UNIVERSITY OF CAPE COAST

OPTIMUM COMBINATION OF FOOD CROP FARM ENTERPRISE AMONG SMALLHOLDER FARMERS IN THE ASSIN NORTH DISTRICT OF GHANA

AUGUSTINE KOUFIE

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BY

AUGUSTINE KOUFIE

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

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DECLARATION

Candidate's Declaration

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

Candidate's Signature:…...…………………. Date…………………………….
Name: Augustine Koufie

Supervisor's Declaration

I hereby declare that the preparation and presentation of this thesis was supervised in accordance with the guidelines on the supervision of the thesis laid down by the University of Cape Coast.

Supervisor's Signature ……………………..… Date ………………………..
Name: Prof. Henry De-Graft Acquah

ABSTRACT

The purpose of this study was to determine the optimum combination of food crop farm enterprises among smallholder farmers in Assin North District of the Central Region of Ghana. The data collection for the study was done through the administering of structured questionnaire. A multistage sampling procedure was the sampling technique used to sample 360 smallholder farmers. The LP model was used to determine the optimum farm plan as well as the optimum gross margin for the farmers. The results suggest that the farmer should plant 2.70 acres of plantain and 2.66 acres of rice to realize a maximum gross margin of Ghc14011.70 without planting maize, cassava, cocoyam and garden eggs. The most limiting constraints were identified by both the LP model and the Kendall's Coefficient of Concordance to be capital followed by labor. The LP model was robust to changes in capital and labor in the sensitivity analysis. The results further showed that the LP model provides a basis for alternative crop combinations to address subsistence issues of the farmer. Maize/plantain/rice and Cassava/ plantain/rice had the least tendency to depress the gross margin if forced into the optimum plan for farmers. The study recommends that farmers should channel their resource to produce the optimum crops to get the maximum profit. Thus, farmers should adopt crop combination system to reduce production risk and to ensure income stability. Also, financial institutions should provide credit in a form of capital to enable farmers increase their productivity and income since capital was the most limiting constraint.

KEYWORDS

Linear Programming

Optimum Combination

Sensitivity Analysis

Resource Allocation

Smallholder Farmers

Food Crop

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DEDICATION

To Prof. Nina Banks and her sons, Emiliano and Julian

TABLE OF CONTENTS

Contents Page

CHAPTER TWO REVIEW OF RELATED LITERATURE

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

LP	Linear Programming
GDP	Gross Domestic Product
FAO	Food and Agriculture Organisation
MoFA	Ministry of Food and Agriculture
IEG	Independent Evaluation Group
AfDB	The African Development Bank
IFAD	International Fund for Agricultural Development
FFG	Fairmount Food Group
GSS	Ghana Statistical Service
ECG	Evaluation Cooperation Group
ANMA	Assin North Municipal Assemblies
MMDA's	Metropolitan Municipal and District Assemblies
SRID	Statistics Research and Information Directorate
SPSS	Statistical Package for the Social Sciences
Df	Degree of Freedom
WFP	World Food Program
GFS	Global Food Security
FAPDA	Food and Agricultural Policy Decision Analysis

CHAPTER ONE

INTRODUCTION

Background to the Study

On a worldwide basis, agriculture plays a valuable role in our everyday lives, not only by providing us with food, but also helps to improve economies of nations and provides employment to the rural population (FAO, 2014). Also, agriculture contributes to the economies of countries which in turn influence their GDP. As of 2018, agriculture only represented 3 percent of the world's GDP, down from 4 percent in 2010. Even though agriculture represents a small share of the world's economic output, this sector employs almost 30 percent of all workers globally (FOASTAT, 2018). Overall, agriculture's contribution to the backbone of an economy that gives fundamental ingredients to humans and raw materials for industrialisation is total GDP, which is largest in Africa and South Asia (FAO & FAPDA, 2015).

Also, a common thing that is needed world-wide is food (WFP, 2009). Based on this, agricultural food production is critical to the global economy since it is the primary source of food supply for all countries, developed and developing alike. (FAO, 2014). However, due to rapid population increase in underdeveloped and emerging countries, food demand is rising at a rapid rate, and if it fails to fulfill the rising demand for food goods, it will have an impact on the economy's growth rate and also bring about food security issues (IFAD, 2011).

Food security as well as ensuring there is food for all is one pressing issue that is posing a challenge to the world community (Global Food Security, 2011). Food security is an important concept that refers to a situation "when all people at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preference for an active and healthy life" (FAO, 2010). Thus, food security is a major challenge in global agriculture, which requires massive expansion to support the world's projected expanding population. (Global Food Security, 2011). A lot of people regard it as a basic necessity, but nearly a billion people worldwide, particularly in food-deficit and low-income developing nations, continue to suffer from chronic poverty and malnutrition. (IEG, 2011). Two major ways of curbing this food security issue are increasing agricultural productivity and also addressing resource allocation problems.

With respect to the growth of agricultural productivity has slowed in recent years. The annual growth rate of key food crops around the world is around 1%, while the recent global population growth rate is around 1.2% (FAO, 2009a). Therefore, in order to alleviate the problem of global hunger, improved agricultural productivity is required all over the world. In comparison to other developing regions such as South Asia and Latin America, agricultural production in Sub-Saharan Africa is poor (IEG, 2011). For instance, in Sub-Saharan Africa, an average farmer earns a maximum of 2 metric tons of grain per hectare, whereas a Chinese farmer gets four times more, an American farmer gets five times more, whiles an Indian farmer get two times more than what a typical Sub-Saharan African farmer receives (AfDB-IFAD, 2010). There is the need to increase productivity and understand factors that help to increase productivity. Optimum food crop combination helps the farmer to get high yields coupled with optimum profit for the farmer. Also, resource allocation problem when properly addressed helps to increase agricultural food production. This then calls for the need for the farmer to plan properly.

Ghana, a middle-income West African country, is no doubt an agriculturally dependent nation. FFG (2014) noted that Ghana has been a productive African country over the past two decades because of its constancy in growth and poverty reduction. The southern part of the country agriculture has fueled the economy, which primarily employs smallholder farmers who produce food and cash crops. (MoFA, 2015). However, given its agricultural advancements, Ghana still imports roughly 70% and 15% of its maize and rice, respectively (FAO, 2014). This is due to the fact that the food crop production sector is faced with low productivity coupled with resource allocation problems and since Ghana's agriculture is dominated by smallholder farmers, there is the need to address these issues.

One of the districts in Ghana noted for growing food crops is the Assin North district which is faced with resource allocation problems coupled with low food crop productivity. Farmers in this area, when faced with resource allocation problems and low productivity, often rely on their intuition or compare with neighbours which does not guarantee the optimal result and often leads to their incurring losses and not getting the optimum food crop enterprise. This lowers their productivity level, prevents them from obtaining the maximum profit, and further affects the economy as a whole (Darfor, 2000; Larkai, 2019). There is therefore the need for farm planning activity.

In farm planning, the farmer is faced with two main decision problems and this is to allocate his farm resources so as to increase his income or to maximize his utility whiles taking into consideration a stochastic element called risk, by treating it to avoid income variability. Hazell and Norton (1986) noted that this kind of complexity has been modeled and made very flexible with the help of a linear programming model. The linear programming model can be treated at the deterministic level or the stochastic level. At the deterministic level, the LP model helps to achieve the maximum profit solution and provides prudent solutions to whole farm planning problems. However, there is some kind of criticism levelled against the assumption of the deterministic model which is that all coefficients are known with perfect knowledge.

Statement of the Problem

In Ghana, the agricultural sector is predominantly dominated by smallholder farmers who cultivate not less than two acres of food and cash crops (MoFA, 2015). These smallholder farmers are often caught in a trap of low savings, low investments, and low earnings which often result in low levels of production and productivity (FAO, 2011). Thus, these farmers depend on rainfall and the soil's inherent fertility for production which leads to low productivity. Even FAO (2017) confirms that although, there are major barriers in adopting to agricultural practices, however, crop combination and crop diversification can make food crop production more resilient and efficient. With this statement made, practising crop combination alone is not enough, therefore, there is the need for farmers to know the optimum crop combination in other to maximize revenue or production. In achieving this, Hassan (2005) asserted that the output of farmers can only be maximized when there exits an optimum cropping plan, which will ensure efficient usage of available resources. Therefore, there is the need to search for an optimal crop combination while satisfying a system of constraints, hence the application of the linear programing model helps addresses these complexities.

Based on the above, several studies such as Darfor (2000)-Ghana, Igwe (2011)-Nigeria, Majeke (2013) - Nigeria and Larkai (2019) - Northern Region of Ghana adopted the LP model to find the optimum cropping plan as well as optimum revenue. However, considering food crop production in Ghana, Central Region is recognized as one of the food hub which serves about 12.5% of food production, with Assin North district as it predominant area, with a population of about 49,801 smallholder farmers (MoFA, 2015). Therefore, with this large number of farmers, if we are to develop a farm planning model for farmers in the Central region, then, Assin North District cannot be overlooked.

In Assin North district of Ghana, farmers do produce different crops and are often confronted with the complex problem of choosing among the right enterprise to produce in other to maximize profit. Align with the above, other studies such as Larkai (2019) conducted in the area also indicated that there has been history of under production of food crop which has affected the revenue maximization of these farmers as well as their welfare. Therefore, there is the need to investigate and determine the optimum crop combination using the LP model. Most of the Studies conducted on LP model thus, studies such as Igwe (2011), Majeke (2013), and Larkai (2019) conducted in their area and year of study only focused on the profit of the farmer, however, the objective of the farmer is not only about profit maximization but resources utilization and subsistence issues among others. Also, prices and resources used in building the model are estimates which can change coupled with the seasonality nature of agriculture, it is therefore of essence that the model be built to withstand shocks by performing a sensitivity analysis**.** Therefore, in this context, the goal of this research is to find that the optimum combination of food crop farm enterprise among smallholder farmers in the Assin North District of Ghana.

Purpose of the Study

The purpose of the study is to determine the optimum combination of food crop farm enterprises in Assin North District.

Objectives of the Study

1. Identify the various enterprise patterns for food crops operated by the farmers in the Assin North District.
2. Compare existing and optimum farm plans for farmers with regard to resource allocation and profit.
3. Analyze the farmers' resource utilization pattern and constraints in their food crop farm production.
4. Compare the level of gross margin between that of the farmer's plan and the LP model.
5. Carry out sensitivity analysis on some of the resource restraint conditions.
6. Examine the various alternative food crop combinations that did not enter the optimal cropping pattern and its corresponding profit to the farmer.

Research Questions

1. What are the various cropping enterprise patterns operated by farmers in the study area?
2. What is the difference between the existing crop farm plan and the optimum plan for farmers?
3. What are resource utilization pattern and which of the factors of production is/are most limiting in the study area?
4. What is the difference in gross margin between that of the farmer's plan and that of the LP model?
5. How would change in a particular resource affect the optimum food crop combination activities?
6. What are the various alternative food crop combinations that did not enter optimal and their corresponding profit?

Significance of the Study

The findings of the study showed the optimum cropping plan that will give the farmers the maximum revenue to be plantain (2.7 acres) and rice (2.66 acres). The study is of importance because it addresses resource allocation problem in the study area and give the farmers the optimum cropping plan which will make them efficient in production. Thus, farmer's production level will improve which will increase their income-earning capability "all other things being equal". Also, information from this study will assist farmers, government, decision-makers of both private and public firms with their decisions; researchers and students inclusive will be able to get literature to do their work.

Delimitation of the Study

The study focused on the optimum combination of food crop farm enterprise among smallholder farmers in the Assin North District of Ghana. The study addressed specific objectives such as identifying the various enterprise patterns for food crops operated by the farmers in the Assin North District, comparing the existing and optimum farm plans for farmers with regard to resource allocation and profit, analysing the farmers' resource utilization pattern and constraints in their food crop farm production. Cross sectional survey design was employed in this study. Also, descriptive statistics, linear programming model and Kendall's Coefficient of Concordance were the analytical tool used for the study. The variable for the study were land, labor, capital, fertilizer, and food crops.

Limitation of the Study

Majority of farmers do not keep proper records of their production activity which affected the calculation for revenue maximization. Also, transport constraints was not addressed in study. The huge nature of the data collection and it financial implication and time constraint on the researcher also affected the progress of the study. In addition, the study was constrained by language barrier between the researcher and the respondents which affected the progress of the study as well as the unwillingness of these respondents to participate in the study.

Definition of Terms

Linear Programming: It is a special type of MP which is a type of allocation model used to determine the best use of scarce and limited resources and to make decisions. The word **linear** means a proportionate relationship of two or more variables in a model. Thus, when one variable is changed, it causes another variable to change as well. Also, the word **programming** in LP means planning and organization that includes the economic allocation of scarce resources by selecting a specific plan of action or strategy from a set of alternatives to accomplish the desired result.

Objective Function: This is an important component of the linear programming that gives direction to the optimization and is expressed in a mathematical form that combines the decision variables to express the decision maker's goal, aim or target. Usually, we produce to get the most profit or revenue or at the least cost. Therefore, the objective function takes one of the following forms:

(1). To maximize gross margin or net revenue from one or a combination of enterprises. (2). To minimize production or transportation cost or cost of diet in nutritional requirements. (3). To optimize subside policies required to achieve production targets.

Mathematically, the objective function is stated as $Max\ Z = CX$ or $Min\ Z = CX$. The objective function coefficient is a variable in the objective function. C refers to the objective function co-efficient and as X is known as the decision variable. For the purpose of this study, the objective function was to maximize gross margin income from one or a combination of enterprises.

Decision Variables: These are the variables that the decision-maker settles on in order to achieve his or her objectives. They are the things that the decision-maker can control or adjust and are characterized by a set of co-efficient be it technical or input-output co-efficient, and are expressed algebraically using the letters of the alphabet such as $X_1, X_2 \ldots\ldots\ldots X_z$ or X, Y, Z

Constraints: They are restrictions or limitations that make it possible to achieve an objective and are usually imposed on the values that decision variables may assume. These limitations are there to make the optimal solution more realistic, logical, and achievable. They are expressed as linear equality or linear inequality. The constraint in every linear programming is made up of functional constraints and non-negativity constraints.

The functional constraints are of the form $AX \leq B$ or $AX \geq B$ whiles the non-negativity constraints are made up of, $x_1, x_2 \geq 0$. The functional constraints are made up of resource constraints, institutional constraints, and subjective constraints. Resource constraints are the limitations of the farmers' resources that limit the scale of his operations. The institutional constraints on the other hand are the government policies that affect production whiles subjective constraints are imposed by the farmers themselves for non-income reasons and are usually due to attitude towards debts, consumption habit consideration, and skills.

Simplex Method

This is an arithmetic method used to solve linear programming problems involving two or more decision variables. It's an iterative technique that is used to solve LP problems and stops when an optimal solution is found. The simplex method makes use of the property of an LP problem of having an optimal solution, only at the corner of the feasible solution space.

An Optimum Combination of Enterprises

There are two main approaches in modeling farm level enterprises and these are the positive approach and the normative approach. The positive approach models the behaviour of farmers whiles the normative approach tries to find out the optimal solution to resource management and allocation. In modeling, the econometric modeling is used when we are dealing with empirical models and the mechanistic, mathematical and the optimization modeling make use of the linear programming model.

Smallholder Farmers: These are small-scale farmers who grow subsistence crops and one or two cash crops on small-based plots of land varying from one hectare to ten hectares that are owned by them.

Valuation of Scarce Resources: It is essential to value scarce resources and this valuation of the limited resources is referred to as dual or shadow price. The shadow price shows by how much the objective function, which is a maximization of gross margin, will increase if the researcher increases the level of resources by one unit.

Sensitivity Analysis

The process of increasing or decreasing the values or relationship within the problem and observing the solution, to know how sensitive the optimal solution is to the changes made. This analysis also tests the robustness of the model.

Organisation of the Rest of the Study

The study is organised in five chapters. Chapter One consists of the background to the study, statement of the problem, the purpose of the study, research questions, significance of the study, limitations, delimitations, definition of terms, and organization of the study. Chapter two of the study looks at the literature review, mainly on findings of research made by different researchers related to the problem under study. Chapter three focuses on the research methods; research design, study area, population, sampling procedure, data collection instruments, data collection procedures, data processing and analysis, and chapter summary. Chapter four discusses the results and methodology adopted for the study. The final chapter, chapter five focuses on summary, conclusions, recommendations, suggestions for further research, and finally, acknowledges the limitations of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter of the study present a review of the literature from a variety of studies that are relevant to this study, as well as an explanation of the theoretical foundation for the study. This chapter discussed the overview of the farming systems, concepts of crop combination enterprise, crop pattern, theoretical underpinnings, empirical and conceptual framework. A review of literature is conducted to know the extent to which other studies support the need for the current study, to critique the literature, and also to find the rationale for further study.

Theoretical Literature

Overview of the Farming System in the Assin North District

Farming system is said to be a suitable combination of farm businesses be it cropping system, fishery, poultry, livestock or horticulture, and means available to the farmer to make a profit out of it. Also, it connects appropriately with the environment without disrupting ecological and socioeconomic equilibrium, and it tries to achieve the national purpose. (Jayanthi, 2002). Therefore, the selection of a farming system in an area is dependent on the ecological environment of the area, which includes the nature of the environment and its suitability to crops. Also, it includes a socio-economic environment which is made up of the production technology, access to the market, and farmer preferences (Darfor, 2000; Larkai, 2019). In the study area, there are two raining seasons with the peak of the major raining season occurring in June (GSS, 2013). The variety of crops grown in the study area is mostly influenced by climate conditions, type of soil, and also the vegetation. The main crops produced in the study area are cereals such as maize and rice; root tubers such as cassava, plantain and cocoyam, and tree crops such as cocoa and oil palm (GSS, 2013).

Concepts of Crop Combination Enterprises

The concept of crop combination enterprises is a mechanism for studying the existing relationship of crops among each other and their land utilization. Weave (1954) was the first to utilize a statistical technique to determine the Middle West's crop combination. (USA) followed by Scott (1957), Bennett (1961), and Coppock (1964) who have also contributed in the same fields. Over the years crop combination enterprises have gained recognition and are becoming more relevant as the days go by (Igwe & Onyenweaku, 2013). Studies on crop combination enterprises are mostly useful in many ways such as providing an adequate understanding of individual crops, helping incomprehensive area development planning particularly for the rural areas, and also it is in a unified reality that necessitates definition and distribution analysis (Majeke, 2013).

The multi-crop combinations are far more widespread on hills as compared to plains (Larkai, 2019). Three to seven crop combinations are usually associated with hilly districts whiles two crop combinations are found in the valley districts. The reason being that hilly districts are accompanied by higher altitude, higher annual temperature and humidity, steep slopes, and red-lateritic soils. On the other hand, the valley districts have fertile alluvial soils, equal distribution of rainfall, and minimum temperature (Seitinthang, 2012).

Concepts of Crop Combination Pattern

The concept of cropping pattern is a static phenomenon that changes over time and space and is defined as the proportions of the area under different crops at any given time. Singh (2005) defines cropping patterns as the extent to which the arable land under different agricultural activities can be put to use. Several factors come to play when dealing with crop patterns and these factors are socio-cultural, geo-climatic conditions, physical, technological, and agronomic criteria. Crop pattern usually varies from province to province, depending on soil type, topography, slope, temperature, rainfall volume and consistency, and irrigation water availability. The strength of individual crops usually becomes a basis for determining the crop pattern of a particular region (Murugesan, Gangai & Selvam, 2018).

Theoretical Framework of the Study

The theoretical framework of the study is optimization theory, rational choice theory, and theory of constraints. These are the theories that underpin the study.

Optimization Theory

Optimization is defined as a statistical and methodical process for selecting the optimal design from a large number of options while remaining constrained Variables, objectives, and constraints are the three main parts of optimization. The earliest optimization approach can be traced to calculus, a point on a one-variable function with its first derivative equal to zero represents the function's maximum or minimum. The earliest calculus-based equations for locating optima were discovered by Pierre De Fermat and

Joseph-Louis Lagrange. Iterative approaches to find an optimum were first proposed by Isaac Newton and Johann C.F. Gauss.

Leonid Kantorovich began formal optimization on "linear programming" in 1939, which was one of the first standard optimization methodologies. The Simplex Method, the first well-known technique, was published in 1947 by George Dantzig in the same year. Many optimization approaches have been created since then. The following ways became well-known and widely accepted among the different methods: Newton's technique, Quasi-Newton methods, the penalty approach, the feasible direction method, and Quadratic programming are all examples of steepest descent methods.

Two distinct groups discovered the Karush-Kuhn-Tucker (KKT) condition in 1939 and 1951 to evaluate the essential condition for a constrained optimum. The classic optimization methodologies were rapidly developed from the 1940s through the 1970s, peaking in the 1970s. Mathematical programming or mathematical optimization were other terms for optimization. Optimization grew fast into a huge research field with numerous branches, including the ones listed below: Linear programming, nonlinear programming, unconstrained optimization, constrained optimization, single-objective and multi-objective optimization, goal programming, and dynamic programming are examples of linear programming and nonlinear programming.

However, this study will focus on the linear optimization problem and employ the Simplex Method. In the context of this study, which is, the optimum combination of food crop enterprises, the farmer’s objective is to maximize gross margin given a set of constraints.

Theory of Constraints

According to the theory of constraints, decision-makers are faced with some kind of constraints that pose limitations for them to achieve their objectives be it profit maximization, loss minimization, or utility maximization. Some forms of constraints are functional constraints and non-negative constraints. With the functional constraints, we have land constraints, labor constraints, capital constraints, and other forms of constraints. The notion of limitations offers a versatile collection of methods for achieving a goal. The theory of limitations was developed and introduced by Dr. Eliyahu Goldratt in 1948. Since, the theory of constraints has continued to evolve and develop and has been employed in many field such as agriculture. In the context of this study, the farmer is faced with labor constraints, land constraints, capital constraints, fertilizer constraints, and non-negativity constraints.

The Rational Choice Theory

Early neoclassical economist who wrote about the rational choice theory includes Agents, according to William Stanley Jevons, make consumption decisions in order to maximize their enjoyment or utility. Also, according to the rational choice theory, decision-makers are assumed to be aimed at maximization of some measure of achievements such as profit or utility. Most farmers are rational decision-makers, that is they choose to participate in programs that they perceive will provide them higher yield. These farmers are often confronted with alternatives when it comes to the decision making process however, they chose the one that gives them the highest profit. In the context of this study, the farmer relies on his experience, intuition, or comparison with his neighbour in selecting the enterprises to combine and also on how to allocate these limited available resources this, however, does not guarantee an optimal result. The alternative which is the application of linear programming model leads to optimum allocation of resources and a combination of enterprises, which results in an increase in crop yield and further increases income.

The History of Linear Programming Model

Linear programming is credited to George Bernard Dantzig for independently pioneering the general linear programming formulation and inventing an efficient method called the simplex algorithm for solving linear programming problems. The problem of solving a system of linear inequalities dates as far back as 1827; in this same year, a French mathematician and physicist born in Auxerre and best known for initiating the investigation of Fourier series, Jean-Baptiste Joseph Fourier published a method for solving a system of linear inequalities.

In 1939, Leonid Kantorovich who was a Soviet mathematician and economist developed the first linear programming formulation problem which is similar to the general linear programming formulation problem. During World War II, he devised it to plan expenditures and returns in order to lower the army's expense while increasing the enemy's casualties. During the same time, T. C. Koopmans and Frank Lauren Hitchcock also formulated the classical economic problems and transportation problems respectively as linear programs.

It was after World War II that the idea of linear programming advanced in the military and it was adapted to improve efficiency and productivity by the civilian sector (Taha, 2011). Although linear programming started in 1947, after the World War II by George Bernard Dantzig, the pre-1947 era Wassily Leontief proposed the Inter-Industry Input-Output Model of the American Economy, which has a huge yet basic matrix structure. – and Game theory by John Von Neuman in 1928 paved the way for the development of LP and its extensions (Lenstra *et al.*, 1991; Kareen & Aderoba, 2008).

Dantzig employed the concept of Leontief which states that the Leontief model had to generalize even though it was a steady-state model, for a highly dynamic model that is computable, with the formulation of what a time-staged, dynamic linear program with a staircase matrix structure is described. (Dantzig, 2002). He realized that developing various plans which were called "Program" by the US military could be formulated as a system of linear inequalities and he introduced the concept of goal which today is called an objective function (Dantzig, 2002).

According to Arsham, Adlakha and Lev (2009), the linear programming theory has been used to tackle capital budgeting, food design, resource conservation, strategic games, economic growth forecasting, and transportation systems challenges. It has been successfully applied to optimization problems in industries as diverse as agriculture, banking, education, forestry, petroleum, and trucking.

Assumptions Underlying the Linear Programming Model

Several assumptions are implicit in the linear programming problems but six basic assumptions underlie the linear programming problem (Olayemi & Onyenweaku, 1999). These include linearity assumption which stipulates that both the objective function and constraints in any linear programming problem must be linear. This property distinguishes linear programming problems from other forms of programming problems such as integer programming, quadratic programming, and non-linear programming. The proportionality assumption also states that the contribution of the objective function or constraints is directly proportional to the value of that variable. This implies that there is no discount or economies of scale.

The additive assumption requires that the direct sum of the individual contributions of all variables in the objective function and restrictions equals the overall contribution of all variables. Simply put, their contributions to an equation must be additive. The divisibility assumption proposes that inputs and outputs are infinitely divisible. The certainty assumption stipulates that all the objective coefficient, constraint coefficient, and technological coefficient of the LP model should all be deterministic, meaning they have known constants. It is also called determinism or single-valued expectation. Finiteness assumption states that a limit exists on the number of activities and resources which can be programmed.

Aside from the six basic assumptions of the linear programming model, there are other assumptions like optimization appropriateness which assumes that an appropriate objective function is either maximized or minimized. Also, objective function, decision variable, and constraints appropriateness are assumptions that deal with appropriateness of the formulation of linear programming problems.

Strength of the Linear Programming Model

For about four decades now the linear programming model has been established as a standard planning tool for farm management and its major advantage is its ability to analyse a wide variety of alternative decisions (Beneke & Winterboer, 1973). It can analyse possible solutions in a fast, thorough, and cost-effective way without devising the solutions. There are other advantages of the linear programming model and they have been elaborated below:

Linear programming model helps to maximize net returns from possible solutions or a combination of enterprises under given conditions of resource constraints. This is done through the computational procedure so the farm planner or researcher doesn't influence the outcome once the problem is stated correctly in the mathematics of linear programming. Thus, since the data are not only derived from research farms but mainly from the farm operations used by the farmer himself, it makes the solution of the LP more realistic.

The Linear programming model helps to evaluate all possible alternatives and this helps to increase objectivity in decision making. This ensures that list of all feasible solutions is generated, from which the best one can be chosen. The mathematical model is objective since all assumptions and criteria are clearly specified. Hence, using it as a reference point makes it possible for that decision-maker to accept or disagree with the result based on the assumptions.

The linear programming model helps to make complex problems more flexible. Farm management planning is mostly complex so employing traditional methods may result in less than the optimal solutions. Therefore, this model makes it easier to solve due to its flexible and adaptive mathematical technique.

The linear programming model facilitates sensitivity or parametric analysis. The sensitivity analysis means that price, demand, and product availabilities assumed in constructing the model are estimated and may differ in practice. In simple terms, the parametric or sensitivity analysis means that the researcher wants to know how sensitive the optimal solution is to changes in the parameters embodied in the linear programming model. It is also called the "What if" analysis.

Despite the numerous advantages of the linear programming model, it also has its weaknesses and these include the following:

The LP model assumes that all parameters are constant, however this is not always the case. This is because the linear programming model is predicated on the assumption of constant returns, whereas in actuality, returns are either diminishing or increasing, as is common in production.

It is possible that as a researcher employs the use of the linear programming technique to model a real problem, he is bound to model wrongly due to the fact that some key variables may be omitted from the model or the model may not be appropriate for the problem. Therefore, to use this technique one has to first convert the problem into a mathematical model by having an objective which is either to maximize profit or revenue or to minimize cost.

Also, there should be decision variables that will help the researcher achieve his stated objective and constraints which are restrictions that limit what the researcher can do. To solve this limitation, objective function appropriateness, decision variable appropriateness, and constraints appropriateness are the assumptions to be considered when constructing the linear programming model.

In linear programming, the decision variables can take integer or fractional values. Very much often researchers face situations whereby the LP model contains integer-valued variables or fractional optimal solution making it difficult to use the linear programming technique so one has to employ other techniques like integer programming technique or quadratic programming model or others different from the linear programming model.

Olayide and Heady (1982) also noted that one major obstacle to wider use of the LP model is that in developing countries it is very difficult to get people with the requisite skills with which they can understand the programming language. More so, the use of the computer also makes the use of this technique quite cumbersome because it needs people with the technical know-how to run the analysis and also in terms of capital resources.

Concept of Crop Calendar in Building the Linear Programming Model

To be able to build a linear programming model, you need to be guided by a crop calendar. A Cropping calendar is prepared to determine the labor requirements for each enterprise under consideration. Thus, the calendars indicate the time needed for land preparation, planting, fertilizing of crops, weeding, and harvesting of crops. They also show the number of labor-days needed for each activity in the calendar, leading to the calculation of total labor requirements per enterprise. It also helps the programmer to be able to calculate the coefficient of the labor-days for each enterprise. The information used in preparing the crop calendar is mostly obtained from the Ministry of Agriculture.

Concept of Crop Budget in Building the LP Model

Crop budgets are prepared for each enterprise to ascertain information on input and output prices, cost of production, yields, and also, the level of input used. Mostly, these enterprise budgets are prepared on per acre basis. The essence of the crop budget is to guide the programmer or researcher on the economic information of the farmers in the study area, for instance not to overprice things or under-price things and also not to be given false information since most of these farmers don't keep proper records of their crop production activities.

The Basis for Selecting the Linear Programming Approach in Place of other Approaches

Extensive work has been conducted on the application of the LP model to agriculture and this is justified below to serve as a basis for choosing the linear programming model for this research. To achieve the aim of the study which is mainly to optimize the combination of food crop farm enterprises, the study employed the LP model and not the econometric model or gross margin analysis and farm budgeting due to the limitations of these techniques and the justification is that aside from the LP model, the others focused on a single-crop enterprise analysis and not a combination or multi-crop enterprise analysis, which is the main focus of this study and this is strongly justified below.

Aside the LP model which determines the farmer's decision making on determining the optimal crop patterns, the profitability of crop enterprises, as well as resource levels and constraints all at the same time, the alternatives to this research which are the econometric model, gross margin analysis, partial budgeting and policy analysis matrix, can only deal with on aspect of the stated objectives.

According to Singh and Janakiram (1986), econometric models have only dealt with a one farm output on the production side, leaving crop composition selections to chance. Also, econometric models lead to estimated elasticity, this is deceptive in terms of the creation of various approaches to a correction (Tibaijuka, 1994; De Janvry & Sadoulet, 1992). The econometric technique has also been employed to determine supply response, as well as to evaluate the influence of structural changes on agriculture and rural household and failed to capture the problems of imperfect knowledge and accountability mechanisms.

Farmers cannot maximize their profit cannot be realized without optimal crop patterns that maximize the use of available resources. (Hassan & Raza, 2005). Some farm planning problems are not feasible enough to determine the optimal farm activity level by employing the gross margin analysis, whole-farm budgeting, or partial budgeting. These techniques do not allow for possible combinations of crop farm activity or rigorous search for all combinations of activity level nor a systematic approach in determining the optimal combination of crop farm enterprises. Policy analysis matrix cannot be employed as the technique for this study since it aims at measuring the inter-regional relationship between production and movement of products and this doesn’t fall within the objectives of this study.

Linear programming model overcomes the limitations of the econometric model, partial or whole-farm budgeting analysis, and also policy analysis matrix as discussed above since it captures crop patterns of combinations of crop enterprises, the profitability of enterprises, and multi-crop enterprises activity which is predominant in the Ghanaian agricultural sector. In this era of crop diversification, planting a variety of crops has become a typical Ghanaian farm set up which helps farmers to hedge against uncertainties and increase their income. The application of linear programming technique is suitable for analysing this situation.

According to Howitt (1995), MP models are widely employed in the analysis of agricultural economic policy. These models can be modeled from a minimal data set with an objective function and constraints which encompass the environmental, resource, and policy constraints. Mathematical programming models are considered useful in assessing the impact of projects and the effect of new policies (Vergani & Bogahawatte, 1989).

Meanwhile, some studies have been conducted using other programming approaches other than the mathematical programming technique, such as the recursive programming model. With this approach, the data set are collected over a period of time, that is, from year to year since the farmers do not keep proper records of their farm activities and it is used to compare performance. Due to its numerous assumptions, there is a decrease in the validity of its result.

Empirical Literature

Empirical Literature on the Application of Kendall's Coefficient of Concordance

Yussif, Obeng and Zakaria (2015) used the Kendall Coefficient of Concordance to determine the farmers' willingness to pay for private irrigation in Ghana's Nandom District is limited. The amount of agreement among farmers in the ranking of limitations was determined using this method. Kendall's (W) indicated 0.596 (59.6%) farmers throughout the district agreed on their rankings.. This implies that 59.6% of the farmers agree among themselves that financial constraint is the most limiting and important among the other constraints identified to be unstable output price, costly private services, crop pests and diseases among others.

Anang, Adusei and Mintah (2011) used Kendall's Coefficient of Concordance to rank the constraints facing Ghana's cocoa sector reform. The results showed that pest and disease are the most limiting constraint, followed by long-distance transportation of beans, with the theft of beans being the least constraint. Kendall's Coefficient of Concordance (W) showed that 46% of the farmers agree to the ranking of the constraints. The significance of this test proves that F-calculated (23.60) was greater than the F-tabulated (2.15), which shows that there is a degree of agreement between the farmers concerning the ranking of the constraints.

Codjoe, Brempong and Boateng (2013) from the perspective of cocoa farmers in Ghana's Eastern Region, Kendall's coefficient of concordance was utilized to examine the restrictions facing the Cocoa-based Agriculture Knowledge Information System (AKIS). The study demonstrated that there was a 100% agreement among the various ranking constraints. This implies that cocoa farmers are in accord about the key limiting restrictions to the efficient operation of the cocoa-based economy Agricultural Knowledge Information System. The result revealed that engagement with researchers and extension agents is insufficient had the highest mean rank which was 4.57 with a few cocoa buying companies ranking the least among the fifteen constraints.

Anang, Zulkarnain and Yusif (2013) used Kendall's Coefficient of Concordance to rank the myriads of constraints confronting tomato farmers in the Wenchi Municipal District of Ghana. The study found out that tomato farmers in Wenchi face several constraints that limit their production and such constraints were identified to be low product price, lack of capital, and high cost of input among others. The result showed that lack of capital is the most pressing constraint, followed by high cost of production and low price. According to Kendall's coefficient of concordance, 39 percent of the farmers agree on the order in which the limits to tomato production should be ranked. At 5% significant, this test showed that the calculated F-value (31.3) was greater than the tabulated F-value (2.43) hence, the null hypothesis was rejected, and this implies that there was no agreement among the farmers.

Wie and Aidoo (2017) conducted a study on the sweet potato value chain's different linkages and product paths, as well as the restrictions of actors along the sweet potato value chain in Ghana to examine the various limitations imposed by actors, the Kendall's coefficient of concordance was utilized. Input providers, producers, collectors, distributors, retailers, processors, and consumers are the primary actors in the sweet potato value chain, according to the findings. At the processor level, the most restricting issues were found as a lack of operating capital, limited access to loans, and high perishability of produce.

Abdul-Rahaman (2016) conducted a study on the economic efficiency and restrictions of smallholder cotton growers in a few regions in Ghana's Northern Region Smallholder cotton farmers' limitations were detected and analyzed using Kendal's Coefficients of Concordance, as well as the amount of agreement among the ranks of constraints by cotton farmers. The results suggest inconsistent financial efficiency levels of smallholder cotton farmers. The most limiting constraints appeared to be poor seed cotton pricing, followed by late delivery of farm inputs, while lack of land access was placed as the least restricting barrier. According to Kendal's Concordance analysis, the ranks of the restrictions were roughly 87.4 percent in agreement.

Adanu, Kuwornu and Kwadzo (2019) conducted a study rubber production's financial feasibility in Ghana's Western Region's Ahanta West District. To examine the various limitations imposed by actors, the Kendall's coefficient of concordance was utilized. The study results revealed that high cost of labour was ranked most limiting constraint with a mean score of 1.67. The District's high labor cost is due to the District's prevalence of small-scale mining activities, which are deemed more lucrative than working on rubber plantations.

Empirical Literature on the Application of Linear Programming Model to Crop Farm Planning

For some time now, due to the increase in the need for an agricultural commodity as a result of population growth and industrialization, agricultural planning has been a key aspect of the agriculture sector with crop planning being an essential part of it. This component of agricultural planning (crop planning) depends on factors such as crop pattern, crop intensity, availability of land, labour, capital, fertilizer, among other factors. In agricultural planning, farmers face complex allocation problems and the LP model has proven to be a very flexible tool for modeling these kinds of complexities (Hazell & Norton, 1986). LP technique can be used to analyse both agricultural and non-agricultural situations, and some of the applications of this model analysis are reviewed below with their findings also presented in relation to the objectives of this study.

Bhatia and Rana (2020) used the LP model to analyse the cropping pattern in different districts of Rajasthan. The result of the study showed that, the income of the farmer increased by 68% (for farmer 1) and 16.4% (for farmer 2) as compared to the existing farm plans. The existing crop combination was identified to be wheat/mustard, wheat/peas, wheat/mustard/ black gram, wheat/mustard/fodder. The LP model is efficient in analysing crop combination and optimum profit as compared to the farmer's plan.

Adewumi *et al*. (2020) conducted a study on an optimal arable crop combination plans that would maximize the net returns of the smallholder farmers in Kaiama agricultural zone of Kwara State, Nigeria. The LP model was employed in this study and the result revealed that the optimal cropping plan was that the farmer should plant1.75 ha of maize/cowpea, 1.64 ha of maize/soybean, 1.40 ha of maize/yam and 0.70 ha of sorghum/soybean to obtain the maximize net returns. The optimal net return was 52.23% higher than that of the farmer's plan. Capital and labour was identified to be the most limiting resource constraints. Also, maize enterprise had the highest marginal opportunity cost while yam had the least.

Ndip *et al*. (2019) conducted a study on farm planning in Cameroon's Southwest Region for a short-term optimal food crop combination using the LP model as the farm planning tool. The result of the LP revealed that the optimum crop combination that gives the farmer the maximum profit were maize and cassava enterprises. Land and labour were found to be the limiting constraints with a shadow prices of $467.7 and $ 0.78 respectively.

Lone *et al*. (2014) used the model to demonstrate how a farmer with limited resource can obtain the optimum. The LP model revealed that the farmer should plant approximately 8.15 ha of corn and 33.70 ha of rice to get the maximum. Ahmed *et al*. (2011) also used the LP model to evaluate the distribution of available resources across the dominant crop combination's competitive field crops The findings demonstrated that investing more resources to the production of food legume crops, such as land, water, labor, and capital, would result in higher returns for tenants.

Haq *et al*. (2020) conducted a Cropping pattern optimization in the district of Hunza, Gilgit-Baltistan. In comparison to the farmer's plan, the LP model resulted in a 10.18 percent increase in net revenue income each year. Adewumi *et al*. (2020) used the LP model to find the optimum farm plans that would raise the income of smallholder cassava-based crop farmers in Kwara State, Nigeria. The result of the LP model revealed that the optimum cropping plan was that the farmer should produce a combination of cassava/maize, cassava/soybean and cassava/sorghum/groundnut on 0.4379 ha, 1.0886 ha and 0.6435 ha respectively to raise their income by 69.82%. Also, cassava/melon and cassava/groundnut had the least tendency to depress farmers' income if forced into the plan.

Ibrahim *et al*. (2019) conducted a study on optimum production plan for maize-based crop farmers in Niger State, Nigeria. The LP model was the farm planning tool used for this study. To earn the best gross profit, the farmer should plant maize/soybeans on 1.1988 ha and maize/cowpea on 0.0468 ha, according to the study's findings. In maize-based crop production systems in Niger State, it was established that production inputs were not effectively utilized and that crop combinations were in a better competitive position than a single crop to boost farmers' income.

Ogunbo (2015) used the LP model during the pepper production/planting season in 2010, researchers looked at resource efficiency and the best farm plan in Ogun State, Nigeria. According to the results of the LP model, the farmer should produce pepper/tomato and pepper/maize/cassava enterprises on a mean farm size of 0.25ha and 0.66ha, respectively, for the two enterprises. The optimum strategy increased the gross margin of the pepper/tomato enterprise by 115.47 percent and the gross margin of the pepper/maize/cassava enterprise by 31.62 percent, which was higher.

Majeke (2013) used the LP model to determine the best crop farm venture combination in Marondera, Zimbabwe. The result showed that the optimal cropping pattern resulting from the LP model is such that there was no production of maize and soya beans, but tobacco and potatoes showed acreage of 128% and 38% respectively. As a result of the optimal solution, the optimal income increased by 35% as compared to the farmers' plan.

Patel, Tharker and Chaudhari (2017) conducted a study in the Patan district of Gujarat, India, the linear programming model was utilized to predict the agricultural land allocation to major crops. The main aim of the study was to determine maximum production as well as maximum profit. The result of this study shows that the LP model obtained both maximum profit and maximum production. Also, the optimum crop patterns obtained were identified to be wheat, potato, summer bajra, rabi, kharifmung, and udad. Land constraint was identified by the LP model to be the most Limiting constraint.

Salimonu *et al.* (2008) employed the LP model for efficient resource allocation patterns for food crop farmers in Nigeria. The results of the study showed that the efficient crop patterns suggested were the cultivation of maize/yam and maize/vegetables. The optimum cropping pattern suggested a higher expected return than that of the farmers' existing plans. That was N31, 959.81 as net returns for the farmers' plans and N98, 861.24 as net returns for the linear programming model satisfying the objective of the study (Increased income).

Majeke *et al*. (2013) used the LP tool to model a small farm livelihood system in Bindura, Zimbabwe. The result of the LP technique was found to be superior to that of the farmers' plan as the difference between the gross income of the LP model and that of the farmers' plan was 44.65%. The cropping pattern under the LP model for this study suggested that the farm should produce 0.25 ha of maize, 2.34 ha of tobacco, and no production of soya beans and cotton to be able to arrive at a gross income of $12,295.10.

Sofi *et al*. (2015) employed the LP model in optimizing increased agricultural production of food crops, owing to better resource allocation and production planning efficiency. The result shows that the crop pattern identified by the LP model was for the farmer to plant 2.57 acres of wheat and 7.11 acres of other crops without producing rice, maize, and pulses to obtain the maximum profit.

Abdelaziz *et al*. (2010) obtained the optimal crop pattern in North Darfur State, Sudan by employing the LP technique and the result was different from that of the farmers' plan. Majeke (2013) applied the LP technique to the optimum combination of crop farm enterprises and obtained a crop pattern result different from the farmers' plan such that he produced 11.4 ha of tobacco and 5.51 ha of potatoes but no maize and no soya beans were produced and obtained a gross income of $86,047.75 which is higher as compared to the farmers' plan of producing 5 ha of tobacco, 10 ha of maize, 5 ha of soya beans and 4 ha of potatoes which earned him a gross income of $63,582.77.

Otoo *et al*. (2015) used the LP model to select the optimum crop combination for farmers drawn from 32 operation areas in the Eastern Region of Ghana. Thus, linear programming was used in determining the optimal crop combinations under different scenarios, given resource constraints, in order to maximize net farm returns.

Udo *et al*. (2015) used the LP and T MOTAD model to formulate for arable crop producers in Akwa Ibom State, Nigeria, optimal farm designs with child farm labor reduction were developed. The result revealed that capital was the most limiting resource and also farmers' existing plan was not optimal and there was an increase in the net return of the optimal plan due to optimization.

An LP model was used to model an optimal arable crop plan that minimizes child farm labor use in Ogun State, Nigeria. The result of the linear programming model showed that reorganizing the food crop enterprise plan might boost annual farm income by around 15.3% while reducing child farm labor in the state (Agbonlahor, Adeyemo, Bamire & Williams, 2009).

Mejeke *et al.* (2013) used the LP model in analysing a farm resource allocation problem using resettled farmers in Bindura, Zimbabwe as a case study. The result of the LP model as compared to the traditional method showed an increase in income of $35,784.00 and a percentage difference of 105.89 %. The strategy was that the farm should produce 28ha of maize, no production of soya beans, and no piggery project to achieve an income of $35784.00.

Bamiro *et al*. (2012) employed LP to optimal enterprise combination in cassava-based food crop farming systems in Nigeria and the result shows that two combinations contribute to the increase in the gross income of which the two optimal combinations were cassava/maize and cassava/maize/vegetable. LP was used to find an optimal enterprise combination for vegetable production under Fadama in North Central Nigeria. Their findings demonstrate that their best plan met 88 percent of their objectives (Ibrahim & Omotesho, 2011).

Igwe, Onyenweaku and Nwaru (2011) conducted a study on semi-commercial arable and fishery enterprises in Aba State in Nigeria using the LP technique. The LP technique was applied to determine the optimum enterprise combination using the 2009/2010 farm data. The result of the LP showed that due to crop optimization, cassava/maize/cocoyam was the dominating and only cropping pattern among the several selected arable crops. In addition, contrary to the farmers' plan of 0.64 hectares for cassava, maize, and cocoyam, the optimal recommendation is 2.58 hectares. There was an increase of 44.6 percent in the gross margin for the optimal plan over the existing plan.

Scarpari and De Beauclair (2010) also used the linear programming model to optimize agricultural planning for farmers in Piracicaba, State of São Paulo, Brazil. The result of the study revvealed that the Linear programming tool as an optimization planning model is a very useful farm planning tool and tends to increase the returns of operation with low additional cost.

Conceptual Base of the Study

The application of linear programming to agricultural production economics both at the micro-level and the macro-economic levels goes as far as the middle of the 20^{th} century. Since then, LP models have been employed in analysing and solving farm planning problems. Consequently, the application of the LP model to optimize a combination of food crop enterprises serves as a measure of improving the farmers' efficiency of crop production which in turn reduces poverty as farmers' earning capability is improved as well as their livelihood.

The Linear programming model is made up of three essential components and these are objective function, various enterprise combinations, and the constraints. The objective of the farmer as far as this study is concerned is to maximize gross margin but the farmer is faced with several constraints such as risk constraints, resource constraints, environmental constraints, and policy constraints among others. The basic resources available to the farmers are land, labor, capital, and fertilizer. The farmer is then faced with the decision of what kind of enterprises to combine and also how to allocate these limited available resources to these crop enterprises.

The farmer has two ways of doing this, one by relying on his past experiences, intuition or comparison with the neighbours which usually does not lead to an optimal result and oftentimes leads to uncertainties; and two, by the application of LP model which leads to optimization of crop enterprises and optimum allocation of resources which in turn leads to increase crop yields and further leads to increase in farm income.

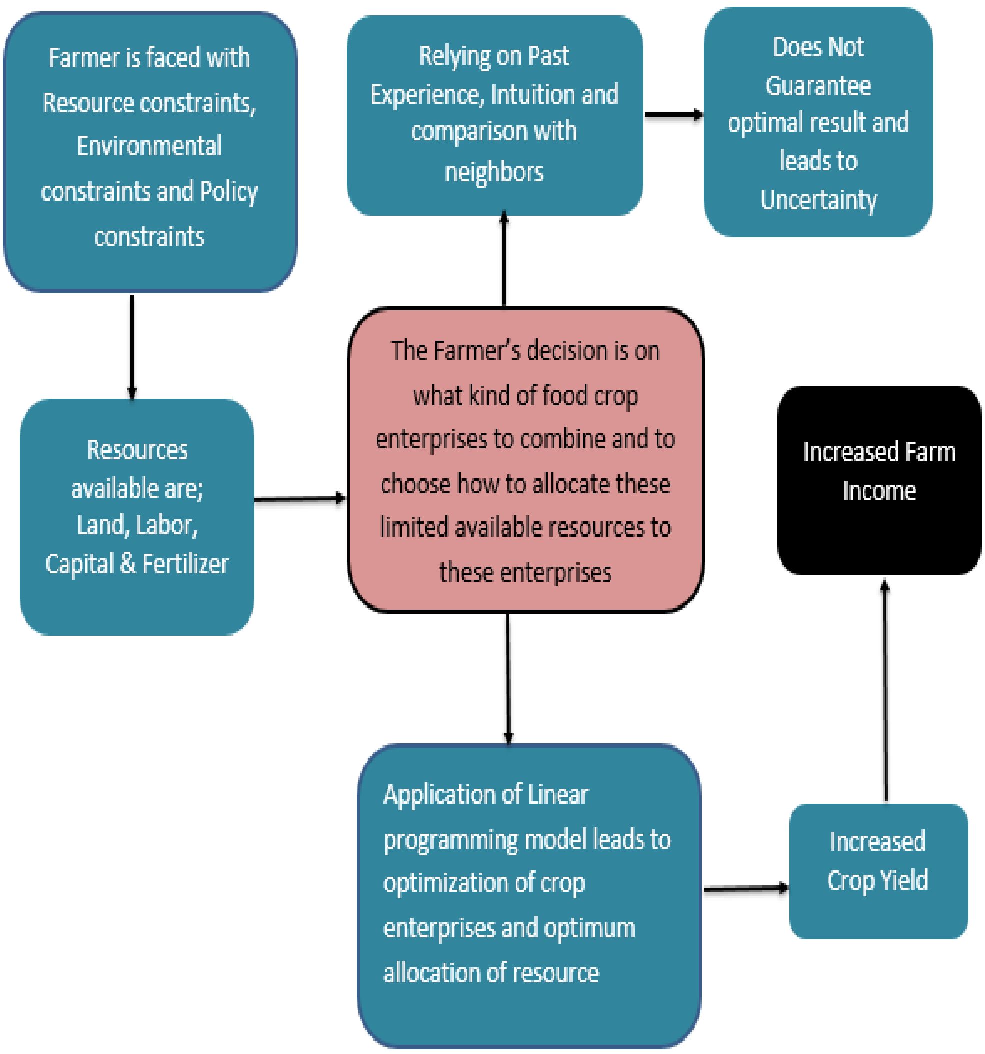

Figure 1: The Optimization Process Flow Chart
Source: Adapted from Majeke (2013)

Chapter Summary

This chapter reviewed relevant literature on concepts such as Crop calendar, crop budget, optimum crop combination as well as theories like optimization theory, rational choice theory and theory of constraint that underpinned the study. The chapter also reviewed the literature on some estimation methods like linear programming model and the Kendall's Coefficient of Concordance used in the research. While review on the history, uses and the assumption of the LP model complimented the review as other relevant topics.

CHAPTER THREE

RESEARCH METHODS

This chapter presented the research methods that were used in conducting the study and were organized as follows; research design, study area, population, sampling procedure, data collection instruments, data collection procedures and data processing, and analysis.

Research Design

A descriptive cross-sectional survey design was used in this study. This survey design involves asking respondents questions and also taking information from a sample to be a representative of the entire population. The design is essential in this study because it helps in planning resource allocation (needs assessments) since that is what the study is about. Also, data on all variables is only going to be collected once. This survey design is relatively quick and easy to conduct (no long periods of follow-up). Despite the strength of this survey design, it is susceptible to due to low response rates, there is a risk of bias and misclassification as a result of recollection bias. The study followed the positivism research philosophy and it uses the quantitative research approach.

Study Area

The study was conducted in Assin North district in the Central Region of Ghana. Ghana Statistical Service (2017) indicates that the Assin North Municipal Assembly (A.N.M.A) is among the twenty (20) MMDA's in the Central Region of Ghana out of which Assin South District Assembly was carved in August 2004. Assin North Municipal is made of Longitudes 1 0 05'

East and 1 0 25' West, and latitudes 6 0 05' North and 6 0 4' South make up the northernmost part of the Central Region. Adansi East (in the Ashanti Region) on the north, Upper Denkyira on the north-west, Twifo Heman Lower Denkyira on the west, Assin South District Assembly on the south, Asikuma Odoben-Brakwa on the south-east, and Birim North (in the Eastern Region) on the east are all within the Municipality's boundaries. The Municipality has a total land area of approximately 1,188 square kilometers.

The population was 161,341 according to the 2010 Population and Housing Census, and with an annual growth rate of 2.9 percent, the predicted population for 2016 is around 191,530. (Females make up 51% of the population, while males make up 49%.) (GSS, 2013). Agriculture (farming), wholesale/retail trade, agro-processing, and tourism are the main economic activities of the municipality (Ghana Statistical Service, 2017).

Figure 2: Map of Assin North District of Ghana
Source: Ghana Statistical Service, 2014

Source of Data

Both secondary and primary data were used for the study but primary data was predominant. A well designed and pre-tested questionnaire with both open-ended and close-ended questions were administered to three hundred and ninety-seven smallholder food crop farmers from Assin North District to answer, and that was used to provide information as a source of primary data. The number of smallholder food crop farmers were obtained from extension offices in the district that was used for the study. The secondary data used for this study was crop calendar and crop budgets obtained from SRID of the Ministry of Food and Agriculture, Ghana.

Population

The target population for the study was all smallholder food crop farmers in the Assin North district. The household population for Assin North district is 161,341 and that of farmers that engage in food crop farming is 49,800 (Ghana Statistical Service, 2014). The target population (49,800) comprised of people from diverse cultural and educational backgrounds, different gender, and age.

Sampling Procedure

The sampling procedure is a process used to select the sample from a target population. The target population was 49,800 smallholder food crop farmers in the Assin North District (GSS, 2014). However, it was difficult to get information from the total farm households in the Assin North Municipal due to the challenges the researcher faced in getting access to the whole population. As a way of addressing this challenge, Saunders, Lewis and Thorn hill (2007) suggest the formation of a sample from the population. Therefore, the sample size was determined using Yamane's statistical sample size determination. Yamane (1967) provides a simplified formula that was used to estimate the appropriate sample size for this study. This is presented in the equation below:

$$n = \frac{N}{1+N(e)^2} \qquad (1)$$

Using the above expression, n = sample size, N is the population size, and e is the level of precision (error margin: corresponds to 95% confidence level) and 1 is a constant term. Thus, according to Ghana Statistical Service

(2014), the population size of food crop farmers is estimated to be about 49,800. Therefore, the sample size for the study was calculated as follows;

$$n = \frac{49{,}800}{1+49800(0.05)^2} = 396.8{\sim}397 \quad (1.1)$$

Multi-stage sampling technique was the sampling technique used for the study. The first stage involved purposively selecting Assin North District. The reason is that Assin North District has high number of smallholder farmers and also studies such as Larkai (2019) and Codjoe *et al.* (2013) have shown that there has been under production of food crop that has affected the revenue maximization of these farmers as well as their welfare. Therefore, if we are supposed to develop a farm planning model for farmers then Assin North District of Ghana cannot be overlooked.

The second stage involved listing all the fifteen farming communities in the Assin North District and randomly selecting eight farming communities using the lottery method. The eight farming communities selected were Assin Senchiem, Assin Breku, Assin Achiano, Assin Akropong, Assin Juaso, Assin Atonsu, Assin Awsem, and Assin Endwa which represented more than half of the fifteen farming communities. With the third stage, a list of food crop farmers who were identified with the assistance of the village heads and the extension agents in each of the farming community were randomly chosen from the eight selected farming communities in Assin North District. Therefore, out of the three hundred and ninety-seven questionnaires administered to the farmers, 360 were filed. However, the 360 represents more than 90.8% of the estimated sample size and as such can be a representative of the population for smallholder food crop farmers in the Assin North District.

Data Collection Instruments

This study employed a structured questionnaire and direct measurement where necessary, as the instruments for the data collection:

Structured Questionnaire

The structured questionnaire was the data collection instrument used and was developed based on the objectives and literature review of the study. A well-structured questionnaire was developed and pre-tested to solicit information from the respondents. A pre-test of the questionnaire was carried out to check the validity of the instrument, to ensure that the questions were clear enough to answer without difficulty and also ensure that the time used to answer them was not unduly long. Also, both close and open-ended questions were posed to the respondents. The open-ended questions were posed to enable the respondents to express their views on some important aspects of the study whereas the close-ended questions allowed for the respondents to select from a restricted set of answers.

The questionnaire was in two sections, that is A and B. Section A was on socio-economic characteristics of the respondents such as educational background, age, marital status, occupation, and size of household. This was followed up by section B which comprised of production information such as types of crops grown, size of land, and ownership of the land.

Validity and Reliability

In testing the validity of the instrument, the researcher sent a copy of the instrument to his supervisor to review the content of the instrument and also check the types of items in the instruments to see if it truly measured the contrast of interest. A pilot data collection using the structured questionnaire was also carried out two weeks before the actual administration of the structured questionnaire. Ten smallholder crop farmers were each selected from six agricultural farming communities that were not included in the actual study and this was used for the pilot data collection that served the purpose of the face and content validity.

In terms of the reliability of the instruments, the Cronbach's alpha was used to test the internal consistency of the instrument. This provided an assessment of items redundancy; the extent to which items on a scale are assessing the same content (Cohen & Swerdlik, 2005). The reliability of the instruments was accepted because the Cronbach's alpha was more than 0.70.

Measurement

In the instance of crop combination, the average number of each crop was determined per hectare or acre yield and applied to the total hectares or acres of the mixture. The current or prevailing market price was used to determine the potential gross margin. A harvested and consumed crop was also estimated.

Data Collection Procedure

After the questionnaire was accepted and approved by the supervisor, the instrument was administered directly to smallholder food crop farmers; some on their farms while others in their houses to achieve the objectives of the study. Two extension agents were selected from each of the farming communities in the district, with two well-trained enumerators, who were hired to help the researcher in the data collection using the questionnaire.

The questionnaires contained a cover letter on the top page that explained the assurance of anonymity, nature of the study, confidentiality, and the fact that participation is voluntary since the study was solely for academic purpose. The enumerators helped the respondents who could not read and write by filling it for them and explaining it in their local dialect (fantse) in the form of an interview. The data collection for the study took one month. This occurred in the month of February 2020.

Data Processing and Analysis

The data was processed using R statistical software package version 4.0.0 and IBM Statistical Package for Social Sciences (SPSS) software version 25.0. The data analysis was done according to the research questions. Descriptive statistics and linear programming were used in the analysis of the data.

Descriptive statistics such as frequencies and graphs were used to address research question one, whiles Kendall's coefficient of concordance was used to address research question two. Also, research question three to six were addressed using the linear programming model to ensure food crop enterprises combination for sole crop and mixed crop and also maximize the gross margin of food crop farm enterprises.

Model Specification

Theoretical Model Specification

The theoretical basis for analysing the optimum combination of food crop farm enterprises rests on Dantzig's linear programming model (Dantzig, 1947). The model was formulated to be used for planning problems in the US Air Force. This work was adopted and expanded to cover farm planning problems in the agricultural sector by several economists such as Ibrahim and Omotesho (2011), Majeke (2013) and Larkai (2019).

The Linear Programming model with an objective function, decision variables, and constraints as used by these economists provides the empirical model for this study. The central idea behind the linear programming model is that there should be an objective function be it maximization of profit, maximization of subsidy, or minimization of cost which provides direction for the model. There should also be decision variables and constraints (both functional constraints and non-negativity constraints).

In Majeke's (2013) revised framework, the LP model was developed to address resource allocation problems whereby the objective function was to maximize net income through optimal crop enterprise combination subject to resource constraints. The crop enterprises used in this model were Tobacco, Maize, Soya Bean, and Potatoes. Also, the objective function was subject to constraints which were land, labour, and capital. These variables were measured as follows; land (Hectares), Labour (Man-days), and Capital (dollars). The model suggested no production of maize and soya beans of which the optimal solution increased income. The results showed that the LP model was worth putting into practice.

The analysis in this study follows a slightly modified version of the LP model by Majeke (2013). The LP model employed by Majeke (2013) is elaborated in equation 2:

$$\max Z = \sum_{j=1}^{n} c_j x_j \qquad (2)$$

In equation 2, (Max Z) is called the objective function, Z is the value of the total gross income, x_j is the decision variables and represent the level of j^{th}activity (j=1…, n), the decision variables (x_i) were Tobacco, Maize, Soya

Bean, and Potatoes in this study. c_j is a performance measure coefficient or the gross income per unit of the j^{th} activity ($).

Equation (3):

$$\textbf{Subject to:} \sum_j^n a_{ij}x_j \leq b_i \qquad (3)$$

$$\forall_i = 1, \dots n$$

In equation 3, b_i is the supply level of the i^{th} resource, thus the amount of resource (i) available (i=1…, n), and in this study the resources available to the farmer were land (ha), labour (Man-days), and capital ($). These were the resources available to the farmer. a_{ij} is the amount of resource (i) consumed by each unit of j^{th} activity. Thus, the i^{th} resource required per unit of the j^{th} activity. The decision variables are x_j and the parameters are c_j, b_i, a_{ij}.

The assumption backing the LP model was that both the objective function and constraints in the model are linear. It also follows the certainty assumption which states that the objective function coefficient, the constraint's right-hand side, and the technological coefficient are known with certainty.

Estimation Technique

Analytical Framework

This study seeks to find the optimum combination of food crop enterprises among smallholder farmers and their limiting resource constraints, employing the mathematical technique known as linear programming. Although, estimation of profitability, crop combinations, and finding the limiting constraints can also be done using the recursive programming model, gross margin analysis, whole, and partial farm budgets as well as policy analysis, however, there are some limitations associated with these techniques.

The recursive programming model has some limitations that make it impossible to use. The reason is that with this approach, data set are collected over a period of time and that is from year to year and since this study is conducted within a year, it makes it difficult to use. Also, because farmers do not keep proper records of their farming activities, it is difficult to even collect data to formulate this model. Moreover, its numerous assumptions also decrease the validity of the result thereby making it difficult to use it.

Gross margin, partial and whole-farm budget analysis, are also difficult to be employed in this study as they focus on a single-crop enterprise analysis rather than a combination of crop or multi-crop enterprise analysis, which is the main focus of this study. Also, these approaches are not able to determine the optimal level of some farm planning problems such as rigorous and systematic combinations of crop enterprises to obtain the optimal solution.

The present study has opted for the linear programming model in view of the fact that the model overcomes the limitations of the other estimation techniques discussed above. Thus, the LP model captures the crop pattern of the various food crop enterprises, the combination of crops that yields that optimal profit, the limiting constraints, and also the certainty assumption coupled with the linearity assumption makes it possible to use the LP model for this analysis.

Empirical Model Specification

Following the previous studies, particularly Majeke (2013) and the theoretical as well as empirical literature reviewed above, the present model has a slight adjustment to cover for minimum food crop combination required. Since the objective of the farmer is not only about profit maximization, but food security and other subsistence farming issues among others, this study incorporated minimum food crop combination into the model to address these issues. This was done based on a special case of the LP model whereby the infeasible (Non-basic activity) is introduced into the model to address the issue stated above.

Therefore, mathematically, the LP model for this study is formulated as follows:

$$\text{Max Z} = \sum_{j=1}^{n} c_j x_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Objective function)} \quad (4)$$

Subject to:

$$\sum_{j=1}^{m} a_{ij} x_j \leq b_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \left(Resource\ Constraints \right) \qquad (5)$$

$$\forall_i = 1, \ldots m$$

Minimum food crop combination:

$$\sum_{j=1}^{n} k_{ij} x_j \geq w_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \left(Min. food\ crop\ combination \right) \qquad (6)$$

$$\forall_i = 1, \ldots n$$

This can be written as:

$$\text{Maximize } \pi = c_1 x_1 + c_2 x_2 + \ldots + c_6 x_6 \qquad (7)$$

Subject to:

(Resource Constraints)

$$x_1 + x_2 + x_3 + \cdots + x_6 \leq b_1 \text{ (Land constraint)} \qquad (8)$$

$$a_{2,1} x_1 + a_{2,2} x_2 + \cdots + a_{2,6} x_6 \leq b_2 \text{ (Labour constraint)} \qquad (9)$$

$$a_{3,1} x_1 + a_{3,2} x_2 + \cdots + a_{3,6} x_6 \leq b_3 \text{ (Capital constraint)} \qquad (10)$$

$$a_{4,1} x_1 + a_{4,2} x_2 + \cdots + a_{4,7} x_6 \leq b_4 \text{ (Fertilizer Constraint)} \qquad (11)$$

$$x_1, x_2, x_3, \ \ldots \geq 0. \text{(Non –negativity constraint)} \qquad (12)$$

Minimum Food Crop Combination:

$$k_{1,1}x_1 + k_{1,2}x_2 + \cdots + k_{1,n}x_n \geq w_n \text{ (food crop combination)} \quad (13)$$

Where,

Z =Value of the Maximum gross margin. This value of profit is restricted by some constraints such as land, labor, capital, and fertilizer as well as the minimum food crop combination known as the infeasible solution which was also introduced into the model by the researcher due to reasons such as food security and subsistence farming among others.

c_j= Profit coefficient of the objective function Z. It is the gross margin per unit of the j^{th} activity (Ghc).That is the vector of the known matrix coefficient.

x_j= is the vector of variables to be determined. Thus, x is called the decision variables and represent the level of the j^{th}activity, where (j=1….,n). The decision variables were identified to be maize (bags), cassava (tonnes), plantain (bounces), cocoyam (bags/basket), rice (bags), garden eggs (bags).

a_{ij} = is the amount of resource (i) consumed by each unit of j^{th} activity. Thus, it is the i^{th} resource required per unit of the j^{th} activity. Also known as the coefficient of the functional constraints equations.

b_i = is the supply level of the i^{th} resource, where (i=1…, n). Thus the maximum limit of the resource constraints available to the farmer. The resource constraints are land (acres), labour (Man-days), capital (GhC), and Fertilizer (kg/acre).

k_{ij}= is the coefficient of the food crops that did not enter the optimal crop pattern. Depending on the kind of combination the researcher wants to look at, the coefficient of the other food crops will be set to zero (0) since that is not the interest of the researcher.

w_i= is the total minimum food crop that the farmer can produce to address the issue of food security and subsistence farming.

Systematic Approach in Modeling the LP Model for this Study

The researcher set up the inequalities describing the problem. This has been stated and described above. The researcher then proceeds to calculate the objective function coefficients (c_j). This was done by calculating the average gross margin out of the total gross margin of each crop enterprise to represent the per-unit gross margin of the crops.

The coefficient of the various constraints(a_{ij}) will be the next thing to calculate. This was also done by calculating the averages of the total value of each constraint such as the average of land size (acres), the average of labor days, the average of capital (GhȻ) and the average of fertilizer (kg/acre) allocated to each crop enterprise to be the coefficients of the constraints for each food crop enterprise. Calculate the average total value of various constraints and that will be the (b_i). Thus, calculate the total value of say land size and then find the average of the total land size.

The researcher then numerically inputs the known values into the model then used the R statistical software version 4.0.0 to run the model. This is known as the initial analysis, whereby the value for the maximum gross margin and the optimum crop pattern is obtained.

The second scenario is to incorporate the minimum food crop combination into the model. This is done by introducing a combination of food crops that did not enter the optimal solution known as the non-basic activity into the model to see its impact on the maximum profit and also to address food security and subsistence farming issues.

The third scenario is to check the robustness of the model by performing the sensitivity analysis. This is done to check if the model can stand changes in the farming season and also to test the ability of the model to withstand shocks. Therefore, the value of the two most limiting constraints will be doubled to check the impact it will have on the model.

According to Winston (1995), the goal of any linear programming issue is for the decision-maker to optimize some function of the decision variables, which is referred to as the objective function. The LP model is created with factors like resource endowment, limits, activities, and consumption requirements in mind.

The Linear programming model is made up of an objective function, constraints, and non-negativity restrictions and its purpose under this study is to maximize the total gross margins of food crop enterprise combinations. The gross margin is then given as total revenue per acre less total variable cost. Also, the coefficients of the objective function are the contributions of the enterprises to the farmers' profit.

Gross Margin

Under this study, in building the LP matrix for the study, the first step was to calculate the gross margin per acre of each farm enterprise. Dent, Harrison, and Woodford (1986), noted that the gross margin of activity is revenue from that activity less than the variable costs incurred in obtaining that revenue, which is usually expressed in per acre terms. Mathematically the gross margin is specified as;

$$\pi = \sum_{i=1}^{n} PY - C \tag{14}$$

$$i = 1,2, \dots \dots . . n, where\ n\ is\ the\ number\ of\ crop\ per\ arce$$

Gross margin is also known as net agricultural returns. The variables P, Y, and C represent the price per unit, the yield in units per acre, and the cash cost (or total variable cost) in Ghana Cedis per acre respectively. Gross margin can be treated in two ways with regards to the LP matrix; it can be entered into the linear programming matrix directly or be broken down into its components (costs and returns).

Kendall's Coefficient of Concordance

Kendall's coefficient of concordance was used to rank the various constraints to know which of the constraint the most limiting constraint to the farmer is. Although, there are ranking methods like the Garret ranking method, Freedman ranking and Spearman ranking method. However, the Kendell's coefficient of concordance was used because of it small asymptotic variance that makes it efficient and small gross error sensitivity that makes it more robust. The Kendall's Coefficient of Concordance is a non-parametric statistical procedure used to identify a given set of constraints, from the most limiting to the least limiting constraints and to measure the degree of agreement among the respondents.

The resource constraints which were identified to be land, labour, capital, and fertilizer were ranked from the most limiting constraint to the least limiting constraint using numerals (1, 2, 3, and 4). The resource restriction with the lowest score was ranked as the most restricting constraint, while the resource constraint with the highest score was ranked as the least restrictive. Kendall's Coefficient of Concordance was calculated using the total rank score

(W). This comes to confirm the solution generated by the LP model concerning the limiting constraints. It was used to address objective two of this study.

Therefore, Kendall's coefficient of concordance according to Anang *et al* (2013), is algebraically presented as follows;

$$W = \frac{12[\sum T^2 - (\sum TP)^2/n]}{nm^2(n^2-1)} \qquad (15)$$

Where, W= Kendall's Coefficient Concordance, T= Sum of ranks for the resource constraints being ranked, m = Total number of respondents (farmers), and n= Total number of constraints being ranked.

The Kendall's Coefficient Concordance (W) was then tested for significance in terms of the F-distribution. The F-ratio is presented as follows;

$$F = [(m-1)W/(1-W)] \qquad (16)$$

From Edwards (1964), the degrees of freedom are given as:

$$\frac{(n-1)-(^2/_m)}{m-1[(n-1)-2/m]} \qquad (17)$$

Test of Hypothesis

The following null hypotheses were tested.

H_0: Farmers do not agree on the ranking of the constraints to show the most limiting constraint pertaining to the study area.

H_1: There is an agreement between the rankings of the resource constraints.

Summary Chapter

The chapter focused on the methodological issues that were studied and used in the research. The chapter describes the research design, research approach and the positivism research philosophy that underpinned the study. There were also descriptions of the study area, thus, Assin north district and processes used for developing quantitative research tools. The section also describes the target population to be smallholder food crop farmers in the study area. The study employed structured questionnaire as the data collection instrument and the data was analysed using SPSS version 25.0 and R statistical software version 4.0.0

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents the results and discussion of the analyses that were performed to meet the objectives of the study. The analysis was divided into three main parts. These included descriptive statistics of the socio-economic characteristics, ranking of constraints, and followed by the analysis of the LP model as it has been stated in the objectives.

Descriptive Statistics

Socio-Economic Characteristics of Respondents

Descriptive statistics were performed on the socio-economic characteristics of the respondents on their gender, age, education, and also off-farm activity. Table 1, presents the socio-economic characteristics and the results showed that 84.44% of the respondents are male while 15.56% are female. This implies that food crop production in the study area is mostly male-dominated. The reason being that the cultural setting in Assin North district grants males easy access to both acquisition of lands and production input that gives them an upper hand in farming than females. This concurs with findings of studies such as Igwe and Onyenweaku (2013) who reported that there are more males in agricultural production than females in the Umuahia Agricultural Zone of Abia State in Nigeria. Other studies such as Larkai (2019) also reported that small-scale farming is usually dominated by males while the females are mostly into processing, harvesting, and marketing.

Age determines how the farmer is able to handle risk and also how innovative he is. Therefore, the ability of the farmer to perform manual work decreases as the age of the farmer increases. 84.44% of the respondents are above the age of 40 years. This implies that there is little involvement of the youth in food crop farming activity probably due to the fact that most of the youth are in school and also engage in off-farm activities other than farming.

With regards to education, majority of the farmers (42.2%) in the study area had attained primary education. Nobody had attained tertiary education whiles 17.8% of the farmers had had no education at all. Very few farmers (17.8%) were also recorded to have attained vocation, technical and secondary education. This implies that with the majority of the farmers having basic education coupled with vocational and secondary education, it will help them access information easily and also adopt and apply new technologies such as application of the LP model. This reflects the findings of Igwe and Onyenweaku (2013), who reported that the average farmer in Umuahia Agricultural Zone of Abia State is relatively literate. Studies such as Owusu-Amankwah (2018) and Larkai (2019), contradicts the findings of this study, as they report that majority of the farmers are illiterate.

Farmers' involvement in off-farm activities provides them with capital in the absence of capital borrowing to finance farm activity and also to supplement household income. The majority of the farmers (97.8%) interviewed reported that they do not engage in off-farm activities. It shows that they have fertile lands to farm on all year round and also their main source of finance comes from their farming activities.

Table 1: The Socio-Economic Characteristic of Respondent

Characteristics	Frequency	Percentage
Age		

≥40	304	84.44
<40	56	15.56
Total	360	100
Gender		
Male	264	73.3
Female	96	26.7
Total	360	100
Education		
No school	64	17.8
Primary school	152	42.2
MSLC/JHS	80	22.2
SHS/Technical/Vocation	64	17.8
Tertiary	0	0
Total	360	100
Engagement in Off-Farm Activity		
Yes	8	2.2
No	352	97.8
Total	360	100

Source: Field Survey, Koufie (2020)

Summary Statistics on the Socio-Economic Characteristics

From Table 2, it is shown that the average household size is 6.60 which was higher than that of the Region 4.4, slightly higher than that of the national average 5.1 which was obtained in the 2010 National Population Census (GSS, 2013). This implies that this large family size will probably help reduce the labour cost of the farmers. This is in line with studies such as Igwe and Onyenweaku (2013) and Effiong (2005) who also reported that large family size increases family labour which in turn reduces labour costs in agricultural production. The mean average age of the respondents is 48.5years and that of the mean average experience is 23.3 years.

The average land size owned by the farmers was 4.84 acres (equivalent to 2 hectares). This concurs with the studies of Agbonlahor *et al*. (2009) in Ogun State, Nigeria and also the report of the Ministry of Food Agriculture, which maintains that agriculture in Ghana is predominantly on smallholder basis and that 90% of land holdings are less than 2 hectares in size (MOFA, 2017). This is contrary to the findings of Larkai (2019); Makate *et al*. (2016) and Asante *et al*. (2017) who recorded that the average land size for smallholder farmers was higher than 2 hectares.

Table 2: Summary Statistics on the Socio Economic Characteristics

Variable	Minimum	Maximum	Mean	Std. Deviation
Age	33	70	48.53	8.115
Household Size	3	12	6.60	1.839
Experience	12	45	23.33	7.116
Size of Land Owned	10	2	4.84	1.665

Source: Field Survey, Koufie (2020)

Identification of the Existing Crop Pattern or Crop Combination in the Selected Farming Areas

The major crop types identified in the study area are maize, cassava, plantain, cocoyam, garden eggs, and rice among others. This is in line with what was recorded in the 2010 National Population Census Report (GSS, 2013). Table 3, shows the various crop combination or crop patterns that the farmers in the study area operate, the number of occurrences, and the number of respondents under the category. From Table 3, three crop combinations have the highest number of farmers which is 152 (42.2%). This is contrary to studies by Larkai (2019) who recorded two crop combinations as the highest level of crop combinations with 124 farmers (41%) and Dembele (2018) who recorded four crop combination as the highest level of crop combinations with (40%) of farmers from the sample. The difference is based on the fact that cropping patterns or combinations differ in regions on the basis of area strength of individual crops, cultural, climatological and agronomical criteria.

Table 3: Summary Classification of the Existing Crop Pattern

Crop Combination	Number of Different Crop Occurrences	Number of Respondents
One Crop Combination	0	0
Two Crop Combination	38	136
Three Crop Combination	40	152
Four Crop Combination	16	48
Five Crop Combination	8	16
Six Crop Combination	8	8
Total	**110**	**360**

Source: Field survey, Koufie (2020)

Optimal Crop Combination and Resource Allocation

From Table 4, the result of the farmers' plan indicates that; the farmers' plan are to cultivate approximately 0.6 acres of maize, 0.4 acres of cassava, 0.5 acres of plantain, 0.2 acres of cocoyam, 0.2 acres of garden eggs and 0.2 acre of rice to obtain an average gross margin of GH¢7,688. This result differs from studies conducted by Antwi (2016) and Larkai (2019) in the Northern Region of Ghana which revealed that the existing plan of the farmers are to produce 1.1 acres of Maize, 1 acre of cassava, and 0.38 acres of millet, 0.92 acres of groundnut, 1.52 acres of rice, 0.76 acres of cowpea respectively. The differences in the crop patterns is based on the fact that crop patterns differs on the basis of the strength of individual crops, region and culture of the farmers.

The Optimal plan from the initial LP scenario as illustrated in table 4 indicates that the farmers should produce approximately 2.70 acres of plantain and 2.66 acres of rice while not planting any cassava, maize, cocoyam, or garden eggs to attain a maximum income of GH¢ 14,011.70, "all other things being equal". With this optimal plan, the farmer earns more income of GH¢ 14,011.70 than as suggested by the farmer's plan which is GH¢7,688 (an increase of GH¢6,323.7) and the farmer is able to save 1.64 acres of land and 2.57 kg of fertilizer. Studies conducted by Darfor (2000) in the Central Region of Ghana indicated that the initial analysis of the LP scenario revealed that the farmer should produce 2.1 acres of maize, 3 acres of garden eggs and an acre of a combination of maize, cassava, plantain, and cocoyam while not planting cassava and plantain as a single crop enterprise which is different from the initial plan of this study.

The second scenario for the LP optimal plan which is the minimum requirement illustrated in Table 4 shows that a minimum production of an acre of cassava was introduced into the model due to other objectives of the farmer that is substance farming and food security issues and the result shows that a combination of 1 acre of cassava, 1.48 acres of plantain and 2.69 acres of rice was the optimal cropping plan to realize a maximum income of GH¢12,042.10. The result further revealed that there had been a decrease in the land size allocated to plantain and a slight increase in that of rice. Thus, a decrease of more than an acre which led to a reduction in the income by GH¢1,825.27 and a slight increase in rice which led to an increase of income by GH¢144.33. This attests to the fact that since the marginal value of cassava is -1825.27, which means an acre of cassava produced will reduce the maximum income by GH¢1,825.27 as it has been stated earlier on. This is in line with studies by Larkai (2019), Mejeke *et al*. (2013), and Darfor (2000).

The third scenario is to carry out sensitivity analysis or the "what if" analysis. This analysis was undertaken to check the stability of the model in case of any changes or shocks on the model. From Table 4, hired labour was doubled holding all other parameters constant whiles satisfying a minimum requirement of cassava production. Although family labour cannot be increased but hired labour can, the latter is common in many rural communities and also was one of the most limiting constraints after capital. It then becomes necessary to make it available to the farmers to see its effect on the LP model. The result showed that the optimal cropping plan under this scenario was that, the farmer should produce an acre of cassava, 5.33 acres of plantain, and 0.67 acre of rice to realize a maximum income of GH¢14,778.40. "All other things being equal", this makes economic sense since plantain is not all that capital intensive but rather labour-intensive, it makes economic sense that there is the need to increase plantain production.

The production of rice reduced since rice production is capital intensive. Therefore, doubling hired labour without not equally increasing the amount of capital available to the farmer will mean to reduce the production of rice. Since hired labour comes with additional cost and it forms a greater percentage of the total cost of the farmer, it is certainly going to reduce the existing capital available to the farmer, leading to a reduction in the production of rice. The income increased due to the fact that labor comes with a cost, even though labor does not operate in isolation, therefore, doubling labour with land available will lead to an increase in the yield of the enterprises thereby leading to an increase in the income. This is backed by the optimization theory.

Studies conducted by Darfor (2000), whereby hired labor was increased from 30% to 60% had no change in the LP model. This is due to the fact that labour was not the most limiting constraints in that model but rather land, therefore, increasing labour without increasing land which was the most limiting constraint will have no effect on the model because labour was in abundance and is not a constraint if varied in isolation. Thus, increasing labour without land to farm on will have no effect on the model.

Table 4: Comparison of the Existing and Optimum Farm Plans as Suggested by both the Farmer and LP Model on Small Holder Farms

Farmer's Plan/ LP Scenarios		Optimal Values of Decision Variables (Acres)					
Crops	**Maize**	**Cassava**	**Plantain**	**Cocoyam**	**Garden Eggs**	**Rice**	**Gross Margin**
Farmer's Plan	0.60	0.40	0.50	0.10	0.20	0.20	7688
Initial Analysis	0.00	0.00	2.70	0.00	0.00	2.66	14011.7
Minimum Requirement	0.00	1.00	1.48	0.00	0.00	2.69	12042.1
Sensitivity Analysis	0.00	1.00	5.33	0.00	0.00	0.67	14778.4

Source: Field Survey, Koufie (2020)

Resource Utilization Under the Optimal Solution for Smallholder Farm as Suggested by the Linear Programming Model

From Table 5, the initial analysis on resource utilization indicates that 5.36 acres of land were used whiles 1.64 acres of land were left unused. Capital and labour were all used up while 255.4 kg of fertilizer were also used leaving behind 2.6 kg of unused fertilizer. This is contrary to studies such as Igwe *et al*. (2015) and Larkai (2019), whereby capital was the only limiting resource whiles resources such as land, labour and fertilizer had been underutilized. Also, Igwe and Onyenweaku (2013) noted that labour was the only limiting resource whiles the marginal value product of land was zero. Studies such as Ibrahim and Omotesho (2011) also noted that land and insecticide were the most limiting resources whiles labour and fertilizer fully utilized, which is different from the result obtained by this study. Babatunde *et al*. (2007) also The only limiting resource in achieving the best farm plan in sweet potato cropping system for farmers in the Offa Oyun Local Government Area of Kwara State is capital, according to the study. This discrepancy in the limiting resource constraints is due to the fact that limiting constraints are area, culture, farmer group, and region-specific. Thus, what might be the most limiting resource to one farmer group might not be for the other farmer group or region.

On the side of the minimum requirement, where an acre of cassava was introduced into the model, some amount of capital was left unused. The left-over capital approximately amounts to GH¢133.2 and the acres of land unused also increased from 1.64 acres to 1.83 acres of land. This makes economic sense since plantain which was part of the optimal cropping plan reduced more than an acre and cassava not being capital intensive resulted in capital not being fully utilized. The optimum gross margin reduced to GH¢12,042.10, whereas the reduction was caused by the shadow cost of the cassava crop being introduced into the optimum cropping plan. This is contrary to studies by Larkai (2019), who introduced maize as a minimum consumption into the optimum cropping plan and still had all the capital being fully utilized.

With regards to the sensitivity analysis, after doubling hired labour which is measured in man-days, all the acres of land and capital were fully utilized and 215 man-days of labour were left unused whiles 194 kg of fertilizer was also left unused. Also, since cassava does not necessarily need fertilizer, it will not be necessary to apply any fertilizer to the cassava enterprise. This will cause the labour days to increase since fertilizer and chemicals like agrochemicals and weedicides can be used for operations such as weeding which in turn will render labour days unused. This is backed by rational choice theory.

Table 5: Resource Utilization under the Optimal Solution for Smallholder Farmers Suggested by the Linear Programming Model

Resource		**Initial Analysis**		**Minimum Requirement**			**Sensitivity Analysis**		
	Available	Usage	Left Over	Avail.	Usage	Left Over	Avail.	Usage	Left Over
Land	7.00	5.36	1.64	7.00	5.17	1.83	7.00	7.00	0.00
Labor	300	300	0.00	300	300	0.00	600	385	215
Capital	4490	4490	0.00	4490	4356.8	133.2	4490	4490	0.00
Fertilizer	258	255.4	2.60	258	258	0.00	258	64	194

Source: Field Survey, Koufie (2020)

The Most Limiting Constraints according to Kendall's Coefficient of Concordance

Kendall's coefficient of concordance was used to find the most limiting constraints among the resource constraints. From Table 6; Land, labour, capital, and fertilizer were the resource constraints identified in the study area. The resource constraints were ranked on a scale of 1 to 4, with 1 being the most limiting constraint and 4 being the least limiting constraint. In the course of the analysis, the farmers' responses were averaged to obtain the mean rank for each constraint. From Table 6, the most limiting resource constraint is capital constraint with a mean rank of 1.34 and the least resource constraint is land with a mean rank of 3.51. Lack of capital was found to be the most limiting constraint to the majority of the farmers in the study area.

Kendall's coefficient of concordance was used to determine the level of agreement between the ranks and the Chi-square test was used to test the significance of the constraints at 0.05 significance level. 55.1 percent of the farmers consider capital constraint to be the most limiting constraint in the study area, followed by labour constraint with a mean rank of 2.57. This is in line with studies such as Yussif *et al*. (2015) who reported that financial constraint is the most important constraint to the farmer's readiness to pay for private irrigation. This is backed by the theory of constraints.

Other studies such as Thuysbaert *et al*. (2011), showed that lack of capital was a major reason for non-adoption of technology in Africa. The studies of Ayoade and Akintonde (2012) also concur with the findings of this study; which revealed that unstable market price and inadequate finance are the two most limiting constraints to the adoption of agricultural development.

Table 6: Ranks of Resource Constraints in Order of Importance

Resource Constraints	Mean Ranking	Rank
Land Constraint	3.51	4
Labor Constraint	2.57	2
Capital Constraint	1.34	1
Fertilizer Constraint	2.58	3

Source: Field Survey, Koufie (2020)

Sample size (n) =360; Number of constraints ranked= 4; df= 3; Rank1= most limiting constraint; Rank 4= least limiting constraint; Kendall's W= 0.551; chi square (x^2)= 7.815; Level of sig= 0.05.

From Table 7, it can be seen that the gross margin obtained by the initial analysis of the LP model was GH¢ 14,011.70 which is 82.25 higher than that of the farmer's income. This is in line with studies such as Salimonu *et al*. (2008) who also employed the LP model for efficient resource allocation patterns for food crop farmers in Nigeria. The optimum cropping pattern suggested a higher expected return than that of the farmer's existing plans. Majeke (2013) used the LP model to determine the optimum combination of crop farm enterprises in Marondera, Zimbabwe. As a result of the optimal solution, the optimal income increased by 35% as compared to the farmers' plan.

Scarpari and de Beauclaire (2010) also used the linear programming model to optimize agricultural planning for farmers in Piracicaba, State of São Paulo, Brazil. The result of the study showed that the Linear programming tool as an optimization planning model is a very useful farm planning tool and tends to increase the returns of operation with low additional cost. Majeke *et al*. (2013) used the LP tool to model a small farm livelihood system in Bindura, Zimbabwe. The result of the LP technique was found to be superior that of the farmer's plan as the difference between the gross income of the LP model and that of the farmer's plan was 44.65%.

The consumption requirement of cassava when introduced into the model lowered the optimal gross margin to GH¢12,042.10 as compared to the initial analysis of the LP result but was 56.63% higher than that of the farmers' plan. This is substantiated by studies such as Larkai (2019), who introduced consumption of maize as a requirement into the model and also recorded 30% increased income as compared to farmer's income. Studies such as Otoo *et al*. (2015) also reported that strategies obtained by the LP model increase the gross margin of farmers by a certain percentage.

With regards to the sensitivity analysis, after doubling the labour days, it led to an increase in the gross margin to GH¢ 14,778.40 which is 92.22% increase in income as compared to the farmer's plan. This is in line with studies such as Igwe *et al*. (2011), who reported that a unit increase in the labour days by one man-day leads to gross margin increasing by 0.26% of the obtained gross margin. Contrary to this study, Darfor (2000) doubled labour days in her analysis to optimize the maize-based farming system in the Central Region of Ghana but it had no effect on the gross margin. The reason is that labour cannot operate in isolation and also, labor was not a limiting constraint in that study.

Table 7: Comparison of the Level of Gross Margin by both the Farmer and the Linear Programming Model

Farmer's Plan/ LP Scenarios	Gross Margin (GH¢)	% increase in Farmer's Plan
Farmer's Plan	7688	-
Initial Analysis	14011.7	82.25
Minimum Requirement	12042.1	56.63
Sensitivity Analysis	14778.4	92.22

Source: Field Survey, Koufie (2020)

Sensitivity Analysis

The sensitivity analysis or the "what if" analysis, allows you to draw attention to any changes in the value of the goal objective that may occur as a constraint is eased or tightened (Mellaku *et al*., 2018). This analysis was undertaken to check the robustness and the stability of the model in case of any changes or shocks on the model. Thus, to check the stability of the model, some production variables such as capital and labour were varied and observed. These production variables were chosen on the basis that they were the two most limiting resources to the farmer according to the results obtained by both the LP model and the Kendell Coefficient of Concordance. Both labor and capital were doubled to see the effect on the model, following the findings of some researchers such as (Darfor, 2000; Majeke, 2013; Igwe & Onyenweaku, 2013; Larkai, 2019).

Effect of the Sensitivity Analysis on the LP Model by Doubling the Size of Capital

Capital as a production variable was doubled whiles satisfying the initial requirement. From table 8, the result indicates that the optimal land size used was approximately 5.36 acres whiles 1.64 acres of the available land was left unused. Labour and fertilizer were fully utilized but about GH¢4,501 out of the GH¢8,980 of the available capital was left unused, which is approximately 49.88% of the total capital doubled. This led to an increase in the gross margin by approximately 82.41% as compared to the farmers' plan or the base model. This is in line with studies such as Nedunchezhian and Thirunavukkaras (2007), Majeke *et al.* (2013), Otoo *et al.* (2015), and Larkai (2019)

Table 8: Effect of the Sensitivity Analysis on the LP Model by Doubling the Size of Capital

Resource	Land	Labor	Capital	Fertilizer	Gross Margin
Available	7	300	8980	258	
Usage	5.36	300	4501	258	
% Usage	76.60	100	50.12	100	
Left Over	1.64	0.00	4479	0.00	
%Left Over	23.40	0.00	49.88	0.00	
% Increase of Farmer's Plan					82.41

Source: Field Survey, Koufie (2020)

Consumption Requirement for Different Food Crop Combinations if the Farmer decides to farm this Crop Mix

The objective of the smallholder farmer is not only about profit maximization but also takes into consideration food security issues, subsistence issues, and also wealth accumulation (Mlambiti, 1985; Ali-Olubandwa *et al*., 2010). Subsistence farming issue and food security, among other objectives of the farmer, makes it difficult for the smallholder farmer to channel all his/her available resources into producing the optimum food crop combination to attain the maximum income. There is therefore the need for alternative food crop combinations. These alternative food crop combinations which are also known as the excluded activity or non-basic activities refer to the crop combination that did not enter the optimum solution.

These food crops, if forcefully introduced into the model, will reduce the optimum gross margin by its marginal opportunity cost or its income penalties. From Table 9, the alternative food crop combination that recorded the lowest gross margin was Maize/ Cassava/ Plantain/ Garden Eggs/ Rice with a reduced gross margin of GH¢9,153.94 and the excluded activity that recorded the highest level of gross margin was Maize/Plantain/Rice with a gross margin of GH¢13,018.00. This is contrary to studies such as Udo *et al*. (2015), who recorded three crop enterprises such as Maize/Cassava/Millet as the excluded activity with the lowest income whiles the LP model for this study recorded Maize/Cassava/Plantain/garden Eggs/Rice as the excluded activity with the lowest gross margin.

Studies such as Igwe *et al*. (2011) also recorded two crop combinations such as yam/melon as the excluded activity with the lowest propensity to depress income whiles fish is reported to have the highest propensity to depress income in Ohafia Agricultural Zone, Abia State, Nigeria. As stated earlier, Table 8 shows the alternative food crop combination, its percentage reduction, and also it reduced gross margin as compared to the optimum gross margin.

Table 9: Consumption Requirement for Different Food Crop Combinations and Gross Margin

Alternative Crop Combinations	Gross Margin (GH¢)	% Decrease in Optimum Income
Plantain/Rice(LP-OPTIMUM)	14,011.70	-
Maize/Plantain/Rice	13,018.00	7.09
Cassava/Plantain/Rice	12,042.10	14.05
Cocoyam/Plantain/Rice	12,537.70	10.52
Garden Eggs/Plantain/Rice	11,990.20	14.43
Maize/Garden Eggs/Plantain/Rice	11,135.50	20.53
Maize/Cassava/Plantain/Rice	11,036.60	21.23
Maize/Cocoyam/Plantain/Rice	11,532.20	17.70
Cassava/Garden Eggs/Plantain/Rice	10,154.40	27.53
Cocoyam/Garden Eggs/Plantain/Rice	10,655.00	23.96
Maize/Cassava/Plantain/Garden Eggs/Rice	9,153.94	34.67
Maize/Cocoyam/Garden Eggs/Plantain/Rice	9,649.53	31.13

Source: Field Survey, Koufie (2020)

Chapter Summary

This chapter presented the results and discussed the findings of the study. The chapter was introduced to reflect the content of the chapter. The socioeconomic characteristics of food crop farmers' in the study areas was presented in a tabular form. The results of the crop combination pattern, existing and optimum farm plans, resources utilization, and ranking of the resource constraints was also discussed. The last part of the chapter also looked at the consumption requirement for different food crop combinations and gross margin.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter deals with the summary of findings in relation to the study. This is followed by conclusions drawn from this study and the result from other studies. Needed policy recommendations are made to policymakers and future researchers with regards to the way forward in dealing with resource allocation problems and the optimum combination of food crop enterprises.

Summary

The general objective of the study was to determine the optimum combination of food crop enterprises using the LP model, which will give the farmer the maximum profit higher than the farmer's plan. Its specific objective includes examining the various enterprise patterns for food crops operated by the farmers in the Assin North District, compare existing and optimum farm plans for farmers with regards to resources allocation, analyse the farmers' resource utilization pattern and constraint in their farms. Lastly, to compare the gross margin of the LP and that of the farmer's, carry out sensitivity analysis on the limited resource constraints, and also look at the effect of the alternative combinations on the gross margin.

The crop enterprise pattern as determined by the LP model shows that the farmers in the study area practise crop combination that is mostly three crop combination as well as two and four crop combination.

Under the existing plan, the farmers' plan was to plant 0.6 acres of maize, 0.4 acres of cassava, 0.5 acres of plantain, 0.2 acres of rice, 0.2 acres of garden eggs and 0.1 acre of cocoyam to realize a profit of GhȻ7,688 whiles for the optimal result, the LP model showed that the farmer should plant 2.7 acres of plantain and 2.66 acres of rice to realize a maximum profit of GhȻ14,011.70 which is higher as compared to the existing plan.

Under the farmer's plan, farm resources were not fully utilized as shown in their resource levels whiles in the LP model resources were fully utilized. Also, resource constraints such as land, labour, capital, and fertilizer were ranked using Kendall's Coefficient of Concordance, to know the most limiting constraints that the farmer is facing. It was realized that the most limiting constraints were capital followed by labour, fertilizer, and lastly, land constraint. Kendall's W showed that 55.1% of the farmers in the study area agree that capital is the most limiting constraint followed by labor.

Comparing the gross margin of the three LP scenarios which are the initial analysis, minimum crop combination as well as sensitivity analysis to that of the farmer's plan, it can be seen that the LP model gives higher gross margin compared to that of the farmer's plan.

Sensitivity analysis was also carried out to check the stability of the model in the face of any shock to the model. In this study, the sensitivity analysis was carried out on the two most limiting constraints, which were capital and labour and these were doubled to see their effect on the model. It was revealed that after both capital and labor were increased the gross margin increased by 82.41% and 92.22% respectively, as compared to the farmer's plan.

Alternative food crop consumption requirement was also provided by the model in case the farmer does not want to produce the optimum crop mix which was found out to be plantain and rice. The farmer could then rely on these alternative crop combinations which are different combinations of maize, cassava, plantain, rice, cocoyam, and garden eggs. These alternative combinations reduced the gross margin of the farmer compared to the base model but satisfy the other objectives of the farmer which are subsistence issues and food security among other objectives of the farmer.

Conclusions

The main objective of this study was to develop an optimum food crop mix with the help of a linear programming model that will help the farmers in the Assin North District to combat the resource allocation problem. The farmers are faced with limited available resources such as land, labour, capital, fertilizer among other constraints coupled with choosing the right kind of food crops to combine in order for them to achieve the goal of maximizing gross margins. The farmers usually rely on their intuition, compare with their neighbours, or sometimes rely on past experience which does not guarantee the optimal results and often leads to uncertainty when they resort to this traditional approach.

The results shows that, three crop combinations was the most practised crop combination in the study area with maize/cassava/plantain being the dominant among the rest. Comparing both the existing plan and that of the LP model, the optimal cropping plan as suggested by the LP model revealed that the farmer is better off using the LP model than relying on his intuition and past experience as this does not guarantee optimal results. This is substantiated by their incomes as it clearly shows that the LP model gives the farmer a higher income than that of the farmer's plan.

The results of the linear programming model employed in this study shows that resources were fully utilized compared to the existing plan of the farmer. The LP result further showed that capital and labour are the most limiting constraints. This substantiates the findings of Kendall's Coefficients of Concordance, which was used to rank the constraints in this study and it also revealed that 55.1% of the farmers agree that capital is the most limiting constraint followed by labour. On the basis of the gross margin obtained, the LP model was realized to be more efficient than that of the farmer's plan. In effect the farmer earns more profit if he uses the LP model.

The study also concludes that the model was robust to changes in capital and labour in the sensitivity analysis. Planting alternative crop combination such as cassava, maize, cocoyam and garden eggs alongside the optimum cropping plan enables farmers to achieve other objectives (ie. subsistence farming as well as food security issues).

Recommendations

Based on the findings and the conclusions of the study, it is recommended that farmers should adopt crop combination system to reduce production risk and to ensure income stability. Farmers should also adhere to the optimum cropping plan which was identified by the LP model as plantain and rice, if they want to make maximum profit. In addition, the LP model ensure resources utilization.

The Department of Agriculture in the Local government with the help of MoFA should train extension agent on how to apply the LP model to help farmers solve resource allocation as well as crop mix problems. Thus, extension officers should be very well equipped with the needed information that will help the farmer, concerning having access to certain information such as input prices, output prices and the need for the farmer to sell his produce at the market price to be able to achieve the maximum income suggested by the LP model.

Capital was found to be the most limiting constraint followed by labour in this study, of which the sensitivity analysis performed proved that increasing capital will increase the gross margin of the farmer. Therefore, the government through other corporations and financial institutions should provide credit in a form of capital to enable farmers increase their productivity and income since capital was the most limiting constraint. Also, agricultural development banks and credit institutions in the rural communities should be increased so that most of these farmers can have access to credit facilities to help them purchase the needed farm equipment necessary to help speed up their work and be more efficient.

Also, farmers should channel their resource to produce the optimum crops to get the maximum profit. However, due to subsistence issue, farmers could adopt three crop combination (ie. Maize/Cassava/Rice) since it has the lowest propensities to reduce income and also addresses subsistence issue.

Suggestion for Future Research

Future researchers should note that resource constraints are area specific. The reason is that what might be constraints in one area might not be limiting constraints in another area. Also, the LP model should be treated at the stochastic level to take care of the risk constraints since agriculture is a risky venture.

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APPENDIX

INTERVIEW SCHEDULE

UNIVERSITY OF CAPE COAST

COLLEGE OF AGRICULTURE AND NATURAL SCIENCES

SCHOOL OF AGRICULTURE

DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

Questionnaire Number ……………….. Serial Number……………….………

Name of District………………………Town/Village.…………………………

Name of Respondent…………………… Tel. Number………………………

FARMER BASED QUESTIONNAIRE

THE PURPOSE OF THE QUESTIONNAIRE AND CONSENT

This questionnaire is designed to assess information from farmers in the Central Region of Ghana on the various types of crops grown, various combination of crops, and resource allocation on farm fields in order to develop farmer making decision systems in Ghana. I would be very much appreciative of your participation in this survey. I would like to ask you some questions related to the production information and factors influencing farming decision. This will take you about 15 minutes to complete and also Participation in this survey is voluntary and you can choose not to answer any individual question or all of the questions. However, I hope that you will participate in this study since your views are important.

SECTION A: SOCIOECONOMIC CHARACTERISTICS OF THE FARMER

1. Age (as at last birthday) ……………………………………….... years
2. Gender of farmer
   a. Male [ ] b. Female [ ]
3. Marital status:
   a. Single [ ] c. Divorced [ ]
   b. Married [ ] d. Widowed [ ] e. Separated [ ]
   f. Others (specify)……..…..………
4. Level of Education:
   a. No school [ ] c. MSLC / JHS [ ]
   b. Primary School [ ] d. SHS/ Technical /Vocational [ ]
   e. 05= Tertiary [ ] f. 06= others (Specify)………..…………
5. How many people make up the household?..…………………………....
6. Composition of Family
   a. Adult Males……………………………………………………..………
   b. Adult Females ……………………………………...…………………
   c. Children (under 18)……………………………...…. ……………
7. Is farming your major occupation? a. Yes [ ] b. No [ ]
8. Number of years in farming …………………………………..(Number)
9. Do you have any occupation other than farming?
   a. I don't have any [ ] c. Private [ ]
   b. Civil Servant [ ] d. Other (Specify)…………………
10. Do you engage in any off -farm activities? a. = Yes [ ] b. No [ ]

11. If yes to Q9., how much of the total income of your household comes from outside the farm? (indicate percentages) ....

12. What is your religious affiliation?

a. Christianity [ ] c. Traditional [ ]

b. Muslim [ ] d. Others [ ]

SECTION B: PRODUCTION INFORMATION

13. Land Ownership:

a. Owned land [ ] c. Share Production [ ]

b. Lease [ ] d. Government [ ]

e. Others(Specify) ……………………..….…

14. If Share Production from Q12, please indicate the type of agreement

....

15. What is the size of land owned? ……………………. acres/hectares

16. Size of land Cultivated ………………………………. acres/hectares

17. Cost of rented land (GHS) ……………………………………………

a. Averagely, how many hours per day do you work on the farm? …………………………….hrs

b. How many days per week do you spend working on your farm? ……days

What other types of crops are grown and their share of land?

Types of Crops Grown	Land Area Under Cultivation
Maize	
Cassava	
Plantain	
Cocoyam	
Vegetables	
Others(specify)………………………	

18. What is the major source of labor for your farming activities?

a. Family [ ]

b. Hired [ ] c. Other (specify) ………………………………….....…

19. Crop farming activities and labor requirements for the production season.

Types of Crops Grown	**Unit of Measure -ment**	**Share of Labour (No. of Worker)**	**No. of Hired Labor**	**No. of Hours Per Day**	**No. of Days Per Week**	**Cost Per Day GHS**	**Total Amount per Month for Hired Labor**
		Male	Female				
Maize	Bags						
Cassava	Tonnes						
Plantain	Bounces						
Cocoyam							
Vegetables							

20. Do you keep records of farm activities? a. Yes [ ] b. No [ ]

21. Is crop production in this area rain-fed or irrigated?

a. Rain- fed [ ] c. Both [ ]

b. Irrigated [ ] d. ……......... (If both, indicate relative proportion.)

22. What types of inputs do use? When are they applied during the season? (**Variable Input**)

Items	**Type**	**Amount Used(Kg/Acre)**	**Value (GH₵)**
Seed			
Fertilizer			
Chemicals			
Others(Specify)			

23. Do you have access to the following farm implements /equipment (access includes both ownership and renting)? (**Fixed Input**)

Farm Implements	**Responses**
Hand hoe	a. Yes [ ] b. No [ ]
Cutlass	a. Yes [ ] b. No [ ]
Knapsack Sprayer	a. Yes [ ] b. No [ ]
Others (Specify):	a. Yes [ ] b. No [ ]

24. Please list the farming equipment owned and their costs. Please indicate the quantity, cost price per unit, year of purchase, life span (year) and salvage value of the following capital items.

Farm Implement	**Quantity**	**Cost Price Per unit**	**Total Cost (GH₵)**	**Year of Purchase**	**Life Span (Year)**	**Salvage Value (GH₵)**
Hand hoe						
Cutlass						
Knapsack Sprayer						
Watering Can						
Others(Specify) ………………						

25. For the rented equipment, indicate the rental cost.

Farm Implement	**Quantity**	**Rental Cost (GH₵)**
Hand hoe		
Knapsack Sprayer		
Watering Can		
Others (Specify)………………		

26a. Do you have access to ready market? a. Yes [ ] b. No [ ]

26b. If yes to (a), state the distance from your farm to the market centre?

……………….................… miles ………….............……hours.

26c. Where do you market your output?

a. On the Farm [ ]

b. Local Market [ ]

c. Delivered to Retailers/ Wholesalers [ ].

27. What was your yield and benefits for the past production year?

Crops Grown	Land Size Cultivated (Acres)	Quantity Harvested (Bags/Kg)	Quantity Sold (Bags/Kg)	Unit Price GH₵
Maize				
Cassava				
Plantain				
Cocoyam				
Vegetables				
Others…… ……………..				

28. What is your source of finance? (**Choose all that apply**)

a. Self-financing [ ]

b. Family/friends [ ]

c. Bank loan [ ]

d. Farmer group/co-operatives [ ]

e. NGOs [ ]

f. Other (Please Specify) ………...............………….................………..

29. If your application was approved, how much did you receive?

a. GH₵………...………………

b. At what interest rate?.......................................……………per annum

30. Do you have any contact with the following?

Type Of Institutions	Did You Have Access to These Institutions?	No. of Contact Times in the Season
Farmer Based Organisation Name:	a. Yes [ ] b. No [ ]	
Extension Services	a. Yes [ ] b. No [ ]	
CEDECOM	a. Yes [ ] b. No [ ]	
Other, Specify ……………….....	a. Yes [ ] b. No [ ]	

31. On a scale of **(1- 4)**, rank the various constraints by assigning 1 to the most pressing constraint and 4 to the less pressing constraint to you the farmer?

a. Labor Constraint **[ ]**

b. Land Constraint **[ ]**

c. Capital Constraint **[ ]**

d. Fertilizer **[ ]**

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

Crop Combination Grown	Reasons for Growing this Kind of Combinations
2.	
3.	
4.	
5.	

33. Do you apply fertilizer on your farm? a. Yes [ ] b. No [ ]

33a. What type(s) of fertilizer do you apply?..

33b. How much did you spend on purchase and application last major season?

i. Quantity bought of each type……………......................…………………

ii. Unit price of each type ……………….......................………………cedis

iii. Cost of application ………...…cedis

34. Crop farming activities and fertilizer requirements for the production season

Crops/Crop Combination Grown	**Share of fertilizer Requirement Kg/Acres (Hectares)**
Maize	
Cassava	
Plantain	
Cocoyam	
Vegetables	
Others	

35. Crop Farm activity and capital requirements for the production season

Crops/Crop Combination Grown	**Share of Capital Requirement for each crop enterprise GH₵/Acres (Hectares)**
Maize	
Cassava	
Plantain	
Cocoyam	
Vegetables	
Others	

36. Please feel free to tell us any comment you have in relation to production of this food crop enterprises?

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