. Diversification of crops can be defined as the reallocation of resources, especially cultivated land at the disposal of farmers to accommodate a more varied cropping pattern (Mandal & Bezbaruah, 2013). Two types of diversification are identified by Evans and Ngau (1991) in the same study: farm diversification (crop diversity) and farm income diversification (diversification of activities). Farm diversification involves a variety of agricultural activities situated inside the farm while modification of activities involves revenue diversification generated from different activities carried out within and external to the farm. Crop diversification involves the production of different crops or different species in an area rotationally and or by intercropping (Mwangagi, 2021). This study will focus on food crop diversification.

To boost crop productivity in various circumstances, crop diversification may be helpful. Multiple crop combination can be achieved in two different ways. The primary method and most prevalent idea in horizontal diversification are the introduction of new crops to the current cropping system. Crop diversification refers to the extension or adding various crops into the current cropping system utilizing strategies similar to multiple-cropping techniques in conjunction with other efficient management measures. Observations suggest that the potential for food production can be increased by using several cropping systems. Therefore, agricultural diversity is thought to reflect the financial benefits of various crops. Therefore, the idea of a crop variety is essential to maximizing crop profit.

For this study, term means growing of more than one food crops on the same pieces of land.

The concept of food security

At the World Food Conference in 1974, the phrase was first used. Since that time, it has gained widespread interest across the globe. A lot of organizations and researchers have made an effort to define the phrase. The meaning of food security was categorized into thirteen groups (Maxwell, 1995). The World Bank's version, however, presented in 1986, became a generally recognized meaning of the phrase. " The meaning of "food security" according to Oke (2015) is "access by all individuals at all times to adequate food for an active and healthy life.".

This concept examines food security in terms of the use of food for a healthy existence, as well as the accessibility and availability of food. According to FAO, dietary options and nutritional value in the World Bank's concept of food security. Food security is " a situation where all individuals, at all times, has financial and physical access to enough food that is nutritious, safe, and meets their nutritional wants and food selections for a healthy, active life "(Peng & Berry 2019). Pinstrup-Anderson (2009) asserted that the addition of "safe and nutritious" emphasizes the significance of these components, while include "food preferences" expands the concept of "food security" to including more than just having access to adequate food. On the other hand, according to the Ministry of Food and Agriculture (MOFA), "good quality nutritious food hygienically prepared and packaged, attractively presented, available in sufficient quantities all year round, located at the right place at affordable prices" was the working definition of food security in Ghana as of 2007.

Until this idea was altered in the middle of the 1970s, food security was historically assumed to mean a satisfactory amount of food solely nationwide. This study solely takes into account aspects related to food production and ignored several crucial components, such as distribution and affordability, that have a significant impact on people's access to food. Nevertheless, data indicate that during the last two decades, world-wide food supply has improved (Quaye & Luzadis, 2010). However, Quaye et al. (2010) revealed that Africa's agriculture output growth, has fallen short of overpopulation, and a sizable percentage of the increase in output was brought on by larger cereal farms rather than better land use efficiency

In 2013, the agricultural industry expanded at a pace of 5.2 percent, which was higher than the 2.3 percent increase seen in 2012, in a report by GSS on the nation's GDP from 2014. However, the sector's contribution to the economy as a whole shrank, with its percentage of GDP falling from 23% in 2012 to 22% in 2013. However, MOFEP (2015) asserted that due to inadequate government investment, the agriculture sector's growth status is not improving, with a 0.04 % increase forecast for 2016 instead.

This implies that having an ample food supply at the national level does not translate into food security at the household level. Similarly, abundant food availability on the international scale does not necessarily ensure food security at the regional and local levels. The research conducted by the United Nations Development Programme (UNDP) in 1992 revealed that people worldwide were able to meet 110 percent of their daily caloric requirements in 1990. However, according to UNDP, (1992) during that same timeframe, acute hunger struck more than 150 million individuals, and beyond 25 percent of people worldwide experienced food insecurity. Despite recent increases in food production, critical issues like hunger, malnutrition, and food insecurity continue to be at the top of the global agenda (Barrett, 2002).

Individuals or groups of people may be said to experience food insecurity if they are lacking some components included in FAO's explanation of food security from 1996. Stable food supply and food nutrition safety have been introduced as dimensions of the idea of food security by MOFA and USAID in their definitions. Food availability, accessibility, use, supply stability with the last been dietary security are the five facets of food security covered by (Jrad et al., 2010).

Food availability

According to Gregory et al. (2005) the term means producing enough food on one's farm, purchasing it from a local market, or importing it from another country to ensure that there is sufficient or enough food available and adequate.

Food accessibility

This connotes alleviation and a decrease in food poverty. Everyone must have the means to purchase enough, healthful, and safe food, and the food must be made available at the appropriate time and location. " Physical and financial resources, as well as social and political factors, all influence people's ability to access food," claim Kuwornu et al. in 2011. In other words, simply making food accessible does not suffice unless low-income individuals and households can do so.

Food utilization

This means making sure the body's processes utilize the nutrients in the diet as effectively as possible. To maintain good health and normal growth, UNDP (1995) defined food usage as the consumption and absorption of adequate and healthy food. According to Demi and Kuwornu (2013), "Food utilization is served by the correct genetic use of food, which calls for a diet that is high in energy and essential nutrients for growth, as well as having understanding of food preparation, storage, and basic nutrition."

Food security in Ghana

According to Wolter, (2009), food security continues to be a major issue in Ghana and may be viewed from two different angles, with the food crop sector's supply being steady, which greatly increases food insecurity, and rising exports of horticulture products.

The 1983 West African drought, which resulted in a severe food shortage and forced people to rely on a variety of materials for survival, had a significant impact on Ghana. Kuwornu et al. (2013) revealed that during this time, unripe bananas, cocoyam comb, and bamboo rhizome foods which are often not included in Ghanaian cuisine, were used in place of plantains. Based on the WFP's 2009 report by Biederlack and Rivers, approximately 1.2 million Ghanaians (approximately 6 percent with the population) still face limited access to sufficient and nourishing food. Among these 1.2 million individuals, around 55% belong to households primarily engaged in activities such as farming activities, agro-pastoralist work, food processing, or unskilled labor. Biederlack and Rivers (2009) identified agriculture dependency, illiteracy, limited access to markets, and poverty as the key factors contributing to food insecurity in these households.

GSS (2008) pointed out that 18.2 percent of Ghanaians were chronically food insecure and lived below the extreme poverty limit. WFP (2009) indicate that in Ghana, malnutrition still accounts for roughly twenty-two percent of children who are too short for their age (stunted) and seven percent for children who are too thin for their height, making it an unacceptable problem among children under five and females of reproductive age.

Food insecurity is related to ineffective agricultural methods, limited access to extension services, and inadequate input supply (Change, 2016). According to MoFA's 2007 report, various policies have been implemented in Ghana in order to enhance food security. (Examples of these developmental strategies encompass projects that utilize accelerated agricultural growth and development methodologies. Acheampong's government's "Operation Feed Yourself" subsidies the price of fertilizers, the recent planting for food and job initiative, and the distribution of domestic animals to particular farmers to act as out growers are important among these programs.

The interventions, while worthwhile, faced several obstacles. Taking the fertilizer subsidy as an example, it frequently arrives in periods when farmers have planted their crops, making it less useful to the crops. The selection of committees has been a major setback to these initiatives by the government. Due to this, political allies receive farm resources at the expense of dedicated and seasoned farmers. The programs are now less effective as a result. Moreover, most of these farmers lack finances, and most of our time depend on the government for farm resources. Due to lack of funds, these farmers are not able to invest in their farming activities in other to even practice multiple crop combinations which will safely guard them against food security from time to time.

Analytical Framework

Herfindahl Index

Crop diversification among smallholder farmers was assessed using the Crop Diversification Index (CDI), also known as the Transformed Herfindahl Index (THI). The THI is obtained by subtracting one from the Herfindahl Index, which is computed by summing the squares of the acreage proportions of each crop in the total cultivated area (Ojo et al., 2014). The expression mathematical representation of the model is presented below;

$$HI = \sum_{k=0}^{n} (p_i^2) \text{ ....} \qquad (2.0)$$

This concentration indicator establishes a clear relationship between specialization and diversification, where a value of zero indicates high specialization, and a value approaching one signifies increasing levels of diversification. Thus, the Crop Diversification Index (CDI) can be expressed mathematically as follows;

$$CDI = 1 - \sum_{k=0}^{n} (p_i^2) \text{ ....} \qquad (2.1)$$

Where:

N = the total number of crops, (unknown)

Pi = area proportion of the i th crop in the total cropped area;

The Tobit Model

The Tobit model is any of a class of regression models where the dependent variable's 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 OLS will outcome in skewed and inconsistent parameter estimations, using the Tobit model makes sense. As more observations have a value of 0, the bias will likewise become more pronounced. The following can be said of the Tobit model (Tobin 1958). The general formula for the Tobit model;

$Y_i^* = (y_i^*$ if $y_i^* > 0$ or 0 if $y_i^* \leq 0)$

Where

$Y_i^* = \beta X_i + e_i$ …………………………………………… (2.2)

Y_i^*= dependent variable

X_i = independent variable

B= the vector of unknown parameters

e_i = the error term

Measurement of efficiency

To produce an output, a production process uses a variety of inputs. Example, inputs such as land, labor, and working capital are needed to produce Maize. Such a production efficiency analysis needs a methodology that takes into account each of the required resources. Farrell (1957) first stated that the efficiency of a decision-making unit (a corporation, or farm) might be divided into technical efficiency and allocative efficiency, which led to the development of efficiency measures that take into account various inputs. Technical efficiency shows how well a company can produce the most amount possible from a given set of resources. The capacity of the company to utilize the inputs in the best possible proportions, given their separate pricing and production technique, is demonstrated by the concept of allocative efficiency. According to Diewert (1982), the total cost of economic efficiency is then determined by combining technical efficiency with allocative efficiency. Economic efficiency is thus described as a company's ability to generate a specific amount of product at the lowest possible cost for a particular degree of technology.

Coeli et al. (1998) noted that the minimization of input and the maximizing of output are the two basic goals of efficiency measurement. These objectives are commonly known as input-oriented and output-oriented metrics. The input-oriented perspective determines the extent to which input quantities can be proportionally reduced without affecting the overall output. Conversely, the output-oriented method seeks to examines the potential for proportional increases in output quantities without changing the input quantities used. The output strategy focuses on maximizing input utilization to maximize output, while the input approach focuses on optimizing output by managing production inputs. Since farmers have greater control over managing production inputs compared to output, the research adopted the input-oriented approach to analyze efficiency.

Farrell (1957) emphasized the need to derive the production function from sample data for efficiency measurement, this could be done using either non-parametric or parametric methods. Aigner et al. (1977) specified the use of a stochastic frontier production function with a random error term in the parametric method. In the non-parametric method, Coeli et al. (1998)

explained the generation of a piece-wise linear convex isoquant over the data, ensuring that no observed point lies below or to the left of it. Then efficiency metrics are calculated concerning this surface. Mathematical programming techniques were eventually used to create the data envelopment analysis technique (DEA) (Boles 1966; Afriat 1972).

Data Envelope Analyse (DEA)

An efficiency study has also been performed using the DEA. In this analysis, determining a suitable benchmark is necessary for efficiency assessment. This frontier is defined as all the decision-making units (DMUs) in the sample set using actual observations. The efficient companies in the set are provided by the border as a standard by which to compare the performance of other DMUs. The effectiveness of a DMU is evaluated by contrasting its performance with other DMUs situated along the frontier. Moesen and Person (2002) asserted that Input efficiency is determined along a ray that crosses through the origin since the frontier cuts through the efficient observations. An observation's distance from the frontier provides information about its efficiency or inefficiency, with more efficient observations being positioned closer to the frontier than less efficient ones. As a result, data envelopment analysis specifies the highest levels of output that a decision-making unit is capable of realizing from a particular input mix. As an alternative, it provides the minimal amounts of inputs needed to generate a particular level of output.

DEA is calculated as the ratio of the total weighted inputs to the total weighted outputs. Charne et al. (1978) suggested an input-oriented DEA model to assess the relative effectiveness of DMU:

$$Max = \frac{\sum_{k=1}^{s} v_k y_{kp}}{\sum_{j=1}^{m} u_j x_{jp}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

$$\sum_{k=1}^{s} v_k y_{ki} \Big/ \sum_{j=1}^{m} u_j x_{ji} \leq 1 \forall_i \; \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

Where;

K=1 to s, j=1 to m,

$$\text{Max} \sum_{k=l}^{s} v_k y_{kp} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.5)$$

$$s.t \sum_{k=1}^{s} v_k y_{ki} - \sum_{j=1}^{m} n_j x_{ji} \leq 0 \ldots\ldots\ldots\ldots\ldots \quad (2.6)$$

$$\sum_{j=1}^{m} n_j x_{jp} - 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.7)$$

$$v_k, n_j \geq 0$$

Logistic regression model

In this work, different unique models have been employed to forecast and analyse this kind of data. The most straightforward and well-known probabilistic decision model in the area of discrete choice models is the logit model (Zakir, 2009). This model is categorized as a generalized linear model (GLM) since it uses binomial regression with a binary dependent variable. The logistic model used by Djangmah, (2016) and Osman, (2016) was specify;

$$P_i = F(Z_i) = \frac{1}{1+e^{-(\alpha + \sum \beta_i + X_i)}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.8)$$

where P_i denote the probability of success given X_i, where X_i represent the explanatory variables, α *and* β_i estimateable parameters, and e is the natural logarithm's base.

The logit model can be stated as a log odds ratio to offer a concise and condensed understanding of the coefficients. The likelihood of failure is represented by the log odds ratio (1-P_i)

Therefore,

$$(1 - P_i) = \frac{P_i}{(1-P_i)} = e^{Z_i} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.9)$$

For a linear representation;

$$In\left(\frac{P_i}{(1-P_i)}\right) = Z_i = \alpha + \beta_i X_i + \beta_2 X_2 + \beta_k X_k \ldots\ldots\ldots\ldots \quad (2.10)$$

Adding the error term to the equation, the logit model becomes;

$$Z_i = \alpha + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.11)$$

Measurement of food security status

There are several methods for determining the extent of household food insecurity. "However, Aiga and Dhur (2006) pointed out that there is no one way for determining the degree of food security. Several methods are employed for evaluating the degree of food security, including the cost-of-calorie approach (COC), the food security index approach (FSI), the household dietary diversity score approach (HDDS), the household food consumption score approach (HFCS), and the household food insecurity access score (HFIAS).

Dietary diversity

The population of interest should be decided upon before the data collection process begins, following FAO's recommendations for evaluating household dietary diversity. because it aids in customizing the data collection tool to the specifics of the local survey (Sichoongwe, et al., 2014). Data on dietary diversity can be gathered from homes or individuals using a data collection method. The survey's aim and objectives will determine how information is collected. Assessing household dietary diversity is the recommended course of action if the survey's goal is to determine nutrition (Coates et al., 2007). To calculate the dietary diversity score, the number of different food categories ingested over the preceding seven days is added (DDS). (Rathnayake et al., 2012). The result varies between 0 to 12, where a lower DDS number indicates greater food insecurity and a higher one indicates the reverse. Despite the fact that there isn't a consensus on the food groups that should be included in the scores, the DDS specifies 12 of them (Vickers, 2017).

The calorie intake approach

Greer and Thorbecke (1986) stated that the calorie intake method is the most typical and extensively applied method for determining one's level of daily calorie intake. The method is employed to determine the minimum level of calories required for human existence. The "food security line" is the term used to describe this threshold. According to the estimation, a household is considered to be in a state of food security if the mean value of its daily caloric intake is equal to or higher than the required minimum. In contrast, if the average daily cost of calorie intake for the family is less than this amount, it is considered to be food insecure. In order to account for adult equivalents using consumption factors that take into consideration age and sex categories, the projected calorie provision for each home is divided by the number of occupants.

Household food insecurity access score (HFIAS)

The HFIAS acts as an ongoing indicator of how much access a household had to food during the previous 30 days. According to Ballard et al. (2013), the HFIAS includes three essential characteristics of household food insecurity: anxiety about food security, a lack of food of sufficient quality, and a lack of sufficient quantity. Regardless of the nutritional value of the household's food, this measure captures that view (Deitchler et al., 2011). The hypothesis that households' experiences with food insecurity induce predictable behaviours and emotions is supported. A survey will be used to monitor and evaluate these responses, and the results will be combined to produce a score. A household with a high HFIAS score indicates a heightened degree of food insecurity, whereas a low score suggests a relatively lower level of food insecurity.

However, The GSS and FAO's support for the household food insecurity access score (HFIAS), underlining its acceptance, led to its selection for this study. The HFIAS shows a significant ability to recognize many facets of food insecurity, such as reduced access to acceptable quantities or quality of food, as well as the psychological and social repercussions of stress and uncertainty related to food access. These elements may negatively affect one's health and wellbeing. HFIAS has also been proven to be adaptable and simple to understand within different of environments, including both urban and rural ones (Nordberg, et al., 2020). Finally, it is brief and simple to incorporate as a module into other household surveys. The HFIAS is very easy to use to measure household food security status than the calorie intake which may be inconsistent. It was also easy to compute and user-friendly. Finally, it is understandable and easy to interpreter.

EMPIRICAL REVIEW

Determinant of crop diversification

Kumar and Sharma (2012) while studying the status and determinants of crop diversification in Eastern India, they pointed out that credit access, operation area, household size, age, farm assets, educational level, and infrastructure are the factors influencing diversity of crop. They used Herfindahl Index to establish the degree of crop diversification and the Tobit regression model for analyzing factors of diversification towards vegetable cultivation in the study area.

Heckman's two-stage model was used by Aheibam et al. (2017) to investigate the variables affecting household decisions and the degree of diversification. According to the findings, crop diversification and household head education levels are positively correlated, which is consistent with research from Mithiya, Mandal, and Datta (2018) and Shabzah et al. (2017). According to the study's findings, additional elements that helped diversification were access to fertilizer, availability of plow equipment, irrigation, regular exposure to agricultural knowledge, prior farming experience, and closeness to the nearest market.

Mithiya et al. (2018) while studying patterns, trends, and determinants of crop diversification of smallholders in West Bengal used secondary data from different districts. Using Simpson Index (SI) which was also used by Aheibam (2017), the results showed that every district in West Bengal and the whole state demonstrated increased crop diversification levels during the new millennium compared to the nineties. The parameters that were included among the analysis covered a wide range of topics, including literacy rate, earnings comparison between high-value crops and cereals, regional market density, the percentage of smallholders, and the amount of land set aside for high-yielding food grain varieties. Education, land size, distance from the market as well as income from other sources had a significant influence.

Huang et al.'s (2014) study, which utilized multiple-stage sampling to collect 3330 smallholder farmers, demonstrated the need of crop diversity in China for coping with extreme weather events. In contrast to their younger counterparts, elderly farmers were found to be less likely to diversify their crops, according to the study, which found a negative association between age and agricultural diversification. Young farmers also have less experience hence more likely in practicing crop diversification as a means to avoid production risks. Young people are also more willing to try new things. This is in line with Dube, Numbwa, and Guveya, (2016) and Aheibam et al, (2017).

Shahbaz, Boz, and Ul Haz (2017) reported that crop diversification is positively and strongly predicted by farm size and education level. A farmer with education is more likely to comprehend the status of the market and be able to lessen the effects of unforeseen events. Similarly, ownership of farm machinery enhanced the levels of diversification in crop cultivation. However, the analysis shows a negative association between crop diversification and age. It might be because younger farmers are more imaginative, daring, and physically fit than older ones. The study also revealed that self - owned operated farms were less diversified in crop production than other tenures like renter or shareholder. The study employed the Tobit model which was also used by Kanyua et al. (2013) and Ojo et al. (2014).

Compared to households with female heads, households led by men showed a higher level of crop diversification, according to the research done by Dude et al. (2016). Additionally, the Tobit model analysis revealed that agro-ecological zone, household income, farming experience, livestock units, irrigation access, membership in farmers' organizations, market accessibility, flat terrain on farms, farmer-to-farmer extension services, and education level were significant determinants of crop diversification.

Factors such as access to extension services, soil quality, ownership of assets, and the level of infrastructural development exert a notable influence on crop diversification. The findings of the study suggested that crop diversification decisions and land size have a favorable and substantial relationship. The size of the farm was also discovered to have a large and advantageous impact on diversity. Additionally, the availability of market data, access to well-developed road networks, and the presence of extension services all had a positive and considerable impact on the choice to diversify the crops (Mussema et al., 2015).

According to Aheibam et al. (2017) farmer's land holdings have a substantial impact on the degree of diversification, with a larger farm resulting in a higher crop diversification index. From Kanyua's study, the total of free field cultivated by the farmer had a very significant effect on diversification to horticulture however, other farmers with big lands had little crop diversity since more land had been allocated to tea. Gender was a very significant factor in diversification into horticulture by tea farmers; male-headed households were more diversified than female-headed households. This was similar to the findings of Dube et al, (2016) that male-headed households were more diversified. The degree of diversity is significantly influenced by the household head's experience, possibly as a result of learning curve effects.

The study by Sichoongwe (2014) assessed Zambia's crop diversification levels and identified the key variables affecting farmers' crop-production choices. The factors influencing diversification were examined in that study using a Tobit regression model and bivariate statistical analysis. The extent of diversification was assessed using the crop diversification index (CDI). The findings demonstrated that crop diversification was relatively low among small-holder farmers. According to the study, crop diversification was substantially connected with the distance to the closest market, the amount of fertilizer used, the size of the landholding, and plow tillage. The report recommended that the government establish and support measures to enhance farmers' access to land and agricultural equipment like harvesting, plowing, and other tools. Trading markets should also promote measures that benefit farmers to bring them closer. The findings indicated that the government should think about and implement strategies to increase farmers' access to and control over land.

Investigated ways to boost production over the long run by using excessive chemical inputs. The work by Nishan (2014) highlighted various diversification strategies, including vertical diversification, horizontal diversification, land-based diversification, varietal diversification, crop diversification for pest management, crop diversification for risk reduction, and crop diversification for nutrient management. According to the study, diversification is a new tactic for improving and stabilizing production, making India's exports more competitive, and raising net farm income and economic security. According to the study's findings, crop diversification greatly benefits Indian farmers by generating year-round income and work opportunities for rural youth and improving resource-poor farming communities.

Ogundaris (2013) revealed that cropping patterns considerably increased as crop diversification intensified, as measured by the Herfindahl and Ogive indices. The outcome of the SFPM demonstrates the sign of declining returns-to-scale and technical advancement in the production of food crops in the area. The study identified crop diversification, extension, and level of education as policy variables that would increase efficiency.

Crop diversification should stabilize farm income and encourage improved farm links across the primary, secondary, and tertiary sectors of India's economy (Kumar & Nanwal 2012). Additionally, the preservation of natural resources, giving marginal farmers additional income, opening up job opportunities, and diversifying India's food supply are highlighted reasons for diversification.

The study by Sharma (2011) focused on crucial data for growth and agricultural diversification. First, it made the point that circumstances for encouraging multiple crop combination in agricultural development should be enabled by dedicated state intervention and the adoption of developmental policies incorporating regional specificities. To promote crop variety in agricultural development, fundamental infrastructure facilities including those for transportation, health, and education should be established. Thirdly, it is important to find solutions to issues relating to production and markets so that farmers can develop, experiment, and adopt new production techniques. Fourth, new technologies should be continuously sustainable in terms of both the economy and the environment.

Data from the Cambodia Socioeconomic Survey CSES-2007 was used to analyse the determinants of farmers' agricultural diversification in the country of Cambodia (Seng 2014). According to this study, farmers are deterred from changing their crop combination by high relative prices. Crop diversification and rising intensity were positively and strongly associated with irrigation, agricultural equipment ownership, farming spending, farm size, and agricultural and transportation equipment. In addition, the study found that land disputes were Cambodia's main institutional issue because they had a small influence on farmers' decisions to diversify their crops. The accessibility of arable land per household member and the existence of agricultural and transportation equipment all showed favourable correlations with the choice to engage in crop diversification. Small-scale farmers were shown to have difficulty making decisions and to have a lower level of farming activity. However, the research's main objective was to identify the variables affecting farmers' choices to diversify their food crops, which involved looking at the components that determine agricultural diversification. Also, the size of the land encourages the farmer to engage in multiple crop combinations.

The empirical literature on the determinant of economic efficiency

Sisay et al. (2015) examine allocative, technical, and economic efficiency among smallholder crop farmers in Ethiopia. 385 household heads were chosen using a multi-stage sample process, and they were then interrogated using a standardized questionnaire. The Cobb-Douglas production function was employed in the study to calculate smallholder farmers' allocative, economic, and technical efficiency. In a subsequent stage, a two-limit Tobit regression model is used to model the effects of inefficiency. The outcomes show that maize production is significantly inefficient, with mean scores for allocative technical, technical, and economic efficiency being 56.1, 63.3, and 38%, respectively. The results revealed that several factors, including family size, education level, usage of extension services, membership in cooperatives, size of farms, number of livestock kept, and use of mobile phones, had a big impact on technical, allocative, and economic efficiency. The findings are followed by the following recommendations. The government needs to encourage and engage young people in agricultural work, invest in primary education and provide the necessary resources, improve the agricultural extension system, bring non-member farmers together in cooperative associations, and pay careful attention to improving the productivity of landowners with large holding sizes.

Karani et al. (2015) analyses factors affecting the technical efficiency of fruit producers in Kenya. Cross-sectional data from 124 randomly selected fruit growers were utilized in the study to identify the factors that influence fruit production efficiency in Kenya. The study discovers that technical efficiency was on average 59.66 percent. At the 5 percent level, the age of the orchard, credit use, non-passion fruit revenue, and county variables all significantly improved technical efficiency. Technical efficiency was favourably and significantly influenced at a 10 percent level by educational attainment, the frequency with which extension guidance was used, and market access. Fruit growers and supporting organizations should implement creative ways for resource use efficiency for higher productivity to change the current efficiency status upward.

The study of Wakili and Isa (2015) focused on the impact of cropping patterns, land tenure status, and technical efficiency among farmers in

Indonesia. 95 farmers were interrogated using the structured questionnaire method to collect the data. Utilizing the Cob-Douglass production function and a frontier stochastic approach, data were analysed. The results demonstrated that the key factors of yield were fertilizer, farm size, and seeds. The farmers in Indonesia were efficient, with the technical efficiency level ranging from 0.759 and 8.67 percent of farming activities having an efficiency level was more than 0.70. The technical efficiency of shallot farming was enhanced by twice-yearly cultivation, a fixed-rent structure, and seasoned farmers. Additionally, there is a yield loss of 3.771,86 ha/ kg.

Tesema (2021) examines the determinant of allocative and economic efficiency in crop-livestock integration in the western part of Ethiopia. 155 households' worth of cross-sectional data were gathered throughout the season using standardized data collection tools. The allocative and economic efficiency score was computed using data envelopment analysis. Data envelopment analysis revealed that the mean economic and allocative efficiencies were 37.4 percent and 56.0 percent, respectively. Consequently, the production of mixed crops and livestock has a 62.6% economic inefficiency. Additionally, the Tobit regression model's findings reveal that family education levels in addition to off-farm extension have a positive effect on allocative efficiency. While loan utilization has a good impact on economic efficiency, terrace, and extension services have a negative impact, and the influence of the market's distance was positive. Therefore, the government should take action to raise family education levels, develop terraces, grow non-agricultural sectors, and reform with extension services.

Mbugi, (2020) examines the determinant of economic efficiency among smallholder common beans farmers Songwe region. This study evaluates the factors that affect the common bean farmers' economic efficiency in the study region using data from 131 randomly chosen producers from six communities in the three wards of Magamba, Bara, and Halungu. Concerning the sample of the common bean farmers in the study area, the study specifically aims to quantify their degrees of allocative, technical, and economic efficiency. The findings demonstrate that technical inefficiency was shown to be adversely and significantly correlated with farmer group participation, educational attainment, farming experience, and household size. In a similar vein, extension services, education level, membership in farmer groups, and knowledge of the farmer were discovered to be negatively and significantly associated with allocative inefficiency. The study concludes that all stakeholders (government and private sectors) should make inputs like the application of fertilizer and better seeds, which were the main inputs that increased the production of common beans in the study area, as well as their availability to the farmer on time and affordability. According to the study, procedures must be created to enhance the delivery of extension services to farmers.

In their study, Ara Begum et al. (2009) utilized a data envelope analysis approach to evaluate the economic efficiency of chicken farms. The research involved a sample of 110 poultry producers in Bangladesh, and farm-level survey data was employed to compute the technical, allocative, and economic efficiency using the Data Envelopment Analysis (DEA) approach. The findings from the DEA approach revealed notable levels of technical, allocative, and economic inefficiencies within the poultry production sector in Bangladesh. According to the study's findings, the farms' technical, allocational, and economic efficiencies were, on average, 70%, 88%, 62%, 73%, 89%, and 66% under the constant return to scale and variable returns to scale specifications, respectively. Consequently, the study findings indicate notable variations in efficiency ratings among the selected farms. To shed light on these disparities, a Tobit analysis was conducted to regress the efficiency scores on the human capital attributes of the farms. These attributes include the farmer's household size, farmer's experience, main occupation, education, educational level, poultry farm size, total farm size, and received training. The results obtained from both the constant returns to scale (CRS) and variable returns to scale (VRS) techniques indicate that efficiency is significantly influenced by specific socioeconomic characteristics of the farms. For policymakers, this research finding is useful since it could direct policies in the direction of greater efficiency.

Mohammed et al. (2015) study the technical efficiency of chili pepper production in Nigeria. For the estimate of production functions, it employs the stochastic frontier analysis approach. During the crop season, information from 200 chilli pepper growers was gathered using cross-sectional data. The results of the study revealed that 37.5 percent of the respondents are aged below 35 years. On average, farmers (54%) had a formal education. 8 people lived in each household on average. The majority of chilli pepper farmers (73%) do not belong to any cooperative associations specifically for growing chillies, and the results suggest that 97.5% of chilli pepper farmers used their own money to fund their output. According to the study, extension visits are made by (57.6%) of chilli pepper farmers. All other elements, outside labour and agrochemicals, were shown to be significant. 91% is the average technical efficiency. This study's conclusions showed that none of the sample's chili pepper producers had crossed the frontier. Therefore, utilizing present inputs and technology, the output can still be increased by 9% within the context of efficient agricultural production. Therefore, it was advised that timely and appropriate fertilizer supplies be made available to farmers at a reasonable cost to increase the production of chili peppers.

Kamau (2019) examines allocative and technical efficiency among maize and rice farmers. The study area was carefully chosen. In a household survey, a sample of 449 households was chosen at random using a semi-structured interview schedule. Allocative, technical, and economic efficiency scores were examined using stochastic frontier analysis, and factors influencing productive efficiency were examined using a two-limit Tobit model. The results from the study revealed that maize farmers using an upland irrigation system had a substantially developed degree of technical efficiency (53%). The highest average levels of economic and allocative efficiency were observed in those using the wetland-only system, at 58% and 34%, respectively. Farmers of maize in upland-rainfed systems might save resources by as much as 59% by operating at the 94% level of wetlands' best technical efficiency. The technical, allocative, and economic efficiency levels for rice growers were determined to be 58%, 73%, and 47% respectively. By operating at the 94% level, which represents the wetland's best frontier, farmers utilizing the average technical efficiency could potentially save up to 36% of their resources. The results from the study shows that rice cultivation in the

Kilombero wetland has the potential for sustainable expansion, while the upland-irrigated system has the highest productivity efficiency for maize. The report recommends that stakeholders and the government focus on initiatives that ensure agricultural extension services and formal education, to increase the yield and efficiency of both rice and maize crops. The use of upland irrigation systems for maize growing is advised by national and county governments in order to increase farmers' productivity and achieve sustainable food production in wetland areas. There should be an intervention to help farmers apply the right quantity of fertilizer to increase rice production sustainably while minimizing runoff and degradation.

According to Sekho et al. (20120) revealed that to demonstrate how different regions have embraced the most recent technology, an examination of efficiency at the regional level was conducted in several regions of India as well as in the state of Punjab. Their research found that a farmer's experience and age were the key factors influencing efficiency. The technical efficiency has demonstrated significant regional variance. The highest average technical efficiency is found in the central region (90 percent), followed by the south-western and sub-mountainous regions. Therefore, they advised that policy interventions be established locally because the state would gain more from them.

Luke, Atakelty, and Amin (2012) pointed out that the mean technical efficiency of crop output in Northern Ghana was determined to be 77.26 % in an investigation of technical efficiency using bootstrap Data envelopment analysis. This suggests that technical inefficiency is to contribute for over 23% of output loss. Scale effectiveness as estimated was 94.21 %. Using a two-stage estimating technique, they discovered that the gender, farms' locations, hired labour, and the age of the head of home all have a significant effect on technical efficiency.

Geta et al. (2013) conducted a study in Southern Ethiopia to assess the productivity and technical efficiency of smallholder farmers. The data collection process involved the utilization of a structured interview guide. Based on data gathered from the field, 395 farmers were randomly chosen for the data analyses. According to the study's findings, maize growers exhibit a high degree of inefficiency. Two-stage estimation method, using a translog production function to assess technical efficiency levels and a Tobit regression model to pinpoint the variables that affect technical efficiency. The model's output showed that the usage of fertilizer, manpower, and ox power had a substantial impact on the productivity of maize. The average technical efficiency was discovered to be 40 percent. The factors significantly influencing technical efficiency were oxen keeping, agroecology, land cultivated, and adoption of high-yielding maize varieties.

However, for this study, economic efficiency was employed to determine the level of efficiency among the farmers in the study. Thus, whether, these farmers are minimizing cost and maximizing profit through the limited resource at their disposal. And also, this will help to know the possible factors impacting economic efficiency among the farmers.

The empirical literature on the household food security status

In order to intensify food security, Majumder et al. (2016) studied rice production systems in Bangladesh with the goal of increasing technical efficiency and lowering postharvest losses. The choice of grain-rice cultivating farmers for the study involved a multi-stage sampling design. A total of 944 farmers engaged in rice farming constituted the sample size. The study's conclusions showed that using modern technologies increases productivity and rice production by increasing efficiency. The variables that influenced efficiency were farm size, level of farmers' education, and extension service.

Manu, Akuamoah-Boateng, and Akaba (2013) conducted research in the Ketu Districts of the Volta Region of Ghana to evaluate the factors that affect food security in households that grow vegetables. The researcher used organized interview schedules to gather information from 226 vegetable farmers. The study's subjects were chosen on purpose. The outcome of the study pointed out that financial services, the amount of vegetables grown, household size, land ownership, access to change agents, age, the sum of credit received, and vegetable output were the main determinants influencing whether or not a person had access to food.

Oyakhilomen et al. (2015) conducted a study to evaluate the technical efficacy of farmers' food production through increase sustainable food security in the region under consideration. The study used primary data, and a stochastic frontier approach was used for data analysis. To collect the primary data, 92 farmers from the research region were surveyed. The outcome of the study discovered a link among technical efficiency and food security, highlighting the need of effective food production methods in accomplishing food security objectives. This shows that as average production increases, food security increases.

Baba and Abdulai (2021) conducted an analysis of the factors of crop diversification and its impact on food security in Ghana. The study sampled a total of 1,384 farmers, utilizing a two-stage stratified random sampling technique along with secondary data. The findings of the study showed that crop diversity plays a significant role in enhancing the level of food security among households.

Muche (2014) studied the determinants of household food security in Mana. Farmers were chosen for the study using a purposive strategy. Seventy households in all were chosen using the probability proportional to sampling procedure.. To determine how various factors affected the food security of households, a regression model was utilized. According to the report, 42.9 percent of households lacked access to enough food, compared to 57.1 percent of households. Food security was significantly influenced by the family size, amount of farm input used, number of oxen possessed, and educational level of the household head. Food security in the home was found to be negatively impacted by family size.

Aidoo et al. (2013) conducted a study to examine the factors influencing the food security of farm households in rural Sekyere-Afram Plains. Primary data was collected from 105 selected households using structured questionnaires. The logistic regression model was used to evaluate food security levels among the farm households. The study's findings showed how important it is for off-farm activities, land cultivated, household size, access to financing, and marital status to determine how secure a household's access to food is. To make rural households' access to food better, the study recommended diversifying economic activities to include alternative sources of income beyond farming, as well as improving access to finance.

Nkegbe et al. (2017) conducted a study to examine dietary safety within the savannah accelerated development authority zone in Ghana. The research involved surveying 4,410 farmers, utilizing secondary data. The study employed an ordered probit model to analyze the factors influencing food security in Ghana, using data from the baseline survey of the Feed the Future initiative implemented by USAID in Ghana. The findings revealed that crop production, harvest, and commercialization are significant policy variables affecting food security. The study further emphasized the importance of increasing farm household output and enhancing public utilize to improve commercialization, as these elements are essential to guaranteeing food security. Stakeholders are encouraged to intensify their efforts in these areas.

In the Mwingi district's Food for Work program region, Kaloi et al. (2005) conducted an assessment of household food security status. According to the study's similar methodology, 62 percent of the 125 studied households were identified as having adequate food. The Food for Work program, educational attainment, household size, income from farming, and marital status of the household head were all identified in the study as significant factors in food security. The degree of household food security in the investigated area was found to be highly impacted by these factors.

A study by Babatunde et al. (2007) sought to investigate the demographic characteristics traits and degree of food security among farming households in Kwara State, Nigeria. The study made use of 96 farming households that were randomly chosen from 12 communities. To gauge the degree of food security, an index was developed based on the calories consumed from the easily accessible food in the families. A seven-day recall period was employed to estimate the number of calories in each meal item that the households ate. Using consumption parameters relevant to age-sex groups, the per capita calorie intake was calculated while accounting for home size and adjusted for adult equivalents. Consumption intake for each family was computed by dividing the total quantity of calories consumed by the residence by seven days. Based on whether a household's per capita daily calorie intake exceeded the advised 2260 kcal daily requirement, the level of food security was determined. 36 percent of the 96 agricultural households polled fell into the food secure category, while 64 percent fell into the food insecure category. The amount of food items produced by household members as well as the size and wealth of the household were among the factors impacting food security. The likelihood of having enough food reduced as household size increased.

In Benue State, Nigeria, Ahungwa, Umeh, and Muktar (2013) carried out a comparable investigation. In this study, consumption on food data obtained using a 7-day recall approach were analysed to evaluate the level of food security in farming households. The study used a proposed value of 2,500 kcal to generate a food security index. The findings indicate that, according to the food security index, 180 homes were examined, and 63.33 percent were classified as suffering food insecurity.

For the examine the regional differences in food security among rural households in three regions of the Punjab province, Bashir et al. (2013) undertook a study in Pakistan. After gathering primary data from 1,152 houses, the researchers employed a calorie consumption technique to gauge how secure people's access to food is. The outcome of the study showed that 31 percent of households in the Central region and 14.6 percent and 14 percent, respectively, of those in the South and North were considered to be food insecure. In addition, the research employing the logit model showed that livestock assets had a positive impact on food security while family size had a negative impact on it in all three regions. Higher levels of education (intermediate and graduate) were found to expand food security in the North and Central regions, but not in the South region. Food security in the North region was negatively impacted by household heads' ages, but positively by the overall number of wage workers in the household. In a later study, the same author examined how livestock helped small farmers in rural households in Pakistan's Punjab province maintain a sense of food security. The study analysed a sample of 576 smallholder farmer households using household-level data. Only 19 percent of the tested farm households faced food insecurity, according to the findings. Additionally, the study found that a variety of variables, such as the number of wage earners in the home, monthly income, and higher educational attainment at the graduate level or above, positively impacted food security.

Djangmah (2016) conducted a study on the association among household resource endowment and food security status in Nepal. Calorie consumption was used in the study as a proxy for the degree of food security in the household. A logistic regression model was also employed in the study to look into the variables affecting family food security. More over 75 percent of homes couldn't produce adequate food to meet their own requirements, according to the findings. According to the findings of the logistic regression model, food insecurity was sporadic in households with small landholdings, fewer animals, workers, and lower consumption costs.

In a study published South East Asia, Wiranthi et al. (2014) examined the factors that influence household food security in Indonesia's eastern and western regions. The researchers assessed household food security using secondary data and a calorie intake strategy. The findings indicated that 41.76 percent of Indonesian households faced a food security concern. The study also determined that households in the Eastern region experienced extreme levels of food insecurity (48.56%) than households in the Western region (41.76%). The findings of the logistic regression analysis demonstrated that some variables, in both the Eastern and Western regions, had a positive influence on households' odds of achieving food security. These included a rise in expenditure equivalent, the head of the household's age, level of education, gender, determination to maintain a modest household size, and job in a non-agricultural sector. The study also found particular elements that were unique to each region, such as the ease of access to electricity in the Eastern region and the availability of loans and clean drinking water in the Western region.

In the Central region's Coastal and Forest belt, a study was conducted on the state of food security for agricultural households (Kuwornu et al. 2013). The study employed data gathered from a survey of 130 farming households to estimate the degree of food security using the calorie intake method. The association between socioeconomic characteristics and the extent of food security in a home was modelled using the logit method. The study's results showed that 60 percent of farming households suffered from food insecurity. The results showed that the volume of farm output, household income, and loan availability were all positively and significantly related to food security.

In the Ashanti area of Ghana, Frimpong and Asuming-Brempong (2013) assessed the variables affecting food security in both rural and urban families. The research employed the calorie intake strategy to evaluate the level of food security in households. In addition, the several elements affecting the region's food security were identified using the Tobit model. The findings indicated that factors such as remittances, food spending, total own production, access to credit, household size, the number of income-generating enterprises, and land endowment showed a significant effect on the food security of rural households. The key predictors of food security in urban households were per capital food expenditure, migration, household size, land endowment, and own production.

In examining the degree of food security experienced by farmers in the research area, this study used the household food security status as a major indicator. In addition, the study sought to pinpoint the possible elements that can affect these farmers' households' food security.

Conceptual framework

The rational choice theory holds that the desire for financial gain drives human behaviour. The majority of farmers make rational decisions and frequently select options that they believe will result in a financial advantage for them; otherwise, they would not pursue the endeavour. Crop diversification in the context of agriculture refers to a farmer practicing multiple crops on a plot of land. According to Ashfaq et al. (2008) this method tries to maximize the efficiency of the use of water, land, and other resources so that farmers can successfully cultivate a variety of crops on their land.

There are numerous factors that contribute to farmers' decisions to diversify their crops. Some of these factors include low yields of specific crops, socio-demographic characteristics (such as sex, marital status, age, involvement in farm-based organizations, household size, and proximity to markets), institutional policies (such as access to credit, education, and extension services), and changes in weather conditions or climate variability, which are external factors beyond the control of the farmers. In economics, crop diversification is examined from two perspectives: firstly, as a challenge of identifying the optimal combination of crops on a production possibility frontier, and secondly, as a strategy to integrate risk aversion into a farmer's decision-making process. The rationale behind the latter approach is that specializing in a single crop might lead to unstable income due to fluctuations in yield or price for that specific crop (Hazell, 1977). Crop diversity is commonly recognized for its dual benefits, namely enhancing food security and providing opportunities for farmers to expand their revenue by broadening their production possibilities or allocation of land. Samuelson (1967) highlights that Crop diversity is a risk-reduction technique, reducing the likelihood of a farmer relying solely on specialisation of crop with potential high covariance risk. Consequently, the choice of a farmer to diversify their enterprise is considered a crucial economic choice that significantly affects their well-being in terms of income level and access to food (Pope & Prescott, 1980).

Economic efficiency plays a crucial role in promoting food crop production. It can be assessed through two dimensions: allocative efficiency, which examines the optimal allocation of resources, and technical efficiency, which focuses on achieving the highest output level given a set of inputs. Combining technical and allocative efficiency yields overall economic efficiency. Allocative efficiency involves ensuring a balance or equality between the marginal value product of inputs and product prices, while technical efficiency requires operating at the frontier of maximum output. Factors influencing economic efficiency might be characterised as internal and external factors. External factors that influence economic efficiency encompass various aspects such as the extent of cultivated land, input and output prices, climatic conditions, membership in farmer associations, access to credit, information, and infrastructure like storage facilities and roads. On the other hand, internal factors include individual characteristics like education level, age, gender, and family size (Pingali & Rosegrant, 1995). When farmers can allocate their resources effectively (allocative efficiency) and maximize output with given inputs (technical efficiency), it leads to increased crop production and subsequently enhances food security for farm households. Additionally, the efficient utilization of farm resources by adopting strategies like crop specialization and diversification will significantly impact household food security levels.

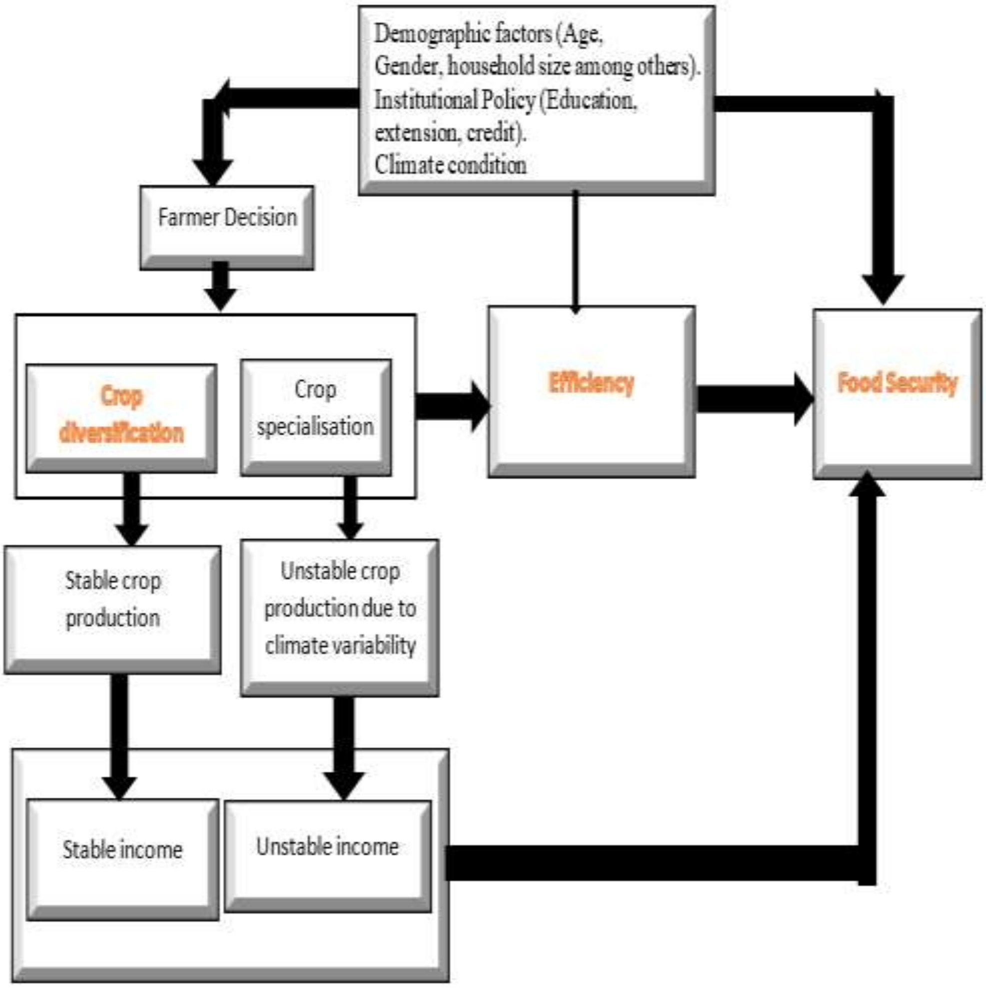

Figure 1 Conceptual framework
Source: Tagoe, (2023)

Chapter Summary

The relevant literature on ideas like crop diversification was reviewed in this chapter and food security (accessibility, availability, and utilization) in Ghana as well as economic efficiency. The choice theory that underpinned the research was reviewed in this chapter. The chapter also examined the research on several estimating techniques, including the Tobit model, Herfindalh Index of diversification, logistic model, and Data envelope analyses. Finally, an empirical review was done on factors influencing crop diversification, the determinant of economic efficiency, and household food security.

CHAPTER THREE

RESEARCH METHODS

General overview

In this chapter, a detailed account is provided regarding the procedures and methods utilized for data collection, management, and analysis. It outlines the research design adopted for the study, the targeted population, the sample selection process, the research instruments utilized, the pilot testing conducted, and the data collection procedures employed. Furthermore, it delves into the data processing and analysis techniques employed, while also justifying the rationale behind the chosen techniques.

Research Philosophy

Research philosophy refers to a system of beliefs regarding the collection, analysis, and utilization of data pertaining to a particular phenomenon (Collis & Hussey, 2014).Two major research philosophies used in research are positivism and interpretivism. 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. According to Collis and Hussey, positivists posit that an assertion should be justifiable and that knowledge is derived from 'positive' information that can be verified scientifically. 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). Positivists believe that reality exists independently of the people and that investigating social reality has no effect on it (Creswell, 2014). Positivists use statistical methods of analysis for quantitative research data.

On the contrary, for interpretivism to gain interpretive understanding, it explores the complexity of social phenomena. Interpretivism believes in society not being objective but highly subjective, as people's perceptions shape it. The line between the researcher's perspective and the social environment is distorted, according to Creswell (2014), because of the researcher's interactions with the study subjects. Interpretivism uses 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. This study followed the positivist philosophy to allow the researcher to dissociate from and acquire knowledge unrelated to personal values and moral content.

In this study, the research was quantitative, hence the positivist viewpoint was adopted. The study also intends to portray the behavioral patterns of farmers by looking at cause and effect. When these cause and effect are established, the extrapolations of results from the sample to the population are permitted by the research philosophy. Additionally, The philosophy establishes the framework for choosing the study's research design.

Research design

A cross-sectional survey was conducted to investigate the analysis of food crop diversification and economic efficiency as well as the effects on smallholder food crop producers in the Okere district of the Eastern Region. The cross-sectional survey design was employed in the study to look at the status and correlations between the variables. To determine the level and factors influencing crop diversification, this design entailed gathering data at a specific point in time. The survey design, in accordance with Babbie (1995) and Creswell (2011), permits researchers to extrapolate results from a sample to a wider population, making conclusions on population characteristics. The design was also chosen for its affordability and ability to facilitate successful data gathering and analysis (Babbie, 1995; Fowler, 2002).

Description of the study area

The research will be conducted in a specific area of Ghana's Eastern Region, which happens to be one of the country's sixteen administrative assemblies. The Eastern Region consists of 33 districts covering a total geographical area of 19,323 square kilometers, or about 8.1 percent of Ghana's total landmass. It is located between 6^o and 7^o north latitude and $1^o30'$ west and $0^o30'$ east longitude. The Volta Lake, which covers enormous swaths of the land, ensures that the region is well drained. In 1988, the area was formerly a component of the larger Akuapim North District. On March 15, 2018, the district's northeastern portion was split off to become Okere District. Adukrom is the capital of the municipality and located in the southeast part of the Eastern Region. The population is 66,446. Agriculture activities was the main backbone of the district which employ about 65 percent of the population (PHC, 2021).

The Okere District is selected for specific reason. The reason is Okere district has a lot of smallholder farmers who are engage in food crop production and it has been proved by Alare et al. (2018) and (MoFA, 2019) that there has been a decrease in crop production which has hampered farmer's production as well as implication on food security. These farmers are also engaged in multiple food crop diversification such as cassava, plantain, maize and among others. Furthermore, MoFA (2019) revealed that the Region is the top producer of cassava and second top producer in maize production both crops are staple food consume in Ghana (Kwapong, Ankrah, Anaglo & Vukey, 2021).

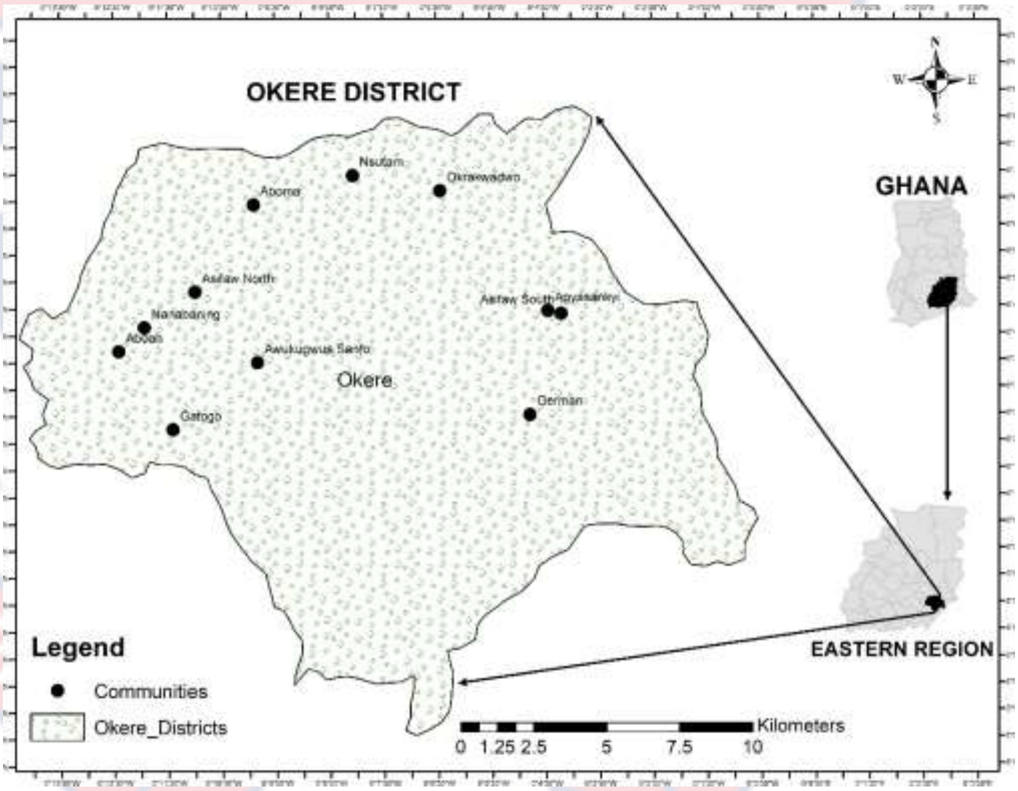

Figure 2: Map of Okere District of Ghana
Source: Ghana Statistical Service, (2021)

The population of the study

A population is a particular, clearly defined group of people who are taken into account for statistical purposes. Smallholder food crop farmers who were registered with the Okere branch of the Ministry of Food and Agriculture made up the study's target group. According to MoFA (2020), there are 1,890 smallholder farmers in the Okere district overall. People from varied ethnic and educational backgrounds made up the population.

Sampling procedure

Sampling is the procedure followed in selecting participants for the study from a population. Sampling is concerned mainly with representativeness. Choosing a sample that fairly depicts the total population and enables generalizations was the goal. The participants of the study were selected using a multi-stage sampling procedure in order to accomplish this. To create a representative and diverse sample, this method required numerous steps of sampling. The first stage involved purposively selecting eleven major food crop farming communities out of the sixteen communities in the district with the help of the extension office. These areas were chosen because they produce a disproportionate amount of food crops. The farmers chosen for the study were chosen using a simple random selection procedure. Producers of food crops were chosen at random from a list of farmers from different communities. This is demonstrated in Table 1.

Table 1: Sample size based on communities

Communities where data was collected	Population	Sample size
Okrakwadjo	217	38
Aboma /Amrahyia	137	24
Nsuta	170	30
Aboa	183	32

Nanabanyin	200	35
Asifaw North	158	28
Asifaw South	183	32
Awukugua-Sanfo	196	34
Gatogo	150	26
Agyeibea	145	25
Gbemimu	151	26
Total	**1,890**	**330**

Source: Department of Agriculture of Okere District, (2021)

Sample size

To determine statistically reliable results, it is necessary to determine the sample size (Roundy, 2017). Therefore, the sample size is elaborated by the appropriate number of respondents needed to obtain the expected outcomes of the analysis (Bryman & Bell, 2003). Therefore, with known population size. The statistical sample size computation by Yamane was employed to compute the sample size Yamane (1967). It is expressed below:

$$n = \frac{N}{1+(Ne^2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.0)$$

N= Sample frame,

n = the sample size and

e = the margin of error.

A margin of error (e) of 5% for this study, and the sample frame was 1,890. Following that, the sample size was estimated as follows:

$$n = 1{,}890 / [1+1{,}890(0.05)^2] = \mathbf{330}$$

A proportionate sampling method was used to determine the number of respondents per community to ensure equal representativeness from the communities. When using proportionate sampling, The proportion of respondents from each community is based on the total number of farmers in that community (Etikan & Bala, 2017). The following formula was employed for proportionate sampling;

$$\frac{sub\ community\ population}{Total\ poulation\ (1{,}890)} * sample\ size\ (n\ or\ 330)$$

Where *n sub* represents the sample to be selected per community and *calculated n* is the study-calculated sample size. This method was ideal because the community differed in the number of farmers. **Error! Reference source not found.** below shows the determined sample sizes per community. The sample size for the study was calculated by summing up the sample size determined from the selected farming areas.

Data collection instrument

In order to collect information from the participants, questionnaires and organized interview schedules were developed as research methods. There were both closed-ended and open-ended questions in the instruments. They were divided into six separate sections, each of which focused on a different component of the study's goals.

Data on the sociodemographic traits of smallholder food crop producers are gathered in the first section (A), which takes into account elements like sex, age, members in the household, marital status, family role, level of education, and similar ones.

Section (B) contains questions pertaining to farm characteristics such the current land holding status, the size of food crop farm cultivated, annual farm income, the type of food crop production system, the quantity of each of the crop harvested, quantity consume, quantity sold, the prices of the various food crops, the various food crop combination, the reasons behind those combinations, where they sell their product and whom they sell their products to.

Section (C) also asks questions on the farmer's source of labour. Whether family labour, hired labour or both and labours used, share of labour, number of hired labour, hours per day for hired labour, the number and the cost of labour.

Section (D) covers set of questions relating to institutional characteristics such as the extension services available to the farmers and number of times they access them within a production season, source of extension service and membership of farm base organisation.

Section (E) assessed the use of input (variable and fixed) during the production season. The fixed includes; land used, cutlass, hoe, water can among others. The variable input includes; fertilizer used, weedicides, pesticides, seed, and insecticides, among others. Questions were asked on the number of quantities used, the unit price for each and the total amount of each item.

Finally, section (F) outlined the criteria set by FAO to determine household food insecurity. The household food insecurity access score (HFIAS) instrument was used

Pre-testing

The pilot exercise was conducted to pre-test the interview schedule survey instrument. The pretesting exercise was necessary to ensure the reliability of the survey tool and observe the length of time required to interview the study participant. Upon the approval for data collection from the office of the Institutional Review Board (IRB, UCC), the field exercise started with a pilot survey at Nsakye within Akuapem North District in the Eastern Region with a target farmer who happens to be food crop farmers. The face and content validity were the driving forces behind the pilot data collection, four smallholder food crop farmers from each of the four agricultural communities that were excluded from the real study were chosen.

Validity and Reliability

A copy of the instrument was sent by the researcher to the supervisor, who reviewed the content and verified the types of items to determine whether it truly measured the relevant material. This was done to evaluate the instrument's reliability. Cronbach's alpha was used to evaluate the instruments' dependability by determining their degree of internal consistency. According to Cohen and Swerdlik (2005), this provided a measurement of item redundancy or the extent that different items on a scale evaluate the same information. Because Croncbach's alpha was greater than 0.70, the instrument dependability was acceptable. The results for Cronchach's alpha based on the household food security access scale are presented in Table 2.

Table 2: Reliability text

Item	No. of Items	Cronbach Alpha
Food security access scale indicator	9	0.803

Source: Tagoe, (2023)

Data collection procedure

A one-day training was organized for four technical staff from the Department of Agriculture and six enumerators on the instrument and how to administer them to the respective respondent after approval have been made from the IRB office to enable the student researcher in the data collection exercise. The training is to prepare the personnel with the requisite skills to enrich the quality of their behaviour in reducing biases and errors during the data collection exercise. The researcher together with 6 trained enumerators and 4 extension offices from the district conducted the data collection exercise. Since the survey was primarily conducted for academic purposes, The responders were assured that their data will be kept as secure as appropriate. The data collection for the study took a maximum of three weeks which occurred between the months of April-May, 2022. The respondents received the instrument(s) at their separate residences and farms. The employed assistants filled out the interview questions for the respondents or aided them in doing so.

Analytical framework

The data were analysed using R software and Stata version 15.

Table 3: Analytical framework for each of the objective

Objective	Variable	Analytical tools
Determinant of crop diversification	Herfindahl index Age, experience, education, credit, etc	Tobit Model
Food security	Food consumes for the last 30 days.	Frequency, mean, standard deviation, and percentage
Determinants of efficiency	Inputs and output, age, sex, credit, etc	Data Envelopment Approach and Tobit

		Model
The effect of crop diversification and economic efficiency on food security.	Diversification. Efficiency, age, land size, etc.	Logit model

Source: Tagoe, (2023)

Estimating the extent of crop diversification

The extent of food crop diversification among smallholder farmers was assessed using the Crop Diversification Index (CDI), also known as the Transformed Herfindahl Index (THI). The Herfindahl Index is obtained by deducting it from one to get the CDI. According to Ojo et al. (2014), the Herfindahl Index is computed by adding the squares representing the percentages of each crop's acreage in the overall area grown. The index can be written mathematically as follows;

$$HI = \sum_{k=0}^{n} (p_i^2) \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

This is an index of concentration with a direct association to diversification where a value of zero value shows specialization while a movement towards one indicates a rising level of diversification. Crop Diversification Index (CDI) is therefore indicated mathematically as;

$$CDI = 1 - \sum_{k=0}^{n} (p_i^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

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

Measuring the determinant of crop diversification

To analyse the determinants of crop diversity, the Tobit model used by Larkai (2019) and Dube *et al*., (2016) was adopted. The dependent variable might be either left-censored or right-censored (above and/ or below). The Herfindahl index of diversification (HID), which indicates the level of diversification, was the dependent variable in the model (censored between 0 and 1). Tobit model allows censoring of the dependent variable from below and above, also called left and right censoring; it is mostly suitable for crop diversification index regression analysis. According to Mesfin et al. (2011) this model, therefore, is the most appropriate because standard linear regression models like ordinary least square assessment would give biased and inconsistent results. The model's general form is indicated as;

$$HID = \beta_0 + \beta_i X_i \ldots\ldots\ldots\ldots \beta X_n + e_i \quad (3.3)$$

HID = Herfindahl Index of Diversification

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 HID will be censored at zero because it is a dependent variable. Previous studies that employed the Tobit model to assess the impact of socioeconomic and institutional variables on farmers' diversification behaviour (Dube et al., 2016; Shahbaz et al., 2017) provided support for the use of the model. The model for this research is as follows:

Crop diversification = $\beta_0 + \beta_1\, Age + \beta_2 Education + \beta_3 Experience + \beta_4 OffarmActivities + \beta_5 Land + \beta_6 Mkt\ dist + \beta_7 Extension + \beta_8 Credit + \beta_9 HHSize + \beta_{10} FramGroup + e_i$

Explanatory variables are access to credit, farm size, age, sex, education, farming experience, age, and sex, among others. A breakdown of the Tobit model's different explanatory factors and their respective a- priori expectation is given in Table 3.0.

Estimation for Economic Efficiency

The Data Envelopment Analysis (DEA) method, which enables the researcher to calculate technical, allocative, and economic efficiencies, was used to calculate the efficiency of smallholder farmers. When there are several inputs and outputs, the DEA becomes the appropriate technique for measuring farmers' level of efficiency (Mitsopoulos et al., 2021).

A linear programming technique called "Data Envelopment Analysis" (DEA) is used to assess the efficiency of organizational units. The sum of weighted outputs is divided by the sum of weighted inputs to calculate the DEA. Charne et al. (1978) suggested using an input-oriented DEA model to assess the relative efficacy of a Decision-Making Unit (DMU). The mathematical representations of the DEA are presented below;

$$Max = \frac{\sum_{k=1}^{s} v_k y_{kp}}{\sum_{j=1}^{m} u_j x_{jp}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{3.4}$$

$$\sum_{k=1}^{s} v_k y_{ki} \Big/ \sum_{j=1}^{m} u_j x_{ji} \leq 1 \forall_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{3.5}$$

Where;

K=1 to s, j=1 to m,

y_{ki} = Quantity of yield K produced by DMU I, x_{ji} amount of input j utilized by DMU I. v_k= weight given to output k, whiles u_j = weight is given to input j. According to Khoveyni and Eslami (2021), the model can be specified as

Max $\sum_{k=1}^{s} v_k y_{kp}$…………….. (3.6)

$s.t\ \sum_{k=1}^{s} v_k y_{ki} - \sum_{j=1}^{m} u_j x_{ji} \leq 0$ …………………………… (3.7)

$\sum_{j=1}^{m} u_j x_{jp} - 1$ ……………………………. (3.8)

$v_k, u_j \geq 0$

Determinants of economic efficiency

Kopp and Diewert (1982) defined Economic efficiency as a company's ability to generate a specific amount of output at the minimum cost for a particular degree of technology. Economic efficiency is the combination of allocative and technical efficiency. The economic efficiency is given as;

EE=TE x AE……………………………………………. (3.9)

While

EE = Economic efficiency

TE= Technical efficiency

AE= Allocative efficiency.

$0 \leq EE \leq 1$

Technical efficiency estimation is commonly used for the assessment of farm productivity. Generally, a farm attains technical efficiency when it increases output using the existing technology without necessarily increasing the use or wasting of inputs (Inkoom & Micah, 2017). The mathematical expression of technical efficiency is given as;

TE=EE/AE………………………. 3.10

$0 \leq TE \leq 1$

The utilization of productive inputs or the input mix that yields a specific amount of output at the lowest possible cost given the input prices is demonstrated by allocation efficiency estimation. This means that in order to achieve allocative efficiency, the input's marginal value product and marginal cost must be equal. If the condition is not met, then there is possible allocative inefficiency because firms are generally cost minimizers.

Allocative efficiency can be expressed as;

AE=EE/TE…………………………………………………… (3.11)

$0 \leq AE \leq 1$

Again, the Tobit model as specified in equation 2.2 was adopted to compute the determinants of allocative, technical, and economic efficiency separately.

$EE/TE/AE = \beta_0 + \beta_i X_i$………..$\beta X_n$+$e_i$

β_0 = Constant or intercept

β_i = Probability of economic efficiency due to X_i or coefficient

X_i = Factor affecting economic efficiency (Independent variable or explanatory variable)

e_i = Error term

The EE/TE/AE is the dependent variable and will be censored at one. The Tobit model was used since other studies (Iticha, 2020; Mbugi, 2020) used the same model to measure the impact of socioeconomic and institutional factors on farmers' economic efficiency. The following is the research's framework:

Economic Efficiency = $\beta_0 + \beta_1\, Age + \beta_2 Education + \beta_3 Experience +$
$\beta_4 Education + \beta_5 HHsize + \beta_6 Land + \beta_7 Mkt\ dist + \beta_8 Extension +$

$\beta_9 Credit + \beta_{10} FramGroup + \beta_{11} Offarmactivity + \beta_{12} FertilizerApp + e_i$

Technical Efficiency = $\beta_0 + \beta_1 \, Age + \beta_2 Education + \beta_3 Experience + \beta_4 Education + \beta_5 HHsize + \beta_6 Land + \beta_7 Mkt\ dist + \beta_8 Extension + \beta_9 Credit + \beta_{10} FramGroup + \beta_{11} Offarmactivity + \beta_{12} FertilizerApp + e_i$

Allocative Efficiency = $\beta_0 + \beta_1 \, Age + \beta_2 Education + \beta_3 Experience + \beta_4 Education + \beta_5 HHsize + \beta_6 Land + \beta_7 Mkt\ dist + \beta_8 Extension + \beta_9 Credit + \beta_{10} FramGroup + \beta_{11} Offarmactivity + \beta_{12} FertilizerApp + e_i$

Explanatory variables that influence economic efficiency and their respective a- priori expectation is given in the table.

Household food security

The food security situation of farm households was evaluated using the Household Food Insecurity Access Scale (HFIAS). Farmers responded to nine questions on the scale that dealt with food insecurity (Engidaye et al., 2019). These inquiries attempted to ascertain whether households had difficulty obtaining enough food in the previous week due to either monetary restrictions or a lack of food. Based on the number of progressively serious signs of food insecurity recorded, as indicated by affirmative responses to a series of survey questions, a scale value was assigned to each home.

The estimation procedure used in this study to arrive at categorizing food crop farmers' household's food security status followed Omega et al., (2022). Farmers were provided with a score of one or zero depending on whether the farmer answered yes or no to the food insecurity items in the instrument. Each food insecurity question received a score of 1 if the farmer responded affirmatively, suggesting food insecurity, and a score of 0 if the farmer responded negatively. Individual farm households could receive a maximum score of nine or a minimum score of zero after analyzing the cumulative scores, each reflecting their unique levels of food insecurity. Based on the overall scores that households received, food insecurity was classed as follows: A household was deemed to be food-secure if it received a score of 0. Food insecurity without hunger was indicated by a total score between 1 and 4, whereas food insecurity with hunger was indicated by a score between 5 and 8. A household was deemed to be seriously food insecure if it had a total score of 9. According to the scale's assessment, farm households' food insecurity status worsened as it rose from 0 to 9.

Food crop diversification and economic efficiency on food security

In this kind of investigation, a number of discrete choice models have been employed to forecast and analyse data of this nature. Among discrete choice models, the logit model is without a doubt the most simple and well-known probabilistic decision model. This model is a generalized linear model (GLM) with a binary regression and a dichotomous dependent variable (Zakir, 2009).

Food security is a dependent variable that also happens to be binary. Therefore, one for a home that is food secure and zero for everyone else. Below is a description of the logistic model employed by Djangmah (2016) and Osman (2015).

$$P_i = F(Z_i) = \frac{1}{1+e^{-(\alpha + \sum \beta_i + X_i)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.12)$$

where P_i denote the probability that an individual is food secure given X_i, where X_i represent the explanatory variables, α *and* β_i are parameters to be estimated and e is the base of the natural logarithm.

For a concise and understandable explanation of the coefficients in a logit model, the coefficients could be represented in terms of the log odds ratio. The log odds ratio illustrates the possibility that a household lacks food. (1-P_i).

Therefore,

$$(1 - P_i) = \frac{P_i}{(1-P_i)} = e^{Z_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.13)$$

For a linear representation;

$$In\left(\frac{P_i}{(1-P_i)}\right) = Z_i = \alpha + \beta_i X_i + \beta_2 X_2 + \beta_k X_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.14)$$

Adding the error term to the equation, the logit model becomes;

$$Z_i = \alpha + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.15)$$

Z_i happens to be the food security status (1 for food secure households whiles zero for otherwise). α and β_i variable to be computed, X_i is a vector of explanatory variables and ε_i is the error term. Two logistic regression model was run separately to determine the effect of crop diversification (3.16) and economic efficiency (3.17) which is expressed below.

$$Z_i = FS_i = \partial_0 + \partial_1 HID + \partial_2 D_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.16)$$

$$Z_i = FS_i = \partial_0 + \partial_1 EE + \partial_2 D_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.17)$$

Where FS represents food security, D_i is the household characteristics such as age, education, gender, experience, extension service, membership group, land size, and distance to market among others. HID is the Herfindal index of diversification whiles EE is economic efficiency. ∂ is coefficient of interest.

Explanatory variables are age, education, household size, extension service, fertilizer application economic efficiency, and crop diversification among others. A breakdown of the Logistic model's different explanatory factors and their respective a- priori expectation is given in Table 3. Using the endogenous treatment effect model, endogeneity in the variables and the error term was investigated.

Estimation of the interdependence of economic efficiency and crop diversification of farmers

The simultaneous equation model, specifically the 3-stage least squares (3SLS) model, is used for the empirical purpose of estimating a model of equations where the dependent variables are hypothesized to predict each other with other explanatory variables in each other's equations of the same model. (Sawar & Anastasopoulous, 2016, cited in [Washington et al., 2011]). From a methodological point of view, the 3SLS estimation procedure consists of three stages (Sawar & Anastasopoulous, 2016, cited in [Washington et al., 2011]). Each endogenous variable was regressed against each external variable in the initial stage of the regression analysis. The 2SLS (Two-Stage Least Squares) parameter estimates were then calculated using the ordinary least squares (OLS) method employing the regression-predicted values from this stage as instruments. The contemporaneous variance-covariance matrix of disturbances was calculated in the second step using the residuals from the first stage. In the third stage, the 3SLS (Three-Stage Least Squares) model's parameters were estimated using the generalized least squares (GLS) approach and the cross-equation variance-covariance matrix of disturbances.

To examine the relationships between technical efficiency, allocative efficiency, economic efficiency, and crop diversity among farmers, the study used the three-stage least squares method. Due to their dual roles as explanatory and response variables in other model equations, these variables were regarded as jointly endogenous dependent variables. Technical efficiency, allocative efficiency, and economic efficiency are hypothesized to explain crop diversification, whereas crop diversification also influences technical efficiency, allocative efficiency, and economic efficiency. With this, there is a system of equations to be modelled simultaneously where the three-stage least square method is appropriate (Sawar & Anastasopoulous, 2016, cited in [Anastasopoulous, Mannering, & Haddock, 2012; Washington et al., 2011; Prozzi & Hong, 2008]). This is because the 3SLS is more efficient, consistent, and asymptotically normal than the single equation estimates and the two-stage least squares. After all, it combines multivariate and two-stage regression (Sawar & Anastasopoulous, 2016; Shankar & Mannering, 1998; Zellner & Theil, 1962).

The structural equation is calculated as

$y_i = Y_i\gamma_i + X_i\beta_i + \varepsilon_i$ ……………… (1), $i = 1, \cdots, n$… (3.18)

where y_i is a vector of observations on the jointly dependent variables; Y_i is the matrix values taken by the explanatory dependent variables, γ_i is the corresponding coefficient vector; X_i is the matrix of values taken by the explanatory predetermined variables, β_i is the coefficient vector; ε_i is a column vector of structural disturbances.

In this study's case of four simultaneous equations to be estimated, where there are four jointly endogenous dependent variables, the system of equations of the 3SLS model are noted as:

$Y_1 = f(Y_2, Y_3, Y_4, X) + \varepsilon_1$ ………… (3.19)

$Y_2 = f(Y_1, X) + \varepsilon_2$ …………. (3.20)

$Y_3 = f(Y_1, X) + \varepsilon_3$ ………… (3.21)

$Y_4 = f(Y_1, X) + \varepsilon_4$ …………. (3.22)

Where Y_1, Y_2, Y_3, and Y_4 are the endogenous variables and X represents the exogenous variables in the equations. The exogenous variables in the four equations have some common variables. ε_1, ε_2, ε_3, and ε_4 are the error terms of the equations.

The model is specified as;

Crop diversification =

$$\beta_0 + \beta_1\ Allocative + \beta_2 Economic + \beta_3 Technical\ \beta_4\ Age + \beta_5 Education + \beta_5 Experience + \beta_6 Education + \beta_7 HHsize + \beta_8 Land + \beta_9 Mkt\ dist + \beta_{10} Extension + \beta_{11} Credit + \beta_{12} FarmGroup + \beta_{13} Off\_farmactivity + \beta_{14} FertilizerApp + e_1$$

Technical Efficiency = $\beta_0 + \beta_1\ Crop\_diversification\ + \beta_2\ Age + \beta_3 Education + \beta_4 Experience + \beta_5 Education + \beta_6 HHsize + \beta_7 Land + \beta_8 Mkt\ dist + \beta_9 Extension + \beta_{10} Credit + \beta_{11} FarmGroup + \beta_{12} Off\_farmactivity + \beta_{13} FertilizerApp + e_2$

Economic Efficiency = $\beta_0 + \beta_1\ Crop\_diversification\ + \beta_2\ Age + \beta_3 Education + \beta_4 Experience + \beta_5 Education + \beta_6 HHsize + \beta_7 Land + \beta_8 Mkt\ dist + \beta_9 Extension + \beta_{10} Credit + \beta_{11} FarmGroup + \beta_{12} Off\_farmactivity + \beta_{13} FertilizerApp + e_3$

Allocative Efficiency = $\beta_0 + \beta_1\ Crop\_diversification\ + \beta_2\ Age + \beta_3 Education + \beta_4 Experience + \beta_5 Education + \beta_6 HHsize + \beta_7 Land + \beta_8 Mkt\ dist + \beta_9 Extension + \beta_{10} Credit + \beta_{11} FarmGroup + \beta_{12} Off\_farmactivity + \beta_{13} FertilizerApp + e_4$

Table 3: The variables for the various model and expected sign

Variables	Type	Description	Expected sign
Sex	Continuous	If the farmer is a male or female	+
Education	Continuous	The years of formal education of the farmer education.	+
Experience	Continuous	Number of years spent in farming	+
HHSize	Continuous	Number of people depending on the farmer for livelihood	+
Land size	Continuous	Farm size in (hectares)	+/-
Market Distance	Continuous	The distance from the farm to the market in km	+/-
Extension service	Dummy	Extension service from the external body (Yes/No)	+
Access to credit	Dummy	Availability of credit to the framer (Yes/No)	+
Farm organisation	Dummy	If the farmer belongs to any farmers' group	+/-
Off-farm activity	Dummy	Income from other activities rather than own farming	+/-
Fertilizer App	Dummy	Application of fertilizer on the farm	+/-
Crop diversification	Continuous	Growing more than one crop (HID)	+
Economic Efficiency	Continuous	The capacity of a farmer to produce a predetermined quantity of output at minimum cost.	+
Marital Status	Dummy	The marital status of the household head	+

Source: Tagoe, (2023)

The Heckman treatment effect model

It is critical to identify a methodological issue when analyzing the specific effects of crop diversification and economic efficiency on family food security. Endogeneity may result from factors that are not noticed having an impact on crop diversification and economic efficiency (Salifu, 2020). Even prior to implementation at the farm level, these unobserved factors may influence a farmer's choice to engage in crop diversification or increase economic efficiency. Since crop diversity and economic efficiency are predicted to have a positive influence on household food security, relying exclusively on standard logit estimation may create bias. This bias may be brought on by problems like measurement mistakes, omitted variables bias, or reverse causality. In addition to using logistic regression to investigate how household food security affects crop diversification and economic efficiency, the study will also make use of a structural equation model and the endogenous treatment effect model, which was developed by Maddala (1983) and Heckman (1976, 1978). This strategy seeks to handle potential endogenous selection problems during the study.

In this method, a binary variable is used to analyze the link between the treatment (crop diversification or economic efficiency) and the result (household food security). The binary nature of the outcome variable and the existence of a latent component are taken into account when estimating the parameters of the endogenous treatment effects model using the maximum likelihood estimator. By examining how the treatment factors affect the level of food security (whether the household is food secure or not), this method enables the testing of potential endogeneity. A vector of explanatory factors representing respondents' sociodemographic traits and the outcome equation's expression of household food security status can be written as follows:

$Y_j^* = \pi M_j + X_j \beta_1 + \mu_j$..................................... (3.21)

In the endogenous treatment model, the response variable Y_j^*, which denotes whether the household has access to enough food, is represented by an equation. It is presumpted that the independent variables $X_j$are exogenous and unrelated to the error terms. The variable M_j makes an attempt to calculate how the treatment π, (such as the choice to conduct crop diversification or not, and the choice to guarantee efficiency or not) will affect the outcome. However, there are other elements that go unnoticed that also affect how households decide on crop diversity and crop production efficiency. Because it is influenced by these underlying factors, the least squares estimator π of is therefore unsuitable for capturing the effect of the therapy alone. As a result, the following treatment details are provided:

$M_j^* = K_j \delta + \varepsilon_j$ .... (3.22)

The treatment equation contains an exogenous variableK_j, to address potential problems with omitted variable bias and reverse causation. This variable, which is shown as a vector, consists of explanatory variables utilized in the study to capture characteristics, like individual educational attainment, that affect a household's decision to practice agricultural diversification or economic efficiency. Including K_j makes the study more thorough by taking into account additional elements that could influence the choice of the treatment.

$$M_j^* = 1 \; if \; K_j \delta + \varepsilon_j > 0 \;\; and \;\; 0 \; if \; otherwise$$

As a result, M_j is a binary variable that, according to the assumption that it was created from an unobservable latent variable, indicates the household's choice to adopt agricultural diversification (or economic efficiency). If there is crop diversification (or efficiency), 1 was assigned to diversification and 0 otherwise. It is assumed that the error terms ε_j and μ_j have a bivariate normal distribution with zero means.

Ethical Considerations

The approval of the study was sought from the Institutional Review Board of the University of Cape Coast with reference number (UCCIRB/CANS/2022/49). Following the approval, a letter from the researcher was sent to the Okere district to the Department of Food and Agriculture in addition to the IRB document. After the approval from the district, the goal of the study was explained to these farmers.

The researcher also ensured that the entire procedure complied with the highest ethical guidelines. Each participant was allowed to provide written informed permission before being included in the study. During the interviews or conversations, the ability to withdraw from the study at any time was made clear to participants.. They were not induced to take part in the study through coercion or fraud. Additionally, the confidentiality of personal information and the restriction of its usage to the intended purpose was assured to participants.

Chapter Summary

The chapter focused on the methodology used. Specifically, the chapter looked at the research approach and research design that underpinned the research. The research employed a structured questionnaire to collect data, R and SPSS statistical software was used to analyse the results.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This study's goal was to look into how smallholder farmers in Ghana's Eastern Region's Okere District may enhance their food security by diversifying their food crop production and becoming more economically efficient. The analysis of the diversity of food crops, their economic viability, and their effects on the security of food production in households is presented in this chapter together with the empirical results. The chapter is divided into six sections: the socioeconomic characteristics of the farmers; the degree of food crop diversification; the factors influencing food crop diversification; the farmers' economic efficiency; a household's likelihood of being food secure, and a household's reliance on economic efficiency and crop diversity.

Socio-economic characteristics of Respondents

The section entails the presentation of the socio-economic findings of the study. These data include age, gender, experience, and among others. Table 5 presents results on the socioeconomic data used in the study.

The results revealed that only about one out of every 10 farmers were females. This is because men have an advantage over women in farming activities due to the cultural background in many Ghanaian communities which makes it simpler for men to acquire lands and production inputs.

Table 5: Background Characteristics of Respondents

Characteristics	Frequency	Percentages
Sex		
Males	300	90.9
Females	30	9.1

Total	330	100
Age		
20-29	4	1.2
30-39	79	23.9
40-49	108	32.7
50-59	107	32.4
60-69	25	7.6
70 and above	7	2.1
Total	330	100
Education		
No Formal Education	39	11.8
Primary	89	27.0
JHS	121	36.7
SHS	81	24.5
Total	330	100
Member of Farm Organization		
Yes	110	33.3
No	220	66.7
Total	330	100
Extension Service		
Yes	205	62.1
No	125	37.9
Total	330	100
Off Farm Activities		
Yes	188	57.0
No	142	43.0
Total	330	100

Variable	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
Age	28	75	46.56	9.72
Household Size	3	9	5.3	1.7
Experience	3	45	3.7	1.3
Size of Land Owned	1	5.8	2.4	0.9

Source: Field survey, Tagoe, (2023)

The conclusions of the study are in line with those of earlier research by Koufie (2020) and Igwe and Onyenweaku (2013), which discovered that men are more likely than women to work in small-scale farming while women are more likely to be involved in duties related to processing, harvesting, and selling.

Almost one-third of each of the farmers (32.7% and 32.4%) were between the ages of 40-49 and 50-59 years respectively. In evaluating a farmer's capacity for managing risk and degree of creativity, age is a key factor. As a result, a farmer's ability to perform manual labour declines as they aged. Ages of the farmers in the study range from 28 years old at the youngest to 76 years old at the oldest. Additionally, the 47-year-old mean age of farmers in the study area shows a greater involvement of adults in the production of food crops. These results concur with a research by Koufie (2020) conducted in the Assin North District, which found that the mean age of farmers engaged in the cultivation of food crops was 49 years old.

With regards to education, a total of 39 farmers in the research area had no formal education, compared to 36.7 percent who had completed junior high school whereas 11.8 percent of the farmers had no formal education. Just about a quarter of each of the farmers had attained Senior High School (24.5%) and primary school education (27.0%) respectively. However, none of the respondents had obtained tertiary education. This shows that most farmers have some level of education, allowing them to obtain knowledge and adopt cutting-edge farming techniques. These results support Koufie's (2020) assertion that farmers with a basic education are more likely to embrace and implement new technologies in their farming operations. Koufie made this observation while researching the ideal pattern in food crop enterprises in Ghana's Assin North District.

Among the surveyed farmers, 66.7 percent indicated that they are not affiliated with any farmer-based organization, while the remaining one-third expressed their membership in such organizations. This shows that when faced with difficulties on their agricultural holdings, these farmers relied on their instincts. The findings of the study agree with Twumasi (2021) who pointed out that 81.75 percent of the farmers do not belong to any farm-based organization when examining optimization analysis of crop farm enterprise and crop diversification.

Sixty-two percent of the farmers surveyed had access to extension services, compared to 37.9% who did not. This shows that the majority of farmers in the study area had the advantage of using extension programs and services. These results are consistent with Azad's research from 2021, which discovered that farmers frequently interact with extension officers.

Engaging in off-farm activities allows farmers to obtain capital for their agricultural operations and supplement their household farm income. The survey revealed that a significant majority of farmers (57.0%) were involved in off-farm activities. These farmers have the opportunity to generate supplementary revenue alongside their farm income through these off-farm pursuits, and this additional income is subsequently used to supplement the farm household budget. The finding was in disagreement with the work of Koufie, (2020) who reported that most farmers (97.8%) do not engage in off-farm activities in the Assin North District. The range of off-farm activities prevalent in each individual research region could be accountable for the variances in the results.

The study area's average household size was 6, exceeding both the Eastern Region's average of 3 and the national average of 4 found in the 2021 National Population Census (GSS, 2021). As a result, family members serve as a substitute for contracted farm labor in the majority of agricultural households in Ghana (Koufie 2020). Utilizing their family members for farm work enables farmers to reduce labor expenditures. Additionally, it was discovered that the farmers possessed 2.4 hectares of land on average. The results of the study are in line with studies by Larkai (2019) and Asante et al. (2017), which also showed that smallholder farmers frequently own land portions larger than 2 hectares.

The extent of crop diversification

The extent of crop diversification among farmers was measured using the Herfindahl index. This index is scaled from 0 to 0.9, where values greater than zero indicate food crop diversification, while zero represents specialization in a single crop. The crop diversification index was calculated to be 0.55, indicating a moderate level of crop diversification. The result further indicated that 93.64 percent of respondents out of 330 engaged in crop diversification whiles 21 were otherwise. A total of 21 farmers, accounting for 6.4 percent of the overall farmer population, opted not to engage in crop diversification in their production. These are farmers who are specialised in producing only one crop. This might be explained by the difficulty in obtaining land for farming purposes. The results from Rajendran et al. (2017) and Asante et al. (2017), who reported a value of 0.47 and 0.5, respectively, are consistent with the average value of the crop diversification index. The study then looked into the various crop combinations that the farmers in the study areas implemented.

The various crop combination on the farm

Farmers in the Eastern Region predominantly cultivate food crops such as plantain, maize, cassava, yam, vegetables, millet, rice, sorghum, and cocoyam. As pointed out by MoFA (2020), the Eastern Region's contribution in terms of food crops towards the national food basket cannot be underestimated, and Okere District is a major contributor to the region's production levels. According to the field survey, plantain, maize, cassava, yam, and vegetables were the primary food crop combinations seen in the study area. This result is consistent with the information provided by MoFA (2020). The various food crop combinations used by the farmers in the research region are shown in Figure 3 together with the matching number of responders for each combination.

The findings from the bar chart show that 21 (6.4%) of the farmers grow only one crop, 105 (31.8%) of the farmers grow two crop combinations and 58 (17.6%) of the farmers grow four crop combinations with 10 (3.0%) engaged in five crop combination. The results of the survey once more showed that 136(41.2%) farmers, engaged in three crop combinations. These findings concur with those made by Koufie (2020) in the Assin North district, where three crop combinations likewise represented 42.2 percent of all practices. In contrast to these results, Larkai (2019) revealed two crop combinations as the greatest level (41.0%), while Dembele (2018) discovered that three crop combinations were the most common (40%) in their respective study areas.

These variations can be attributable to a number of different reasons, including crop strengths in various places, climatic conditions, agronomic concerns, and cultural context (Koufie, 2020).

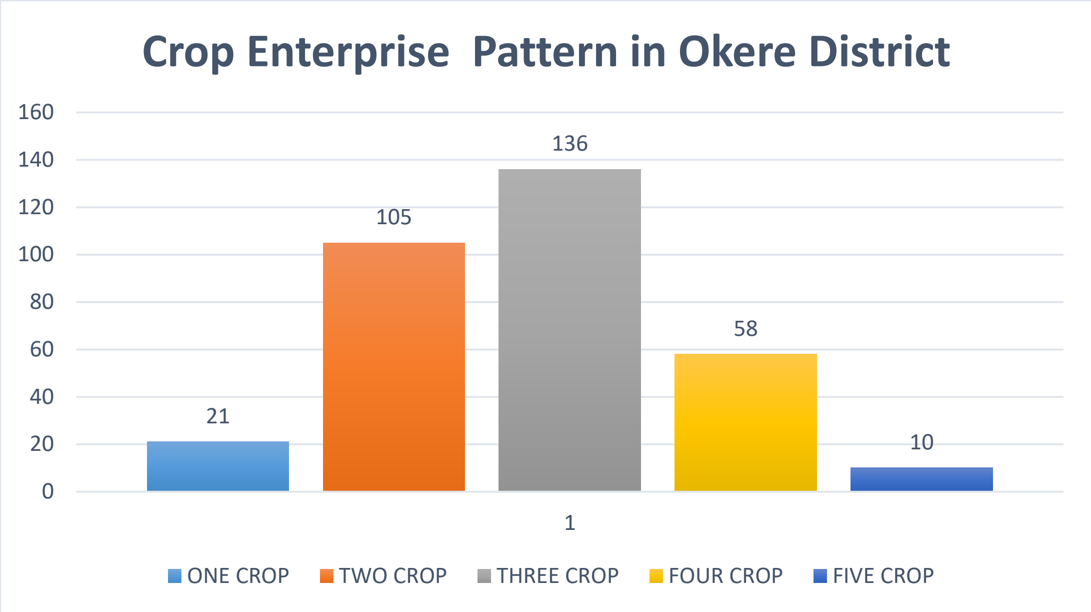

Figure 3 Crop Enterprise Pattern
Source: Field Survey, Tagoe, (2023)

Factors influencing crop diversification among smallholder farmers

A summary of the variables affecting crop diversification in the study area is given in Table 6. Tobin's model, was used to estimate these variables. The table implies that a farmer's choice to diversify his or her crop production is influenced by a number of factors, including age, education level, membership in farm-based organizations, size of the farm household, access to extension services, credit availability, participation in off-farm activities, size of owned land, and distance to the nearest market. Out of the variables listed above, seven of the variables significantly influenced farmers' decision to diversify their food crops.

Table 6: Tobit regression results on the determinant of crop diversification

Variables	Coefficients	Std Error	P Value
Age	-0.0307	0.0079	9.37e-05
Edu	-0.0250	0.0150	0.0943
Membership of FarmOrg	-0.0144	0.0114	0.2041
HHSize	0.0101	0.0044	0.0215
ExtensionService	-0.0494	0.0153	0.0013
AccessCredit	0.0391	0.0126	0.0020
OfFarmActivities	-0.0204	0.0096	0.0332
LandSizedOwned	0.0285	0.0059	1.45e-06
Distance	-0.0087	0.0055	0.1176
Experience	0.0171	0.0054	0.00141
Constant	0.5041	0.0625	7.4e-16

***1%significance, **5%significance, *10%significance

Source: Field Survey, Tagoe, (2023)

The results demonstrate a very statistically significant negative association between crop diversification and age at a 1 percent level. The findings indicate that, with a coefficient of -0.0307, farmers' propensity to engage in crop diversification declines by 0.0307 units as their age increases. This demonstrates that the likelihood of farmers engaging in crop diversification decreases as they get older and closer to retirement due to a tendency toward high-risk aversion. The findings concur with those of Aneani et al. (2011), who made a similar observation about how crop diversity was less likely as farm age increased.

Household size was statistically significant at the 5 percent level and showed a strong correlation with farmers' propensity to diversify their crop production. The findings show that the likelihood of farmers participating in crop diversification increases by 0.0164 units for every unit increase in family size. The size of the household serves as a proxy for the availability of labor, it is vital to highlight. According to these findings, farmers with larger households are more likely than those with smaller households to engage in crop diversification, which may include labor-intensive procedures. Agriculture in Ghana is mainly labour-intensive. Larger family sizes allow households to actively pursue different crop combinations. These outcomes are consistent with that of Babulo et al. (2014), who came to the conclusion that families with more members are more probable to diversify their crop production. Additionally, the outcomes are in line with Baba and Abdulai's (2021) findings, who observed a favorable link between household size and crop diversity.

At a 1 percent level, the amount of land that farmers own is highly statistically significant and shows a positive link with crop diversity. According to this, farmers with greater tracts of land are more likely than those with smaller ones to adopt crop diversification. According to the estimate produced from the study, an increase in a farmer's land holdings correlates to an increase of about 0.0285 units in their likelihood of engaging in crop diversification. This finding is consistent with that of Aneani et al. (2011), who found that farmers were more likely to use several crop combinations when they had access to more acreage. Additionally, this outcome is consistent with research by Ibrahim et al. (2009) and Sichoongwe et al. (2014), which demonstrated that households with more farmland have the capacity and opportunity to cultivate a range of crops in comparison to households with fewer farmland. Similar to this, Ashfaq et al. (2008) found that a big land size influences crop diversity in a substantial way.

Extension services have a negative link with crop diversity and statistical significance at 1 percent level. According to the extension services coefficient of 0.0494, there is a 0.0494-unit reduction in the likelihood that farmers will engage in crop diversification for every additional extension service provided. The extension system's emphasis on enhancing farmers' production and agronomic practices while disregarding the necessity of crop diversity in minimizing dangers may help to explain this. The outcome is in line with the study of Fetien et al. (2009) who asserted that extension services discourage farmers from engaging in multiple crop combinations. Rehima et al. (2013) contend that extension services have a favorable and significant impact on crop diversity in contrast to these findings. Likewise, Ibrahim et al. (2009) discovered that extension contacts increased crop diversification among farmers. The possible explanation is that when making recommendations to farmers, extension agencies frequently take market demand and profitability into account. Extension services may prioritize promoting a crop's cultivation if there is a significant market demand for it to assist farmers in meeting demand and achieving financial stability. Given the current study, most of these farmers were engaged in either cassava or maize production due to the demand for these crops and advice obtained from the extension agents.

Access to credit showed statistical significance at the 1 percent level and a favorable link with farmers' propensity to diversify their crops. According to the results, the probability that farmers will engage in crop diversification increases by 0.0391 units for every unit rise in loan availability. Farmers that have access to loans can invest and diversify their farming operations by growing a variety of crops. This credit makes it possible for the farmer to purchase inputs that will be used in different crop enterprises or expand cropping activities. The findings are in conformity with Bittinger (2010) who pointed out that a farmer receiving loan in the form of cash is more likely to diversify into different crops as compared with one who did not. This is also substantiated by the study done by Aneani et al. (2011).

Farmers' participation in off-farm pursuits exhibits statistical significance at a 5 percent level and exhibits an inverse relationship with crop diversification. The coefficient for off-farm activities, which is 0.0204, shows that as the number of off-farm activities rises, there is a 0.0204-unit reduction in the likelihood that farmers will practice crop diversification. This suggests that farmers are less likely to combine multiple crops if they engage in off-farm activities. The off-farm activities leave the farmers with limited time to venture into new technologies such as crop diversification. The finding concurs with the study of Dembele (2018) who stated that off-farm activity negatively and significantly influences crop farming. The results support the contention made by Omiti and McCullough (2009) that increasing earnings from non-farm activities may deter farmers from practicing farming.

Experience shows statistical significance at the 1 percent level and a favourable link with crop diversification. According to the experience coefficient of 0.0171, crop diversification is more likely to occur among farmers as their years of farming experience grows. Therefore, farmers who have greater farming expertise are more likely to diversify their crops. The outcomes of this study are consistent with those of Muhammed et al.'s (2008) study, which found that diversification is frequently used by farmers with more expertise. Rahman (2008) also found that seasoned farmers choose crop diversity as a tactical move to take advantage of the benefits associated with high returns for particular crops.

Other variables such as distance, education, and membership in farm organization are all statistically insignificant.

Household food insecurity status among smallholder farmers in Okere District

Using the Household Food Insecurity Access Scale indicator created by the FAO, the food security situation of the farmers in the research area was evaluated. The situation of smallholder farmers who are food insecure in the research area is shown in Figure 4. According to the research, a sizable proportion of farmers (74%) reported having trouble affording food, while only 26% were considered to be in a secure situation. As almost three-quarters of respondents were found to be food insecure, this demonstrates unequivocally that smallholder farmers in the district are experiencing food insecurity. It implies that only a limited number of farmers in the study area have consistent access to an adequate food supply throughout the year. Most of these farmers are either unable to acquire adequate food or lack the finances to buy the food they like. These findings are in agreement with those of

Mohammed et al. (2016), who found that only 23 percent of household respondents were food secure compared to 77 percent of farmers in their survey. Furthermore, Wiggins and Keats (2013) claimed that 67 percent of the world's food insecurity is concentrated in smallholder households because farmers who produce small areas of land are frequently net importers of food.

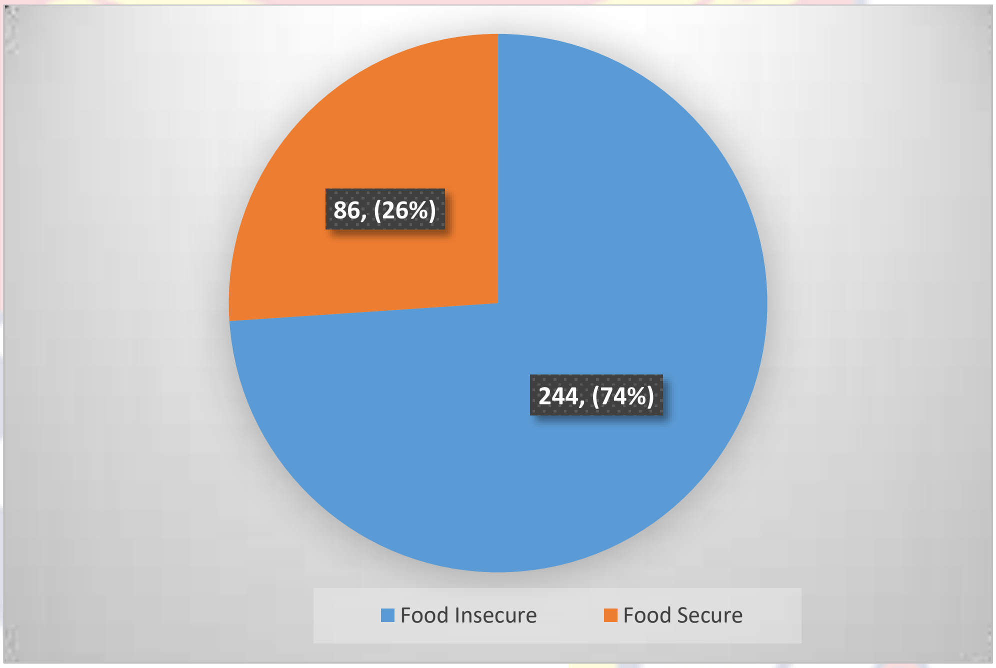

Figure 4: Household Food Insecurity Status
Source: Field Survey, Tagoe, (2023)

Prevalence of food insecurity among smallholder food crop farmers

The study then went on to investigate the degree of food insecurity among smallholder food crop producers after determining their current level of food security. Table 7 provides information on how often farmers in the study area experience food insecurity. Using the FAO-established criteria, the level of household food security was assessed. According to the incidence of household food insecurity, roughly 43.7 percent of farmers were characterized as rarely food insecure, 21.2 percent as moderately (occasionally), and roughly 9.1 percent as frequently food insecure. The majority of farmers were categorized as rarely food insecure, meaning that the members of the household occasionally had to make do with a small selection of food due to resource limitations. The 64.9 percent of households who are occasionally and infrequently food insecure might be categorized as marginal food secure households that occasionally experience food insecurity. They become completely food-secure households during normal harvests, but if the harvest is bad, they may experience temporary food insecurity (WFP, 2012; Nsabuwera, 2019). According to studies by Alidu et al. (2016) and Chinnakali et al. (2014), the majority of farming households experienced minor food insecurity. These findings are consistent with both studies.

Table 7: Prevalence of household food insecurity status

Prevalence	Frequency	Percentage (%)
Rare	144	43.7
Sometimes	70	21.2
Often	30	9.1
Total	244	74.0

Source: Filed Survey, Tagoe, (2023)

The household food insecurity access scale indicated

The frequency of occurrence

The results from Table 8 display the nine instances of each question from the indicator for household food insecurity. Table 7 below presents the average occurrences for each of the 9 questions used in the household food insecurity access scale indicator. The Minority of the farmers surveyed revealed that there is sometimes no food at all in their household because of a lack of resources, with an average of 0.49 representing the least frequent occurrence, and an average of 1.32 representing the most frequent occurrence stating that they are incapable in eat the kinds of food they prefer because of a lack. The findings of this study align with the research conducted by Nsabuwera (2019), who discovered that household members in Rwanda occasionally experience a whole day without eating due to insufficient food. This similarity supports the study's exploration of the socioeconomic factors influencing household food security.

Table 8: The average frequency of occurrence

Occurrence Questions	Mean	SD
HFIASI1	0.99	0.98
HFIASI2	1.32	0.85
HFIASI3	0.83	0.57
HFIASI4	0.77	0.63
HFIASI5	0.94	0.74
HFIASI6	0.91	0.67
HFIASI7	0.13	0.47
HFIASI8	0.59	0.85
HFIASI9	0.49	0.22

n= 330; Min. =0, Max.=3 Least average= 0.13, Highest =1.23

Source: Field Survey, Tagoe, (2023)

Level of efficiency among smallholder food crop farmers

Data Envelopment Analysis (DEA) was used to evaluate the effectiveness of the study area's farmers and estimate their level of efficacy. The output of the input analysis utilizing data envelope analysis, completed in accordance with Coelli's (1996) technique, is shown in Table 9. According to the results, technical efficiency (TE) under variable returns to scale (VRS) spans from 0.4 to 1.0, with an average value of 0.9560. Additionally, under constant returns to scale (CRS), the technical efficiency of farmers in the study area is calculated to be 0.8614. A farmer's scale efficiency might be anywhere from 0.4 and 1.0, with a mean of 0.9025 under technical efficiency.

Table 9: Frequency distribution of Constant return to scale, Variable returns to scale, and Scale efficiency score

Efficiency Score	CRS		VRS		SE	
	Freq.	%	Freq.	%	Freq.	%
< 0.4	-	-	-	-	-	-
0.4 - 0.5	7	2.1	-	-	6	1.8
0.5 - 0.6	9	2.7	5	1.5	6	1.8
0.6 - 0.7	29	8.8	4	1.2	18	5.5
0.7 - 0.8	53	16.1	14	4.2	31	9.4
0.8 - 0.9	71	21.5	38	11.5	58	17.6
0.9 - 1.0	84	25.5	43	13.0	133	23.6
1.0	77	23.3	226	68.5	78	40.3
Total	330	100.0	330	100.0	330	100.0

Summary of Technical Efficiency Score

Efficiency	CRS	VRS	SE
Min.	0.4502	0.5475	0.4502
1st Qu.	0.7619	0.9529	0.8457
Median	0.8962	1.000	0.9551
Mean	0.8614	0.9560	0.9025
3rd Qu.	0.9948	1.000	0.9989

Max.	1.000	1.000	1.000

Source: Field Survey, Tagoe (2023)

Again, according to the study's findings, when assuming constant returns to scale, over half (48.8%) of the farmers operate with high technical efficiency between 0.9 and 1. The production of food crops was determined to be technically inefficient for the remaining portion of farmers (51.2%). The mean efficiency score under the CRS is 0.861. Table 8's findings show that 51.2 percent of the farmers who weren't using their resources as efficiently as they could cut back on their input use by 13.9 percent while still producing at the same level as the 48.8 percent of technically efficient farmers operating under CRS.

Furthermore, with the used of (VRS) model, the technical efficiency score ranged from 0.5 to 1.00, with an average efficiency score of 0.9560. Relaxing the VRS assumption the results shows that at least 4 out of every 5 farmers (81.5%) operate with technical efficiency score ranging from 0.9 and 1.00 while 18.5 percent of the farmers were technically inefficient. The technical efficiency increased from 48.8 percent (CRS) to 81.5 percent, as shown by the VRS study, and the average technical efficiency increased from 0.86 to 0.96. This gain can be as a result of the fact that scale effects are not taken into consideration when computing technical efficiency. Scale efficiency is the ratio of technical efficiency with constant returns to technical efficiency with variable returns. Different types of returns to scale have an impact on efficiency scales.

From Table 9, more than 3 out of every 5 farmers (63.9%) were operating under a scale efficiency score of greater than (0.90). The farmers' scale efficiency scores varying from 0.45 to 1.00, with a mean of 0.90. According to the results, the farmers who showed scale inefficiency (36.1%) had the ability to increase their scale efficiency by 10 percent and work at an ideal scale within the constraints of current technology. By doing this, the farmers could raise the output and income from their crops.

According to the study's findings, the farmers in the study area are efficient under constant returns to scale (CRS), under variable returns to scale (VRS), and under-scale efficiency (SE), with scores of 0.86, 0.96, and 0.90, respectively. These findings, however, differ from those of Ayerh (2015), who claimed that Ghana's Ashanti Region's farmers were technically effective with an average score of 86 percent. In a similar vein, Mussa (2011) exhibited that farmers were technically inefficient, with an average score of 0.62, when looking at the economic efficiency of smallholder crop production. However, the distinct climate conditions present in each study area can be pinned for the discrepancies in the results across several studies. These variations can also be attributed to the main food crops grown in each region and the farming methods used by the local farmers.

Economic, Technical, and Allocative efficiencies among the farmers in the study area

Technical, allocative, and economic factors were taken into account when evaluating the productivity of farmers of food crops. Allocative efficiency is the capacity of farmers to produce a specific output at the lowest possible cost by efficiently utilizing farm inputs, without necessarily increasing input utilization. It stands for the effective distribution of resources to increase crop output while keeping input costs constant. Allocative and technical efficiencies are also included in economic efficiency. The efficiency findings from the food crop farmers in the research region are summarized in Table 10.

Table 10: Summary of allocative, technical, and economic efficiency

Efficiency	Mean	Std.D	Max	Min
Economic	0.4628	0.2541	1.0000	0.0981
Technical	0.9097	0.1471	1.0000	0.4075
Allocative	0.5088	0.2639	0.9815	0.2408

Source: Field Survey, Tagoe (2023)

Economic Efficiency

Farmers in the study area have economic efficiency scores ranging from 0.09 to 1, with an average of 0.46. These results imply that farmers produce below the maximum possible output level but at higher production costs. With the lowest economic efficiency score, farmers may increase their output efficiency by 90% by making both technical and allocative efficiencies better. Again, the average economic efficiency depicts that farmers can improve their production level by 53.7 percent with the same technology used. Again, Osman et al. (2018) discovered that the average economic efficiency for soybean production in Ghana was 0.495. The farmers in our survey had an efficiency range of 0.09 to 0.854, with 0.09 being the smallest and 0.854 being the highest..

Technical Efficiency

The findings showed that the farmers' technical efficiency ranges from 0.40 to 1, or an average of 0.90. This means that, on average, crop growers produce food crops at 90 percent technical efficiency level. There is still potential for improvement, though, as technical inefficiencies have caused production to fall about 10 percent short of the goal. This suggests that production process inefficiencies prevent a sizeable part of potential output from being realized. Thus, by making better use of the available resources, farmers have the ability to increase their food crop production by an average of 10 percent given the current state of technology and input levels. However, the finding from the study is in disagreement with Obwona (2006) who recorded the overall efficiency among the farmers to be 0.784 in Uganda. Hence, the differences in the findings can be attributed to the knowledge of the farmers based on the rightful allocation of farm resources at the farm level for a given amount of output in the individual study area.

Allocative efficiency

The allocative efficiency average score was 0.5088, implying that farmers are 49.1 percent inefficient in food crop production. The results suggest poor use of productive inputs given the input prices. Therefore, farmers do not allocate inputs correctly to produce the possible outputs at minimal costs in their production. This indicates mismanagement of resources, possibly on the farmers' side. Although the government subsidies tractor services and provide seeds to farmers, farmers are responsible for searching for and agreeing with tractor service providers to plow for them. After the government plowing has finished the farm, the management of the farm lies in the hands of the farmer. Again, the minimum allocative efficiency of the farmers was 0.2408 while the maximum was 0.9815. The farmers with minimum allocative efficiency can increase efficiency by 0.76 with the same level of technology. Likewise, the findings of the study are similar to Tijjani and Bakari (2014) who reported that the average allocative efficiency among the food crop farmers was 0.69 in Taraba State, Nigeria. Also, the minimum allocative efficiency was 0.51 while the maximum was 0.90.

Determinants of allocative efficiency among the food crop farmers in the study area

The determinants of allocative efficiency among the food crop farmers within the study area were accessed with the use of the Tobit regression model. Six out of the ten socioeconomic variables included in the model showed statistical significance in affecting the allocative efficiency of the farmers. A summary of the variables affecting allocative efficiency among crop farmers in the research area is shown in Table 11.

Table 11: The Determinant of Allocative Efficiency.

Variables	dy/dx	Estimate	Standard Error	p-value
Age	0.0183	0.0183	0.0154	0.233
HouseholdSize	0.0023	0.0022	0.0087	0.796
ExtensionSer	0.0288	0.0288	0.0298	0.335
AccessCredit	0.0713	0.0713	0.0250	0.005
Off-Farm-activities	0.0077	0.0007	0.0186	0.967
Landsizeowned	0.2191	0.2190	0.0145	0.000
Education	- 0.0088	- 0.0088	0.0290	0.761
ExperienceInCrop	- 0.0224	- 0.0224	0.0115	0.052
Distance	- 0.0222	- 0.0222	0.0122	0.071
FertilizerApp	0.0887	0.0886	0.0325	0.007
Any-Farm-Org	- 0.0954	- 0.0954	0.0225	0.000

Constant	- 0.0377	0.1690	0.823
Model Summary			
Observation	330		
Pseudo r-square	5.776		
Chi-square	325.653		
Prob>chi2	0.000		

Source: Field Survey, Tagoe (2023)

Access to credit was positive and significantly influenced allocative efficiency at 1 percent significant level. Through credit facilities, farmers can increase allocative efficiency by 7.1 percent. The opportunity of the household head to have access to credit affects efficiency for the reason that the credit obtained from the banks or any financial institution might be employed for the acquisition of agricultural inputs such as tractors, fertilizers, insecticides, and drones among others. The availability of the credit facility allows farmers to make timely acquisitions of these inputs which they cannot offer. As a result of the acquisition of these inputs, farmers can increase efficiency through the production season. The study's results align with Tesema's (2021) research, which concluded that there is a positive correlation between access to credit and allocative efficiency. At the 5 percent level, it was determined that the association was statistically significant.

According to the field findings, Land size and allocative efficiency were positively correlated, and this relationship was shown to be statistically significant at the 1 percent level. This suggests that an increase in the farm size by a hectare will increase allocative efficiency by 21.9 percent. Farmers that have bigger pieces of land may profit from economies of scale, allowing for more effective resource allocation. Farmers might have the chance to make investments in cutting-edge equipment, adopt automated procedures, and set up more expansive production systems if their land area grows. The advantages of economies of scale encompass reduced production costs per unit and enhanced allocative efficiency. Consequently, farmers can attain an optimal utilization of production factors more effectively on larger land sizes compared to smaller ones. Similarly, Sibiko et al. (2013) revealed that farmers with large farms exhibit significantly higher levels of allocative efficiency. The results again point out that farmers with large farms portray economies of scale in production, which makes them more efficient in allocating resources.

The results showed that there was a negative association between experience in crop farming and allocative efficiency, and this association was statistically significant at the 10 percent level. This suggests that every additional year of producing food crops will result in a 2.2 percent reduction in allocative efficiency. Crop farming experience is not the same as years spent cultivating crops. Even though a farmer may have been producing crops for a longer period, this does not guarantee that the farmer has experience with crop farming. Farmers can produce crops for a longer period but are resistant to improvements that could improve their allocative efficiency. The results of the study are in disagreement with Sibiko et al. (2013) who pointed out that the degree of experience influences allocative efficiency in a favourable and profound way. This suggests that the productivity of the farmer's crop grows as the length of his or her involvement in crop production increases. The disparities in the results might be related to the fact that most farmers with greater experience tend to disregard new agronomic procedures that can raise their level of efficiency and rely instead on their instincts and their traditional methods of farming.

There was a negative correlation among allocative efficiency and the distance to the nearest market, and this correlation was found to be statistically significant at the 10 percent level. This implies that an extra kilometer to the nearest market lowered allocative efficiency by 2.2 percent. The farmer spends more money getting the finished product to the closest market as the distance increases. Again, the farmer incurred extra costs as a result of buying his inputs from the nearest market due to the distance s/he has to cover to get his inputs. Hence, Farmers' production expenses have increased, which has an impact on allocative costs. These costs include the cost of conveying the final product to the closest market and purchasing farm supplies. Furthermore, poor rural-urban road infrastructure deters some farmers from bringing their goods to market. These results are consistent with those of Mutoko et al. (2015) and Ahmed et al. (2015), whose studies likewise found a negative association between allocative efficiency and distance to the market.

Allocative efficiency and fertilizer application showed a positive connection, which was shown to be statistically significant at the 1 percent level. According to these findings, a one-unit increase in fertilizer application on farms results in a 8.8 percent improvement in resource allocation efficiency. Through the right application of fertilizer during crop production, the probability of an increase in crop production becomes very high for the farmer. The results could be an increase in allocative efficiency by 8.8 percent.

There was a negative correlation between the membership of farm-based organizations and allocative efficiency, and this correlation was found to be statistically significant at the 1 percent level. This shows that an increase in participation in membership of farm-based organizations decreases allocative efficiency by 9.5 percent. The members of this organization's agricultural production are significantly impacted by the education or training they have acquired. The level of allocative efficiency will be dependent on the training received by these farmers. If the training received increases allocative efficiency, then the probability of the farmers becoming efficient in their input's usage becomes high. The findings of the study are at variance with Kamau (2019) who revealed that farmers who belong to farm-based organizations can increase allocative efficiency by 7 percent. Thus, farm-based organizations exhibit positive associations. The study's conclusions varied from study to study because not all farmers put the training they got from the farm-based organization into practice. Again, it is one thing for the farmers to receive training, is also another thing for its implication at the farm level. Finally, the majority of farmers do not participate in these organizations, which results in their lateness and absence from meetings.

Determinants of Technical Efficiency among the food crop farmers

Generally, a farm attains technical efficiency when it increases output using the existing technology without necessarily increasing the use or wasting of inputs. After evaluating allocative efficiency levels, the Tobit model was used to look into the variables affecting technical efficiency among farmers of food crops. Results showing the factors influencing technical efficiency are shown in Table 12.

The farmer's age showed an inverse relationship with technical effectiveness, which was shown to be statistically significant at the 1 percent level. This displays that an additional year on the farm will decrease technical efficiency by 4.4 percent. This may be explained by the older farmers' propensity to rely customary cultural practices and their unwillingness to implementing new agronomic techniques, contemporary agricultural machinery, and technological advancements on their farms. Most of these farmers believe in what they inherited from their parents and are not willing to change. Again, According to Asefa (2011), many of these people demonstrate risk aversion and are hesitant to adopt contemporary agricultural approaches. On the other hand, young people might show more excitement for and willingness to use innovative agricultural methods that could increase crop yield. The young, most at times, are risk lovers and are always willing to venture into or explore new technology on their farm. The finding from the study corroborates with Osman et al. (2018) who revealed that older farmers are economically less efficient than the youth. The findings also show that age negatively and significantly influences technical efficiency at the 1 percent level of significance.

The household size of the farmer had a positive relationship with technical efficiency and was significant at 5 percent. According to these results, the efficiency of the household is increased by about 2.7 percent when an additional individual is added. In agricultural communities, the size of the farm household makes a substantial contribution to farm labour. Most agricultural households in rural areas use household size as a proxy for labour. Larger household sizes can manage multiple crop diversification than smaller household sizes (Etwire et al., 2013). During the period of sowing to the time of harvesting, a larger household size ensures that its members promptly carry out essential farming activities such as weeding, plowing, and harvesting, resulting in increased production efficiency compared to smaller households. Similarly, Sisay et al. (2015) emphasized that a larger family size is positively correlated with technical efficiency and is statistically significant at the 1 percent level.

Technical efficiency and the amount of land the household head cultivates are negatively correlated, and this link is statistically significant at the 1 percent level. This suggests that farmers with small land sizes have an efficiency advantage over farmers with large land sizes. Farmers with tiny farms may manage and produce crops with greater effectiveness by 19.5 percent compared to those with huge farms. Similarly, Sisay et al. (2015); Otitoju and Arene (2010); Idiong (2014) also discovered that land size cultivated had a negative impact on crop level technical efficiency and statistically significant 5 percent. This is because farmers with small farm sizes can manage more than their counterparts with large farm sizes. Contrarily, a number of researches, including those by Endrias et al. (2010) and Hussein (2007), have found a link between efficiency and land size. According to this research, farmers with larger farms seem more inclined to use contemporary agronomic techniques, which may result in increased efficiency because of the benefits of economies of scale and scope that come with larger land areas. As a result, several researchers produced varying conclusions based on how the area of the land cultivated affected the degree of technical efficiency. Nevertheless, the results of this study contribute significantly to the continuing scholarly debate over the connection between technical effectiveness and land size.

Technical efficiency and the household head's education showed a favourable association that was statistically significant at the 10 percent level. This shows that farmers that receive education are better equipped with management skills, and knowledge of current technologies, and agricultural methods. Agriculture best practices, innovations, and discoveries are more likely to be known by farmers who have obtained formal or informal education. Higher technical efficiency results from their ability to make educated judgments, adopt better practices, and efficiently use resources. According to Thabethe (2013), farmers with some knowledge can boost technical efficiency by 62 percent, which is in line with the study's findings.

Technical efficiency showed a negative connection with farmer experience in food crop production, which was statistically significant at the 1 percent level. One possible explanation is that farmers with greater years of experience in crop production may be resistant to change or less inclined to adopt new practices. Experienced farmers can have acquired ingrained prejudices and habits as a result of their successes or failures in the past. These engrained behaviours could keep individuals from contemplating different strategies or putting new procedures into place that might increase productivity. They might rely on obsolete methods or traditional wisdom that aren't necessarily the most effective or long-lasting. The study's findings contradict Ahwireng's (2014) who shown a statistically significant association between farmers' experience and technical efficiency at 1 percent level. According to this study, crop producers with more years of expertise are typically less productive than those with less experience. These discrepancies in findings may be explained by the farmers' varying levels of experience and capacity to adopt new technology that increases efficiency.

Technical efficiency and distance to the closest market have a favourable relationship and statistically significant at 1 percent. This suggests that extra kilometres from the farm to the market increase technical efficiency by 7.9 percent. Long distances to the market often make farmers plan their production cycles and harvest schedules more strategically. Farmers adopt practices such as staggered planting or crop rotation to ensure a continuous supply of products to distant markets. This demand-driven production planning helps to minimize product spoilage, reduce waste, and optimize the utilization of resources, leading to improved technical efficiency. Sibiko et al. (2013) asserted that there was a negative correlation between technical efficiency and distance to the market that was statistically significant at the 5 percent level. This study's findings are in direct opposition to the authors' assertions. The changes in the distance between the farm and the market across different research may be accountable for the variations in results.

Table 12: Determinant of Technical efficiency among the farmers

Variables	dy/dx	Estimates	Standard Error	p-value
Age	- 0.077	- 0.0767	0.0196	0.000
HouseholdSize	0.027	0.0265	0.0126	0.035
ExtensionSer	0.101	0.1011	0.0650	0.121
AccessCredit	0.025	0.0245	0.0416	0.555
Off-Farm-activities	- 0.033	- 0.0330	0.0257	0.201
Landsizeowned	- 0.195	- 0.1951	0.0203	0.000

Education	0.026	0.0264	0.0136	0.053
ExperienceInCrop	- 0.164	- 0.1641	0.0353	0.000
Distance	0.079	0.0786	0.0235	0.001
FertilizerApp	- 0.006	- 0.0057	0.0563	0.920
Any-Farm-Org	0.008	0.0080	0.0442	0.856
Constant		1.9556	0.2579	0.000
Model Summary				
Observation	330			
Pseudo r-square	1.1117			
Prob>chi2	0.000			

Source: Field survey, Tagoe (2023)

Determinants of economic efficiency among smallholder farmers

To analyze the variables affecting smallholder farmers' economic efficiency, the Tobit model was once more used. To ascertain their effects and relevance on economic efficiency, a variety of socioeconomic variables were subjected to regression analysis. Table 13 presents a summary of the findings relating to the variables affecting farmers' economic efficiency.

Economic efficiency was positively impacted by household size, and this effect was statistically significant at the 10 percent level. This shows that compared to a lower household size, a bigger household size is better suited to manage different agricultural operations. The justification for this is that there is frequently a manpower scarcity for carrying out various chores on the farm during harvest or peak seasons. During the harvest season, households can deploy their members to carry out the necessary farming activities such as ploughing, packaging, weeding, fertilizer application, and others. This will enable the farmer to avoid waste due to the availability of labour, and hence promote efficiency. The findings align with those of Sisay et al. (2015), who reported a statistically significant positive correlation between a large family size and efficiency at the 1 percent level. Therefore, having a large family ensures the availability of sufficient farm labour to carry out necessary operations.

Access to credit showed a favourable correlation with productivity which was statistically significant at the 10 percent level. This means that farmers with access to credit can afford agricultural inputs that will enhance productivity. In addition, an increased unit of credit to the farmer will allow the farmer to acquire equipment such as tractors as well as other farm equipment that will make work easier and faster. The results of the study are consistent with the research by Karani et al. (2015) and Wakili and Isa (2015), who stressed that access to finance promotes diverse agricultural methods and boosts productivity by making yield-improving resources cheaper.

The size of the land was shown to be positively correlated with the likelihood of a farmer being efficient and statistically significant at the 1 percent level. The results indicate that for every unit increase in land size, the likelihood of efficiency increases by 0.0840. This suggests that farmers with large land sizes can engage in crop rotation from time to time. This agricultural practice makes the land fertile from time to time. Thus, the land can restore its nutrients after leaving without any cultivation on it. Therefore, large-scale farmers profit from this technique and generate more production. The findings support the results of Itich (2020); Tolesa et al. (2019), who found that farmers with large farm sizes use modern agricultural practices and are therefore more productive because of the advantages they enjoyed from producing on a large scale.

Experience in farming was determined to be statistically significant at the 1 percent level and had a negative impact on efficiency. This suggests that farmers who cultivate the same crop over a long period find it difficult to adopt new technology. These farmers mostly rely on existing farming practices that they are comfortable with, hence they are adamant to change. The findings concur with Mbugi (2020) who found that experience in farming indirectly influences efficiency. However, the study is in contrast with Ara-Begum et al. (2009) who pointed out that experience in crop production influences economic efficiency positively. Also, the findings of Oumarou and Huiqiu (2016) revealed that farmers with additional experience in crop production can predict accurately when to plant and what to plant.

From Table 13, distance to the market is statistically significant at 10 percent and has a negative relationship with economic efficiency. An extra kilometer to the market decreases economic efficiency by 0.0207 units. This implies the cost that the farmer will be incurred as a result of transporting the output to the consumer market. As the distance increases, so does the cost of transportation for the farmer. The farmer is deterred from producing for the market by the high transportation costs. The results support research by Ahmed (2015) and Kamau (2019), which found that proximity to the market had an adverse effect on economic efficiency and was statistically significant at the 1 percent level..

Table 13: Determinant of economic efficiency among smallholder farmers

Variables	Estimate	Std. Error	P values
Age	- 0.0178	0.0104	0.0871.
HHsize	0.0122*	0.0059	0.0385
ExtensionService	0.0243	0.0202	0.2303
AccessCredit	0.0354*	0.0170	0.0374
OfFarmActivity	0.0053	0.0126	0.6733
LandSizeOwned	0.0840***	0.0099	<2e-16
Education	- 0.0134	0.0197	0.4966
Experience	- 0.0324***	0.0078	3.17e-05
Distance	- 0.0207*	0.0083	0.0127
MembershipOrg	-0.0872***	0.0153	1.25e-08
FertilizerApp	-0.0210	0.0220	0.3417
Constant	0.4814	0.1146	2.70e-05

***1%significance, **5%significance, *10%significance

Source: Field Survey, Tagoe (2023)

Membership of farm-based organisation was significant at 10 percent and negatively influenced efficiency. This suggests that a farmer's efficiency declines as their level of involvement in farm-based organizations increases. This can be due to the farmers' incapacity to utilize this organization and successfully put whatever was taught at the farm level into practice. In addition, lateness, absence, and dues taken by some of these farm-based organisations can negatively influence efficiency. The findings of the study contradicted the perspective presented by Sanyang (2014), who highlighted that farmers who are members of farm-based organizations often have access to prompt support from the government and other stakeholders. These groups offer financial support, and other advantages, and promote the flow of technical information in the form of subsidized inputs.

Summary of variables Influencing efficiency

The size of the farmer's household had a considerable and favorable impact on both technical and economic efficiency in the research area, according to discussions regarding the factors that determine allocative, technical, and economic efficiency. This suggests that a big household can deploy its members to undertake various roles from sowing or planting to the period of harvest.

Access to credit also exerted a positive influence on both allocative and economic efficiency. The farmer's ability to obtain credit increases the likelihood of achieving higher levels of efficiency.

Farmers' use of land has a good effect on their technical and financial efficiency. So, in order to increase their level of productivity, farmers are pushed to cultivate a larger area of land.

The experience of the farmers negatively influenced technical, allocative, and economic efficiency. The possible explanation is that some of these farmers are not willing to change and rather prefer to rely on their old methods of crop production.

The distance to the nearest market negatively influenced allocative and economic efficiency. Thus, the extra kilometers to the nearest market sometimes discourage farmers from acquiring inputs to increase production because of the additional cost that they incurred. Again, the farmers are also discouraged from increasing production because of the additional cost to be incurred as a result of transporting the harvest to the nearest market.

Being a member of a farm-based organization negatively influenced allocative and economic efficiency. Thus, farmers who do not take active participation in farm-based organizations are likely to experience a decrease in their level of efficiency. Because these farmers are not abreast with new technology which will enable them increase productivity.

The endogenous treatment effect model to check for endogeneity

The study employed the endogenous treatment effect model, as proposed by Heckman (1979), to examine the potential presence of endogeneity between the error term and the independent variables, as well as the omission of variables. Endogeneity suggests the occurrence of unobserved heterogeneity, which may produce false study findings. The endogenous treatment effect technique was used to address this issue, controlling for potential endogeneity by adding endogenous repressors such as the household head's educational level and the availability of credit. Table 14 also shows the outcomes of the Wald test of independence for the independent variables. The results from the test, which show that the independent variables are exogenous (rho=0: Chi2=1.16, Prob >chi2=0.2806 and rho=0: Chi2=0.30, Prob>chi2=0.5813), support the null hypothesis. This demonstrates that the independent variables in the analysis can be regarded as exogenous.

After examination of the possibility of endogeneity, the study proceeded to use logistic regression to model the dependence of household food security on economic efficiency and crop diversification.

Table 14: The endogenous treatment and effect model (Treatment variable is CDI and EconsEfficiency)

Variables	dy/dx	Std.Err.	P>z	dy/dx	Std.Err.	P>z
Fertilizerapp	- 0.099	0.124	0.425	0.298	0.198	0.133
Off-activities	0.082	0.047	0.085	0.035	0.065	0.592
ExtensionServ	0.085	0.052	0.106	0.284	0.116	0.015
ExperienceCrop	- 0.020	0.035	0.568	-0.014	0.043	0.751
Householdsize	0.058	0.030	0.049	0.023	0.027	0.395
Maritalst	- 0.241	0.058	0.000	-0.350	0.086	0.000
Age	0.101	0.068	0.138	0.185	0.070	0.008
Sex	0.332	0.160	0.039	0.617	0.236	0.009
Education	0.086	0.072	0.232	0.072	0.088	0.415
AccessCredit	0.011	0.086	0.898	-0.249	0.139	0.073
CDI	- 0.141	0.192	0.461	-	-	-
EconsEfficiency	-	-	-	0.780	0.429	0.069
Hazard lambda(CDI)	- 0.051	-0.133	0.649	-	-	-
Hazard lambda(EE)	-	-	-	- 0.409	0.256	0.111

Model Summary			
Number of Obs	330	Obs	330
Wald chi2(21)	175.31	Wald chi2	116.13
Prob > chi2	0.0000	Prob >chi2	0.0000
Rho	- 0.129	Rho	- 0.827
Sigma	0.399	Sigma	0.493

EE LR test of indep. eqns. (rho = 0): chi2(1) = 1.16 Prob > chi2 = 0.2806
CDI LR test of indep. eqns. (rho = 0): chi2(1) = 0.30 Prob > chi2 = 0.5813

***1%significance, **5%significance, *10%significance Source: Field Survey, Tagoe (2023)

Effect of Allocative, Technical, and Economic Efficiency on household food security status

The relationship between household, individual, and institutional variables and the level of food security in farming households was examined using a logistic regression model. Table 15 shows the marginal impact of the variables used. Eight of the twelve variables thought to affect the household food security were shown to be statistically significant based on the logistic regression model. These include economic efficiency, extension services, household size, experience, marital status, age, and sex. Allocative efficiency (AE), technical efficiency (TE), and economic efficiency (EE) were all examined at the same time. Table 15 presents the study's findings, including those pertaining to these efficiency indicators.

The findings revealed that economic efficiency is statistically significant at the 10 percent level and has a favourable effect on the chance of obtaining household food security. The marginal impact predicts that a one-unit gain in efficiency will lead to a 0.33 increase in household food security under the assumption that all other factors remain constant. This result might be explained by the fact that farmers who can optimize output while minimizing costs can reduce waste and raise productivity on the farm. In addition, these farmers can increase productivity and provide enough food for their households and sell the surplus to make a profit to support their household budget. Through profit maximization, these farmers can earn more income that will help them to access the various food from time to time thereby reducing household food insecurity status. The study supports the findings of Majumder et al. (2016), who highlighted that farmers can increase crop production's economic efficiency and reduce food poverty. The study done by Oyakhilomen et al. (2015) further highlighted the fact that technical efficiency helps to improve family food security.

The results showed that, across allocative, technical, and economic efficiency indicators, the household head's off-farm activities were positively correlated with the level of food security in the home and statistically significant at the 5 percent level. Under the assumptions that other variables remain constant and there is allocative, technical, and economic efficiency, the marginal effect values show that an additional off-farm activity by the household head increases the probability of achieving household food security status by 9.96 percent, 9.98 percent, and 10.09 percent, respectively. Farmers in the studied area frequently engaged in off-farm occupations like trading, building work, and livestock rearing. This implies that farmers who participate in off-farm activities in addition to their core farming may generate additional income to cover the needs of the household for food. The study by Mohammed et al. (2016), which found that off-farm activities have a favourable and significant impact on household food security, is consistent with this finding.

Household size exhibited statistical significance at the 10 percent level for both allocative and economic efficiency, and it had a positive impact on household food security status. This suggests that as the household size increases, the level of household food security status also tends to rise. This observation might be explained by the fact that larger households have the capacity to manage multiple food crop enterprises compared to smaller households, considering that agriculture in Ghana relies heavily on labour-intensive practices. In Ghana, many farm households leverage their larger household sizes to boost food crop production through the utilization of family labor, as highlighted by Etwire et al. (2013). The outcome of the study is in line with Taylor's (2017) earlier research, which demonstrated a negative correlation between the level of food insecurity in a farm household and the size of the household. Additionally, these results concur with those of studies by Gebre (2012) and Aidoo et al. (2013), which similarly found a link between household size and food insecurity.

Allocative, technical, and economic efficiency indicators all showed a negative correlation with marital status and statistical significance at the 1 percent level for this relationship. One argument is that families headed by single people are more likely to attain food security than families headed by married people. This could be because married household heads must provide food for more of their members than labour, which places more strain on their households' food consumption, and vice versa. The marginal impact shows that a rise in the proportion of households led by single people is associated with a better likelihood of achieving household food security. The research by Osman (2016), which likewise came to the conclusion that single household heads typically experience better levels of food security than married household heads, is supported by these findings.

The sex of the farmer exhibited a positive association with household food security status, reaching statistical significance at the 1 percent level across allocative, technical, and economic efficiency measures. The value of the marginal effect under efficiency connotes that the tendency of the household head to be a male will increase the probability of household food security by 13.2 percent, 13.6 percent, and 34 percent under allocative, technical, and economic efficiencies respectively. This implies that men are traditionally regarded as the head of the family whereas their counterparts the women are usually perceived to undertake housekeeping responsibilities such as washing, and cleaning among others. Not only that but the males can engage in other activities in addition to their farming occupation to make enough food available for their household than the females. The women on the other hand are engaged in house chores, and washing among others, which limits them to involve in other income-generating activities. Farm households with male heads tend to have greater levels of food security than those with female leaders, according to research by Namaa (2017) and Osman (2015). Thus, women are frequently viewed as housewives, whose responsibilities are to carry out housekeeping chores such as cooking, providing food, and breastfeeding.

For allocative, technical, and economic efficiency, the age of the farm household head showed statistical significance at the 1 percent, 5 percent, and 1 percent levels, respectively. Additionally, It increased a household's level of food security. The marginal effects demonstrated that, under the assumptions of allocative, technical, and economic efficiency, there was a likelihood of raising household food security status by 34.1 percent, 33.1 percent, and 13.8 percent, respectively, for every year rise in the farmer's age. As the household head's age increases, it tends to bring forth insights and ideas that enable the farmer to adopt measures or strategies to safeguard the farm household from food insecurity. A typical example is a household diversifying its food crop to hedge against food insecurity. In addition, some individuals strive to participate in off-farm activities as a means to safeguard their households from food insecurity. This finding, which is statistically significant at the 1% level, backs up Namaa's (2017) assertion that the household head's age has a favourable effect on the level of food security in the home.

The farmer's experience exhibited a favourable correlation with the level of food security in the home and was statistically significant at 10 percent, under allocative and economic efficiency respectively. According to this, the likelihood of achieving household food security increases by 5.1 percent and 5.3 percent under allocative and economic efficiency, respectively, with each additional year of agricultural experience. Farmers with more years of experience understand the seasonal nature of crop production over the years. These farmers know the season for each crop and the time of harvest as well. This informs them of what to sow or plant during the minor season and the major season. With this knowledge, it becomes difficult for the farmer to experience food insecurity issues within the year. Therefore, smallholder food crop farmers take advantage of these background experiences to sow their crops according to minor and major farming seasons to have enough food throughout the year. Agidew and Singh's (2018) study found a statistically significant correlation between the farmer's experience and household food security of 5 percent. Thus, as the experience of the crop farmer increases, skills and knowledge about effective utilization and sustainable land management of the available small farmland will be increased which will translate into more production of food crops.

However, allocative and technical efficiency also positively influenced household food security but were insignificant. The marginal effect under allocative, technical, and economic efficiency was 28.5 percent, 14.8 percent, and 32.8 percent respectively. This implies that economic efficiency which deals with the maximization of output and minimization of cost influence household food security more than other level of efficiency. As a result, household food security will rise by 32.8 percent for every unit gain in economic efficiency.

Table 15: Effect of Allocative, technical and economic efficiency on household food security

Variables	Allocative efficiency			Technical Efficiency			Economic Efficiency		
	dy/dx	Coef.	St.Err.	dy/dx	Coef.	St.Err.	dy/dx	Coef.	St.Err.
Allocative	0.2850	1.7394	1.2024	-	-	-	-	-	-
Technical	-	-	-	0.148	0.8978	0.0992	-	-	-
Economic	-	-	-	-	-	-	0.3286	2.0111*	1.1350
Off-Farm-activities	0.0996	0.6081**	0.2921	0.099	0.5981**	0.2897	0.1009	0.6175**	0.2923
ExtensionServ	0.0625	0.3813	0.4441	0.073	0.4419	0.4443	0.0629	0.3852	0.4446
Experience	0.0505	0.3081*	0.1618	0.039	0.2388	0.1522	0.0534	0.3270**	0.1628
HouseholdSize	0.0378	0.2309*	0.1299	0.042	0.2544*	0.1301	0.0374	0.2288*	0.1300
MaritalStatus	- 0.2174	- 1.3273***	0.2994	- 0.207	- 1.2589***	0.2977	- 0.2119	- 1.2971***	0.2970
Age	0.3408	2.0801***	0.8025	0.331	2.0086**	0.7989	0.1377	0.8427***	0.3048
Sex	0.1326	0.8091***	0.3020	0.136	0.8266***	0.3045	0.3405	2.0837***	0.8036
Edulevel	- 0.0018	- 0.0108	0.1434	- 0.004	- 0.0235	0.1426	- 0.0019	- 0.0117	0.1431
Accesscredit	- 0.0467	- 0.2851	0.3825	- 0.015	- 0.0907	0.3686	- 0.0424	- 0.2598	0.3742
Landsizeowned	- 0.0431	- 0.2634	0.2303	- 0.000	- 0.0028	0.1990	- 0.0332	- 0.2029	0.1961
Constant	-	- 3.2106	1.9632	-	- 4.6682***	1.8058	-	- 3.4044*	1.8427
Summary				**Summary**			**Summary**		
Observation	330			Observation	330		Observation	330	
Prob>chi2	0.0000			Prob>chi2	0.0000		Prob>chi2	0.0000	
Pseudo	0.1317			Pseudo	0.1265		pseudo	0.1339	

***1%significance, **5%significance, *10%significance
Source: Field Survey, Tagoe (2023)

The Effect of food crop diversification on household food security

After performing a rigorous endogeneity assessment, the logistic model was used to analyse the effect of food crop diversification. Seven variables were shown to be important influences on family food security out of the eleven variables in the model (shown in Table 16). Access to extension services, education, credit, and the size of the land were found to have a big impact on household food security in the model. Additionally, Age, sex, marital status, crop type, extracurricular activities, farmer experience, family size, and other factors had statistically significant effects on household food security. The model kept the sociodemographic factors listed in Table 15 as inputs.

Table 16: Effect of Crop Diversification on household food security

Variables	Margins (dy/dx)	Estimate	Standard Error
Crop diversification	0.9180	5.7212***	2.2009
Off-Farm-activities	0.0880	0.5486*	0.2952
ExtensionServ	0.0172	0.1075	0.4588
Experience	0.0499	0.3112**	0.1553
HouseholdSize	0.0488	0.3043**	0.1327
MaritalStatus	- 0.2058	- 1.2824***	0.2983
Age	0.9984	0.6222**	0.3014
Sex	0.3111	1.9366**	0.7974
Edulevel	- 0.0007	- 0.0035	0.1444
Accesscredit	0.0125	0.0776	0.3921
Landsizeowned	0.0309	0.1924	0.2077
Constant	-	1.6821	2.0147
Model Summary			
Number of Obs	330		
Prob>chi2	0.0000		

Pseudo R2	0.1339

***1%significance, **5%significance, *10%significance
Source: Field Survey, Tagoe (2023)

The results show a favourable relationship between crop diversification and household food security status, which reached statistical significance at the 1 percent level. According to this, farms with different crop combinations have higher rates of food security than those with mono-cropping practices. As a result, growing multiple crops on the same piece of land enhances the likelihood of achieving family food security by 0.9180. Ghana's food crop production depends significantly on suitable weather conditions for maximum yield. According to Antwi-Agyei et al. (2012), any changes in the environment are anticipated to have a major impact on crop productivity. Crop diversification, which involves growing various food crops on the same piece of land, is seen to be less dangerous than mono-cropping. Farmers can upgrade their production techniques and lessen their vulnerability to food shortages during periods of unanticipated crop failures by implementing crop diversification practices. Thus, failure in one crop (A) which is not perfectly correlated with other crops (B) will lead to some form of food production in crop (B). The farmer who is a rational individual who strives to maximize his or her satisfaction (food security), would employ crop diversification to lessen the risk that arises as a result of climate conditions. Thus, income from a variety of crop combinations can be used toward farming to boost output and family food availability. Hence these farmers become better irrespective of the production season.

The results of this study support Baba and Abdulai's (2021) claim that households cultivating different crops are more likely to consistently have access to food than households involved in mono-cropping. The results, however, differ from Nkegbe et al.'s (2017) study, which showed an adverse association between farm household food security and crop diversification, statistically significant at the 1% level. Their research suggests that households with different crop combinations may find it difficult to effectively manage their farming techniques, which could result in production inefficiencies. On the other hand, households that practice mono-cropping can find it simpler to manage their businesses, leading to increased productivity. Because of the attention of the farmer, resource allocation is channelled into a single enterprise to increase production.

However, economic efficiency and food crop diversity both had a significant impact on household food security. According to the marginal effect analysis, growing a second crop of food on the same piece of land might boost food security by 91.8 percent. In addition, when taking into account how economic efficiency affects household food security, a one-unit increase in economic efficiency was associated with a 32.8 percent increase in food security. The finding from the study revealed that crop diversification increases household food security more than twice as compared as economic efficiency. Finally, the study then looked into how crop diversification and economic efficiency are related to one another..

The Interdependence between Technical, Allocative, Economic Efficiency, and food crop diversification

The study employed a three-stage least squares regression model to estimate the association between technical efficiency, allocative efficiency, economic efficiency, crop diversification, and socio-demographic characteristics. The discussion of the results was done simultaneously. Table 17 depicts the relationship between technical efficiency, allocative efficiency, economic efficiency, and food crop diversification.

Across all efficiency measures, crop diversification showed a positive connection with technical, economic, and allocative efficiency and reached statistical significance at the 1 percent level. This shows that further increasing food crop diversification is related to an increase in technical, economic, and allocative efficiency of 2.81 percent, 3.20 percent, and 6.69 percent, respectively. The findings further revealed that allocative efficiency increase about three times as compared to technical efficiency while about two times as compared with economic efficiency. Thus, the substantial increase in allocative efficiency shows that farmers efficiently use inputs related to crop diversity, producing a particular level of output while minimizing expenses based on input prices. This finding also shows that the marginal value of the input is equal to or greater than the marginal cost of the inputs that are used. Through crop diversification practices, farmers can spread the risk associated with mono-cropping throughout the production season. Farmers who are into mono-cropping are likely to be inefficient during drought periods. Thus, when the said crop practice by the farmer is vulnerable to drought and is not able to withstand the climatic conditions. However, the farmers who are into crop diversification become better off throughout the year of production. This is because, through crop diversification, the climate condition that will not be favourable to a particular crop will be favourable to another crop. Crop diversity, a farming approach in line with climate-smart techniques, not only improves resilience but also provides extra advantages by fostering efficiency (Makate et al., 2016). The research of Mzyece and Ng'ombe (2021) reveals the favorable link between crop diversification and economic efficiency, achieving statistical significance at the 1 percent level. The conclusions of this study are compatible with their findings.

Moreover, socio-demographic factors that affected the model's technical, economic, and allocative efficiency included extension services, household size, off-farm activities, experience, and farmer age. These factors also showed statistical significance. However, it was discovered that factors including sex, credit availability, education, and distance to the nearest market had statistically insignificant effects on technical, economic, and allocative efficiency.

Furthermore, the results showed that, at the 1% level, crop diversification and allocative efficiency have a positive and statistically significant connection. However, it was discovered that the impact of economic and technical efficiency on crop diversity was statistically insignificant. This suggests that a 3.52 margin increase in crop diversification is related to a one-unit gain in allocative efficiency. The rightful allocation of the various input among the various crop enterprise at the farm level without any inefficiency or waste of economic resources, will increase the profitability of the various crop enterprise. Again, through the effective utilization of economic resources at the farm level, the extra or the additional resource left can be invested in additional crop enterprise to increase crop diversification by the farmer. The inefficiency arises when the farmer fails to rightfully allocate their available resource effectively among the various crop enterprises at the farm level.

Finally, technical and economic efficiency are insignificant as well as marital status, education, age, experience, household size, and credit opportunities as well as extension services were insignificant in influencing crop diversification whiles land size was otherwise.

Table 17: Interdependence of Technical, Allocative, Economic Efficiency and Crop Diversification.

3 stage least square	Technical Efficiency		Economic Efficiency		Allocative Efficiency		Crop diversification		
Variables	**Estimates**	**Standard Error**	**Estimates**	**Standard Error**	**Estimates**	**Standard Error**	**Variables**	**Estimates**	**Standard Error**
Crop diversification	2.8056***	0.6586	3.1969***	0.7244	6.6921***	1.4790	Allocative	3.5249*	2.1411
Off-farm-activities	- 0.0586*	0.0302	0.0662**	0.0332	0.1253*	0.0679	Economic	- 2.2696	5.0844
Extension service	- 0.1422**	0.0629	0.1949***	0.0692	0.3823***	0.1412	Technical	1.1044	0.7724
Experience	0.0469**	0.0223	- 0.0979***	0.0245	- 0.1708***	0.0501	Extension Service	- 0.1309	0.1057
Householdsize	0.0314**	0.0143	- 0.0192	0.0157	- 0.0560*	0.0321	Accesscredit	- 0.1136	0.1454
Age	- 0.1401***	0.0285	0.0887***	0.0313	0.2425***	0.0640	Landsizeowne	- 0.3572*	0.2123
Sex	- 0.0727	0.0531	- 0.0101	0.0584	0.0791	0.1193	HouseholdSize	0.0027	0.0495
Access credit	0.0776	0.0519	- 0.0653	0.0571	- 0.1660	0.1165	Experience	0.09153	0.1330
Education	0.0139	0.0154	- 0.0183	0.0169	- 0.0300	0.0345	Age	- 0.0608	0.0787
Distance to Market	- 0.0020	0.0187	0.0331	0.0205	0.0562	0.0419	Education	0.0010	0.0291
Constant	2.6753***	0.4008	- 1.3892***	0.4408	- 3.4779***	0.9000	MaritalStatus	- 0.0636	0.1109
Model Summary	-	-	-	-	-	-	Constant	- 0.1570	1.7370
Equation		**R-square**			**Chi2**	**P-values**			
Technical		- 1.9004			69.12	0.0000			
Economic		- 2.9031			32.57	0.0003			
Allocative		- 3.9759			38.19	0.0000			
Crop diversification		- 9.1810			32.42	0.0000			

***1%significance, **5%significance, *10%significance

Source: Field Survey, Tagoe (2023)

Chapter Summary

The relationship between crop variety, economic efficiency, and its consequences for household food security was thoroughly examined in this chapter. The analysis started with a thorough summary containing descriptive information for the farmers, including their sociodemographic traits. The study then went into the elements affecting farmers' economic efficiency and crop diversity. The chapter also explored the factors affecting household food security status as well as the prevalence of food insecurity..

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter includes an in-depth account of the study's findings as well as corresponding inferences from the analysis and findings from earlier research. Additionally, the issues of food insecurity, economic efficiency, and the diversity of food crops will be addressed with recommendations for future scholars and lawmakers.

Summary

This study's objectives were to assess the degree of crop diversity among smallholder farmers growing food crops in the Okere District of the Eastern Region and to point out the factors influencing crop diversification and economic efficiency. The study explored the relationship between home food security, economic efficiency, and food crop diversity as well as the prevalence of household food insecurity. The various food crop grown among the farmers were plantain, cassava, maize, yam, and vegetables, among others.

Three crop combinations were widely practiced among the farmers. Food crops such as cassava, maize, and plantain dominated and related to other food crops. The average crop diversification value derived from the Herfindahl index of diversification indicates that farmers in the study area engage in the cultivation of multiple food crops as a common practice.

Using Herfindahl's index of diversity, the degree of food crop diversification among the farmers in the research area was evaluated. According to the Tobit model's results, which focused on crop diversification, factors like land size, household size, access to credit, off-farm activities, the farmers age, and farmer experience significantly contribute to explaining the degree of crop diversification intensity.

Furthermore, the Tobit regression model was employed to analyze the determinants of economic efficiency. The estimations derived from the Tobit regression indicated that variables such as household size, access to credit, land ownership size, farming experience, distance to the nearest market, and membership in farm-based organizations had a significant impact on economic efficiency. In terms of efficiency levels, the mean efficiency was 0.86 under constant returns to scale, 0.95 under variable returns to scale, and 0.90 under scale efficiency. These results suggest that, overall, farmers demonstrated efficiency in their food crop production practices.

Again, the prevalence of household food insecurity status was assessed using the household food insecurity access scale recommended by the FAO. The findings revealed that among the farmers, 26 percent were classified as food secure, 43.7 percent experienced rare instances of food insecurity, 21.2 percent encountered occasional food insecurity, and 9.1 percent faced frequent food insecurity.

Finally, the association between household food security status, food crop diversification, and economic efficiency was examined using a logistic regression model. The findings from the logistic model show that crop diversification and economic efficiency as well as socio-economic characteristics such as off-farm activities, extension service, household size, marital status, age, and sex significantly influenced household security status.

Conclusions

From the various discussions, the following conclusions are drawn. The research area's farmers cultivated three different crop combinations, with the production of crops like cassava, maize, and plantains being particularly common. Farmers that grow food crops were found to employ crop diversification to a moderate extent. The farmers practiced crop diversification to hedge against household food insecurity. With this, the farmer is assured of food availability irrespective of the weather condition throughout the production season. Again, extension services, household size, the farmers age , access to credit, off-farm activities, land-owned size, and experience in farming influenced the farmers' decision to practice 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.

Secondly, the farmers were technically efficient in their food crop production with efficiency levels of 0.86, 0.95, and 0.90 under constant, variable, and scale efficiency respectively. Again, household size, availability of credit, land owned size, experience in farming, distance to the nearest market, and membership of farm-based organisation influenced the level of efficiency of the farmers. Thus, the farmer’s ability to secure a loan or credit will enable him to purchase agricultural inputs such as drones, tractors, and, fertilizers which will increase the level of efficiency.

Thirdly, The majority of farm households, or 64.9 percent of the sample, experienced only rare and infrequent episodes of food insecurity, according to the data on the prevalence of household food insecurity. Although their food insecurity is frequently transient and reliant on harvest results, it should be underlined that these households are only regarded minimally food secure. Usually during the normal harvest seasons, they become entirely food secure households, but in the event of bad harvests, they can experience temporary food insecurity.

Finally, the findings regarding the impact of household food security on economic efficiency and food crop diversification reveal that factors such as economic efficiency, crop diversification, and other socio-demographic characteristics play a significant role in influencing household food security. Efficient farmers are able to enhance productivity, ensuring an adequate food supply for their households while also generating surplus crops for sale, thereby supporting their household budgets. Consequently, this enables them to mitigate the food insecurity status within their households. Moreover, food crop production in Ghana is highly reliant on favourable climate conditions for optimal output, and changes in the environment can significantly affect crop productivity. Engaging in crop diversification, where different food crops are cultivated on the same plot of land, reduces the risks associated with mono-cropping, making farming practices less susceptible to unexpected crop failures. By adopting crop diversification practices, farmers can modernize their production methods, thereby minimizing the likelihood of food shortages during periods of crop failures. Additionally, the income generated from cultivating multiple crop combinations can be reinvested in farming activities to increase overall production and enhance food availability at the household level. As a result of crop diversification, farmers experience improved wellbeing both during the off-season and on-season production, leading to greater resilience and better outcomes for their households

Recommendation

The following policies are suggested for consideration based on the study's findings and conclusion.

Food crop farmers who are into monocropping should consider improving food security through crop diversification.

Again, MoFA through the Departments of Agriculture should educate farmers on crop diversification measures as well as how they can be sustained over time to avoid food insecurity during the off-season.

Moreover, the financial institutions should consider an argic financing package for farmers to increase food crop enterprise.

Furthermore, the Department of Food and Agriculture (MoFA) should consciously educate farmers to improve their level of efficiency by combining their resources and managing their farm to increase productivity.

MoFA and Other extension service providers, should encourage farmers to increase productivity by expanding the level of land cultivated

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APPENDICES

Appendix A

UNIVERSITY OF CAPE COAST

DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

FARMER BASED QUESTIONNAIRE

This questionnaire seeks to conduct an Analysis of Food Crop Diversification and Economic Efficiency of Smallholder Farmers: Implication on Food Security in Eastern Region. I would be very much appreciative of your participation in this exercise. I would like to ask you some questions related to crop production which will take you about 20 minutes to complete. Participation in this survey is voluntary and you can decide to opt out. However, I hope that you will participate in this study since your views are important. You are therefore at liberty to ask any question you which about this survey

1. District: ....
2. Community..
3. Questionnaire Number ....
4. Enumerator ....

SECTION A: Demographic charateristics Of The Farmer

1. Sex of the respondent? (1) Male [ ] (2) Female [ ]
2. What is your age? .... in years
3. What is your marital status? 1. Married [ ] 2. Single [ ] (3) Widowed [ ] (4)Separated/Divorced [ ]
4. Have you had any formal education? 1. Yes [ ] 2. No [ ]
5. If yes, what is your highest level of education? : 1. Primary [ ] 2. JHS [ ] 3.SHS [ ] 4. Vocational/ Technical [ ] 5. Tertiary [ ] 6. If other specify....................
6. What is your household size? Male.................. Female ....
7. How many members of your household are?

Household size	Male	Female
Under 6 years		
Between 6 – 18 years		
Above 18 years		
Adult Males		

Adult Females		
Aged (<80 years)		

8. Religion: 1=Christian [ ] 2=Muslim [ ] 3=Traditionalist [ ] 4=I prefer not to say [ ]
9. Status in the household. 1=Head [ ] 2=Spouse [ ] 3=Child [ ] 4=Others, specify

Section B: Farm and Production Information (Extent of Crop Diversification)

10. Is crop farming your major occupation? 1. Yes [ ] 2. No [ ]
11. If yes, how long have you been growing food crop? (1) 1-3years [ ] (2) 4-7years [ ] (3) 8-11years[ ] (4) 12-15years [ ] (5) Above 16 years [ ]

12. Do you have any other occupation than crop farming?

Occupation	**Yes/No**	**N.K**
Trading		
Livestock sales		
Butchery		
Mason		
Artisan		
Others		

13. What is your annual farm income?..(GHC)
14. What is your current land holding status?

1. Own [ ]……… (Acres) 2. Lease [ ]…... (Acres) 3. Share Production [ ]...(Acres) 4. Rented [ ]……(Acres)

15. Land size owned ………… (Acre(s))
16. If not self-owned, what is the cost of rented land…………………………..
17. If shared production, what are the terms of agreement……………………...............
18. Is crop production in this area rain-fed or irrigated? 1. Rain fed [ ] 2. Irrigated [ ] 3. both [ ]

19. Crop produce by the farmers.

Please indicate the quantity harvested, consume and as well as the unit price of each of the crop sold.

Crop produced	Land size cultivated	Quantity harvested (Bags/kg)	Quantity Sold(bags/kg)	Qty Consume	Unit price GH
Cassava					
Plantain					
Maize					
Yam					
Cocoyam					
Vegetable					
Others…					

20. The type of crop grown and why

Crop produced	Type/variety of crop	Why that type/variety of crop grown
Cassava		
Plantain		
Maize		
Yam		
Cocoyam		
Vegetable		
Others…		

21. What crop combination do you basically grow? Please tell us why?

Crop combination grown	Reasons for growing this kind of crops

22. Do you keep records of farm activities? 1. Yes [ ] 2. No [ ]

23. What is your main aim for crop production? (1). Subsistence [ ] (2). commercial [ ] (3) subsistence and commercial [ ] (4) Other specify [ ]

24. Do you have access to ready market? 1. Yes [ ] 2. No [ ]

25. Whom do you sell your product to? (1) individuals[ ] (2) retailers [ ] (3) aggregators [ ] (4) processors[ ] (5) others, specify ______________

26. Where do you sell your produce? (1). Farmgate [ ] (2). Local Market [ ] (3). District Market [ ] (4). Other, specify ______________

27. State the distance from your farm to the market center? ……………………………km

SECTION C: SOURCE OF LABOUR AND LABOUR REQUIREMENT

28. What is your major source of labour for your farming activities? (1) Family [ ]

(2). Hired [ ] (3). Both [ ]

29. Crop farming activities and labour requirements for the production season.

Types of crop grown	Unit of measurement	Share of labour (No. of Worker)	No. of hired labour	No. of hours per day	No. of Days per week	Cost per day GHS	Total amount per month for hired labour

SECTION D: SOCIAL AMENITIES AND EXTENSION SERVICE

30. Do you have access to any mobile telecommunication network in your community? 1) Yes [ ] 2) No [ ]

31. Do you belong to any farmer organization (s) in the area? (1) Yes [ ] (2) No [ ]

32. If Yes, which association/cooperative?

____

33. Do you have access to extension services? 1. Yes [ ] 2. No [ ]
34. If yes, how often? 1. Once a month 2. Once every three months 3. Once a year

35. If yes, what service and source?

Extension services		Source of extension services	
Pricing		Radio	
Agronomic practices		Government extension officers	
Post-harvest handling		NGOs	
Output Marketing		Television	
Formation of cooperative		Fellow producer	

Input acquisition		Seed companies	

36. What was the effect of this extension service on your activities and output?...

SECTION E: INPUT USED (EFFICIENCY)

37. Do you apply fertilizer to your farm? (1) Yes [ ] (2) No [ ]

38. What type (s) of fertilizer do you apply..................................

39. what is the source of your fertilizer? (1) Free [ ] (2) purchase [ ]

INPUT USED DURING PRODUCTION ACTIVITIES

40. Fixed inputs used for the production activity

Fixed inputs	**Use (Yes/No)**	**Quantity**	**Unit cost (GHs)**	**Total cost (GHs)**
Land				
Cutlasses				
Hoes				
Watering can				
Knapsack sprayers				
Other (Please specify)				

41. Variable inputs used

Variable inputs	**Use (Yes/No)**	**Quantity**	**Unit cost per acre (GHs)**	**Total cost (GHs)**
Labour				
Fertilizer				
Pesticides				

Seed				
Weedicides				
Insecticide				
NPK				
Other (Please Specify) …………………………				

SECTION F: FOOD SECURITY

Household Food Insecurity Access Scale Indicator

42. In the past four weeks, did you worry that your household would not have enough food?

No ()　　　　　Yes ()

If No, answer the following questions
1.a. How often did this happen?
1 = Rarely (once or twice in the past four weeks)
2 = Sometimes (three to ten times in the past four weeks)
3 = Often (more than ten times in the past four weeks)

No.	Occurrence Questions	No	Yes (How often)		
			1	2	3
1.	In the past four weeks, did you worry that your household would not have enough food?				
2.	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?				
3.	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?				
4.	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?				
5.	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?				

6.	In the past four weeks, did you or any household member have to eat fewer meals in a day because there was not enough food?				
7	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?				
8	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?				
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?				

Appendix B

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

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13[TH] APRIL 2023

Mr Jacob Adam Tagoe
Department of Agricultural Economics and Extension
University of Cape Coast

Dear Mr Tagoe,

ETHICAL CLEARANCE – ID (UCCIRB/CANS/2022/49)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted Provisional Approval for the implementation of your research on **Crop diversification and economic efficiency of smallholder food crop farmers: It Implication on food security in the Okere District, E0astern Region.** This approval is valid from **13th April 2023** to **12th April 2024**. You may apply for a renewal subject to the submission of all the required documents that will be prescribed by the UCCIRB.

Please note that any modification to the project must be submitted to the UCCIRB for review and approval before its implementation. You are required to submit a periodic review of the protocol to the Board and a final full review to the UCCIRB on completion of the research. The UCCIRB may observe or cause to be observed procedures and records of the research during and after implementation.

You are also required to report all serious adverse events related to this study to the UCCIRB within seven days verbally and fourteen days in writing.

Always quote the protocol identification number in all future correspondence with us in relation to this protocol.

Yours faithfully,

Kofi F. Amuquandoh
Ag. Administrator

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