

**MODELLING OPTIMAL RESOURCE ALLOCATION PATTERNS FOR CROP
FARMERS IN THE KARAGA DISTRICT OF GHANA**

By

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DECLARATION

I, HAKAM LUKMAN, do hereby declare that except for references cited, which have been duly acknowledged, this work, “**MODELLING OPTIMAL RESOURCE ALLOCATION PATTERNS FOR CROP FARMERS IN THE KARAGA DISTRICT OF GHANA**”, is the result of my own research. It has never been published or presented either in whole or in part for any other degree of this University or elsewhere.



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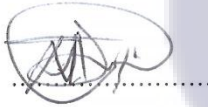
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DEDICATION

To my lovely parents: Sahadatu Mohammed and Lukman Abdulai and my lovely wife Fatima Ahmed. Also, to my siblings and all loved ones who supported and believed in me, I say Thank you.



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ABSTRACT

This study sought to investigate the potential of optimal resource allocation patterns in ensuring food security and increase farm incomes. The study identified various crop enterprise mixes that farmers engaged in and also determined the factors that influence the number of crop enterprises that farmers grew. The study further determined the optimal farm plans and the trade-off between expected returns of plans. The study randomly selected 398 farm households in fourteen communities in the Karaga District of Ghana. Interviews conducted showed that farmers were involved in cereal-legume cropping system. The study categorised farmers into four groups based on their farm sizes. Farmers who cultivated on farmlands 4 ha and above are regarded as large farms, and those who crop on farmlands between 2 ha to 3.99 ha are considered medium farms, produced maize, soya bean and groundnut. Farmers cultivating on small land sizes between 1 ha and 2 ha grew maize and either groundnut and soya bean. Another category of farmers was marginal, who produced on farmlands below 1 ha grew maize or soya bean or groundnut. The Poisson regression model was used to identify the factors that determine the number of crops enterprises farmers operate revealed that land and distance to market have a positive influence on the number of crops farmers grow. The Target Minimisation of Total Absolute Deviation (MOTAD) analysis results from all farm groups revealed that both the profit maximisation plan and the risk efficient plan(s) were more remunerative than the farmers' existing plan. The farmers' existing plan and the profit maximisation plan had higher standard deviations but the risk-efficient plan(s) had a smaller coefficient of variation(s). The two-tail test revealed a statistically significant difference between the expected returns of various plans. Farm management and efficient resource allocation programmes should be developed by agricultural departments other agricultural development partners and farmers should be sensitised on the importance of efficient resource use.

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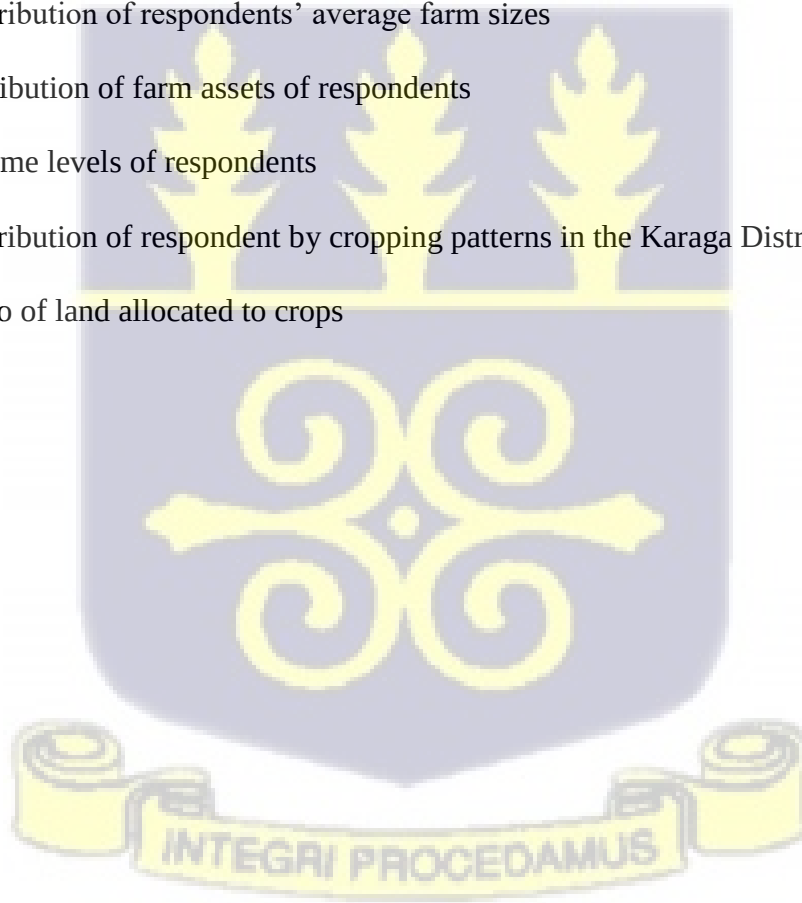
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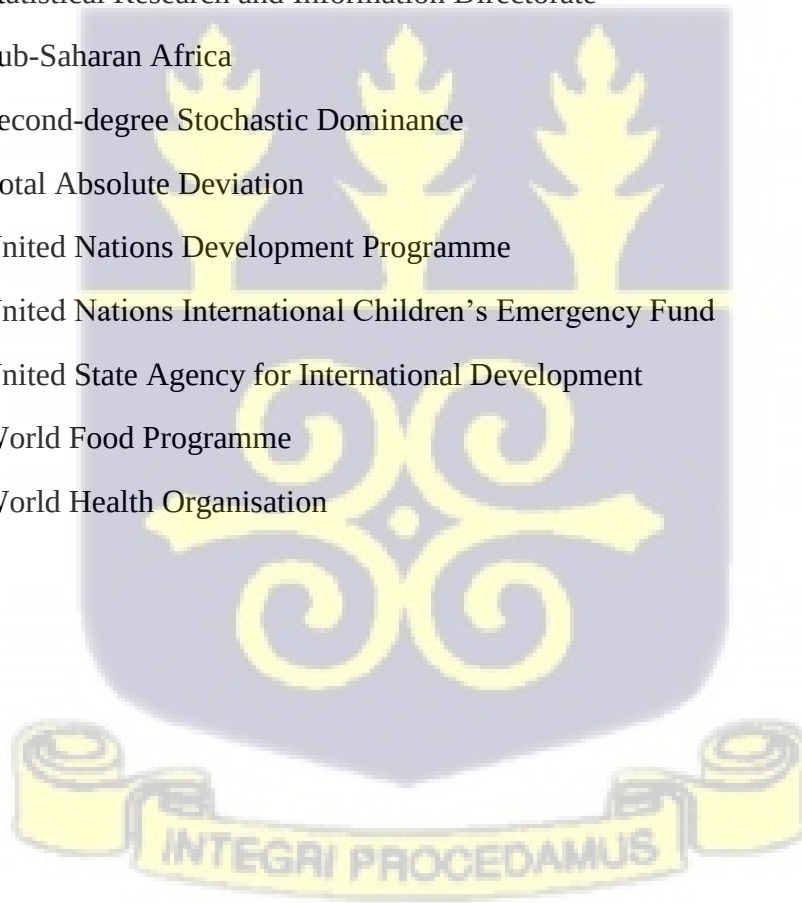
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LIST OF ACRONYMS

ADVANCE	Agricultural Development and Value Chain Enhancement
AGRA	Alliance for Green Revolution Africa
CSA	Climate Smart Agriculture
CSRI	Centre for Scientific and Industrial Research
ERP	Economic Recovery Plan
E-V	Expected mean Variance
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
FASDEP	Food and Agricultural Development Policy
GDP	Gross Domestic Product
GOG	Government of Ghana
GSS	Ghana Statistical Services
GSSP	Ghana Strategy Support Programme
IAAE	International Association of Agricultural Economists
IAPRI	Indaba Agricultural Policy Research Institute
IFAD	International Fund for Agricultural Development
IFRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IJAERD	International Journal of Advance Engineering and Research Development
INDC	Intended Nationally Determined Contribution
LEAP	Livelihood Empowerment Against Poverty
LIPS	Linear Programming Solver
METSS	Monitoring, Evaluation and Technical Support Services
MGDS	Malawi Growth and Development Strategy
MoFA	Ministry of Food and Agriculture (Ghana)
MOTAD	Minimisation of Total Mean Deviation

MP	Mathematical programming
OECD	Organisation for Economic Co-operation and Development
PFJs	Planting for Food and Jobs
QP	Quadratic Programming
SARI	Savanna Agriculture Research Institute
SLWMP	Sustainable Land and Water Management Programme
SRID	Statistical Research and Information Directorate
SSA	Sub-Saharan Africa
SSD	Second-degree Stochastic Dominance
TAD	Total Absolute Deviation
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
USAID	United State Agency for International Development
WFP	World Food Programme
WHO	World Health Organisation



CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Various efforts by world leaders have been made to reduce world hunger to zero by 2030, that is to say living in a world without hunger (de la O Campos, Villani, Davis & Takagi, 2018). Food security and poverty are primary issues that every country likes to address. Some results have been achieved in reducing the percentage of world hunger for past decades since there had been a decline in the prevalence of undernourishment from 14.5 percent in 2015 to a little below 11 percent in 2018 (de la O Campos *et al.*, 2018). The number of undernourished people still increases yearly and now, about a billion people still go to bed without food indicating that for every nine people, there is one individual who is starving. Africa and Asia have the highest prevalence of food insecurity (de la O Campos *et al.*, 2018). Africa has the largest number of individuals who are undernourished and also has the highest percentage of food insecure individuals. Africa, since 2015, has seen a slight increase in food insecurity in all the sub-regions. West Africa has had the most increase in the prevalence of food insecurity in Africa, from 12.3 percent in 2005 to 14.7 percent in 2018 (FAO, IFAD, UNICEF, WFP & WHO, 2019).

The major source of food insecurity in the world is poverty (Nkegbe, Abu & Isah, 2017; Grobler, 2016). Poverty is the major cause of food insecurity and food insecurity is a common feature of poverty (AGRA, 2017; de la O Campos *et al.*, 2018). Poverty lingers in most households in the world, especially in rural areas of developing countries where about 700 million people are considered extremely poor. (Castañeda, Doan, Newhouse, Nguyen, Uematsu, Azevedo & World Bank, 2018). They also reported that about 70 percent of people who live in these rural areas are into agriculture, one way or the other. The poverty rate among

agricultural workers is four times higher than off-farm workers, as seen in Figure 1.1 (Castañeda *et al.*, 2018). One essential tool to eradicate extreme hunger and poverty is through agriculture which rural folks engage in.

Ghana like other lower-middle-income countries is an agrarian country. About 49.10 percent of its citizens live in rural areas. Upon the huge numbers in food production, most households are not food secure. Similar reports go to poverty levels of Ghanaians, close to 25 percent of Ghanaians are defined as poor. The situation is even worse in the five northern regions where about 30 percent of people live in poverty.

However, growth in incomes through agriculture is two to three-times better in raising rural incomes than any other sector making agriculture a key sector in poverty and food insecurity reduction (de la O Campos *et al.*, 2018; AGRA, 2017; Christiaensen, Demery, & Köhl, 2006). Within agriculture, one of the strategies suggested as a pathway to poverty and food insecurity alleviation is crop diversification (Makate, Wang, Makate & Mango, 2016; Perz, 2004). Feasible, cost-effective and easier way of reducing the effects of risk and uncertainty among farmholds is through crop diversification (Romeo *et al.*, 2016). Evidence indicates that market-oriented on-farm crop diversification is the most viable option to ensure food security, improve infant nutrition, smallholder welfare and resilience to risk due to its ability to raise incomes from various crops (Bellon, Kotu, Azzarri & Caracciolo, 2020; Dagunga, Micheal Ayamga & Danso-Abbeam, 2020).

Moreover, most countries in Sub-Saharan Africa (SSA) identify the value of crop diversification in improving farm holds nutrition and income. Recognising the importance of crop diversification various agricultural policies in various underdeveloped countries. For example, the Malawian government formulated the Malawi Growth and Development Strategy (MGDS) in conjunction with the Malawi Economic Recovery Plan (ERP 2012) which aims at

reducing poverty through the promotion of crop diversification away from the historic reliance on maize and tobacco and a shift to cassava and sweet potatoes (World Bank, 2019). Benin in 2006 launched the Crop Diversification Policy which aims at promoting and strengthening livelihood diversification and reducing risk to ensure food security in the country (Adjimoti, Kwadzo, Sarpong & Onumah, 2017).

On the part of Ghana, the Ghana Strategy Support Programme (GSSP) of the International Food Policy Research Institute (IFPRI) report showed that the growth led by the agricultural sector will be effective in reducing food insecurity and poverty in Ghana through the support and strengthening the growth and productivity of staples and export-oriented crops (MoFA, 2007). FASDEP II, a food and agriculture document, stated as one of its objectives, ensure food security and emergency preparedness, improve incomes and sustainable management of land and environment. The FASDEP II sought to ensure food security and emergency preparedness and increase farm income by forming special programmes which will enhance diversification opportunities, reduce risk, enhance access to productive resources and ensure the interlinkages between farmers and the internal and external consumers. Sustainability of agriculture is key to ensuring future food security and poverty reduction and as part of MoFA's objective, the Ministry plans to support and facilitate adoption and widespread adoption of farming and land-use practises which, while in harmony with natural resource resilience, also support viable and sustainable production levels. Examples of just programmes are the Sustainable Land and Water Management Project (SLWMP), Climate-Smart Agriculture (CSA) programmes, just to mention a few. All these programmes are fine-tuned to cope with climate change, crop diversification-cropping patterns and agroecosystem management approaches are encouraged.

Crop diversification can be easily defined as the addition of more crops into the cropping system (Stabinsky, 2014). The cultivation of more than one crop is known as crop

diversification (Asante, Villano, Patrick, & Battese, 2018). Crop farmers like any other investor make economic decisions on what crop to produce, how to produce, in which season, period and how much quantity. The world agricultural system is dominated by small farmers who take decisions and invest in the main staple crop(s) and also diversify into the production of other crops to participate in the market, improve dietary diversity and also reduce the adverse effect of risk (Stabinsky, 2014). Only judicious use of farm resources by adopting remunerative cropping mixes, scientific rotation of crops and multi-cropping may help ensure food security and improvement in incomes (Rahman, 2020). Resource allocation optimisation has been used to identify alternative crop or livestock production options that ensure food and nutrition security by changing the crop combinations and reallocating land and other resources to high-yielding and nutritious crops.

One of the current discussions in farm management is optimal resource allocation. It is difficult to ignore because it benefits ensuring the welfare of farmers, that is, increasing farm profitability and ensuring food security. Farmers often decide on the resource allocations to each crop which may be suboptimal making them vulnerable to risk, therefore, crop diversification will achieve its objective when resources are optimally allocated (Rahman, 2020). Optimal resource allocation is defined as achieving the farm household's goals as efficiently as possible in the face of whatever constraints of a physical, environmental, legal or socio-cultural nature may be relevant (McConnell & Dillon, 1997). The objective of farm households is to meet the socio-economic welfare of farm family members, thus, answering the food security needs and adequate income for a decent livelihood. To meet these goals, these farmers have to make efficient food production decisions. Meeting the welfare of family members is conditional because these farm household resources are constrained and unstable.

The low-income capital base of farmers, the small size of farmland, and the gradual decline in crop productivity necessitate efficient resource allocation to increase farm income. Resource

constraints, food diversity desire and risk that small farms face drive them to engage in crop diversification, hence, efficient resource use is called for.

1.2 Problem Statement of the Study

Food production decisions are made by resource-poor, small-scale farmers who dominate the agricultural sector accounting for 80 percent of total agricultural production in Ghana with average farm holdings of less than two hectares (GSS, 2014). Family farmers are faced with complex decisions to make in every growing season. Decisions are made based on the farmer's subjective plans or income target, the land resources available, climate, farmer's experience and skill, other resources available, soil type, and biological factors such as disease and pest prevalence, prices of outputs and others (AGRA, 2017).

However, these decisions are affected by risk and uncertainty. Farmers face risks ranging from economic to biological. Economic in the sense that they find it difficult to predict input and output prices and biologically, they are faced with unpredictable pest or disease invasion like the recent invasion of the fall armyworm in Ghana. Climate change and its undesirable characteristics intensify farmers' exposure to risk.

For resource-poor households who are into agriculture, the most viable, convenient and effective way of coping with the risk of all dimensions is to diversify production (Asfaw, 2019; McElwee & Bosworth, 2010; Iizumi & Ramankutty, 2015). Farmers in the Karaga District still practise the traditional mixed cropping system (UNDP, 2011). The main mix cropping systems are cereal/legumes, root and tuber crops/cereals and legumes/legumes and so on. However, little is known about the specific crop enterprise mixes that are or are frequently operated by farmers in the District.

Diversification into several crops increases competition among these crops for fewer resources at the poor farmers' disposal. Financial resources available to farmers determine the size and

nature of crop enterprises smallholder farmers engage in. Studies show that access to credit facilities in Karaga is limited and production finances are provided by the farmers themselves (Abdul-Jalil, 2015; GSS 2014; Wiredu, Gyasi, Sanogo & Langyintuo, 2010). GSS (2014) estimated that ninety percent (90%) of investment in farm activities are from the farmers' own pockets, meaning that their most important resource, capital, is very limited and so they have to be very efficient in their spending.

There are multiple pathways of ensuring food security and poverty reduction and given this, efforts and interventions through policies and projects have been formulated by the Government of Ghana and its developing partners and other organisations. These policies, programmes and projects are introduced to remove farmers from poverty and ensure that they are food secured year-round. These efforts include Feed the Future and ADVANCE projects sponsored by the USAID, Planting for Food and Jobs, just to mention a few. These efforts have been quite impressive in improving the livelihood of vulnerable households but poverty and hunger still linger among farm households in the District. These projects are centred on improving crop productivity and sustainability, nutrition smoothing, reducing post-harvest losses and promoting the production and marketing of non-traditional crops. Fewer efforts are driven toward efficient and effective management of resources and decision-making.

Little empirical evidence of studies is carried out on mathematical programming in Ghana. The few studies used the conventional linear programming model which analyses to find optimal farm crop combinations and income in Ghana (e.g. Antwi, 2016; Joseph *et al.*, 2015; 1971). LP model results ignore risk and results from its analysis are misleading. Combinations of enterprises that ignores risk can result in wrong farm planning decision and farmers' profitability (Hazell 1971).

It is therefore essential for a study to be carried out to determine whether optimal resource allocation in risky environments would improve dietary diversity and increase farm returns. This study modelled an optimal resource allocation pattern for crop farmers in the Karaga District by trying to address the fundamental question.

Specific questions the study sought to address were as follows:

1. What are the crop enterprise mixes of farm households?
2. What are the factors that influence the number of food crop enterprises farm households grow?
3. What is the optimal farm plan that yields higher profits for farm households?
4. What is the nature of the trade-off between risk and expected return for farm households?

1.3 Objective of the study

The major objective of the study is to model optimal resource allocation patterns for crop farmers in the Karaga District.

Specific objectives were:

1. To determine food crop enterprise mixes of farm households in the District
2. To determine the factors that influence the number of food crop enterprises farm households grow
3. To determine the optimal farm cropping pattern that would yield a satisfactory return to farmers
4. To determine the nature of the trade-off between risk and expected return for food crop farmers

1.4 Justification of the Study

The continuous widening of the gap between average and actual yield has pushed the government and other organisations to make policies and form projects directed toward improving crop productivity. These efforts are instituted to increase farm productivity and ensure food security but these efforts do not consider the management of farm resources and decision-making. Farmers make decisions in every cropping season and planning of what and what to produce is very important to them. A study on which food crop enterprise combinations maximise farmer farm profit will be beneficial to them. This study will identify these crop enterprises combinations and developmental programmes that could be directed towards these crops.

Some factors influence farmers to grow a certain number of crops and this study will help identify these factors. This study would predict the economic effects of the changes in these factors resulting from policy reforms and social and economic restructuring, on the type of crop enterprises that are grown and the amount of resources that farmers allocate to these crops. Such information will prompt policy-makers in their decision making.

Knowing the crop enterprise combinations that maximise profit and minimise the risk that farmers face will drive stakeholders to concentrate efforts on the development of these crop enterprises. The study will inform various stakeholders who are concerned about rural enterprise development to recognise crops that best generate incomes for farmers. The study will provide farmers with the necessary tools for planning crop enterprises in the area. This would provide food crop farmers with a manual to follow in their farm planning activities.

Risk programming studies in Ghana are few and this study would also serve as literature for further studies.

1.5 Organisation of the Report

Apart from the introduction, Chapter Two presents the relevant literature to this study. Chapter three describes the methodology of the study, including the methods of data analysis for each specific objective of the study. In Chapter four, the result will be presented and discussed. The summary, conclusion and recommendations were presented in the final chapter.



CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, the relevant theoretical and empirical literature on the study are presented. The chapter elaborates literature on optimal resource allocation of farmers among their food crops. The chapter is broadly divided into four sections. Firstly, the chapter reviews the literature on resource allocation patterns, crops diversification and its determinants. Also, various risk programming techniques are examined. This is followed by a literature review on how optimal resource allocation ensures household food security and farm profitability.

2.2 Global Farm Resource Allocation Patterns

Farm resource allocation patterns vary across various agro-ecological zones, and socio-economic, infrastructure and institutional conditions (OECD/FAO 2016). Within regions, farm resource allocation patterns differ in many ways, including, resource endowment, production orientation, ethnicity, education, skills, and attitude toward risk. Family farms appear to allocate more land and labour to staple food crops rather than cash crops, although, a small proportion of them specialises in the latter. Moreover, areas cultivated under energy staples dominate among these farmers compared to ‘minor food crops’ like fruit, vegetables, and pulses (FOA, 2015; Haque *et al.*, 2016; OECD/FAO 2016). In Asia, small farms allocate more resources in the production of cereals like rice, wheat and maize. For instance, farmers in Asia-Pacific regions are biased with two major crops, which are rice and wheat which takes 60 percent of farmers land space (Haque *et al.*, 2016).

North America and Latin American, oilseeds dominate the production systems. In these areas, wheat takes less than 1 percent of the area under cultivation, maize slightly above 10 percent,

soya beans about 25 percent, sugarcane about 3 percent and the rest is shared among other oilseeds, oil palm cotton, and others.

Unfavourable national conditions and unstable political situations in many countries in Northern Africa and the Middle East constraints agricultural production. The climatic conditions in the area suit the production of wheat which occupies 60 percent of production fields (OECD/FAO 2016). The domination of wheat production reduces the resource made available for the production of other coarse grains like maize resulting in the importation of these crops to supplement local production (OECD/FAO 2016).

In SSA, resource allocation is geared toward the production of cereal-legume-tuber cropping system with maize sharing large areas under cultivation (OECD/FAO 2016).

2.3 Crop Resource Allocation Patterns in SSA

Within each of the four regions of SSA, five crops contribute more than 45 percent of total land under cultivation, with maize considered the most important staple crop hence more resources are allocated to its production (OECD/FAO 2016). In all parts of SSA, cereals (maize, millet and sorghum) and root and tubers (yam and cassava) take large portions of farmers farm resources (Moyo, 2016). The farming system is located between the agro-pastoral farming system to the north with rainfall less than 800 mm, and the root crop farming system to the south with more than 1200 mm rainfall. Dixon *et al.*, (2001) reported that the cereal-root crop mixed farming system occurred in parts of southern, central and eastern Africa. However, as farmers increased the area of maize in the system during the period 2000–2015, in some areas the cereal-root crop mixed farming system evolved into the maize mixed farming system, while still retaining some small pockets with cassava, sweet potato, sorghum and millet. Despite a substantive resource allocation to cereals in Southern Africa, fruits and vegetables had a strong

share in average household production status and also in Central Africa oil seeds production share more cropping resources than cereals.

In confirmation to the above, FOA (2015) reported that maize-mix farming system is the most important food production system in East and Southern Africa, extending across plateaus and highlands areas from Kenya and the United Republic of Tanzania to Zambia, Malawi, Zimbabwe, South Africa, Swaziland and Lesotho. For instance, in Kenya maize is considered as the more important staple food and make up more than 50 percent of the household's agricultural production.

2.4 Farm Resource Allocation Patterns in Ghana

Ghana is divided into four agro-ecological zones: The Coastal Savanna, the Forest Zone (comprising the rainforest and the deciduous forest areas), the Southern Savanna (Deciduous Forest) and the Northern Savanna (Nin-Pratt & McBride, 2014). Each of these zones has its ideal characteristics relative to the climate and weather. Zones in the southern part of Ghana are characterised by high rains and fertile soil except the Coastal Savannas. The southern zones for its characteristics support perennial food crops and cash crops such as plantain, cassava, cocoa, coffee, yam and cocoyam.

The Northern Savanna experiences low rains about 1000 mm with poor and highly degraded soils. The Savanna is characterised by cereal-legume based farming system but yam and cassava are also highly cultivated in some parts of the zones (Bellon *et al.* 2020; Kotu, Alene, Manyong, Hoeschle-Zeledon & Larbi, 2017). The area stretches 40 percent of the total land area of the country and lies within five regions (MoFA, 2010). The five Northern Savanna zones have generally similar farming systems but variations occur in cropping patterns across various regions in the zone. In the Northern region, the Savanna region, the North-East region and the Upper West farmer place more emphasis on maize, thus, allocating more resources to maize

whilst in the Upper East maize is less important but among the top five crops with millet considered a better grain. Sorghum is the second important crop in the Upper East and the Upper West regions but fourth in the Northern region making rice takes its place in second (Ellis-Jones *et al.*, 2012; Kotu *et al.*, 2017). Rice is also an important crop to farmers in the Upper East and the Northern region but less is cultivated in the Upper West.

With legumes, groundnut is the first most important crop in the Northern region and the Upper West region but second in the Upper East. In the Upper East, cowpea is allocated more land than any other legume. Higher and stable price of soya beans encourages farmers to decrease their land allocation to groundnut and maize and increase allocation to soya bean production. Other crops like yam, cassava, sweet potato, tomato, pepper, onion, mango, also bear some economic importance to farmers (Ellis-Jones *et al.*, 2012).

2.5 Crop Enterprise Diversification and Risk

Farmers in many Sub-Saharan African countries face different types of risks affecting their yields and income. Crop diversification is an ancient agricultural technology that has long been practised by poor households across various countries, especially in the developing world to mitigate risk in crop production. Asante *et al.*, (2017) define crop diversification as the cultivation of two or more crops with available productive resources. This system does not only reduce risk but also ensure dietary diversity for households. Asravor, (2018) reported that farmers in the Northern region are faced with yield variation risk and market risk. So, to reduce variation in production and income, farmers grow many crops. Diversifying crop production is seen as an insurance strategy that farmers employ to reduce the risk in production. Like any other risk reduction measure, returns are forgone for risk (Micheal & Margot, 2000).

Risk and uncertainty are problems that farmers have to face every year. The future is uncertain and experience cannot only be used to predict future events and this can be unhelpful at times.

No sector faces more risk than agriculture (Maure, 2014). They face all dimensions of risk, from price fluctuation, yield variations, and financial risk. Crop production which is the primary focus is the most subjected to risky situations than other agricultural sectors. This is because crops production is affected by weather variations and can cause total crop failure in the event of drought or floods.

Diversification like any other risk-reducing strategy involves giving up some amount of revenue to prevent some deviations of the total returns. One problem of diversification is that return and specialisation are lost. That is to say that there is a trade-off between risk and returns, returns are sacrificed for risk.

As long as crops are not perfectly directly associated in returns, that is, if there is an increase in the price of one crop will lead to an increase in the prices of the associated crops, risk will be reduced (Paut, Sabatier & Tchamitchian, 2020; Nally and Barkley, 2010). As a farmer increases the number of crop portfolio, overall crop risk exposure decreases due to changes in prices and yield decrease at a decreasing rate (Paut, Sabatier & Tchamitchian, 2020). Researchers also suggest that the decline in risk may be affected by the inherent riskiness of the individual crop enterprises considered. From portfolio theory, as more or less risky crop enterprises are added to the existing crop(s), risk is measurably reduced. The degree of risk reduction will, therefore, depend on the number of crop enterprise combinations, the proportion of risk of each crop bears, the proportion of each crop in the portfolio, the degree of correlation of crops in the crop mix. Risk of the portfolio can be less than the variance associated with a single crop depending on the degree of correlation with other crops in the crop mix (Markowitz, 1991; Micheal & Margot, 2000).

2.6 Resource Allocation Based on Economics of risk and Returns

In general, it is reasonable to expect farmers to choose productive activities that maximise their wellbeing, given the resources and opportunities available to them. However, as farmers are typically regarded as risk-averse, strategies to reduce the uncertainties inherent to agricultural production may provide beneficial effects (Ogurtsov *et al.*, 2008). Farmers will, consequently, not only seek high average but also low standard deviation (SD) of discounted future net revenues. Risk-averse farmers may achieve high levels of risk reduction by mixing two or more land-use options whose financial yields fluctuate independently from one another (with low correlations). In other words, in periods when returns from one asset drop, another one may generate unexpectedly high returns, thus, moderating the effects of economic booms and busts (Knoke *et al.*, 2011).

Crop diversification consists of producing crops in separate parcels of land relatively small but still large enough to permit agricultural intensification like mechanisation. A well-recognised method for finding the optimal combination of crops is the mean-variance approach. The mean-variance approach outlines strategies in resource allocation to various crops that maximise economic returns for a given level of risk. Through a careful selection of the proportion of resources that should be made available to various crops.

2.7 The Crop Choice(s) and Crop Resource Allocation Framework

African farmers are risk-averse, and decisions are taken to minimize risk rather than maximize profit. This attitude drives farmers to diversify their investment activities and allocate their resources to favour activities that bear the lower risk (Ranganathan, Gaurav & Singh 2018). To reduce the negative risk effects of risk, farmers put their eggs into numerous baskets. Crops are expected to behave like assets, thus risk may be significantly reduced by combining several crops in a portfolio (Paut *et al.*, 2018).

Farmers face different aspects of risk and uncertainty in their everyday economic activities. Farmers face many risks but the most prevalent is the production and the price risk. A farmer facing these risks may wish to select an enterprise mix that reduces the variability of incomes from their productive enterprises. Most literature widely used the mean-variance (E-V) approach in dealing with risk minimisation of a portfolio. The decision rule used by farmers to choose the best enterprise mix from many intended possibilities (if not unlimited possibilities, as feasible crop combination to operate by a farmer is severely limited by agro-economic conditions) is maximising the utility of returns to be derived from the possibility enterprise portfolio under reasonable risk levels. The utility depends positively on the relationship between the mean and the variance of returns.

In the present context, thus, crop diversification can be seen as a strategy adopted by the farmers to strike a balance between expected income and uncertainty of reforms associated with crop cultivation.

2.8 Risk Programming Models

Risk is inevitable in agriculture and farmers face it every day. To reduce risk, farmers spread their limited resources among several agricultural enterprises making farm production diversification a very viable and essential production system for farmers (Jacob, 2018). Farmers also face the problem of how to allocate their productive resources among agricultural activities. Mathematical programming (MP) models were developed to develop optimal plans for farmers that yield a viable expected gross margin.

The most popular, frequently used MP model is the conventional LP model. This model is used in terms of maximising a linear objective subject to linear constraints. The model is popular and much software are available to run the model of any magnitude. The LP model assumes that the objective function of farmers is linear but this is not the case. Various studies pointed

out that the objective function of farmers is a utility function. The utility function is quadratic because the function is subjected to diminishing marginal utility. Also, every plan is subjected to risk and uncertainty. These risk and uncertainty are measured in variances, standard deviation and these measures are quadratic. Because of the limitations of the LP, quadratic programming model (QP) and its linear forms were developed to draw reliable plans.

2.8.1 The conventional Linear Programming model

When resources, particularly capital and land, are used properly, households can maximize agricultural profitability and food security (Antwi, 2016; Otoo, Ofori and Amoah, 2015). The optimally status of agricultural households was determined using linear programming. The traditional linear programming model is a mathematical technique for determining the best or optimal crop allocation combination that maximizes on-farm profit while utilizing limited farm resources. The model aims at maximising or minimising a linear objected function Z subjected to linear resource constraints, either equalities or inequality and non-negative constraints:

$$\text{Minimise or maximise } Z(x) = rx \quad (\text{Maximising on-farm profit}) \quad (2.1)$$

$$\text{Subject to change} \quad Ax \leq q \quad (\text{Land, Capital, and Labour}) \quad (2.2)$$

$$\text{and } x \geq 0 \quad (\text{Non-negative constraints}) \quad (2.3)$$

and x is the vector of the decision variables, q represent the vector of the coefficients of resource allowed in the model and A is the predetermined matrix of the coefficients. The LP matrix can be solved manually using graphs or simplex method or by using LP software like EXCEL, LINGO, LIPS, GAMS and others.

2.8.2 Quadratic risk programming

The Quadratic Programming assumes that a farmer holds preferences among alternative farm plans mainly based on their expected income and associated income variance (Hazell, 1971).

Quadratic risk programming (QP) can be used to generate the set of farm plans lying on the E, V efficient (Freund, 1956). Markowitz (1959) suggested that investors are risk-averse and their iso-utility curves are convex to the origin. This implies that the decision-maker would prefer a farm plan with higher income variance (V) if only the expected gross margin (E) is greater and E is rising at an increasing rate relative to V.

A rational farmer would like to choose a farm plan that has a small variance relative to an expected income or maximum expected income for alternative levels of risk variance. QP algorithm generates E, V pairs and a rational choice can be selected from this set of feasible pairs. From the efficient set of pairs, farm plans can be selected in two ways. When iso-utility curves are derived, one of the iso-utility curves would be tangent to the E-V frontier, and that point of tangency produces the optimal plan (see Figure 2.6). QP Solution is derived by minimising covariance and variance (risk) subject to resource constraints and solutions are obtained by increasing the total gross margin and variance until the maximum possible total gross margin under the resource constraints has been attained (Norton & Hazell 1986; Harry & Kent, 2011).

A solution is derived for the alternative of risk aversion coefficient. The risk coefficient is the relationship between the objective function and the farmer's utility function. When the risk coefficient is zero, then the solution obtained is risk-free and when the risk coefficient is greater than zero, then the solution is optimal for farmers with various degrees of risk. The QP model which produces E-V solutions are consistent with the assumptions: (1) the decision-makers have a quadratic utility function, (2) returns are normally distributed, (3) the utility function can be truncated after the second-order moment of its Taylor series expansion. The model produces feasible pairs that are subjective to farmers, the plan which farmer A would prefer would be different from that of farmer B.

However, farmers are risk-averse and would normally select farm plans with minimum variance. The QP model solutions do not meet the second-order stochastic dominance (SSD) test. From Figure 2.1, plans below the income-risk curve are feasible but not optimal, and as said earlier, optimal plan is the plan that is generated at the point when the iso-utility curve is tangential to the income-risk curve and from Figure 2.1, C is that point.

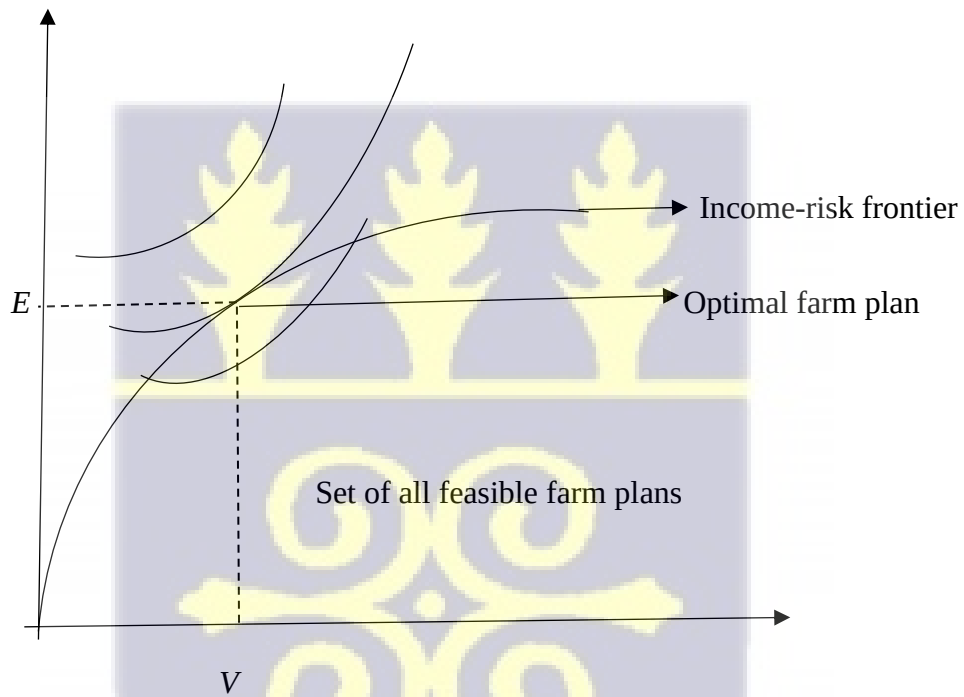


Figure 2. 1: Graphical determination of the optimal farm plan in the E-V frontier

The Quadratic programming can be expressed as:

$$\text{Maximise } U = \sum_{j=1}^n E(c_j)x_j - b \sum_{i=1}^n \sum_{j=1}^n V_{ij}x_i x_j \quad (2.4)$$

$$\text{Subject to: } \sum_j^n a_{ij} x_j \leq b_i \quad i = 1, \dots, n \quad (2.5)$$

(Harry & Kent, 2011)

Where: $E(c_j)$ is expected returns of the j th activity, x_j is the level of the j th activity, b is farmer's absolute aversion coefficient, V_{ij} variance of the j th activity when j is equal to i and covariance

j th and i th activity when i is not equal to j . a_{ij} is the amount of resource i required per unit of j th activity and b_i is the amount of resource i available.

2.8.3 Minimisation of Total Mean Deviation (MOTAD)

Some years back, sophisticated computers and computer programs were not available and the QP model was very difficult to solve so researchers developed linear forms of the QP model to solve allocation problems. One of them was the MOTAD developed by Peter Hazell in 1971. An important idea about this model is that rather than using the variance-covariance matrix in QP, one can use the linear approximation of the expected income variability. The MOTAD model uses the total absolute deviation (TAD) to measure set over observations and for activities or enterprises risk. Hazell (1971) proposed that it is possible to minimise the negative part of the TAD if the expected returns of crop enterprises are the sample means. Solutions can be derived firstly by determining the maximum expected income using the conventional LP model.

The MOTAD model is then incorporated and the maximum expected income as the maximum is parameterised at different income and risk levels. The solution of the MOTAD and QP model produces a similar solution but the variance of the MOTAD are higher than the QP variance. This is because the MOTAD model is not as efficient as the traditional nonlinear variance estimate. The MOTAD model also generates E, V pairs that do not meet the SSD criteria.

The MOTAD model can be expressed as:

$$E(C_j) = \sum_{r=1}^m Z_{rj} / m \quad (2.6)$$

The Absolute deviation from the mean of each observation over all possible observations is

$$\sum_{j=1}^n |(z_j - E(c_j))x_j| \quad (2.7)$$

Where $||$ is the absolute value of operator representing the absolute deviation from the mean for an observation. The absolute deviation about the mean are defined as the deviations from the mean gross margin (Harry & Kent, 2011).

2.8.4 Target Minimisation of Total Mean Deviation (Target MOTAD)

After realising that the above models do not meet second-degree stochastic dominance (SSD), Tauer proposed in 1983 the target MOTAD models that meet the SSD test. Investors (e.g. farmers) are concerned about returns falling below a predetermined revenue target. Any returns below this target are known as deviation. The model involves maximising the expected utility of income subject to resource constraints and risk constraints. The Target MOTAD has a linear objective and constraints function, so the linear programming algorithm can be used to solve problems (Tauer, 1983). Tauer, therefore concluded that the Target MOTAD is therefore superior to other risk programming models. The solutions of the model on the efficient frontier are SSD and plans that are not feasible are not included in the solution. Second-degree stochastic dominance (SSD) states that when concave utility increases, a risk-averse farmer will prefer one farm plan (say, plan A) over another (say, plan B) because plan A's likelihood of returns and associated risk are better than plan B's.

2.9 Empirical Studies on Optimal Resource Allocation Patterns

Farmers are sceptical about losing their investment in production and marketing due to risk. They invest in several crops to mitigate risk. Farmers in northern Ghana are poor and resources have to be utilised to obtain optimal incomes. They allocate resources to several crops based on their intuitive knowledge and experience. Growers allocate more resources to crop that they expect will ensure food security and will be profitable. There is a need for a plan that shows how to allocate resources for farmers to achieve the maximum utility of expected returns.

Linear Programming model was developed to solve the allocation problem (Dantzig, 1963; Agrawal & Heady, 1972). After many researchers have used the LP model to determine optimal agricultural resource allocation. Several empirical studies treat farmers as profit maximisers rather than utility maximisers. Such studies (e.g. Antwi, 2016; Joseph *et al.*, 2015; Drafor *et al.*, 2013) had to treat profit maximisation as the primary motive of farmers. This pushed them to use the conventional linear programming model to determine farm plans. The LP is not recommended for farmers since it assumes yields, prices, resources and others are constant (Sayed *et al.*, 2008).

Moreover, the utility of more risk-averse farmers has a quadratic utility function but the LP model assumes that the individual utility function is linear meaning farmers are risk-averse (Markowitz, 1991). Therefore, risk programming model is appropriate for determining farmers optimal resource allocation. Several risk programming techniques have been developed: Quadratic Programming (QP), Minimisation of Total Absolute Deviation (MOTAD), Target MOTAD, and others. The model of choice for this study is the Target MOTAD. MOTAD and Target MOTAD are the linear form of QP that were developed because of the complexity of the QP and it was expensive to run QP model some decades back (Harry & Kent, 2011). These programming models produced similar results.

Lu, Huang and Horlu (2020) examined the effect of climate change-induced agricultural risk on land use in Chinese farms using MOTAD model. The study used panel data from farmers in seven counties in the Jiangsu Province from 1998 to 2017. Their study documented that crop yield deviation is liable to variation in temperature than sunlight and rainfall. Farmers were reported to consider maize and wheat to be their most important grain but more land was allocated to legumes like soya beans and rapeseed. Using the LP model, the researcher observed that 25 percent, 24 percent and 21 percent should be allocated to rice, cotton and tomatoes respectively and the rest of the land (30 percent) is allocated to other crops. The

MOTAD analysis reveals more resources should be allocated to wheat, rapeseed, groundnut and tomatoes and this resulted in a reduction in the area allocated to maize, potato cabbage, and melon. The MOTAD solutions required less land compared to the LP model solution. The model results from their study reveal that less land was allocated to grains, vegetables and melon. Substantial land allocation to cash crops like rapeseed, soya beans and groundnut but land allocation to cotton has to reduce.

Italy like most developing countries is dominated by small farmers, majority in the rural areas, are unable to deal with the complexities of agriculture find resorts to crop diversification. A study by Rosa, Taverna, Nassivera and Iseppi (2019) modelled allocation patterns that will shield farmers from the effects of risk. The risky nature pushes these farmers to cultivate seven crops namely wheat, maize, barley, sorghum, soya beans and sunflowers. Farmers will make a substantive increase in returns compared to their current situation. The authors suggested that farmers maximise returns and reduce risk when they shift their resources to the production 20, 40, 20 percent to wheat, maize and barley respectively, soya bean 10 percent and 7 percent to sunflower. This crop portfolio solution will result in a coefficient of risk aversion of 2.35. They also reported that the group of solutions with risk between 2.36 and 2.42 show similar results in crop diversification and distribution with its economic implication being that risk induces farmers to diversify their crop portfolio and land use when risk aversion increases; in this case, land use also increases consistently.

Osaki and Batalha (2014) used the MOTAD modelled to determine the optimal production levels of grains under risk in Sorriso, Brazil. Their linear programming model analysis reveals that 76 percent of land should be devoted to early soya beans and 23.08 percent to normal soya beans and also 76.92 percent to second season maize. This cropping pattern results in the maximum point on the EV frontier, that is the profit maximisation plan and in monetary terms results in R\$ 416,799.00. With this pattern, farmers are exposed to a risk level of R\$ 64,430.11

representing 15.46 percent of the gross margin. The MOTAD analysis brought out a different pattern, the point where utility curve was tangential to the risk curve resulting in a total gross margin of R\$ 407,299.00 and risk level of R\$ 56320.61 where 10 percent should be allocated to early soya beans, 90 percent to normal soya beans in the first season and 32.5 to second corn.

Jordan is among the poorest countries in the world in terms of water resources but the increase in demand for fruits and vegetables convinced farmers to grow autumn beans, autumn potato, spring potatoes summer beans, and PH beans. Each crop has its water requirements and attracts different returns increase competition among these crops. Haddad and Shahwan (2012) used the target MOTAD model to horticultural crops in the Jordan Value at various water reduction levels. With the reduction of water by 30 percent, expected income reduced by 22 percent. Their model reveals that autumn and spring beans, pH beans and autumn eggplants were been encouraged regardless of the risk associated with the expected income. A similar reduction of expected income was recorded when water was reduced by 50 percent but the

Kehkha *et al.* (2005) used the MOTAD risk-programming model to study the effect of risk on cropping and farmers' income in Ramjerd and Sarpanirian districts in the Fars provinces of Iran. The result indicated that variability of crops gross margins has an effect on cropping pattern but it varies over different farmers and regions with various conditions. The results show that farmers earn high incomes with the profit maximisation plans with high-risk levels and few crops are entered into the plan. However, with the risk modelling, farmers will earn incomes that are higher than their existing plan, and also lower than the profit maximisation plan but at lower risk levels. Their study stated that farm plans with a high number of crops have lower risk levels but with a high degree of certainty.

Sayed (2002) used the MOTAD and quadratic model to crop production in Bangladesh. Farmers are multi-crop producers who allocate 78 percent to cereals(rice), 6.2 to pulses, 5.7 to

oilseeds and 7.2 percent to vegetables. With this plan, farmers are a risk of 18.75 percent. With the risk efficient plan, higher incomes were recorded at lower risk levels. Risk level of the prevailing plan is about 48 percent higher than the quadratic efficient plan. The efficient plans in their study area advocated in favour of rice, jute and vegetables. Crops like pulses are highly risky and less remunerative and so they find it difficult to enter into the risk efficient plans. Since the farmer's plan is low in income and highly risky, they recommend that more jute and vegetables should be planted to achieve higher returns.

Greenhouses have been used in the United Arab Emirates (UAE) to produce vegetables that contribute toward UAE food security, including offering fresh vegetables produced in the off-season. However, to manage such greenhouses, farmers face both technical and environmental limitations (that is, high water scarcity), as well as price instability. Fathelrahman *et al.* 2017 explored the trade-off between returns (gross margin), of selected vegetables (tomato, pepper, and cucumber) and an environmental constraint (water salinity) using the target MOTAD model to support UAE farmers' decision-making process. The optimal target MOTAD results show included all the three vegetables, thus, no corner solution. The results also showed a trade-off between returns and risk and confirmed that products diversification reduces overall risk. The analysis was consistent with farmers' perceptions based on the survey of 78 producers in the region. The search of the optimal mix of vegetable production under UAE greenhouse conditions reveals that a reduction in tomato production should be offset by an increase in cucumber production while maintaining a constant level of pepper production. In other words, risk is reduced as cucumber production increases due to the high level of tomato and lettuce price volatility as the alternative to cucumber. The results also demonstrate the importance of water salinity environmental constraints, as it was found to have a positive marginal value in the optimal vegetable mix solution (an important factor). The study results also demonstrate that the target MOTAD approach is a suitable optimisation methodology. As a practical

approach, a decision maker in the UAE can consider gross margin (total revenue-variable costs) maximisation with risk and water quality constraints to find the optimal vegetable product mix under greenhouse conditions.

Al-Karablieh and Amer (2004) studied risk-efficient cropping plans using an optimal allocation of irrigation water at different levels of expected income. A linear optimisation model was used to allocate irrigation water among agricultural activities in Jordan Valley. Results of the linear programming model showed that the optimum allocation of areas was 21,933 ha, which is close to the cultivated areas, with a lower amount of water to achieve the same expected income, due to optimal reallocation of water use. The optimal cropping pattern generated \$92.6 million, whereas the actual cropping pattern generated \$76 million. Results of MOTAD models showed that at low expected income, cultivated area declined and there was excess of irrigation water. By increasing the expected income, land and water restricted the solution. In the three models, citrus and bananas were dominant at all levels of expected income. All models have in general similar water schedule during autumn and spring seasons in the Jordan Valley. Finally, risk-efficiency frontiers were derived from the three models and showed that the model with three years unequally weighted moving average about the mean of historic gross margin has the lower standard deviation and variability than other two models at the same expected income levels. The results could help the decision makers to judge how many quantities of water should be supplied in a certain month during production seasons in the frame of risk-averse behaviour of farmers.

Boustani *et al.* (2010) applied that target MOTAD with minimum variance in developing risk-minimising cropping systems associated with different income levels for farmers in Fars Province in Southern Iran. The study parameterised water consumption for irrigation. The study used a regional-based water deficit to determine optimal cropping patterns. The target MOTAD solution produced optimal plans with a trade-off among water use, reduce risk and

gross margins. The results also showed that wheat tends to increase, causing government price support programmes. This implies that farmers support programmes in the region influences farmers cropping patterns. Production and gross margins of maize and vegetables were increased in all selected solutions compared to their existing allocated plots.

Wencong *et al.* (2006) analysed the Chinese small-scale farmers' attitude to agricultural risk using the MOTAD model. The study was carried out in two villages, Wangjia and Damao in the Zhejiang province, which are rural settlements of the province. The study shows that like other farmers, farmers in the province are risk-averse and so are highly sensitive to risk. Farmers risk preferences do not only affect the type of agricultural activities and management systems used, and the corresponding scale of production they prefer but also affect the micro agricultural production structure and stable growth of household income. Given the quantity of productive resources like land, capital and labour, combinations of productive enterprises with a higher level of expected returns or risk would be chosen if the decision maker is willing to take risks. Combinations with lower risk level, diversification would reduce expected income for risk to some extent. The MOTAD reveal that farmers select food crops that are less risky in returns.

Salimonu, Falusi, Okoruwa, and Yusuf (2008) used the target MOTAD to determine the optimal plan that would ensure farm profitability and ensure food security in Osun State, Nigeria. The resource allocation behaviour of farmers was modelled and efficient patterns were suggested. The results of such studies may be mis specified if the farmers make production decisions in the face of risk that characterised Nigerian agriculture. A two-stage random sampling procedure was used in the collection of primary data in Osun State. Data collected from 165 respondents were analysed using descriptive statistics and Target Minimisation of Total Absolute Deviation (T-MOTAD). The study demonstrated that the optimal farm plan would provide farmers with more returns than their existing plan, thus satisfying the increase

in income objective. The profit maximisation model was associated with a higher risk than the suggested efficient plans. It is concluded that farmers rather possess multiple objectives in their allocation behaviour other than a single objective of profit maximisation.

In Akwa Ibom State in Nigeria, a study by Unoh (2008) was conducted on the important risk factors and risk management measures as well as optimal farm plans in wetlands. The study revealed that farmers risk scare was drought and they mitigate this risk event by sequential cropping, planting short maturing and flood-tolerant crops. The Target MOTAD results demonstrated that farmers do allocate their resources optimally in their production activities. The results stated that crops that are less risk, most viable and profitable, and should be grown were cassava, cocoyam, maize, and flute pumpkin and vegetable crop mixes were most risky.

Maleka (1993) used the target MOTAD model to examine plans for production of grains in Gwembe Valley in Zambia. The target revenue which was based on farmers, policy-makers and agricultural experts was empirically estimated as K20 million. The study revealed that an optimal plan pattern that would improve farm profitability was growing, sorghum, rice, and soya beans. The existing cropper system consisted of maize, rice, sunflower and cotton. The overall policy implication of adopting the cropping pattern obtained from the model solution is that resources had to be reallocated to new crops to ensure that households are food secured.

Abimbola (1992) used the Target MOTAD and the multiple Regression technique to examine the extent to which farmer perceives risk and develop farm plan for farmers under the Agriculture Development Project (ADP) in Northern part of Nigeria. The study revealed that sole cowpea was identified as the riskiest crop enterprise and planting mixed crops reduce farmers risk levels substantially. A sensitivity analysis showed that when farmers are given more money as credit and by optimising and including better crops, farmers would increase their farm income than they are presently taking. The study concluded that challenges farmers

face is not their inability to take risk but nut the lack of information and knowledge about opportunities available for making necessary decisions around risk.

2.10 Empirical Studies on Factors that Determine the Level of Crop Diversification.

Maggio, Sitko, and Ignaciuk (2018) suggest that incentives to diversify by farmers are influenced by two factors: “push” and “pull” factors. Push factors relate to needs and income desperation of the farming household, and/ or market imperfections that farmers face. Pull factors relate to factors that create a positive environment for crop diversification. Literature findings on factors that influence crop diversification so far has fallen within these two factors.

Meraner, Heijman, Kuhlman and Finger (2015) determined drivers of farm diversification in the Netherlands. The authors grouped driver of diversification into three. The results of the binary Logit model suggest that age has a negative significant effect on the probability of diversification, implying that as farmers age, they are likely to reduce the number of crops they cultivate, this was contrary to their hypothesis younger farmers are more likely to engage in several agricultural activities. Economic size of a farm is also reported to have a positive effect on-farm diversification. They postulated that large farms are likely not to diversify. The availability of family workforce endowment has a significant positive influence on diversification. This support the assumption that farm diversification can be thought to make family labour force more profitable. Type of farm influences diversification in that mixed farms are most likely to diversify. Soil type also influences diversification according to the study. Farmers who cultivate on fertile soils tend to increase the number of crops they grow.

Shahbaz, Boz and Haq (2017) studied on the determinants of crop diversification in mixed cropping zone of Punjab Pakistan. They used multistage sampling techniques to select 100 crop growers in the District of Faisalabad. The Herfindahl index (HF) was applied to calculate the diversification level and determinants of the crop diversification index were analysed by Tobit

model. Younger farmers were more diversified than older farmers and also farmers who seek off-farm income source were also found to be more diversified. The result of the econometric model depicts that the education and farm size positively and significantly affect the crop diversification. Similarly, the ownership of farm machinery enhances the diversification level of farms in crop cultivation. The self-owned operated farms will be less likely to be diversified in crop cultivation than another form of tenure types like renter and shareholder.

Climate-driven water availability in the tropics agricultural system will force farmers to significantly alter their production practises. In agricultural systems dominated by water-intensive rice cultivation, farmers may need to diversify away from rice to crops that perform better in the new climate. Burchfeild, Tozier and de la Poterie (2018) examine the factors that influence the intensity of crop diversification in rice-dominated Sri Lankan agricultural systems. They combined data from interviews and household surveys with the Sri Lankan farmers to identify the factors that influence the farmer's decisions to diversify away from rice monoculture. Results indicate that many farmers cannot diversify away from rice production because of the characteristics of their rice fields. As a result, they recommend that policies and action should be taken to intensify crop diversification. Farmers whose fields can support diversification, poor market access, market instability, limited government support, and relatively high input costs reduce diversification rates. In addition to creating a supportive institutional environment for the cultivation of other field crops, leveraging existing water management institutions to identify and support farmers with fields suitable to diversification could decrease agricultural water demands and increase water access for farmers unable to engage in diversification.

Tesfaye and Tirivayi (2019) used the Composite entropy model, a modified version of the Shannon-Weaver index to measure the extent of diversification to analyse the drivers of crop diversification, household welfare and consumption smoothing under risk in rural Uganda.

Crop diversification is measured using four interspecific crop diversity indices that capture both the number of crops in the crop production portfolio and their evenness: Count (richness), Shannon-Weaver, Composite entropy and Berger-Parker. The count index measures richness of cultivated crops and assumes that different crops contribute equally to the household crop portfolio, although this is not always the case. The results revealed that rainfall shock is found to influence farmers decisions to diversify with the point that households have the incentive to use crop diversification as an adaptative strategy against rainfall shocks. The degree of diversification increases with an elevation of the area, households located at higher altitudes tend to diversify crop production. Although the average temperature of the planting season has no significant effects on diversification, the interaction of temperature with elevation has a negative effect on crop diversification. This implies that environmental effects play a key role in determining crop diversity. The study also reported that a farm household's location also plays an important role in crop diversification. This means that the peers of farmers in a locality influence farmers production decision. Households demographic characteristics are found to be important in determining the drivers of crop diversification. More crops were grown by older households and suggested that it is because of their experience in the importance of crop diversification.

Ji-kun, Jing, Jin-xia, and Ling-ling 2014) examined crop diversification in extreme weather events in China using the OLS model. The main objective of their study was to whether farmers to adopt extreme weather events through crop diversification and which factors influence them. The data from nine provinces revealed that farmers use crop diversification as risk-reduction strategy against unfavourable weather. The decision to diversify was also influenced by the previous year's weather experience rather than the current weather events. Moreover, household characteristics like age and gender of farmers also drive crop diversification.

Sichoongwe (2014) used the Tobit model to analysis determinants of crop diversification among southern Provinces of Zambia. In his thesis, he reported that crop diversification is dependent on the size of farm holding, quantities of fertiliser, time of tillage, and distance to market since they were statistically significant. This implies that a percentage increase in the farmer's farm holding would increase the probability of a farmer diversifying. When farmers have substantial access to fertiliser, he or she is likely to increase the number of crops he or she grows. His study also revealed that when farmers have timely access to plough, farmers are likely to grow more than one crop. When farmers have reliable markets, then he or she is likely to diversify crop production. He recommended that government and traditional leaders should make land available to the farmer if they are to promote diversification. Another important recommendation noted by the authors is that policy-makers should encourage farmers to use other means to improve the soils that they can easily afford.

Another study of interest is by Rehima, Belay, Dawit and Rashid (2013) in Ethiopia. Their paper assessed the determinants of crop diversification using data on three stages randomly selecting 393 farm households. The value of the Margalef index was the dependent variable. The Heckman two-stage model was applied to estimate separately the farmers' decisions and level of diversification. Factors affecting diversification were gender, education and trade experience, membership in cooperatives, resources ownership, features in the land owned, access to extension services and transportation cost. They recommended that since the government encourages crop diversification to ensure dietary diversity, it should encourage female participation, build the capacities of the extension officers, encourage the availability of inputs and agricultural research, generating agro-ecology based technologies and disseminate them. Non-crop activities (trade experience) and social organisations underline the need for designing integrated agriculture system (crop-non-crop) and improving social

organisations as powerful tools to increase diversification capacity of the farmers. Transaction costs need strengthening rural-urban infrastructure to link crop diversification with markets.

Makate *et al.* (2016) demonstrates how crop diversification impacts on two outcomes of climate-smart agriculture; increase in productivity (legumes and cereal crop production) and enhance resilience (household income, food security and nutrition) in Zimbabwe. Using data from 500 smallholders, they jointly combine crop diversification and each of the outcome variables within a conditional (recursive) mixed process framework that corrects for selectivity bias arising due to the voluntary nature of crop diversification. They documented that crop diversification depends on land size, farming experience, assets wealth, location, access to agricultural extension services, information on output prices, low transportation cost and general information access. They recommend that wider adoption of diversified cropping systems notably those currently less diversified for greater adaptation to the ever-changing climate.

A recent study by Asante *et al.* (2017) in Ghana used the Herfindahl index to determine indicators of diversification and determinants of diversification was analysed using the Cragg two-step model. By examining the integrated farming systems of 608 smallholders, the study presented a piece of empirical evidence to support the development of effective strategies that influence diversified farming systems. The estimated diversification index was 0.45, 0.32, and 0.59 for crop, livestock and crop-livestock diversification systems respectively. The analysis of determinants diversification revealed that farm-level factors like the quantity of fertilisers, and the use of tillage equipment increase the probabilities of growing more than one crop. The findings also illustrated that ploughing allows greater land to be cultivated within a shorter period than using labour. Farmers' ability to cultivate a greater range of crops was increased by the area available for farming. The quantity of fertiliser increased both the extent and probability of crop diversification and this connoted that fertiliser subsidies would increase

fertiliser usage and increase crop yields and diversification. Other factors like share family labour, dependency ratio had negative effects on the probability of crop diversification.

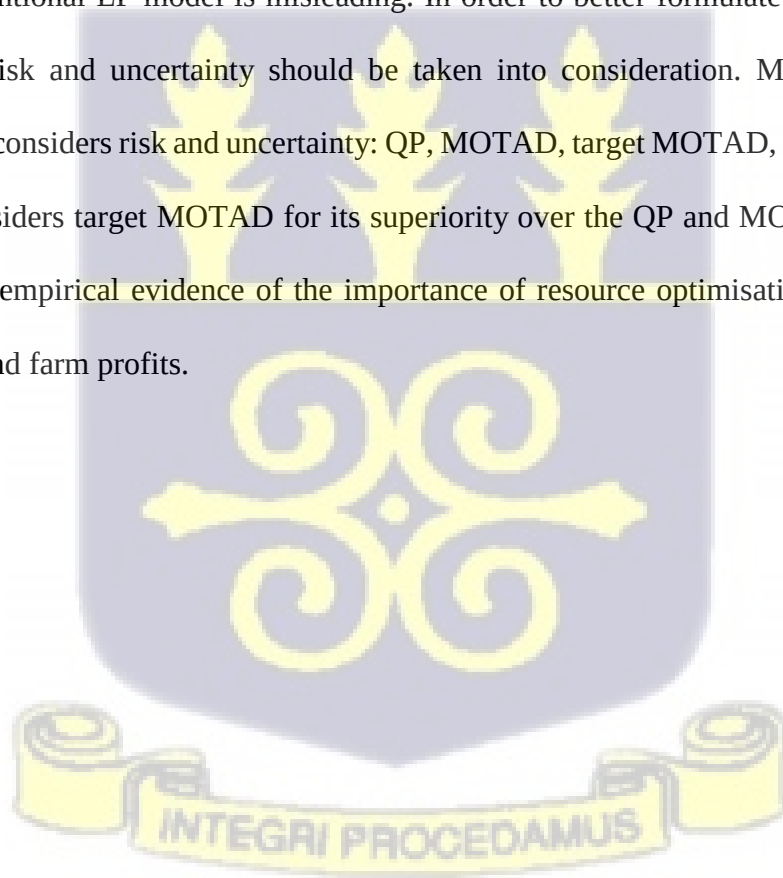
Owing to the importance of crop diversification, some cocoa farmers in the Ashanti and Western region of Ghana have diversified in vegetable production, producing different vegetables on the same plot of land or different plots (Djokoto, Afari-Sefa, & Quaye 2008). These authors conducted a study that seeks to assess the extent of diversification and identify factors that account for variability in diversification. Their study used the Simpson, Herfindahl and entropy indices were employed and the best set of indices are selected based on the statistical procedure. The functional regression approach of the Logit transformation was used to assess the determinants of diversification. The result revealed that the Western region has the highest SDI of 0.80 and the Ashanti region was 0.75. The research also revealed that out of the ten factors of diversification, only three were statistically significant. Marital status of household head, cocoa cultivation and land endowment of households were significant. Farmers who have established cocoa farms can earn diversified income through vegetable production before the cocoa is ready for harvesting. A large farm size would encourage the establishment of more vegetable farms. The recommended an increase in land access to farmers.

2.11 Summary of Literature Review

From the literature reviewed in this study, it can be released that various interventions have been instituted by various governments and NGO, with their primary motive to increase agricultural production and market access in order to increase farmers' income and ensure farmers are food secured. These programmes have achieved some success on their mandates. Most of these programmes promoted diversification and increase in crop yield without considering how a farmer should manage their scarce economic resources. Resource management involves the efficient and optimal resource allocation among farmers crop

enterprises. The review has revealed that farmers resource allocation had increase farm profitability and also endure that farmers are food secured. A study on how farmers should allocate their resources in the Karaga District is essential.

Studies on resource allocation in Ghana primarily focus on the use of the conventional Linear Programming model. Various authors criticised this model and their argument is that the model ignores the risk preferences of farmers and overstate optimal output levels. Using the results from the conventional LP model is misleading. In order to better formulate models for farm planning, the risk and uncertainty should be taken into consideration. Models have been developed that considers risk and uncertainty: QP, MOTAD, target MOTAD, to mention a few. This study considers target MOTAD for its superiority over the QP and MOTAD. The study would provide empirical evidence of the importance of resource optimisation on household food security and farm profits.



CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter of the study presents theoretical and empirical approaches that would help in explaining smallholder farmers allocation of their scarce resources under risky condition. Next, the method of data analysis and the analytical frameworks are presented. This chapter further discusses the description of the study area, sampling and sampling procedure.

3.2 Conceptual Framework

Conceptual framework on crop diversification and resource optimisation and its impact on the farm household can be seen in the flow diagram below (Figure 3.1)

Farmers in developing countries grow several crops on a piece of land or over several plots of land. They grow numerous crops because they want to improve household food diversity and also to reduce crop production and marketing risk. Farmers are rational beings and so, therefore, try as much as possible to reduce risk as much as possible. One way most farmers in northern Ghana do reduce risk is through crop diversification (Asravor, 2018). Farmers grow several crops and these crops compete for resources like capital, labour and land. Moreover, farmers decision to grow more than one crop is influenced by human, socioeconomic institutional and risk factors.

Crop diversification is a strategy that increases income at reasonable risk levels which is the goal of most households. Crop diversification would increase farm profitability and ensure food security if resources available to the farmer are optimal allocated. Studies show that farm households that are in multiple cropping would not reap the maximum return from crop production if the optimal plans are not followed. Farm households who specialise in growing a single crop are more exposed to risk. Specialisation without resilient markets would lead to

poverty. Some other studies revealed that crop diversification has been known to increase yields and stabilise farm households' income (Kassie *et al.*, 2015; Arslan *et al.*, 2015; Makate *et al.*, 2016; Steward *et al.*, 2018; Hansen *et al.*, 2019).

For that matter, there is a need to develop a good farm plan that ensures that the right proportion of resources are allocated to each crop enterprise. This was a problem some time ago but thanks to mathematical programming, this is no more a problem. However, most farmers do not optimally allocate production resources among their diversified crops. Linear programming is one of the ideal mathematical programming models that is used to determine optimal resource allocation for farmers.

However, farm plans developed by the conventional linear programming model has the problem, which is that it assumes farmers are profit maximisers. But in real situations in Africa, farming is highly risky and farmers are more concerned about their income not reaching the desired target. Farmers are more concerned about security rather than profit maximisation. The target MOTAD model was developed because it is assumed that the utility function of farmers is characterised by diminishing marginal utility causing the utility function to be concave to the origin.



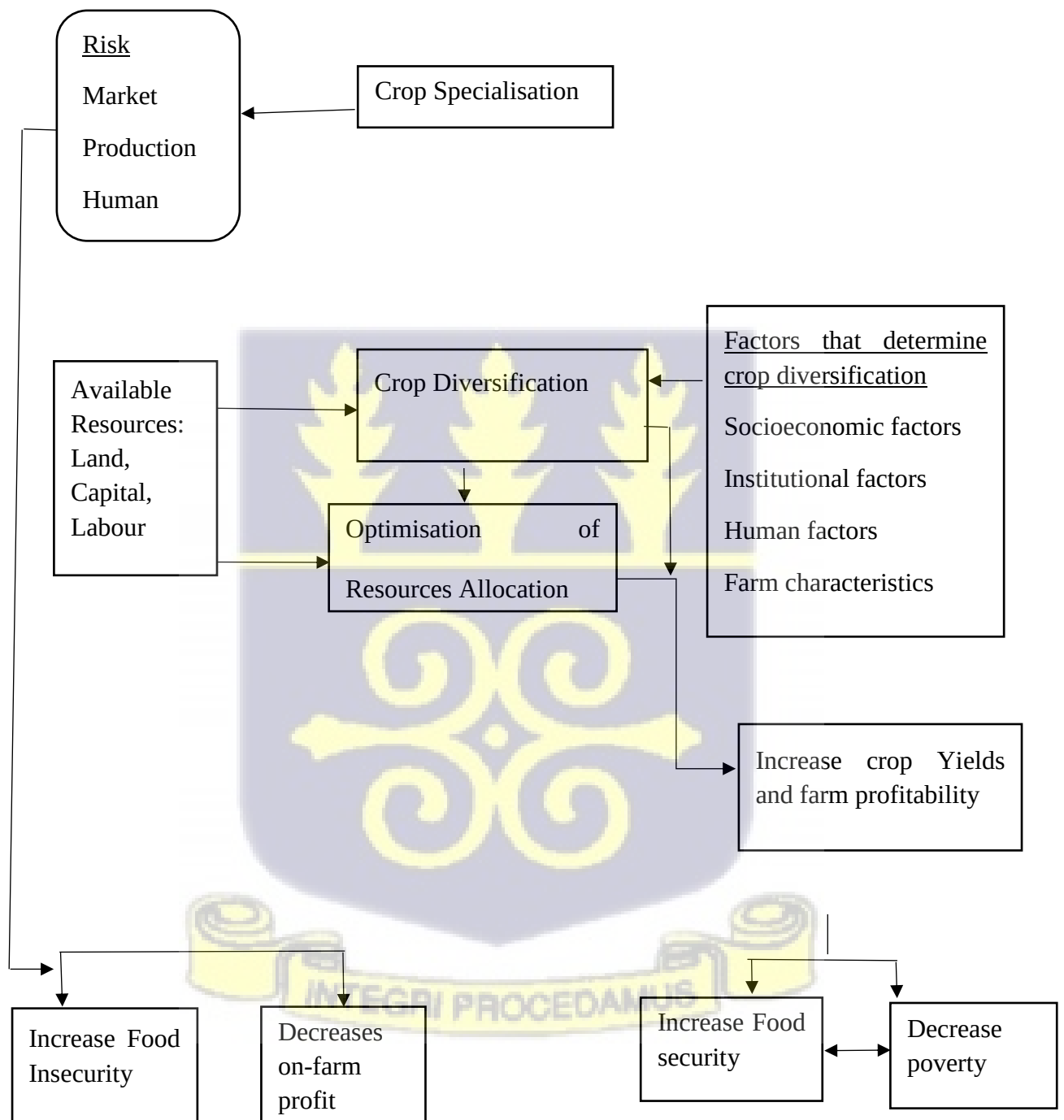


Figure 3. 1: Conceptual Framework

Source: Adapted and modified from Sichoogwe (2014)

3.3 Theoretical Framework

A basic economic theory that underlines this study is the theory of the firm. Farmers are rational being and commit their limited resources in order to maximise utility. Farmers like other entrepreneurs commit their resources to the production of food products for household consumption or market participation. Given resource constraints, farmers are expecting their production process to yield economic benefits or utility. They expect to maximise utility of possible given the limitation on his or her land, labour and capital resources and production options available to him or her when.

Utility to the farm firm is in three folds, farmers are concern about maximising returns, ensuring that the yields satisfies the food requirement for the farm holds and also returns from production not falling below certain threshold. They are only concerned about maximising utility of income, they also return not falling below certain threshold. Farmers would opt for farm plans that provide some level of security even some returns are forgone. This can be expressed mathematically as:

$$\text{Maximise } f(U) = f(Z, d, \alpha Z, L, l, K) \quad (3.1)$$

Where U is the utility of the farm firm, Z represent the return from production, d is the food requirements for the farm firm, αZ represents risk associated with income Z , and L, l, K are the Land, labour and capital available respectively.

Farmers depend on their managerial skills and experience to operate on the farm to generate the desired income. These decisions are affected by market, yield and human risk. Risk and uncertainty create problems for the farmer profit maximisation given physical constraints and production options. This was a problem solved by a mathematical programming model (LP).

The LP model provides farmers with an optimal plan that when he or she adopts will result in profit maximisation. LP model is widely used in maximisation and minimisation problems

where production parameters like output are not known for sure. This is a very useful model but when production deviates downward from their expected average values, the risk of incurring net financial losses exist and the basic LP model will no longer be useful as a method for analysis and its usage will produce misleading results and not good for decision-making.

A tool recommended for such analysis is the Quadratic Programming (QP) model. At first, researchers found it difficult to compute for solutions of the QP model due to its complexity, lack of powerful computers and software. A linear alternative of the QP model was developed by Hazell called the Minimisation of Total Absolute Deviation (MOTAD). This model incorporates risk in its analysis and risk is considered as a negative deviation. Decision-making is selecting a course of action from choices. Outcomes of choices are uncertain but there are probabilities associated with each choice. These probabilities indicate that each choice made has an associated risk.

3.4 Method of Data Analysis

This section enlightens how various specific objectives would be addressed and attained.

3.4.1 Identifying crop enterprise mix practised by farm households

Farmers cultivate numerous crops to meet household food and financial needs. However, there are some crops that most farmers grow in a particular geographical area because these crops do well in those areas. For this study, descriptive statistics such as frequency, percentages, and summary statistics like means mean, mode, the median were used to determine the crop mixes practised by farm households. Crop mixes that have high-frequency scores would be considered and those that have less attention by farmers are not considered.

3.4.2 Identifying factors that influence the number of crop farm enterprises

Since factors that influence the number of crops that farmers grow is count data, the Poisson regression model was used for this analysis.

The number of independent crop enterprise farmers grow i is supposed to follow a Poisson distribution at rate $n_i \times \lambda_i$. according to our assumptions. The number of crops grown by farmers is denoted by n_i , while the linear predictor is denoted by $\log \lambda_i$. If Y has a Poisson distribution, then the effects of the variables considered can be modelled using a log-linear model of the form

$$\ln(Y_i) = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \dots + \beta_k X_{ki} \quad (3.2)$$

Exponentiating both sides of gives the predicted value of Y in counts and this gives the equation

$$Y = e^{\beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \dots + \beta_k X_{ki}} \quad (3.3)$$

Where the Y is the independent variable measured as the number of crop enterprises farmers engage in, X 's are the independent variables which can be grouped into socioeconomic, personal, demographic institutional and other factors. These variables can be seen in Table 3.1. The Poisson regression was analysed using STATA 15.

Description and measurements of variables in the Poisson regression model

Y: This is the dependent variable of the model and considered the total number of crops grown by each respondent.

Sex of the household head: Every individual belongs to two sex categories, male and female. Households in Northern Ghana are mostly headed by males who most of the time make productive decisions. Males are more likely to have access to productive resources than their female counterparts. Hence, they are likely to grow more crops than females (Asante *et al.*, 2017; Etwire, Dogbe & Nutsugah, 2013). After various land reforms in Ghana which were aimed at giving equal chances to individuals irrespective of their sex, yet women in Ghana find it difficult to access land and other resources (Antwi, 2016). This implies that male household heads would have a positive effect on the crops that would be cultivated. On the contrary,

women are surprisingly likely to specialise in a single crop (Helena, Richard, & Olofsson, 2010).

Age of household head: Increase in the age of farmers is associated with the increase in farmers' experiences and is a key factor in household decision-making. It is believed that older people allocated more resources to several crops than younger ones. This is because older farmers are said to be risk-averse and well experienced and have knowledge of the benefit of crop diversification (Asravor, 2018; Asante *et al.*, 2017; Min, Huang, & Waibel, 2017; Wondimagegn & Nyasha, 2019). Research also indicated that younger people are susceptible to growing more than one crop than older generations (Singh, *et al.*, 2004; Helena, *et al.*, 2010). It can be predicted that age has a positive or negative effect on the number of crops that would be grown by household head.

Farm Size: When the farm size of the household is large, then farmers are more likely to increase the crop portfolios. Smaller farm sizes are also more likely to produce few crops. The number of crops increases with an increase in arable land area. Larger farm sizes encouraged households to grow more cereal crops in Kenya than small farms (Mbaye, Lagat, & Kelvin, 2014; Ji-kun, Jing, Jin-xia, & Ling-ling, 2014). However, when farm sizes increase to an extent, specialisation sets in (World Bank, 2019). Singh, Ahmad, Sinha, Singh and Mishira (2018) highlighted that large farms concentrate on a single crop rather than multiple crops. This is rational because large farms want to enjoy economies of scale and scope. Hence, farm size is likely to affect the outcome positively or negatively.

Household size: This is the number of people who share expenses and live and eat together and the household head who provides for the unit. Larger households are likely to have higher dependency ratios. The study area has a high dependency ratio of 96 percent so it is likely that, household heads will diversify in crop production because large family size means more

mouths to feed. Hence dependency ratio will have a positive effect. Torres, Vasco, Günter and Knoke (2018) reported that larger household size is related to labour availability to work on farms hence influencing the household heads venturing to more than one crop.

Farming experience: This variable in a way is aligned with age. This is how experienced farmers are and older farmers are likely to be more experienced than younger farmers and these old farmers tend to diversify than specialise. On the contrary, farmers who are more experience in crop production are more likely to specialise in a single crop because they can cope and minimise risk than inexperienced farmers (Ji-kun, Jing, Jin-xia & Ling-ling 2014). Makate, *et.al.* (2016) observed that a year increase in farming experience would result in a decrease in the probability of growing more than one crop. So, a positive or negative effect is expected

Non-farm income: When farmers get income from activities other than farming, then farmers are likely to grow a single crop. This is a two-sided situation. When the off-farm activity is less profitable relative to on-farm activities, then labour will be concentrated on farms and hence increase the probability of diversification (Asante *et al.*, 2017). Off-farm income drains farms off labour and other resources and this negatively affects the number of crops grown.

Previous year's rain experience: This explains the farmers' experience of the past year's rainfall pattern. The rainfall experience influence farmers crop production behaviour. If previous rainfall was adequate then farmers are more likely to diversify crop production to the following year (Ji-kun, Jing, Jin-xia, & Ling-ling, 2014).

Access to credit: access to credit has a significant effect on crop productivity and diversification. Farmer getting access to credit in the form of loans and/or in-kind has a positive significant effect on the number of crops that are grown with cocoa among cocoa farmers in Ghana (Aneani, *et al.*, 2011).

Table 3. 1: Description, measurement and a priori expectation of variables of the model

Dependent variable	Explanatory variable	Measurement	A priori effects or expectation
Number of Crop enterprises	Age of household	Number of years	±
	Sex	Male=1 Female=0	±
	Farm size	Acres of land of household (acre)	+
	Household size	Number of persons belonging to a household	+
	Farming experience	Number farming years	
	Educational level	No education=0 Basic=1 Secondary=2 Tertiary=3	±
	Off-farm income	Involve=1 Otherwise=0	—
	Distance to Market	Kilometres	±
	Availability of inputs	Access=1, Otherwise=0	+
	Access to credit	Access=1 No access=0	+
	PFJs fertiliser subsidy	Benefited =1 Not benefited=0	+
	Availability of hire labour	Able to hire=1 otherwise=1	+

PFJs fertiliser subsidy Programme awareness: The PFJ like other subsidies was instituted in 2017 to provide farmers with viable seeds and subsidised fertiliser. The reduction in the cost

of production motivates farmers into other crop enterprises. Fertiliser subsidies have a positive effect on the number of crops that would be grown (Asante *et al.*, 2017: Chibwana, Fisher, Shively 2011).

3.4.3 Determining the optimal cropping pattern for farmers under a risky environment

In drought-prone areas like the Northern part of Ghana, studies on agriculture development explicitly need to incorporate risk and uncertainty associated with the drought-prone area (Maleka, 1993). Decisions on the possible combinations are infinite but there is a particular combination that maximises the utility of income. When more than one crop is grown, there should be a plan that will be followed on how much resources should be allocated to each crop to attain the highest gross margin with associated risk. This was made possible by Gilbert B. Dantzig in 1947 by mathematical programming. He developed a linear algorithm for optimising operations. After him, many economists and mathematicians developed many algorithms to solve the optimisation problem.

Many agricultural economists used the conventional linear programming model to help farmers and rangers determine the right farm plan that yields the highest utility. However, this model is limiting in that the model assumes farmers are risk-neutral but actual farmers are risk-averse. Tauer in 1983 developed a model called the Target Minimisation of Total Absolute Deviation (T-MOTAD). This model is preferred to other models because it provides solutions that comply with the Second-order Stochastic Dominance. For this study, optimal resource allocation patterns were determined using the T-MOTAD model specified as:

$$\text{Max } E(z) = \sum_{j=1}^n G_j x_j \quad \text{Objective function} \quad (3.4)$$

$$\text{Subject to } \sum_{j=1}^n a_{jk} x_j \leq b_k \quad k = \text{land, capital, and labour hour}, \quad (3.5)$$

$$\sum_{j=1}^n C_{rj} x_j + y_r \leq T \quad r = 1 \dots s, \text{ risk constraint} \quad (3.6)$$

$$\sum_r^n p_r y_r = \lambda_r \quad \lambda = M \rightarrow 0 \quad (3.7)$$

$$\sum_{j=1}^n Q_{jk} x_{jk} \geq d_k \quad \text{Food consumption constraints} \quad (3.8)$$

Where y_r is the negative deviation in total net revenue in the r th state of nature below the targeted net revenue level, T is the target net revenue level, and λ is the maximum amount of shortfall in net revenue permitted. G_j is the gross margin from crop enterprise j , cr_j : Revenue of the enterprise j for the state of nature or year r . x_j : the level of crop enterprise j , a_{jk} : the technical coefficient of the enterprise j for the production resource constraint k , b_k : is the level of resource k available to the whole farm, p_r : the probability of the occurrence of the state of nature or time or year r , λ : the level of risk and parameterised from 0 to M and M being a large number, n is the number of constraints, s is the number of state of nature or years, Q_{jk} is the yield of the crop k and in the j th activity and d_k is the minimum quantity of crop k requirement of households.

Equation (3.4) and (3.5) are the normal linear programming standard forms. Equation (3.4) maximises the expected returns from crop enterprises of an average farmer and equation (3.5) models the technical coefficient of resources required by each crop enterprise and the resources available to the farmer. Equation (3.6) measures the revenue of each production plan for the state of nature r . If this revenue is lower than the target level T , the difference is transferred to equation (3.7) via the variable y_r . Equation (3.7) measures the sum of the negative deviation from the target multiplied by the probability of occurrence of the state of nature r . It can be seen that all equations in the Target MOTAD model are linear and they can be solved using the linear programming algorithm. The target MOTAD analysis was performed using the LIPS 1.11.1.

Estimation of the Target MOTAD

The objective function is the maximisation of the sum of gross margins from all crop enterprises. This function provides alternative farm plans which include various crop combinations with their respective returns and risk associated with each return. The solution is expected to provide results that make it easy to choose between different farm plans. Plans with higher returns are highly risky. That is if the plans have a higher expected return then, the variance of the return would also be high. Conversely, lower returns have a lower variance or deviation. Since farmers are risk-averse, they will like to increase utility rather than maximise expected income. Expected return or the total gross margin is the sum of gross margin from all crop enterprises.

There are two stages in computing or solving using the model. This involves firstly finding the solution for the conventional linear programming algorithm and this gives solutions without the risk constraints. This provides a solution at the highest point on the expected return and variance (EV) frontier. Secondly, the risk element is formulated as a matrix of the gross margin deviation from expected returns. Points on the risk efficiency frontier are obtained by parametrically decreasing the value of T and λ in arbitrary reductions.

Estimating gross margin of crop enterprises

Gross Margin

One essential element of a linear programming model is the gross margin per unit area, hectare. Gross margin is the revenue over farm total variable cost, where variable cost is the season cost for producing per unit area of output. Gross margin varies among crop enterprises due to the differences in prices of outputs and inputs relative to each crop. The formula for estimating gross margin is specified as:

$$GM = yp(x_i) - TVC_i \quad (3.9)$$

where y is the output per hectare of crop enterprise i , p is the price of the outputs of crop enterprise i , TVC is the Total Variable Cost for the crop enterprise i .

Land Constraint

Land is measured in hectares. Land constraints indicate the total area cultivated under different crops. That is the total area of land available to the farmer in some situations. The total area allocated for crops in the season must be less than or equal to the sum of the area cultivated under different crops.

$$\sum_{i=1}^n l_i x_i \leq TL \quad (3.11)$$

n : is the number of crops cultivated, l is the land required to grow crop i , x is the area land cultivated under crop enterprise i , and TL is the total land under cultivation.

Capital Constraints

This is the total capital available to grow all crops the farmers' desires. This is the sum of the capital required per hectare of the crop multiplied by the number of hectares the crop occupies. This can also be expressed as the total equity capital and borrowed capital. Working capital is the capital required to produce a crop enterprise i . Farmers are human and susceptible to forgetfulness so they could not tell us the monies spent in production. Capital in this study is considered to be the cost of production. Capital constraints can be measured as:

$$\sum_{i=1}^n WC_i x_i \leq TWC \quad (3.12)$$

Where n : the number of crop enterprises, WC_i is the working capital required to grow crop i , x_i is the level of crop enterprise i , TWC is total working capital.

Labour Constraints

Labour is required for on-farm activities, harvesting and post-harvesting activities. This measures the total labour days available for production, harvesting and marketing of crops. This is the sum of the labour days required for land preparation through harvesting multiplied by the number of acres or hectares the crop is cultivated. Labour is sourced from family and hired. Labour constraints are the product of the number of adult males and females working on a particular crop enterprise times the labour-days of work. Total labour days available to the farmer is the sum of labour days of the two sources of labour.

$$\sum_{i=1}^n (lp_i x_i + lpsthvst_i x_i) \quad (3.13)$$

Where n is the number of crop enterprises, lp_i : the labour required for on-farm activities for crop i , lp_i : is the technical coefficient of labour required for on-farm activities and $lpsthvst_i$ is the technical coefficient for off-farm activities related to a crop enterprise and TL sum of household labour.

Risk consideration

Risk is measured as deviations from the target. Farmers try as much as possible to manage risk. The target MOTAD includes risk in its analysis. With risk consideration, a target income is set which should be equal to the expected returns without risk. The deviation below the target should be confirmed to a specific value. Tauer determined the probability of the deviation by summing the individual probability of the state of nature as seen in equation 3.7.

3.4.4 Trade-offs between risk and returns

Risk reduction strategies result in a sacrifice of income or utility for risk (Micheal & Margot, 2000). The Target MOTAD analysis is expected to yield several possible crop combinations with optimal gross margins. Standard deviation and coefficient of variation were used to measure the risk of all possible returns from various plans. The standard deviation and the

coefficient of variation measure the risk returns trade-off of farm plans. Decisions can be made based on the magnitude of each farm plan's standard deviation and coefficient of variation. The conventional LP model results in a risk-unconcerned plan and this is compared to farmers' plan, and the risk modelled farm plans.

In the EV frontier, one can observe that the Target MOTAD model minimises the mean absolute deviation (MAD) for any expected gross margins. The standard deviation of returns can be measured using the estimator:

$$\sigma = D\left(\frac{\pi s}{2(s-1)}\right)^{\frac{1}{2}} \quad (3.14)$$

(Norton & Hazell, 1971)

The standard deviation allows the model to determine the set of solutions that is along the EV efficiency frontier. What the model does is minimise risk and select crop enterprises that are less risky or has less variance or have negative (or less positively) correlated returns. Therefore, an estimate of each crop enterprise's level of risk or risk associated with a particular farm plan would result from the estimation of the standard deviation and/or coefficient of variation for that crop enterprise. This is done for the farmer to determine the risk farmers face in their production activities. Farmers will choose farm plans that maximise their utility depending on the risk attitude.

A T-test would be employed to test the significant difference in expected returns of all resulting farm plans. According to Sirkin (1995), t-statistics can be expressed as:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (3.15)$$

here $\bar{x}_1$ and $\bar{x}_2$ are the mean gross margins of various modelled result combinations. s_1 and s_2 are the standard deviation and n_1 and n_2 are the number of observations.

3.5 Methods of Data Collection

This section of the study provides the types of data sources, the sampling size determination and the sampling techniques and instruments and the geographic area of the study.

3.5.1 Sources of data and instruments employed

The study used both primary and secondary data sources or groups. Primary data was obtained from a field survey through the use of structured and semi-structured questionnaires. Information regarding the cost items of farmers, yields of various crop enterprises, crop mixes grown, inputs use and requirements, just to mention a few, for the 2017 to 2019 season were obtained from the respondent. Secondary data like the labour requirements, market prices of inputs and outputs and associated costs were obtained from the Karaga District Agricultural office.

A well designed and pre-tested questionnaire was used to obtain relevant information from the respondents. A pretest of the questionnaire was carried out to ensure that the instructions and questions were clear, there were no problems in providing the kind of answers expected and the duration of the interview was not unduly long. Close-ended questions were posed which enabled the respondent to select a restricted set of answers.

Open-ended questions were also added which allowed the respondents to express their views on some important aspects. The questionnaire was composed of three sections. The first section described the household, demographic, farm and institutional characteristics of the farmers. In the second section, data on resource use and allocations among food crop enterprises were collected through the same questionnaire. The third section was then designed to collect data on the maize required for household consumption and production targets that farmers are wished to achieve.

3.5.2 Sampling Size and Sampling Techniques

A multistage sampling technique was used for this study. The target population for this study is crop farm households in the Karaga District. The first stage involves purposively selecting the district and the Karaga District was purposively selected based on its per capita food production and distribution.

The District was divided into five clusters namely, Karaga, Bagli/Zandua, Sakulo/Namburugu, Kupali, Pishigu Zones (District Assembly suggestion). From four zones, three communities were randomly selected and one from one zone. Farm households were randomly selected in each community. Table 3.2 shows the proportion of farm household heads that were visited in each community for questioning.

At the house level, when the number of farm households were more than one then a random sampling was used to select a farm household head through balloting.

From Yamane (1967), sample size (n) used in the study was determined using the formula:

$$n = \frac{N}{1+Ne^2} \quad (3.16)$$

where n is the sample size, N : the number of farm households in the District, and e is the desired margin of error. For this study, the basic unit for consideration and sampling is the number of farm households. From the District assembly office, the total population of farmers in the district is 95,870 (GSS, 2019) and with an average household size of 10 and 6,565 houses (GSS, 2014). The desired margin for error was given as 0.05 (that is, 5 percent). Substituting all variables, then n , sample size, will be 398 farm households.

$$n = \frac{95870}{1+0.05(95870)} = 398$$

However, 400 farm households heads were interviewed to take care of possible outliers.

3.5.3 Study area

The study would be conducted in the Karaga District in the Northern Region of Ghana. The district was officially established in 2004 from the Gushegu-Karaga District.

Physical Features of the District.

The Karaga District is one of the agrarian districts in the Northern region. It was carved out of the Gushegu-Karaga District in 2004. The district is considered one of the poorest among the fourteen districts of the Northern region with about thirty percent of individuals considered poor (GSS, 2014). The District is located on the North-Eastern part of the Northern Region. It is one of the largest District in terms of land size in Northern region occupying a land size of 3119.3 square kilometres. It shares boundaries to the east with Gushegu District, to the west is the Savelugu Municipality and Nanton District, to the North is the West and East Mamprusi. The District capital, Karaga is 94 km from Tamale, the Northern Regional capital. The District is considered a rural district because the majority live in rural areas (UNDP, 2011).

Demographics of the Area

As at 2010, the Ghana Statistical Service estimated the population of the area to be 77,706, with population distribution by sex being 37,336 for males and 40,370 for females for all ages. With a population growth rate of 2.7 percent per annum, the District population is expected to be 94,921 (Males: 47132 and Females: 46683) (<https://data.gov.gh/>; UNDP, 2012). The district mainly consists of rural settlements, the majority living in the rural areas and 18 percent live the urban and this may be attributed to the fact that most of the population are engaged in agriculture. The District is estimated to have a household size of 10 and the total number of households to be 7,664 (GSS, 2014).

Table 3. 2: Communities that are selected for the study with their respective sample sizes

Communities	Number of farmers	Sample size
Kupali	534	20
Shebo	362	14
Bagli	1064	40
Kpasong	810	31
Yemokaraga	660	25
Namang	835	32
Namburugu	499	19
Zandua	864	33
Nyong-guma	1454	55
Sung	2286	86
Gunaayili	228	9
Shelilan yili	305	12
Nakundugu	687	26
Total		400

Climate, Soil and Vegetation

The area like any Guinea Savanna area has an annual rainfall between 900 mm and 1300 mm which is considered enough for food crop activities. Rainfall is unimodal and comes between April to October each year. The area experiences high temperatures throughout the year and highest at 36°C between March and April and minimum between November and February during the harmattan season. Soils in the area are ochrosols and good for traditional leafy vegetables, cotton, root and tubers, cereals and legumes production and grass for grazing animals. Tree crops like cashew, mango, shea, African locust beans (*parkia biglobosa*) and baobab trees also do well in these soils. These trees are mostly wild except mango trees and are scattered over farmlands and settlements.

Economic Characteristic of the District

The economic or employment activities of an area determine the development and poverty status of that area. The District is dominated by the youth who are actively engaged in agricultural and agribusiness-related enterprises. According to GSS (2014), most of the inhabitants are self-employed indicating that the private sector is the largest employer in the District. The district is characterised by the normal northern economic setup where the majority of men are into agriculture and related activities and women help their husbands on the farm and also involve petty trading, agro-industrial businesses and home duties. Agriculture is not the only economic activity that engages the populates. There are people employed in the formal sector like teaching, nursing, extension work, financial sector, and other professional jobs. A UNDP report in 2011 documented that minorities are into non-agricultural activities. Next large employment sectors are the manufacturing sector which employs 1.6 percent of the population, financial services employing 1.4 percent followed by retail and wholesale activities and fishing, and community or social services taking the rest (UNDP, 2011).

Agriculture in the District

About nineteen out of twenty people are into agriculture. Most agricultural activities are in rural areas where 98 percent are into agriculture and 88 percent of the urban households. Agriculture is a primary source of livelihood in the District. The major agricultural production is crop farming constituting 98 percent and 63 percent of households engage in livestock raising. Soils in these parts are good for grain production and 80 percent of households grow several crops (UNDP, 2011). The major crops grown in the district include maize, rice, soya bean, cowpea, cassava, yam, sorghum, millet and traditional vegetables. Food crops are mainly grown on a subsistence basis whilst soya beans and groundnut are their main cash crops. Few farms are devoted to mango and cashew production.

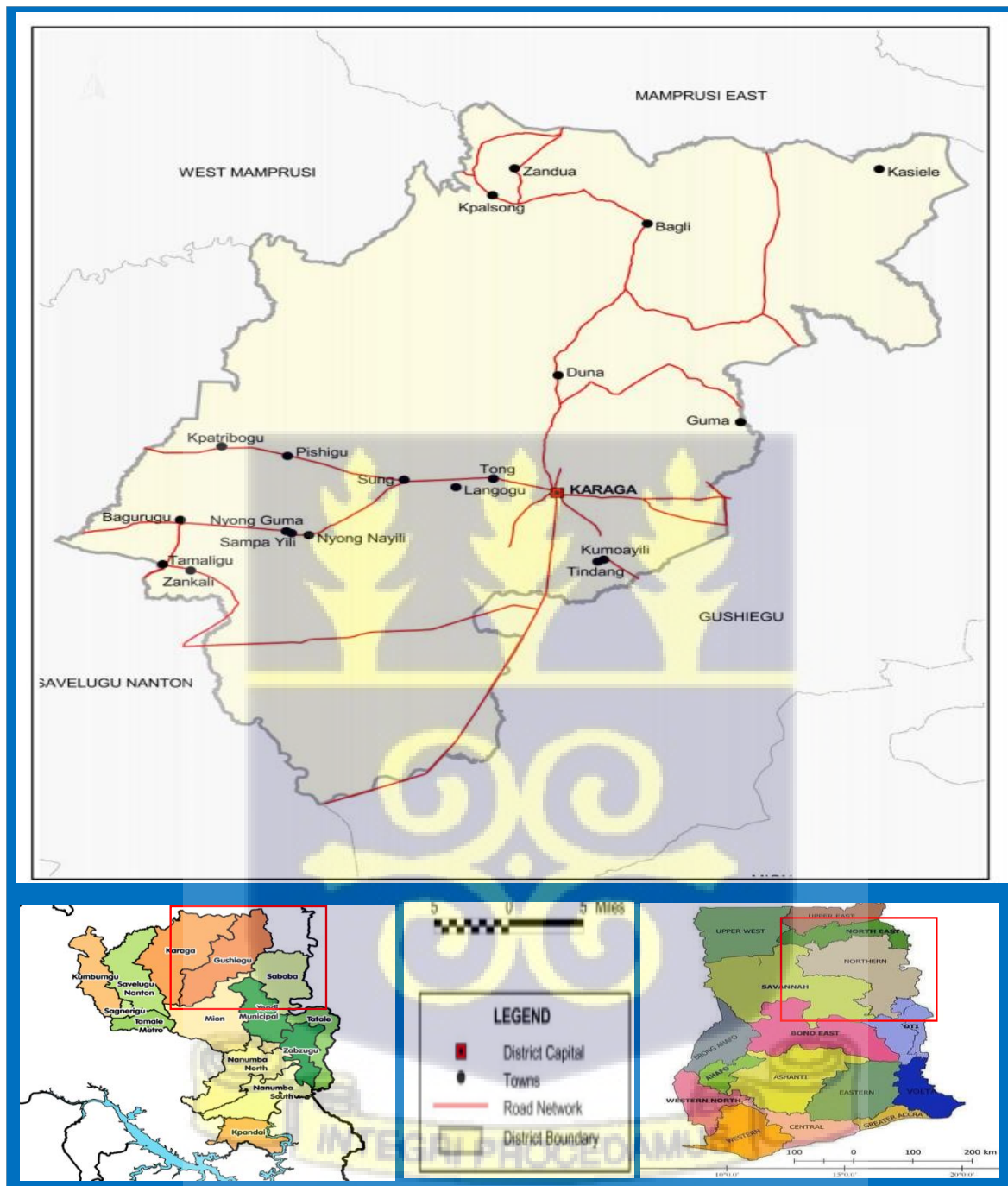


Figure 3. 2: Karaga District Map

Source: Adapted and modified from GSS, 2014

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Results of the study are presented in this chapter. The first section describes the socio-economic background of respondents. The next immediate session also gives an account on the types crop enterprise mixes farmers engage in. This chapter also elaborates on the factors that propel farmers to engage in several crops. Farmer's decision to grow multiple crops is influenced by several factors like, their age, household size, educational background, number of years in farming, just to mention a few. This socio-economic background on these factors is explored through a field survey and supporting secondary data.

This chapter later discusses the nature of incomes from crop enterprises respondents in Karaga District. This discussion will extend to the determination of the best cropping patterns using risk programming. The optimisation will lead the derivation of profit maximisation farm plan, and several risk efficient plans, from which one will be selected based on the standard deviation and coefficient of variation. Further to determining the optimal farm plan is a discussion on the nature of the trade-off between the current farm plan, the risk efficient farm plan and the profit maximisation farm plan. It is hypothesised that there would be a significant difference between these farm plans.

4.2 Background of the Study Respondent

4.2.1 Demographic and social characteristics of farmers in the district

Table 4.1 below provides information on the overall picture of the characteristics of farmers in the district. The average age of farmers is 40.37 years with a maximum age being 80 years. A minimum age of 20 years and an average age of 40 years signals that younger farmers are into

agriculture. This may be considered as a result of high unemployment problem or many people are less educated in the district pushing them to go into farming.

From Table 4.1, it can be seen that farmers have about 24.4 years of experience in farming. The minimum and maximum farming experience are 3 years and 60 years respectively and this may be as a result of farmers starting their farm enterprises at a younger age. The average household size of farmers is 10.30 with an average number of children 2. Most farmers have more than one wives, increasing the number of children per household head. The large household size comes in handy during labour-peak periods like sowing, fertiliser application, harvesting and dehusking and shelling. Smaller households are at a disadvantage because they have to rely on hired labour at labour peaks increasing their cost of production. The household size is similar to the household size reported by the Ghana Statistical Services, population and housing census, 2010. This household size can be regarded as large because it is more than the regional average (7.7).

The difference between the average farm size of 2.30 ha and the cropped area of 2.03 ha indicated that less than a hectare is left to fallow. The small difference between the cropped size and farm size is the perception that farming is now easy because of the use of a tractor for land preparation and the use of herbicide and other modern technologies. Table 4.1 shows that farmers own more farmland(s) than they use averaging 3.36 ha. This means that fewer farmers rent land for production. Farmers, on average, earn GH¢ 1084.84 from crop sales per annum which is considered very low and this pushes them to invest in other economic activities like blacksmith, firewood haunting, butchery, trading, motor king business, share picking and processing and others. These off-farm income sources are thought to be lifesavers but they do less in improving farmers' livelihoods because they earn on the average GH¢ 62.55 per annum from these off-farm income sources. Low incomes of farming and off-farm activities result in low saving and low capital.

Table 4. 1: Summary statistics of selected variables of respondent

Variables	Minimum	Maximum	Mean	Std. Deviation
Age (years)	20	80	40.37	1.01
Household size (No.)	1	50	10.3	7.02
Number of AEAs visit (No. per annum)	0	10	2.19	1.27
Farming experience	3	60	24.87	0.95
Distance to the farm	0	25	10.53	8.22
Number of children of a farmer (No.)	0	20	1.96	2.06
Farm size (ha)	1	5	2.3	1.44
Cropped farm size (ha)	0.4	20.24	2.03	2.41
Farm land owned (ha)	0.4	28.33	3.39	3.77
Income from crops sales per annum (GH¢)	80	20,000.00	1,084.84	1,681.73
Off-farm income (GH¢) per annum	0	6,251	62.55	413.68
Household labour (No.)	2	157	8.15	8.8
Hours Household work farm (hours)	1	8	5.02	0.83

Source: Field Survey Data, 2020.

Farmers are occasionally visited by agricultural extension agents averaging 2.67 times per annum. Farmers were not satisfied with the number of agricultural extension agents contact but these agents responded that they were recently posted so they are yet to familiarise themselves with the farmers and communities.

Household characteristics of the respondents

Age and farming experience

Age of farmers plays a very important role in enterprise development. The age and age distribution imply that the level of crop production and technology use. Holding all other things constant, older farmers are more endowed than younger farmers. Older farmers may be blessed with multiple wives and many children, older farmers are observed to have high household sizes so more hands are available for farm activities that require more labourers. Age of a farmer has been observed to have a significant impact on the farmers' mobility, farm size cultivated, and the ease of technology adaptation. Age in most studies positively correlates with farming experience and influences the decision-making processes of the household.

From Table 4.2, 13.3 percent of farmers are between the ages of 20 to 29 years while majority of farmers are in their middle ages ranging from 30 to 49 years, constituting 67.3 percent. With older farmers, 15 percent are within the ages of 50-59 and older farmers between the ages of 50-59 constitute 3.5 percent. It was observed that farmers started farming at an early age, about 20 years. A high number of farmers with the youth ages prove that the younger generations are interested in crop production and when youth is accompanied with a high literacy rate and good output prices relative to inputs prices, agricultural production will increase. With a minimum age being 20 and an average age being 40.37, one can expect the mean years in agriculture to be above twenty. A correlation coefficient of 0.74 also indicates a positive relationship between age and farming experience. From Table 4.3, individuals with more than twenty years of farming experience account for 78.7 percent.

Household size

Household size of farmers is considered as members of the nucleus family and the extended family living with the farmer and eating from the same food pot is an essential factor in the

farmer's activities. Farmer household size positively correlates with the number of children and wife a farmer has as labour who are important in labour-intensive activities. The study revealed that the average household size is 10 which is similar to the results reported in the (GSS-Ghana Statistical Services, 2014).

Table 4. 2: Age distribution of respondents

Age groups	Number of farmers	Percent
20-29	53	13.3
30-39	118	29.6
40-49	150	37.7
50-59	63	15.8
60+	14	3.5
Total	398	100

Source: Field survey data, 2020

Table 4. 3: Distribution of respondents farming experience in years

Farming experience	Number of respondents	Percent
0-9	8	2.0
10-19	77	19.3
20-29	134	33.7
30-39	144	36.2
40+	35	8.8
Total	398	100.0

Source: Field survey data, 2020

Educational Background

Education plays an essential role in technology adaptation and decision-making processes. Figure 4.1 showed that majority of farmers (88.7) have no formal education. Few farmers have

at least a basic education meaning that farmers have been in school between 1-12 years. Two (2) percent of farmers have attained a senior high school education. The presence of 0.5 percent of farmers having a tertiary education implies that these farmers were born farmers and due to current high unemployment rates, they had to go in their family occupation, farming. This may also be attributed to graduates from polytechnics, universities, professional training schools, and others, being influenced by the government policies and programmes like youth in agriculture (YIA), the planting for food and jobs (PFJs) initiative, or government posting to the district.



Figure 4. 1: A distribution of farmers educational status in the Karaga District
Source: Field survey data, 2020

4.2.2 Farm Characteristics of the Respondents

Farm size

Farmland is a primary resource endowment that differentiates farmers' production levels is grouped based on the size of their farms. Farm size determines the scale of production and also influences the number of crops rural farmers grow. From Figure 4.2 average land size of 2.3

ha satisfied the myth that farmers in Ghana are smallholder farmers who crop on less than 2 ha of farmland. Farmers with higher farm sizes tend to grow more crops than farmers with relatively smaller farm sizes. The study like other studies of rural enterprise developments has more farmers owning farmland less than two hectares (62.6 percent). When farmers are asked why they are unable to increase their farm sizes the reply they gave was that increasing farm size is expensive and unavailability of working capital to hire machinery or labour to do so. The study revealed that 23.4 percent of farmers have more than two hectares but less than 4 hectares. The farmers with more than 4 ha land sizes make up 14.1 percent. Having more farmland does not guarantee that the farmers will cultivate the entire plot. However, from Table 4.1, less farmland is left to fallow.

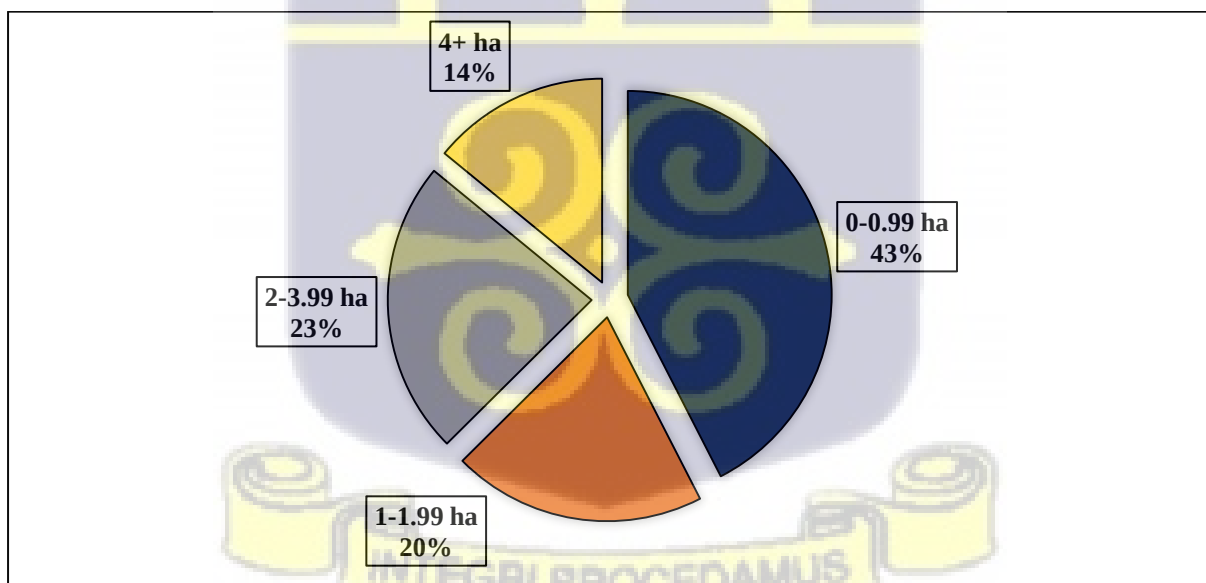


Figure 4. 2: Distribution of respondents' average farm sizes

Source: Field survey data, 2020, farm size groupings are based on Agriculture Production Survey (Amanor-Boadu *et al.*, 2015)

From Table 4.4, it can be seen that male farmers have more land sizes than their female counterparts. The table shows that female 88 percent of female farmers own land less than 2 ha. This may be attributed to female farmers being land resource-constrained. Similar results were also reported by Antwi (2016). Only two females were able to own land more than 4 ha.

Male farmers, on the other hand, produced on higher land sizes. More males produce on more than 2 ha of land constituting 61.2 percent of male farmers.

Women are excluded from household production decisions. Women in northern Ghana and involved in agricultural production often obtain land from their husbands so smaller land sizes are often allocated to them. Also, these women often find it difficult in accessing productive resources and labour for their farms.

Table 4. 4: Cross-Distribution of farm size and gender of the respondent

Gender		0-0.99	1-1.99	2-3.99	4+	Total
Farm size						
Gender	Male	31	50	77	53	211
	Female	138	30	16	2	191
Total		169	80	93	56	398

Source: Field survey data, 2020

Capital Resources

Capital is the major determinant of production across various production activities. It determines the technology adaptations and scale of production. Capital is grouped in two, working capital and fixed capital. Fixed capital are assets obtained and used for more than one production season. Working capital is the liquid cash made available for farming. Most farmers produce at the subsistence level so rudimentary tools like hoes, cutlasses, mattock and others. At the beginning of the cropping season, farmers keep little capital for crop production. This capital may not be enough for farming. When they are faced with financial difficulties, they sell some of their properties like stored crops and animals. For this reason, smallholder farmers face extreme financial difficulties between June and September. The majority of these farmers, according to the report, are unable to obtain loans from formal lending institutions. The form of credit they receive is in the form of tractor services which they pay for with harvested crops.

Farmers own simple tools which they use for their farm operations. These tools include hoes, cutlass, sickles, wellington boots, donkey carts, tractors, bullock ploughs, mobile phones, bicycles, and motorcycles. Each equipment has its ideal use to the farmer. Some tools are also used for off-farm activities. Figure 4.3 also show that 95.5 percent of farmers own hoes, 88.7 cutlasses, 32 percent own bicycles, 29.1 percent own sickles.

Farm Income

Farmers plant seeds with the expectation of these seeds germinating and growing into plants for harvesting which they will use as food. Small-scale and smallholder farmers grow food crops to feed their families and sell the surplus for income. The study revealed that bulk of household income comes from crop production constituting 98 percent. Crops sales were not the only income source to farmers because most farmers produce at the subsistent level. There was no male farmer without another source (s) of income.

Female farmers revealed that they obtain income from shea hunting and processing, firewood hunting and burning and small trade. This was mostly women, for its thought share hunting and processing occupation are for women so it is dominated by women. Some farmers reported that they are involved in poultry and poultry products sales, crop sales, textiles print sales, and others. Motor king business and butchery had the lowest percentages as an income-generating venture. Some farmers obtain income through serving as labourers on bigger farms when their services are needed.

Agro-inputs use

The use of agro-inputs has become a necessity in agriculture. Smallholders, no matter how small his or her farm holding is, used agro-inputs in one way or the other. Farmers in the Karaga District are also familiar with the use of agro-inputs. They use fertiliser, herbicides, seeds and others. The study revealed most farmers use fertilisers with more using fertilisers on maize

farms and less on leguminous crops. Few farmers reported using fertiliser on his or her groundnut and soya bean farm(s). Herbicide became useful to all farmers for the control of pre-emergence and post-emergence weeds. Farmers use it a week before ploughing, use it immediately after sowing to kill pre-emergence weeds. Seeds are fundamental in crop production. The study showed that most farmers obtain their seeds from other farmers whom they trust had a good yield or who bought seeds from an inputs dealer the previous season.

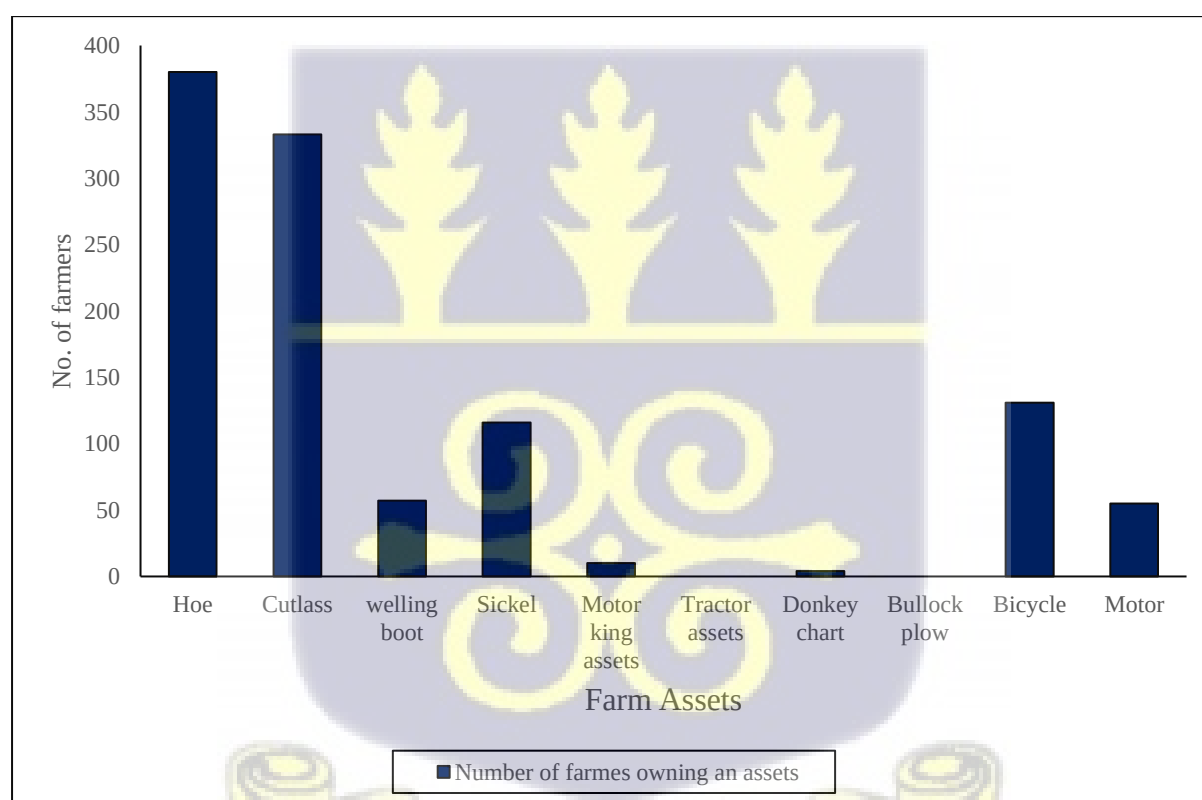


Figure 4.3: Distribution of farm assets of respondents

Source: Field survey data, 2020

4.3 Farmers' crop enterprise combinations

The important inputs for every farm enterprise are labour, land and capital. These inputs are combined in the right proportion to achieve desired outcomes. The topography associated with climate, soil type, the technology available and economic and risk factors determine the nature of crops grown in an area. Cropping patterns indicate the yearly sequence and spatial arrangements of crops that a particular farmer grows. Socio-economic factors determine the

cropping patterns that farmers grow and this causes differences in cropping. When a farmer could not cultivate the desired crop on his farmland, he acquires land suitable for that crop elsewhere.

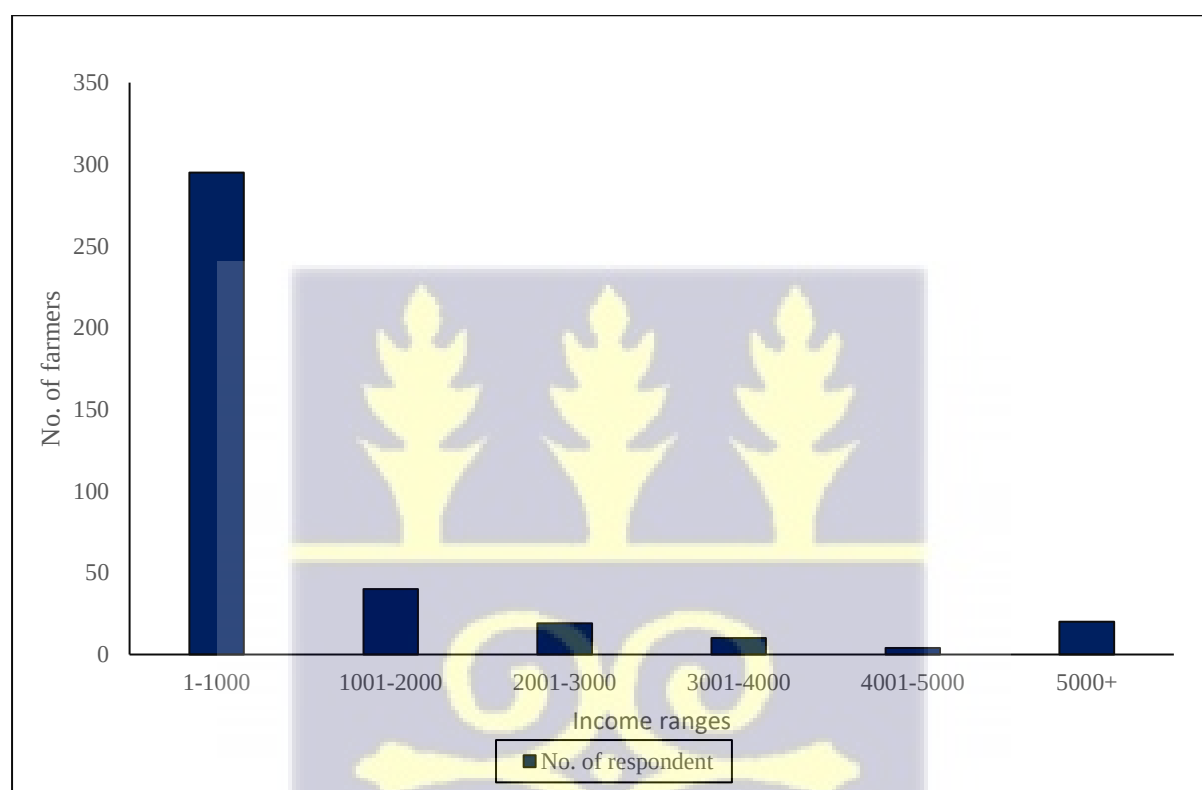


Figure 4. 4: Income levels of respondents

Source: Field survey data, 2020.

The study area is suitable for various cereals, legumes, tubers and vegetables. Karaga district is appropriate for maize, rice, millet sorghum, groundnuts, cowpea, soya beans, yam and cassava. The most dominant crops grown were maize, soya beans, and groundnut. Cowpea, yam and cassava were cropped by a few farmers on small plots. Farmers testified that the soils are ‘dying’ meaning, soils were no longer good for yam production. From Table 4.5, most farmers in the study area grow soya beans constituting 93.7 percent.

The study shows that most farmers practise the cereal-legume cropping system where the most important crop is maize followed by soya bean and groundnut. The study revealed that 85.2

percent of farmers cultivate maize. The reason why there are more farmers cultivating soya beans than maize is that more women grow soya beans than maize. Women say that since men grow maize for the family, so there is no need to grow maize. Because most farmers rarely use fertiliser to soya bean fields, it is considered a cash crop with lower production costs. Women grow this crop to provide additional household income. Groundnut is also regarded as a tangible crop that is produced by 56.3 percent of farmers. Rice is the fourth most cropped enterprise grown by 12.6 percent of respondents. The rest are grown in minute quantities. Millet was grown by 3.3 percent of farmers, yam, cowpea and okra were grown by less 2 percent of farmers. The rest, leafy vegetables, sorghum and pepper were established by less than 1 percent of farmers. Cassava and tomatoes were not grown by any farmer. Similar results were also recorded by, Bellon *et al.*, (2020), Kotu *et al.*, (2017) and Ellis-Jones *et al.* (2012)

From Figure 4.6, it can be seen that there is some degree of diversification. Farmers grow at most three crops. The study considered three crops; maize, soya beans and groundnut for large and medium farms but maize and either groundnut or soya beans were cultivated by smaller farms.

From Figure 4.5, farmers allocated more land and resources to maize (45.4 percent) than any other crop. More land is allocated to maize because farmers regard the crop the most staple crop and served as Tuo zafi almost every evening. Soya beans and groundnuts are grown as cash crops but soya bean is allocated more resources than groundnut. Soya bean is apportioned 30 percent of farmland and groundnut is allocated 0.40 ha (11.4 percent). Other crops are not regarded that much that is why they take less land and other resources.

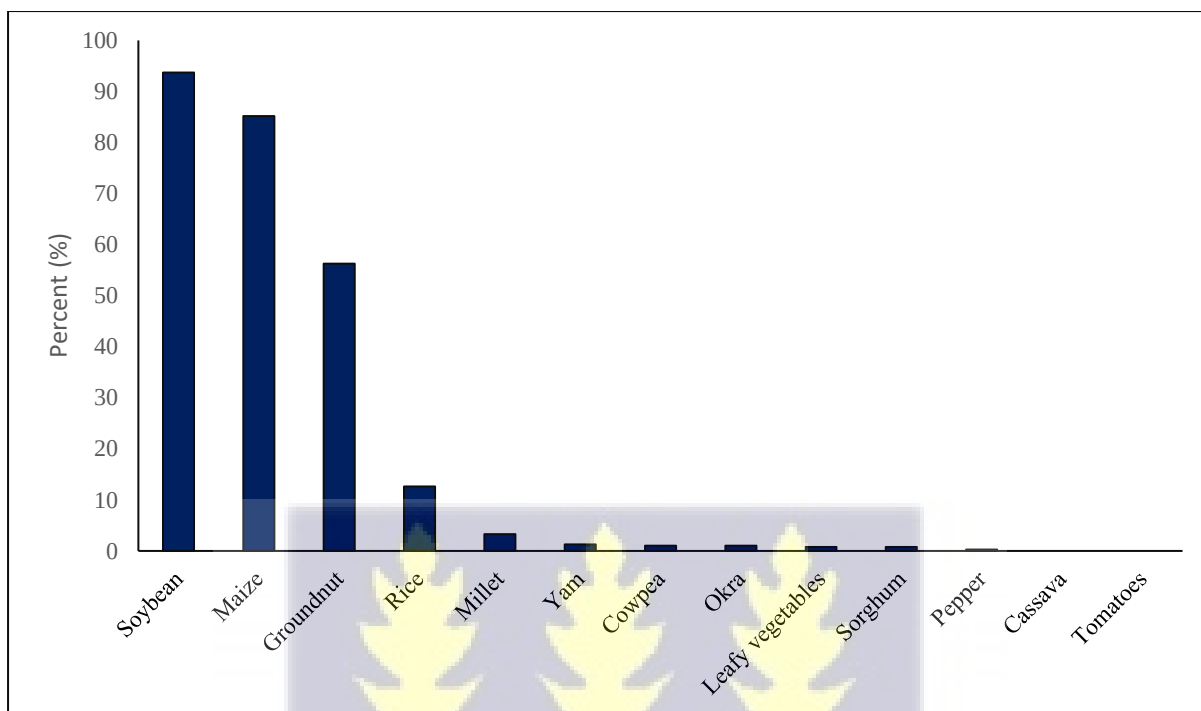


Figure 4. 5: Distribution of respondents by cropping patterns in the Karaga District

Source: Field survey data, 2020.



Figure 4. 6: Ratio of land allocated to crops

Source: Field survey data, 2020

Table 4. 5: Cropping combinations operated by various farmer groups

Farmer group	Number of farmers (%)	Crop combination
Large Farms (Above 4 ha)	55(13.8)	Maize, Soya bean and Groundnut
Medium (2 to 3.99) ha	87(21.9)	Maize, Soya bean and Groundnut
Small (1 to 1.99) ha	77(19.3)	1. Maize and Soya bean 2. Maize and Groundnut
Marginal (Under 1 ha)	177(45.0)	1. Maize 2. Soya bean 3. Groundnut

Source: Field survey data, 2020

Figures in parentheses are the percentages of respondents in each farm group

4.4 Factors that Influenced Farmers Cropping Patterns Decisions

Farmers growing more than one crop depends on certain characteristics of the household, farm, social and institutions. Twelve independent variables were used to determine factors that determine the level of crop diversification in the Karaga District, Ghana. The test for multicollinearity revealed that there was multicollinearity when all the independent variables were included in the Poisson regression analysis but when some variables were excluded, there was no multicollinearity with the independent variables after the variance inflation factor test was conducted, hence those variables were included in the model as it is seen in Table 4.6. The Pearson Chi-square of the Poisson regression model indicates that the model is significant at 1 percent ($p < 0.01$).

The value of the Deviance goodness-of-fit was 71.73642 with and the Pearson goodness-of-fit was 70.96041 and. The test results show that the data is not overdispersed and also has fewer number of zeros meaning the Poisson regression model is fit for the analysis.

Table 4.6: Multicollinearity test of the Poisson Regression Model

Variable	VIF	$\frac{1}{VIF}$
Gender	8.80	0.113669
PFJ fertiliser awareness	8.43	0.118567
Farming experience	7.61	0.131372
No extension visits	4.42	0.226425
HH size	3.37	0.235712
Distance to Karaga market	2.78	0.297046
Own Land	2.22	0.360356
Amount from crop sale	1.97	0.449996
Level of education	1.22	0.507652
Mean VIF	4.51	

Source: Field survey data, 2020

Table 4.7 represents a regression model of the factors that determine the extent of crop diversification. The model results suggest that land size and distance to the market are the only variables that affect the level of crop diversification.

The findings of the study show that land size is highly statistically significant at 1 percent and with a positive coefficient. This means that an increase in land sizes positively and significantly affect the extent of crop diversification among farm households. When the size of the farm household increases by a hectare, the number of crops that the household cultivates also increase by 2.7 percent. The results indicate that large farmer grows more varieties of crops than small farm size households. The finding is in agrees with other studies which also found a positive relationship (Dessie *et al.*, 2019); Singh *et al.*, 2018, Mussema *et al.*, (2015) and Mofya-Mukuka & Hichaambwa (2016).

As hypothesised, distance to market had a positive effect on the level of crop diversification and was statistically significant at five percent ($p > 0.05$). These results indicate that a farmer is a kilometre away from the main market, that is the Karaga market, the number of crops they grow increased by 0.4 percent.

Table 4. 7: Poisson regression model results of the determinants of diversification

Drivers of crop diversification	Coef.	Robust Stand Error	p-value
Gender (Male=1)	0.036	0.032	0.266
Level of education	0.051	0.036	0.154
Farming experience (years)	0.002	0.002	0.288
Number extension visits	0.013	0.01	0.172
Household size	0.002	0.002	0.184
Distance to Karaga market (km)	0.004**	0.002	0.047
Land size (ha)	0.027***	0.006	0.000
Own Land	-0.019	0.03	0.538
Amount from crop sale (GH¢)	0.000	0.000	0.264
PFJs fertiliser subsidy awareness	-0.026	0.04	0.505
Constant	0.719	0.097	0.000
Mean dependent var	2.575	SD dependent var	0.738
Pseudo R-squared	0.009	Number of obs	398
Chi-square	87.288	Prob > chi2	0.000

Note: ***, **, * indicate 1%, 5%, and 10% percent significant levels respectively

Source: Field survey data, 2020

This could be because those who are closer to the market have easier access to the input and output markets, as well as market information. Dessie *et al.*, (2019) and Rehima *et al.*, (2013) also found out the high cost of transport and market information of those far from the market encourages them to grow more crops to meet the household food demands.

4.5 Deriving Optimal Farm Plan for Farmers in the District

Farmers have two alternative decisions criteria. One is to allocate resources to maximise returns and the other is to resources that maximises utility by striking a balance between increasing income and minimising risk. Optimal allocation of resources among crop enterprises has been reported to increase farm income between 1 and 400 percent. To determine the right choices on crop(s) to produce and how much resources should be allocated to each crop, mathematical programming models are used.

Farmers are risk-averse and are always seeking a way to minimise risk and an effective way they do that is through crop diversification. This strategy is not a perfect way to eliminate risk in decisions and activities. They face risk from the onset of decisions to the execution. Risk programming models have been developed that integrate risk. Risk programming has recognized the importance of risk in agricultural planning and has led to the development of normative decision theory based on the inclusion and stochastic elements in whole farm planning. It is, therefore, necessary to include the stochastic elements in the study as happens in real life.

The target-MOTAD programming model was used to determine a risk efficient farm plan. The solution reveals the expected return-risk trade-off for farmers. The objective of the model is to maximise expected income under risk. A conventional linear programming model was used to determine the profit maximisation solution which then related to the existing farmers operating farm plan. The expected income and risk farm plan were derived by parameterising varying the predetermined level of the constant T and λ to a maximum of the total Absolute Deviation of Returns.

4.6 Derivation of the Technical Coefficients

Agriculture is a production activity where inputs of varying quantities are used to produce an input. These factors influence the level of production. Farm size, labour availability and working significantly influence the level of production. Farm size was collected asking farmers the size of their farmlands and farmers are then categorised based on their land sizes and based on the ASP reported (Amanor-Boadu *et al.*, 2015). In this study farmers who have farm sizes below 1 ha were not included for modelling. This is because such farmers also produce multiple crops but farmers themselves were not able to determine the plot size allocated to these crops, to some extent some were insignificant. For example, some farmers on a typical maize farm may have a few stands of okra and pepper.

4.6.1 Labour constraint

Labour plays an important role in food production. It is one of the four factors of production. Labourers are human beings who exert physical and mental effort to cause a change in raw materials using tools and equipment. Labour is required for land clearing, herbicides spraying, planting and other farm activities. Labour comes in two for this study sake, family labour, hired labour. Family labour are those who are of the same household and provide labour support to the household members. The household head is often the manager of household labour. Family labour in the study area was identified as the household head him or herself, his wives if male, children, cousins and nieces and others. More often, farmers belong to extended families, so most of these households are large, providing an important source of labour.

Household labour is important during planting, weeding and harvest because these activities require more labour. Hired labour come in handy when farmers are short of household labour because more hands are needed. Those farmers who travel long distances to farm often require hired labour. Hired labour charge based on a recognized price for a particular activity in the area. For instance, the cost of spraying herbicides is GH ₵15.00 per acre and sowing with a

cutlass is GH 30.00, on and on. For many medium and smaller farmers, family labour is essential and provide a significant labour force.

Hired labour work on the farms when there are household labour shortages. Farm owners visit their farm from time to time to do minor jobs on the farm. From the survey, farmers visit their farm in the morning, go on break at around 1 to 4 p.m. and go back to work at 4 and work till nightfall. On average male farmers reported that they work for eight to nine hours when they have much to do on the farm. Women because of kitchen services and household chores work at most six hours a day on their farms or household head farms. Children provide important labours services to household heads and their mothers. They go to school and report to farms after school to help with farm activities.

Labour is measured in labour days and a labour-day for the study is the normal eight hours. Children are assumed to work for four hours during working days and for 8 hours during the weekend. Farmers and their families do not work normally on Fridays and other social events like weddings, naming ceremonies, *Eids*, funerals and others. Normally they 6 workdays in a week during the farming season. Farmers revealed that they work on them for ten months, from April to February and implies that they work for forty weeks. Given that they work at least six days a week, the number of labour days is 240 days in a year per permanent labour.

Table 4. 6: Average labour required for each crop at various production scales

Crop	Small-sized(man-days/ha)	Medium-sized(man-days/ha)	Large-sized(man-days/ha)
Maize	67	54	40
Groundnut	66	48	38
Soya bean	64	44	37

Source: Field survey, 2020

4.6.2 Capital constraints

Capital is the fixed assets like land, equipment and tools and liquid cash available to the farmer. Capital influences the scale of crop production. The study revealed that the average farm size of farmers is 2.3 ha. They also own and use simple tools like hoes, cutlasses and welling boats and others. Working capital is the money made available to the farmer and also the amount of money spent on production, harvesting, processing and marketing of crops. Farmers before the cropping set money aside for crop production.

Hardly are these monies enough to cater for farm expenses. In times of money shortage, farmers sell some items to meet these expenses. They sell stored crops which might be meant for home use or sell the livestock like local fowl, guinea fowls, goats' sheep or cattle. Sometimes some sell their stored crops or livestock to start the season's farming activities. For effective analysis, capital was calculated based on the cost incurred for all cropping activities per hectare multiplied by farm size or cost incurred in all cropping activities.

4.6.3 Risk coefficients

Prices and yield variations are the primary risk factors farmers face in northern Ghana. Yield variation results from the lack of money to buy enough fertiliser for their crops or periodic droughts in the rainy season. Prices fluctuations or variations result from the forces of demand and supply. During harvest periods, prices of agricultural produce fall below favourable farmers' prices. Six months after harvest, prices increase. These increased prices favour farmers and aggregators who have good storage systems or can store produce at public or private warehouses.

In this study, for the risk formulation for the model, yield variation was considered. Yield variations occur year after year. And quite unpredictable. Unlike yield variation, price variations are predictable, in that prices are within the same range for the same months in

several years. For instance, the data from the District Department of Food and Agriculture Office revealed that prices of maize are higher in the cropping months, that is, between May to July. The data from the department suggest that prices for maize within these months at wholesale prices were between GHC 140.00 and GHC 160.00 per 100 kg sack. Immediately after harvest, prices drop like a wilted flower. However, unshelled groundnut (Chinese cultivar) has a different story. Farmers who grow groundnut early will harvest early and these times prices of unshelled groundnut are high. This is because women buy, boil and sell unshelled groundnut as snacks. The period of low prices is recorded between August to November each year. Within these months, prices of maize are between GHC 90.00 and GHC 110.00 per 100 kg sack. Farmers were asked about the prices of harvested crops. Middlemen and women travel to the hinterlands with their transport vehicles and go around farmer households to buy stored produce.

In this study, risk is measured by the statistics Mean Absolute Deviation (MAD), standard deviation (SD) and Coefficient of Variation (CV). The target MOTAD model solves for the maximum expected income that satisfies the model constraints. The MAD is transformed into an estimate of the standard deviation by the model. Standard deviation examines the spread of expected returns. When income increases, variation or standard deviation increase as well, meaning there is a direct relationship between expected income and standard deviation. The coefficient of variation statistic is measured as a percentage and calculated by standard deviation and the expected income. The selection of the best farm plan along the risk efficient frontier depends on the individual farmer's perception of risk and his resource capacity.

4.6.4 Food consumption constraints

Most farmers produce at the semi-subsistent level and so they grow crops to feed their family and surplus is sold to the market. It will be incomplete not to include a food consumption constraint into the programming model. From the above, three crops were identified for

modelling, which are maize, soya beans and groundnut. Maize is a staple crop for the people of Ghana. Almost every farmer interviewed grow maize and they regarded it as the first most important crop. To highlight the importance of maize to the respondents, maize constraint was integrated into the model.

4.6.5 Determining crop enterprise budgets for three years

Budgets are prepared for each crop to determine the gross margin. Prices are based on the purchase and sale prices and cost of services hired. Crop enterprise budgets are prepared based on per hectare bases. Revenue is determined based on the value of harvested crops (in tonnes) and variable or production cost is determined by adding the cost of land rent, tractor services, seeds, fertiliser used per hectare, labour hiring cost and harvesting cost if machinery is used for harvesting.

Farmers are price takers and prices are determined in the market based on market forces. Farmers in most cases have information on prices. These farmers were able to recollect these prices. The table shows the average price of crops in the District. This information was also supported by the data from the District agriculture office. Maize has more gross margins than groundnut because the yields of groundnut are relatively low. On average, maize yields 1.4 tonnes per hectare and groundnut yields 0.3 tonnes. Table 4.8 represents the gross margins of large farms and medium-sized farms. From the table, it can be seen that farmers with larger farm sizes have more expected gross margins for soya beans and maize and groundnut.

From table 4.9, it can be seen that farmers with larger farm sizes have more expected gross margins for soya beans and groundnut than maize. This is attributed to the fact that farmers do not use fertiliser on their leguminous crop farms reducing their cost relative to maize and also the yields and price per tonne of soya beans are relatively high. The total variable cost of growing a hectare of soya bean is relatively less compared to maize. On the contrary, maize

has more gross margins than groundnut because the yields of groundnut are relatively low. On average, maize yields 1.4 tonnes per hectare and groundnut yields 0.3 tonnes.

Table 4. 7: Average farm gate prices of crops for the past three years

Crop	2017	2018	2019
	Price/tonne	Price/tonne	Price/tonne
	(GH¢)	(GH¢)	(GH¢)
Maize	950.00	1,100.00	1,400.00
Soya bean	1,300.00	1,400.00	1,651.38
Groundnut (Unshelled)	2,162.16	2,162.16	2,432.43

Source: Field survey, 2020

4.7 Production Enterprise Combination

4.7.1 Crop enterprise mixes for large and medium farms

To determine the optimal combination(s) of productive enterprises, the conventional linear programming model is used. It determines the profit maximisation combination. This model is usually used by many researchers to find the best farm enterprise combinations that ensure optimal use of resources. However, due to the risky nature of agriculture, such models are inappropriate, in that the model assumes that prices and outputs are fixed or known with precision

Then Target MOTAD is then used to determine the risk efficient plans. The Target MOTAD model identifies the best crop enterprise combinations by varying at various degrees a reduction in a target income level and its associated risk. Farmers are more concerned about achieving a maximum income from their farming activities and also concerned about their returns not falling below certain income levels.

Table 4. 8: Gross margins of crops enterprises for large and medium farms for years 2017-2019

		Maize	Soya bean	Groundnut
Large farms				
		GHC	GHC	(GHC)
2019		643.00	1549.01	398.00
2018		418.19	1394.30	398.54
2017		324.91	913.41	614.92
Expected margin	gross	462.03	1285.57	470.49
Medium farms				
2019		562.00	1081.01	346.999
2018		275.16	1231.19	244.58
2017		195.55	951.73	375.45
Expected margin	gross	344.23	1087.98	322.34
Small farms				
2019		878.00	941.00	151.00
2018		990.34	1092.91	754.49
2017		323.71	1295	418.8
Expected margin	gross	730.68	1109.62	441.421

Source: Calculated from field survey, 2020

Table, 4.11 represents the prevailing and optimised farm plans for large farms. The plan labelled I is the farmers' existing plan. Given their endowed resources, farmers earn GHC 3,459.06 by allocating 2.87 ha to maize, 1.67 ha to soya beans and 0.79 ha to groundnut. This plan is not desirable since more income can be attained with optimal resource allocation. From Table 4.11, with the profit maximisation plan IV, a farmer will earn more income of GHC 6,146.20 when they adopt this plan. An average farmer will obtain the highest expected return on the E V frontier by allocating 0.86 ha to maize, 4.47 ha to soya beans and nothing to

groundnut. Plan IV also reveals that the cropping area for maize reduced by 37.1 percent causing soya bean to increase to 3.12 ha.

Table 4. 9: Existing and optimal cropping plans for large farms

Crop Enterprises	Existing Plan I	Risk efficient Plan II	Risk efficient Plan III	Profit Maximisation Plan IV
Total expected Income (GHC)	3,459.06	4,766.69	5,201.93	6,146.20
Maize (ha)	2.87 (53.8)	0.86 (16.1)	0.86 (16.1)	0.86 (16.1)
Soya bean (ha)	1.67 (31.3)	2.78 (52.2)	3.31 (62.1)	4.47 (83.9)
Groundnut (ha)	0.79 (14.8)	1.69 (31.7)	1.16 (21.8)	-
Total land used (ha)	5.33	5.33	5.33	5.33

Source: Calculated from field survey, 2020

Figures in parentheses are the percentages of crop area allocated to each crop enterprise

Plans II and III are risk-reduced plans. From Table 4.11, with plan II, farmers with large land sizes earn GHC 4,766.69. Plan II will cause farmers current income to increase by 37.8 percent and decrease allocation to maize by 2.01 ha and soya beans will increase by 39.9 percent compared to what is in plan I. Unlike plan IV, groundnut was introduced into plan II at 1.69 ha. A similar report was reported in plan III. When farmers shift to III, farm profit will be GHC 5,201.93 and 0.86 added to maize, 3.31 had to soya beans and 1.16 to groundnut. The land allocation to maize has been consisted through the optimised plans because of the consumption constraints introduced into the modelling and without it, maize may not have been included in the solution because of the risk associated with growing maize and high cost of production. The optimised plans reveal lower land allocation to maize and more lands to cash crop signalling that maize is considered to be produced subsistent level and cash crops are produced as a household cash cow.

Table 4.12, which represent existing and optimal plan for medium-sized farms. Like in the previous table, plan I present the current farm plan for medium-sized farms. At the farmers' existing plan, farmers earn GH¢ 1,465.82 from growing 1.3 ha of maize, 1.01 ha and 0.21 ha of soya beans and groundnut respective. When farmers optimise the resource allocation patterns, the potential returns may be GH¢ 2,249.44 when they allocate 0.66 ha to maize, 1.86 ha to soya beans.

When TAD is parameterised to zero, two risk efficient plans were developed, which are plan II to III Plan II reports that GH¢ 1,802.94 would be earned by allocating 1.06 ha to maize and 1.32 to soya beans. With farm plan III, farmers can earn GH¢ 1,915.59 by allotting 1.11 ha to maize and 1.41 ha to soya beans. Comparing plan IV to II, and III, the area to be allocated to maize increased in all the two risk efficient plans, causing a simultaneous decrease in the number of hectares for soya beans. All the modelled plans of medium farms are 'corner point solutions' because groundnut is not included in all optimised plans since the variability in returns is associated with groundnut.

Table 4. 10: Existing and optimal cropping plans for medium farms

Crop enterprises	Existing plan I	Risk efficient Plan II	Risk Plan III	efficient Plan IV	Profit Maximisation Plan
Total expected Income (GH¢)	1,465.82	1,802.94	1,915.59	2,249.44	
Maize	1.30 (51.5)	1.06 (44.5)	1.11 (44.0)	0.66 (26.4)	
Soya bean	1.01 (40.1)	1.32 (55.5)	1.41 (56.0)	1.86 (73.8)	
Groundnut	0.21 (8.4)	-	-	-	
Total land used (ha)	2.52	2.38	2.52	2.52	

Source: Calculated from field survey, 2020

Figures in parentheses are the percentages of crop area allocated to each crop enterprise

4.7.2 Crop enterprise mixes for small farms

Table 4.13 illustrates the existing plan and optimised farm plans of the small-sized plan that produce maize and soya beans. Plan I is the present plan and plan IV is a profit maximisation plan with expected returns of GHC 1,140.99 and maize being allocated 0.5 ha (41.67 percent) and soya bean 0.7 ha. Plan II and III are plans with less income variation.

With these risk-efficient plans, Table 4.13 reveals that less farmland is required to obtain an income greater than the existing farm plan. This was attributed to a lack of liquid capital. An average farmer will earn GHC 992.52 (plan II) and GHC 1,020.25 (plan III) when they allocate 0.60 ha to maize, 0.50 ha to soya beans and 0.5 ha to corn, 0.59 ha to soya bean respectively.

With these risk-efficient plans, Table 4.13 illustrates that less farmland is required to obtain an income greater than the existing farm plan. This was attributed to a lack of liquid capital.

Table 4. 11: Existing and optimal cropping plans for small farms cultivating maize and soya bean

	Existing plan	Risk efficient Plan		Profit Maximisation Plan
	I	III	IV	IV
Total expected Income (GHC)	978.23	992.52	1020.25	1140.99
Maize (ha)	0.68 (56.9)	0.6 (54.5)	0.5 (45.9)	0.5(41.7)
Soya bean (ha)	0.52 (43.1)	0.5 (45.5)	0.59 (54.1)	0.7 (58.3)
Total land used (ha)	1.20	1.10	1.09	1.20

Source: Calculated from field survey, 2020

Figures in parentheses are the percentages of crop area allocated to each crop enterprise

An average farmer will earn GHC 992.52 (plan II) and GHC 1020.25 (III) when they allocate 0.60 ha to maize and 0.50 ha to soya bean and 0.5 ha to corn and 0.59 ha to soya bean

respectively. The reduction of cropping area is consistent with Lu, Huang and Seyram (2020) who also found that the risk models solutions reduced the cultivated area.

Table 4.14 displays various farms plans of small-sized farms where maize and groundnut are cultivated, which includes the prevailing plan (plan I), the profit maximisation plan which is plan IV, and plan II is the risk minimised plan. Table 4.14 reveals that with the prevailing plan, farmers obtain GHC 598.60 from growing 0.68 ha of maize and 0.21 ha to groundnut. With the profit maximisation plan, farmers may earn GHC 899.76 when they allocate all their resources to maize production. The risk efficient plan also reveals the same allocation pattern where no land is allocated to groundnut. Plan II shows that farmers would be safer from risk if they allocate 0.82 ha to maize and this will lead to an income of GHC 663.84. Optimise plans neglected groundnuts because it is considered highly risky.

Table 4. 12: Cropping plans for small Farms growing Maize and Groundnut

Crop enterprises		Existing plan	Risk efficient plan	Profit Maximisation Plan
		I	II	III
Total	expected	598.60	646.94	899.76
Income				
Maize		0.68 (76.40)	0.89	1.23
Groundnut		0.21 (23.6)		
Total land used (ha)		0.89	0.89	1.23

Source: Calculated from field survey, 2020

Figures in parentheses are the percentages of crop area allocated to each crop enterprise

From the results, farmers are better off shifting their production resources to either profit maximisation output or the risk efficient plan. These plans record more returns compared to the farmers' current plans. Highly risky crop enterprises are represented with small land allocation or no allocations at all and more lands are allocated to highly remunerative crops.

The study sought to agree with Fathelrahman *et al.* (2017), Osaki and Otavio, (2014) Alkarablieh and Amer (2004), Salimonu, Falusi, Okoruwa, and Yusuf (2008), who shared the

view that optimal resource allocation increase farm profitability at relative risk levels, more profitable crops were allowed in modelled solutions and highly risky enterprises like maize and groundnut are hardly represented.

4.8 Trade-off between Return and Risk

Risk is inevitable in agriculture. Farmers commit resources into a production venture with no certainty of the enterprise(s) yielding desired outcomes. The trade-off is the relationship between risk and returns. The trade-off between returns and income variation determines the suitability of the plan and is measured by the use of the coefficient of variations and standard deviation.

4.8.1 Measuring Risk and Returns Trade-off of Large and Medium Farms

Table 4.15 reveals various plans of large and medium farms with their associated standard deviations. From the table, it can be seen that the prevailing plan of farmers, plan I, yields GH¢ 3,459.06 of returns and has a standard deviation of GH¢ 2,201.42 and 45 percent coefficient of variation of returns for large farms. This means that the average farmer classified in this farm group is likely to lose GH¢ 2,201.42 or 52.2 percent of the expected income.

The table also reports that farmers with larger farm sizes will earn substantively higher incomes when they adopt the profit maximisation plan. This plan is very volatile because they may report a standard deviation of GH¢ 2,201.42 representing 45 percent of the coefficient of variation. This means that the average farmer classified in this farmer group is likely to lose GH¢ 2,201.42 at the rate equivalent to 45 percent of the total gross margin when they shift to the profit maximisation plan. From the same table, all the risk efficient plans (II and III) have a lesser standard deviation and coefficient of variation. For risk-averse farmers, which most of them are, taking plan II which is the most risk-efficient plan, farmers are losing GH¢ 194.61

or 4 percent of total expected returns. For plan III, also a risk efficient plan, farmers will probably lose GHC 473.48 or 9.7 percent of the total gross margin.

Table 4. 13: Risk and returns level of various plans for large and medium farms

Large farms						
			Existing plan	Risk efficient Plan		Profit Maximisation Plan
			I	II	III	IV
Total expected	Income	(GHC)	3,459.06	4,766.69	5,201.93	6,146.20
Standard Deviation (GHC)			2,201.42	194.61	473.48	1921.81
Coefficient of variation (%)			45.0	4.0	9.7	39.3
Medium farms						
			Existing plan	Risk Efficient Plan		Profit Maximisation Plan
			I	II	III	IV
Total expected	Income	(GHC)	1465.82	1802.94	1915.59	2249.44
Standard Deviation (GHC)			603.63	85.21	87.71	600.17
Coefficient of variation (%)			12.3	1.7	1.8	12.3

Source: Calculated from field survey, 2020

From Table 4.15, when farmers with medium farms sizes operate with plan IV, the standard deviation and coefficient of variation will be GH C600.17 and 12.3 percent respectively which is quite similar to the farmer's plan. Similarly, it is observed that risk minimised plans have less standard deviation and coefficient of variation. The average farmer, when they shift to the most risk-efficient plan, that is plan III may reduce the variation in income by 1.7 percent.

4.8.2 Measuring Risk and Returns Trade-Off of Small Farm

For small farms, farmers who allocate their resources between maize and soya bean with their current production situation obtain GH ¢978.23 for allocating 0.68 ha to maize and 0.52 to soya beans. With this plan, farmers are at risk of losing their investment at 6.6 percent compared to 13 percent of plan IV. An income variation of GH¢ 15.97 was recorded with plan III which a rational risk-averse farmer will adopt. Small farmers that allocated their resources between maize and groundnut as seen in Table 4.17, with their current plan has a risk level of 8.7 percent. This high-risk level can be averted when they adopt plan II which has a lower coefficient of variation of 4.9 percent.

Table 4. 14: Risk and returns level of various plans for small farms producing maize and soya bean

	Farmer's plan	Risk efficient Plan		Profit Maximisation Plan
	I	II	III	IV
Total expected Income (GH¢)	978.23	992.52	1020.25	1140.99
Standard Deviation (GH¢)	68.63	50.73	15.97	135.35
Coefficient of Variation (%)	6.6	4.9	1.5	13.1

Source: Calculated from field survey, 2020

4.9 Test the Significance Differences Between Farm Plans

4.9.1 Measuring Risk and Returns Trade-Off of large and medium farm

Testing the significant difference between the current plan and the optimised plans is important to determine whether it is useful for farmers to do shift the optimised plans. Table 4.17, shows a comparison between the farmers existing plan, the profit maximisation plan and the risk efficient plan. Table 4.18 shows a t-value of 6.81 comparing plan I and plan IV for large farms and was highly statistically significant at 1 percent ($p < 0.01$). The interpretation is that large

farms allocate resources, not for profit maximisation but rather to spread risk. Also, associating I and II, a t-value of 4.33 was recorded and was statistically significant at 1 percent ($p < 0.01$). The difference here implies that farmers are losing with their current production plan which has a higher risk associated than the risk efficient plan. A t-value of 5.2 was also recorded when plan II and plan III were compared and was also highly statistically significant at 1 percent ($p < 0.01$) meaning that farmers are at a greater risk adopting the profit maximisation plan.

Table 4. 15: Risk and returns levels of plans for small farms producing maize and groundnut

	Farmer's plan	Risk efficient Plan	Profit Maximisation Plan
	I	II	III
Total expected Income (GH¢)	598.60	646.94	876.82
Standard Deviation (GH¢)	167.08	92.88	259.97
Coefficient of Variation (%)	6.6	4.9	13.6

Source: Calculated from field survey, 2020

For medium farms, like the large farms, a significant difference was reported between plan I and the profit maximisation plan, IV. However, no significant difference was recorded between I and the most risk-efficient plan, II, since the t-value is 4.3381, and this can be interpreted that farmer existing plan is closer to the risk minimised plan and farmers are better off producing under plan II

Table 4.17 shows a significant difference between plan II and IV for medium farms and this can mean that farmers are at a greater risk of losing their investments if they adopt the profit maximisation plan.

4.9.2 Measuring Risk and Returns Trade-off of small farms

Table 4.18 also shows the significant difference between the expected return of various plans of a small-sized farmer who produce maize and either soya bean or groundnut. Results in the table show that there is a significant difference between plan the farmers, plan I, and plan IV while the t-value is 1.98 and this is significant at 10 percent, that is $p < 0.1$ and such significance level can mean that plan I is quite closer to plan IV and farmers will do themselves harm if they do not adopt plan IV. Also, the t-value was 0.53 between plan I and II for farmers who grow maize and soya beans. This implies these farmers allocation behaviour is geared toward risk reduction rather than profit maximisation.

For maize and groundnut farmers, a t-value of 4.04 for I and III was significant at 1 percent ($p < 0.01$) and signifies that farmers are losing their investment with their current plan because with the same resources more returns can be earned. T-value of 2.07 for plan II and III was also significant at 5 percent ($p < 0.05$) and can be interpreted as farmers will achieve more returns with the same resources at a lesser risk compared to I and III. When comparing the profit maximisation plan, III and the risk efficient plan II, a t-value of 7.5 was recorded and this can be interpreted as farmers are at greater risk of losing their investments when adopting the profit maximisation plan.



Table 4.16: T-test results of the trade-off between plans for large, medium and small farms

Large farms			
	Mean Difference (GH¢)	t-value	p-value
I and IV	2,687.14***	6.8195	0.000
I and II	1,307.63***	4.3381	0.000
III and IV	1,379.51***	5.2964	0.000
Medium Farms			
I and IV	783.62***	8.4874	0.000
I and II	337.12	5.0985	0.143
III and IV	446.50***	6.7908	0.000
Small farms (maize and soya bean)			
I and IV	162.76*	1.9800	0.056
I and II	42.02	0.5300	0.598
II and IV	120.74***	3.8400	0.000
Small farms (maize and groundnut)			
I and III	301.16***	4.049	0.000
I and II	65.24***	2.074	0.000
II and III	235.92***	7.499	0.000

Note: ***, **, * indicate 1%, 5%, and 10% percent significant levels respectively

Source: Calculated from field survey, 2020

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Major Findings of the Study

This study examines optimal resource allocation patterns for various farmer groups in the Karaga District. The study had to identify the various cropping patterns of farmers in the study area, identify factors that influence the number of crop enterprises farm households engaged in, also determine the optimised farm plans for farms of various cropping groups and finally determine the trade-off between the farmer's existing plan, the profit maximisation plan and risk efficient plan(s).

Farmers are investors just like other investors who put resources in a course with an expectation of a favourable outcome. These farmers live in a world where agriculture is faced with immense risk and uncertainty. To reduce these eventualities, farmers diversify into the growing of many crops. To better gain from this strategy, they have to optimise the use of their scarce resources. Mathematical programming, a risk programming model was used to determine an optimise cropping pattern that reduces risk and also ensure that farmers get better returns than in the past.

Primary data were generated from a field survey of farmers in the Karaga District in the Northern region and secondary data like farm-gate prices of produce and inputs were also sorted from the district agricultural offices in Karaga. The primary and secondary data reveals that farmers can be sub-divided into three groups based on the resource endowment, farm size to be precise. These farm groups are big farms, medium farms and small farms. Concerning the crops and cropping patterns, both big and medium farms cultivate maize, soya beans and groundnut, with maize regarded as the most important crop. Farmers with small farms grow maize and either soya beans and groundnut.

Poisson regression was used to examine how the characteristics of a farm, society and institution that influence the number of crops that a farm household produces. The model revealed that land size and distance to the market were the two independent variables statistically significant. Distance away from the district market increases the level of crop diversification. Moreover, farmers with more land have more crop varieties on the plot(s) than those constrained by land.

Large farms make GHC 3,459.06 from cultivating 2.87 ha of maize, 1.76 ha of soya beans and 0.79 ha of groundnut. After modelling, potential returns, using the same amount of resources increased returns to GHC 6,146.20 when 0.86 ha is grown with maize 4.47 ha allocated to soya beans and none to groundnut. The modelling also reveals two risk efficient plans. Farmers can earn an income of GHC 5,201.93 from allocating 0.86 ha to maize, 3.31 to soya beans and 1.16 ha to groundnuts. Another risk-reduced plan shows that farmers are likely to earn GHC 4,766.69 when they cultivate 0.86 ha of maize, 2.78 ha of soya beans and 1.69 ha of groundnuts. Farmers who own land classified as medium farms also earn GHC 1,465.82 from allocating 1.30 ha of maize, 1.01 ha to soya beans and 0.21 ha of groundnut. A profit maximisation plan reveals that return can increase by 34.8 percent should they cultivate 0.66 ha of maize, 1.86 ha to soya beans. The two risk-minimised plans were derived with one reporting that farmer will make GHC 1,915.59 from producing 1.11 ha of maize and 1.41 ha of soya beans and the other states that an average farm can earn GHC 1,802.94 from a 1.06 ha maize farm and 1.32 ha soya bean farm.

Small farms that produce maize and soya beans, their current plan earns them GHC 978.23 ha from 0.68 ha maize and 0.52 ha soy farm. A profit maximisation farm reveals a profit of GHC 1,140.99 if they grow 0.5 ha of maize and 0.7 ha of soya beans. In trying to develop a risk-reduced plan, two plans were developed where farmers would be able to earn GHC 1,020.25

from 0.5 ha maize plot and 0.59 ha of soya bean plot while earning GH¢ 992.53 from allocation 0.6 ha of maize and 0.5 ha of soya beans.

For small-scale farmers who allocate their resources in the production of maize and groundnut and the current earnings were GH¢ 598.60 with 0.68 ha grown with maize and 0.21 ha to groundnuts. The profit maximisation plan shows a profit of GH¢ 899.76 when 1.23 ha of only maize is grown. To save from immense risk, farmers have to grow 0.82 ha of maize. Groundnut did not enter in all optimal plans of these farmer groups because it is considered risky.

The choice of farm plan to adopt depends on the risk attitude of the farmer in question. Risk loving farmers would adopt the profit maximisation plan but risk-averse farmers are likely to adopt the risk efficient plan. Risk and return are negatively related. Returns are forgone to minimise risk. Risk and return are negatively related. Target MOTAD solutions reveal multiple plans and standard deviation and coefficient of variation were used to measure the level of risk for each plan. For large farms, the farmer's plan had a standard deviation of GH¢ 2,340.15 and coefficient of variation of 45 percent, whereas the profit maximisation plan had a standard deviation of GH¢ 1,921.81 with and coefficient of variation of 39.27 percent. The risk efficient plans record a deviation of GH¢ 194.61 and coefficient of variation of 3.98 percent and the other GH¢473.48 for standard deviation and 9.68 coefficient of variation.

Medium farms recorded a risk level of GH¢ 603.63 for their current farming situation and a coefficient of variation of 12.3 percent. When a farmer with medium-sized farms wants to adopt the profit maximisation, his or her return is likely to have a standard deviation of GH¢ 600.17 and a coefficient of variation of 12.3 percent. A standard deviation of GH¢ 85.21 and a coefficient of 1.7 percent were recorded for one of risk reduced plans and other stated a GH¢ 87.71 and 1.8 percent standard deviation and coefficient of variation respectively.

Small farms that grow maize and soya beans with their current situation have a risk level of GH¢ 668.63 representing a coefficient of variation of 8.7 percent and at the profit maximisation plan, both standard deviation and coefficient of variation increase to GH¢ 135.35 and 13.1 percent respectively. The standard deviation for the risk minimised plans were of GH¢ 50.73 and GH¢ 15.97. The coefficient of variation for these plans were 4.9 percent and 1.5 percent respectively. For farmers who grow maize and groundnut, the current plan revealed a standard deviation of GH¢ 167.08 and a coefficient of variation of 8.7 percent. A standard deviation of GH¢ 876.82 and coefficient of variation of 13.8 are associated with the profit maximisation plan. To reduce the risk level to GH¢ 92.88 and coefficient of variation to 4.9 percent, a risk reduced plan has to be adopted.

Testing the significant differences between the expected returns, there was statistically significant among the farmer's plan, the profit maximisation and the most risk efficient for large farm sizes. For farms with medium farm sizes, there was a significant difference between the farmer's plan and the profit maximised plan, between the most risk minimised plan and the profit maximised plan and no significance between the farmer's plan and the most risk efficient plan. The same results were found for farmers who grow maize and soya beans on small plots of land. There was a significant difference between all plans for farmers who cultivate maize and groundnut on small lands.

5.2 Conclusions of the Study

The Karaga District is a district blessed with vast arable lands that support various crops especially cereals and legumes. The dominant cropping mix operated is the cereal-legume system.

The study revealed that the more land a farmer possesses the more he or she cultivates different crops. Those farmers who are closer to the Karaga market grow fewer crops compared to those far away from the Karaga market.

The study revealed that farmers at the current production are at a higher risk, in some cases riskier than the profit maximisation plans. Farmers are at a similar risk level as in their current plan when they shift to adopt the profit maximisation plan. The selection of the best production pattern will be depended on the risk attitude of the farmers. Risk-neutral and risk-loving farmers will always select the profit maximisation plan because they do not consider risks whilst risk-averse farmers, which most of them are, will select the most risk-efficient plan.

Farmers were better off selecting the most risk-efficient plan that had a low-income variation. With the risk minimised on-farm income is increased and also enough income is generated to cater for future food shortages.

5.3 Recommendations of the Study

1. Government and rural development institutions should formulate policies that increase farm income and reduce return variability like encouraging the use of good seeds and fertilisers and also increase credit access. Crop insurance policies can also be smartly made to suit the needs of farmers and reduce losses and food insecurity.
2. Markets should be easily accessible to farmers through good road networking or the creation of community markets to ease the distribution of food and inputs.
3. For farmers with land size above 4 ha should allocate 0.86 had (2.12 acres) to maize, 3.31 ha (8.18 acres) to soya beans and 1.16 had (2.87 acres) to groundnut.
4. Farmers with medium-sized farms (2 had to 3.99 ha) should be advised to apportion 1.06 ha (2.62 acres) to maize and 1.32 ha (3.26 acres) to soya beans.

5. Smaller farm holders who often produce maize and soya beans are likely to increase their returns when they grow 0.6 ha (1.48 acres) of maize and 0.5 ha (1.24 acres) of soya beans.
6. Farmers cultivating maize and groundnut on small plots will likely increase their farm income by allocating all their resources into maize production.
7. Farmers should be educated on efficient resource use and optimal resource management should be instituted and programmes modelled or piloted in the district.
8. Land and other resources should be easily accessible to women who constitute major farmers with smaller land sizes.

5.4 Limitations of the Study

The study came with some challenges. During the data collection, the enumerators faced some language barriers. Most of the enumerators could speak Dagbanli and English but some of the respondents spoke other languages like the Komkomba language which they could not understand.

Many crops were grown by farmers but on small plots or mixed with very important crops like maize in small quantities. The farmers and the enumerators found it difficult to determine the land allocated to such crops so they were not included in the analysis.

The study also involved the collection of information on past prices, yields and activities which some farmers found difficult to recollect.

Food crop farmers are not only involved in cropping activities but also engaged in off-farm activities and could have been included in the objective function but data obtained was inadequate for such modelling.

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APPENDICES

Appendix 1: Poisson regression results from Stata 15

Variables	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Land (ha)	.027	.006	4.71	0	.016	.039	***
Own land	-.019	.03	-0.62	.538	-.078	.041	
sex	.036	.032	1.11	.266	-.027	.098	
Educational	.051	.036	1.42	.154	-.019	.121	
Farming experience	.002	.002	1.06	.288	-.001	.005	
Number of extension visits	.013	.01	1.37	.172	-.006	.033	
Household size	.002	.002	1.33	.184	-.001	.006	
Distance to mkt	.004	.002	1.99	.047	0.000	.007	**
Amount from CS	0.000	0.000	1.12	.264	0.000	0	
PFJs fert awrnss	-.026	.04	-0.67	.505	-.104	.051	
Constant	.719	.097	7.40	0	.528	.909	***
Mean dependent var	2.575		SD dependent var		0.738		
Pseudo r-squared	0.009		Number of obs		388.000		
Chi-square	87.288		Prob > chi2		0.000		
Akaike crit. (AIC)	1184.345		Bayesian crit. (BIC)		1227.916		

*** p<.01, ** p<.05, * p<.1

Appendix 2: GDP deflator of Ghana from 2016 to 2019

Year	GDP deflator of Ghana (GH¢)
2016	159.92
2017	176.48
2018	194.50
2019	212.37

Source: The World Bank, [data.worldbank.org/indicator/NY.GDP.DEFL.D? locations/gh](https://data.worldbank.org/indicator/NY.GDP.DEFL.D?locations/gh)

Appendix 3: Historical Gross Margins of Various Crops

Small-sized farms							
Crop enterprise	Labour cost (GHC)	Cost of inputs (GHC)	Total Variable Cost (GHC)	Price per bag (GHC)	Total yields (ton)	Total revenue (GHC)	Gross Margin (GHC)
2019							
Maize	531	593	1124	1400.00	1.43	2002.00	878.00
Soya bean	642	235	877	1651.38	1.10	1818.00	941.00
Groundnut	568	235	803	2432.43	0.39	954.00	151.00
2018							
Maize	494	568	1062	1100.00	1.79	1969.00	907.00
Soya bean	605	210	815	1400.00	1.30	1815.94	1000.94
Groundnut	531	210	741	2162.16	0.66	1432.00	691.00
2017							
Maize	445	521	966	950	1.30	1235.00	269.00
Soya bean	581	185	766	1300	1.42	1842.10	1076.10
Groundnut	507	185	692	2162.16	0.48	1040.00	348.00

Medium-sized farms							
Crop enterprise	Labour cost (GHC)	Cost of inputs (GHC)	Total Variable Cost (GHC)	Price per bag (GHC)	Total yields (ton)	Total revenue (GHC)	Gross Margin (GHC)
2019							
Maize	754	630	1384	1400.00	1.39	1946.00	562.00

Soya bean	754	235	989	1651.38	1.25	2070.00	1081.00
Groundnut	667	237	904	2432.43	0.51	1251.00	347.00
2018							
Maize	680	531	1211	1100.00	1.33	1463.00	252.00
Soya bean	692	210	902	1400.00	1.45	2029.58	1127.58
Groundnut	630	210	840	2162.16	0.49	1064.00	224.00
2017							
Maize	618	521	1139	950	1.37	1301.50	162.50
Soya bean	630	237	867	1300	1.28	1657.89	790.89
Groundnut	586	198	784	2162.16	0.51	1096.00	312.00

Large-sized farms							
Crop enterprise	Labour cost (GH¢)	Cost of inputs (GH¢)	Total Variable Cost (GH¢)	Price per bag (GH¢)	Total yields (ton)	Total revenue (GH¢)	Gross Margin (GH¢)
2019							
Maize	729	630	1359	1400.00	1.4	2002	643.00
Soya bean	766	259	1025	1651.38	1.6	2574.006006	1549.01
Groundnut	667	222	889	2432.43	0.5	1287.00	398.00
2018							
Maize	680	531	1211	1100.00	1.33	1463.00	252.00
Soya bean	692	210	902	1400.00	1.45	2029.58	1127.58
Groundnut	630	210	840	2162.16	0.49	1064.00	224.00
2017							
Maize	618	521	1139	950	1.37	1301.50	162.50

Soya bean	630	237	867	1300	1.28	1657.89	790.89
Groundnut	586	198	784	2162.16	0.51	1096.00	312.00

Appendix 4: Recourse use matrices

Large Farms	Plan II			Plan III			Plan IV		
		Slack	Shadow price		Slack	Shadow price		Slack	Shadow price
	Land (ha)	0	188.65	Land (ha)	0	188.65	Land (ha)	0	1285.57
	Labour (Labour-days)	161	0	Labour (Labour-days)	161.05		Labour (Labour-days)	159.89	0
	Capital (GHC)	796.95	0	Capital (GHC)	470.49	0	Capital (GHC)	566.93	0
Medium-sized farms	Plan II			Plan III			Plan II		
		Slack	Shadow price		Slack	Shadow price		Slack	Shadow price
	Land (ha)	0.14	0	Land (ha)	0	1109.62	Land (ha)	0.13	0
	Labour (Labour-days)	136.38	0	Labour (Labour-days)	103.64	0	Labour (Labour-days)	125.36	0
	Capital (GHC)	208.63	0	Capital (GHC)	32.12	0	Capital (GHC)	386.91	0
Small-sized farms (maize and Soy)	Plan II			Plan III			Plan IV		
		Slack	Shadow price		Slack	Shadow price		Slack	Shadow price
	Land (ha)	0.13	0	Land (ha)	0	1.53	Land (ha)	0	1109
	Labour (Labour-days)	125.36	0	Labour (Labour-days)	127	0	Labour (Labour-days)	103.64	0

	Capital (GHC)	386.91	0	Capital (GHC)	52.3	0	Capital (GHC)	32.12	0
Small-sized farms (maize and Soy)	Plan II			Plan III					
		Slack	Shadow price		Slack	Shadow price			
	Land (ha)	0.31	0	Land (ha)	0	730			
	Labour (Labour-days)	149.11	0	Labour (Labour-days)	125.36	0			
	Capital (GHC)	607.84	0	Capital (GHC)	386.91	0			



Appendix 5: Questionnaire for the Study

University of Ghana

Department of Agricultural Economics and Agribusiness

Modelling Optimal Resource Allocation Patterns for Crop Farmers in the Karaga District

The purpose of this study in partial fulfilment of a two-year MPhil Agribusiness programme, any information provided would be for educational purposes and would not be disclosed to third parties. Information obtained about respondents' profiles is highly regard confidential and would not be shared with anyone other than the survey team and the Department. Please spare me 30 minutes of your time for the exercise and hope to have a cordial discussion. Respondents are not obliged to answer all questions. I will highly regard any of your questions and you can reach me via mobile through 0247998090.

Questionnaire for crop farmers:

Name of Interviewer:	Contact of Interviewer:
Questionnaire number:	Date:
Village or town:	
Contact of respondent:	

Section A: Background of Respondents

1. What is the name of the respondent? (Householdhead):.....
2. What is the sex of the respondent? (1) Male [] (2) Female []
3. What is your age?
4. What is your marital status? (1) Married [] (2) Single [] (3) Widowed []
5. Can you read and write English? (1) Yes [] (2) No []
6. What is your religion? (1) Christianity [] (2) Islam []
(3) Traditionalist [] (4) Others(specify).....
7. Ethnicity? (1) Mole Dagbani [] (2) Ewe [] (3) Gruma []
(4) Gruni [] (5) Konkombas [] (6) others (specify).....
8. What is your household size?.....
9. What is your main occupation? (1) Farming [] (2) Livestock sales [] (3) Motor king []
(4) Butchery [] (5) Trading [] (6) Share butter processing [] (7) Blacksmith []
(8) Others (specify).....
10. How often are you visited by extension offices to your farm in a year?..... times
11. Do you belong to any farmer organisation(s) in the area? (1) Yes [] (2) No []
12. If Yes, please specify the name and purpose of the organisation(s)

.....
.....
13. Did you get any technical assistance from any organisation? (1) Yes [] (2) No []

14.(i) If Yes, what form of assistance did you get? (1) Source of seeds [] (2) Fertiliser []

(3) Tractor services (4) Cash [] (5) Marketing [] (6) Others(specify).....

14.(ii) What are the term and conditions of the agreement?
.....

14. Have you heard of the Planting for Food and Jobs (PFJs)? (1) Yes [] (2) No []

14i. If Yes did you benefit from the programme in 2019 cropping season (1) Yes [] (2) No []

14ii. If Yes in 15i, what form of assistance did you get?

(1) Improved seeds [] (2) Fertiliser subsidy [] (3) Market access []

(4) Assistance in agro-processing []

15. What is the distance of your between the house and the market products?.....km

Section B: Crop enterprise Mix identification

15. What crops did you grow this season?

(1) Maize (Mz) [] (2) Soya bean (Sb) [] (3) Rice (R) [] (4) Yam (Y) []
(5) Groundnut(Gn) [] (6) Cowpea (Cp) [] (7) Millet (Mt) [] (8) Sorghum (Sg) []
(9) Cassava (Cv) [] (10) Pepper (Tm) [] (11) Tomatoes (T) [] (12) Okra (O) []
(13) Leafy Vegetables (LV) [] (14) Others(specify).....

16. Rank five major crops you grow in the other of importance (from the most important to the least important.

Major cultivated	Crops	Number of years grown	Reason for its cultivation (1) Food [] (2) Income=[] (3) Both []		
1.			(1) Food []	(2) Income=[]	(3) Both []
2.			(1) Food []	(2) Income=[]	(3) Both []
3.			(1) Food []	(2) Income=[]	(3) Both []
4.			(1) Food []	(2) Income=[]	(3) Both []
5.			(1) Food []	(2) Income=[]	(3) Both []

17. Please indicate the area cultivated per major crop grown in the 2019 season?

Major Crops	Area cultivated (acres)
1.	
2.	
3.	
4.	

5.	
----	--

18. Would these major crops be the same for 2020 cropping year? (1) Yes [] (2) No []

19. How would you allocate land among crops in the 2019 season?

5 Major Crops						
Acres						

20. What are the problems you face in multi-cropping?

(1) Weeding problem [] (2) Lack of capital [] (3) Striga [] (4) Untimely machine

Section D: Crop Allocation Patterns of Farmers

Section D (i) Determination of farm activities, resources and cost

21. What equipment are available for the cropping year?

Equipment	Yes =1 [] No =0 []	Cost	Expected useful life
1. Hoe			
2. Cutlass			
3. Wellington Boots			
4. Sickle			
5. Motor king			
6. Tractor			
7. Donkey cart			
8. Bullock plough			
9. Bicycle			
10. Motorcycle			

22. What was the quantity and cost of seeds used per acre for the major crops?

5 Major Crop	Quantity of seed or sticks or sets (Bowls or bags)	Source of seed: Farmer = (1) Others farmer = (2) Input dealer = (3)	Cost of seeds (use market price for farmers' seeds)

1.			
2.			
3.			
4.			
5.			

23. Do you use fertilisers on your farms? (1) Yes [] (2) No []

23. (i) If Yes, complete the table below

5 Major Crop	Quantity of fertiliser applied per acre (50 kg bag)	Cost per acre (GH¢)
1.		
2.		
3.		
4.		
5.		

23.

24. Did you use a tractor for land preparation for the past three seasons? (1) Yes [] (2) No []

25. Did you use herbicide last cropping season? (1) Yes [] (2) No []

25. (i) If Yes please complete the table below

Type of herbicides	Quantity herbicides applied per acre (L)	Cost per unit (GH¢) 2017	Cost per unit (GH¢) 2018	Cost per unit (GH¢) 2019

26. Did you store your grains with chemicals before storage? (1) Yes [] (2) No []

26(i). Please complete the table below

	Qty per acre	Qty per acre	Qty per acre
Chemical used/crop	2017	2018	2019

27. Did you use any external storage system? (1) Yes [] (2) No []

27(i) If Yes, what is the cost incurred in storing these foods? GH\$..... per bag or tubers

27(ii) How long has your produce been in the external storage system?time in a year

28. How much was spent in transporting and selling crops?

5 Major Crops	Transportation cost from field to storage			Selling Cost		
	2017	2018	2019	2017	2018	2019

29. What are the costs incurred in producing various major crops?

5 Major Crops	2017 (GH\$)	2018(GH\$)	2019(GH\$)

Section D(ii) Land:

30. What is the total area of your farmland?acres

31. What is the total area of your farmland cropped? acres

32. What type of land ownership do you have?

(1) Own [].....acres

(2) Rent [].....acres

(3) Family land [] acres (4) Shared cropping []acres

32 (i) If you use rented land, how much did you pay for each cropping season for the land use? GH¢ per acre, (write the value for whatever is exchanged for rented land).

32 (ii) If sharecropping, please indicate the sharing arrangement?

.....
.....

Section D(iii) Labour:

33. How many people in the household are available as labour?

Men

Women

Childing

Total

34. How many days a week on the average did the household labour on the average work on the farms?.....

35. Did you hire labour in the 2019 season? (1) Yes [] (2) No []

35(i) If Yes, how many workers did hire for your farms in 2019 season?..... persons

35(ii) Who work were they hired to do? (Please indicate the number of workers hired for jobs)

(1) Land preparation [] (2) seeding [] (3) 1st Herbicide application []
(4) 1st Weeding [] (5) 2nd Herbicide application [] (6) 2nd Weeding []
(7) Harvesting (8) Post-harvest [].....

36. How many hours in a day is spent on the farm?

(1) Yourself.....hrs (2) Other family members.....hrs

(3) Hired labour.....hr

Section D (iv) Capital:

37. What is/are your source(s) of capital?

(1) Crop sales [] GHC..... (2) Savings [] GHC.....

(3) Loan [] GHC..... (4) Family and friends GHC [].....

38. How much money should be made available for growing major crops in 2019 season?

5 Major Crop	Amount (GH\$)		
	2017	2018	2019

Section D(v) Risk:

39. From your experience, for the past five years which of the major crop(s) is/are susceptible to drought

.....
.....

40. What did you think caused the yield deviations?

(1) Periodic drought [] (2) Low use of fertiliser [] (3)Untimely machine services []

(4) Low rains []

Income:

41. How do you sell your produce?

(1) Fresh green from harvest [] (2) Dried from harvest []

(3) Stored for later date [], for how long?.....months.

42. Please tell me how you sold your produce?

(1) Directly to the Market [] (2) To meddle Men []

(3) To cooperatives [] (4) others (please specify).....

43. Do you purchase food crops from the Market? (1) Yes [] (2) No []

44. How many times do you purchase food in a year?.....times.

45. Please complete the following table below on how harvested produce for the 2019 season are deposited.

Crop	Quantity harvested (attached units)	Quantity consumed	Quantity Sold	Quantity given as Zakat

46. Please tell me on the yields target and the actual yields for the 2019 cropping season.

Crop	Target yields	Actual Yields

47. Please fill the table below on yields for the past three years.

Crop type	2017 (with units attached)			2018 (with units attached)		
	Acres	Target	Actual	Acres	Target	Actual

48. Did you earn income from other sources?

45 (i). Please complete the following table on the other sources of income.

Source of off-farm income	Amount earned GH¢	How often in a year?
1. Livestock sales		
2. Motor king		
3. Butchery		
4. Trading		
5. Share butter processing		
6. Blacksmith		
7. Others (specify)		

Section E: Food requirement to meet household needs

49. Do you purchase food crops from the Market? (1) Yes [] (2) No []

50(i) If Yes, how often do you buy food crops? Number of times in a year [].....times

50. Please complete the table below on the food required for household consumption

Crop	Requirements (with units attached)		
	2017	2018	2019