ANALYSIS OF FARM ENTERPRISE COMBINATIONS UNDER RISK AND LIMITED RESOURCE CONDITIONS AMONG SMALLHOLDER FARMERS IN KWARA STATE, NIGERIA

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ABSTRACT

Optimal combination of farm enterprises through efficient allocation of existing resources in smallholder agricultural production in Nigeria has remained evasive occasioned by low literacy levels and production inefficiencies. This study derived optimum farm enterprise combination patterns under risk and limited resource conditions among smallholder farmers in Kwara State, Nigeria. Multi-stage sampling procedure was used to select a total of 384 smallholder farmers involved in crop, livestock and/or fishery enterprises from the four Agricultural Zones in the state. Data were collected through limited cost-route approach with interview schedules and structured questionnaire. Data were analyzed using descriptive statistics, farm budgeting technique, LP and T-MOTAD models and Kendall's non-parametric test statistics. A total of 91% of the respondents were males, 89% married, 78% had formal education and only 14% had access to agricultural credit. A typical farmer in the study area was 50 years old, had household size of 9 persons and had 18 years farming experience. The study identified 31 crop enterprises, 3 fishery enterprises and 14 livestock enterprises giving a total of 48 farm enterprises in the area. Results show that cassava/maize/okra with gross ratio of 0.20 for crop enterprises; catfish/fingerlings with gross ratio of 0.35 for fishery enterprises; and sheep and cattle/sheep with gross ratios of 0.31 and 0.31 for livestock enterprises were the most profitable. LP results prescribed enterprise combination of millet on 1.1420ha, maize/cowpea on 0.1587ha, maize/groundnut on 0.0718ha, maize/soybean on 0.3331ha, cassava/sorghum/groundnut on 1.1957ha, maize/sorghum/soybean on 0.8317ha, 0.6037TLU of broiler, 0.0137TLU of cockerel, 0.0064TLU of broiler/layer and 0.2782TLU of goat respectively in the optimum plans, while 1.1420ha of millet, 0.2406ha of maize/groundnut, 0.0613ha of sorghum/groundnut, 1.0000ha of maize/sorghum/soybean, 0.6028TLU of broiler, 0.3121TLU of cockerel and 0.1282TLU of cattle respectively were prescribed under the limited resource condition plan. A set of feasible risk efficient farm plans I, II and III were obtained with the T-MOTAD model. The plan I prescribed millet on 1.1288ha, rice on 0.2969ha, maize/cowpea on 0.0010ha, cassava/sorghum/groundnut on 0.1241ha, maize/sorghum/soybean on 1.0097ha, 0.0555units of catfish, 0.0983units of catfish/fingerlings, 0.1266TLU of layers, 0.5029TLU of cockerel and 0.2597TLU of cattle respectively. Plan II prescribed 1.0980ha of millet, 0.0408ha of rice, 0.1014ha of maize/cowpea, 0.0619ha of sorghum/yam, 0.1927ha of cassava/sorghum/groundnut, 0.4267ha of maize/sorghum/soybean, 0.5998TLU of broilers, 0.4838TLU of cockerel, 0.0353TLU of cattle, 0.0296TLU of goat and 0.0121TLU of sheep, while plan III prescribed millet on 1.1420ha, rice on 0.0719ha, maize/groundnut on 0.6545ha, maize/sorghum/soybean on 0.2436ha, 0.0013units of catfish, 0.6025TLU of broiler, 0.0004TLU of layer, 0.5482TLU of cockerel, 0.0005TLU of cattle and 0.0020TLU of sheep. Capital was the major limiting resource across all the plans for the farm enterprises. Gross margin increased from ₦228,597.90 in the existing plan to ₦582,711.40 and ₦516,863.10 in optimum plans I and II respectively and to ₦547,169.80, ₦478,763.40 and ₦412,647.10 in risk efficient plans I, II and III respectively. Farm enterprise gross margin was more sensitive to variation in the prices of output than other variables. Mixed farm enterprises were in a better competitive position than sole farm enterprises in the optimum and risk minimized plans. A typical smallholder farmer in the study area has the potential to realize more profit per unit enterprise in the optimum and risk efficient farm plans. Limited capital, facilities, high cost of credit and farm inputs, low and unattractive prices for farm produce, inadequate cooperative support were the major constraints faced by the smallholder farmers. The study concluded that farm enterprises were profitable in Kwara State but farmers were not efficient in their level of resource allocation. The study recommends that farmers should reallocate resources at their disposal in line with the derived optimum and risk efficient farm plans towards attaining maximized farm profit.

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ACRONYMS

GDP	Gross Domestic Product
FAO	Food and Agriculture Organization
QP	Quadratic Programming
LP	Linear Programming
MOTAD	Minimization of Total Absolute Deviation
WPR	World Population Review
OECD	Organisation for Economic Co-operation and Development
MP	Mathematical programming
QRP	Quadratic Risk Programming
T-MOTAD	Target Minimization of Total Absolute Deviation
KWSMANR	Kwara State Ministry of Agriculture and Natural Resources
GM	Gross Margin
NFI	Net Farm Income
TLU	Tropical Livestock Unit
MOC	Marginal Opportunity Cost
MVP	Marginal Value Product

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Agriculture has contributed immensely to the economic, sociological and cultural needs of Nigerians as it provides food, raw materials for agro-based industries as well as income to the farmers (Sani *et al.,* 2013). Foraminifera Market Research (2012) observed that Nigeria have an advantage in the agricultural sector compared to other countries in the world given the favourable climatic condition, good soil structure and a very large arable land mass which supports the production of varieties of crops and rearing of animals.

Igwe *et al.* (2011) stated that food crop farmers who engage majorly on arable crops constitute about 95 percent of the aggregate food crop farming units in Nigeria producing about 90 percent of the food output. Food crop production has remained a major component of all production activities in Nigeria agricultural sub-sector parading a large array of arable crops that include cassava, yam, maize, rice, sorghum, millet, cowpea, soybean, groundnut, sugarcane, potatoes, cocoyam, cotton, pineapple, banana, plantain among others as reported by Akande (2005) and Foraminifera Market Research (2012).

Ojiako and Olayode (2008) argued that the livestock industry as a vital segment of the general agriculture is a significant contributor to the growth and development of the economy any country as it has the capacity for providing food, employment, farm energy, manure and revenue for the farmers and even the government. Ogunniyi and Ganiyu (2014) reported that livestock production in Nigeria constitutes 6% of the total Gross Domestic Product (GDP) and 25% to the agriculture sector over the last two decades. The authors further reported that there are about 1 million heads of sheep and 7 million goats in the sub humid region of the country representing 3% and 16% respectively of the total ruminant animals in the region.

The importance of fisheries in the food sector is seemingly on the increase as the knowledge and understanding of the positive effects of fish consumption on human health and well-being grows. Fishery industry has continued to contribute to the incomes and livelihoods of substantial portions of the global population especially among the rural poor (Ibeun, 2017). As reported by Food and Agriculture Organization (FAO) (2014), African countries as at 2012 contributed 1,485,367 million metric tonnes to world aquaculture production of 66,633,253 million metric tonnes, that is, 2.23 %. Nigeria is one of the leading fish producing countries in Sub-Saharan Africa with a domestic production of about 800,000 metric tonnes of culture fish (Akinsorotan *et al.*, 2019). It is crucial to understand that in Nigeria, fish farming is undertaken by small-scale operators in small freshwater ponds as reported by Nwabeze *et al.* (2015).

Smallholder farmers are the backbone of many economies around the world, as they provide a vital source of incomes for the rural poor. These farmers are characterised with limited level of resources and are faced with the challenge of competing choices for allocating these limited farm resources between crop and animal enterprises. The farmers' ultimate aim is to make efficient allocation and utilisation of the limited farm resources at their disposal and combining farm enterprises optimally so as to attain production objectives as affirmed by Ohajianya and Oguoma (2009) and Igwe *et al.* (2015).

Agricultural planning has become an important task due to the increasing population and the demand for agricultural commodities. Sofi *et al.* (2015) opined that the increasing population and agricultural commodity demand has created a need to also increase production so as to meet up with the demand. The authors further argued that the field of agricultural economics which involves planning scientifically for agricultural development has become an important and special area of interest for specialization in that it provides vital information for agricultural planning such as optimal farm plans towards achieving maximum profit using optimization methods. Farm planning according to Sarker and Quaddus (2002) is the most important factor of agricultural planning.

The limited resources available to the smallholder farmers can be efficiently allocated only through proper farm planning guided by proper scientific planning tools for agriculture (Udo *et al.,* 2015a). The authors also opined that smallholder farmers have two alternative decision criteria in farm planning. The first one is to allocate resources in a way to maximize farm profit, while the second one is to allocate resources in such a way that utility will be maximized by striking a balance between increasing expected income and minimizing variability to reflect risk behaviour. Risk has been defined as a pervasive phenomenon, a product of hazard and vulnerability in any economic activity which is particularly important in traditional agriculture where it affects production decisions and adoption of technology among others (Adubi, 1992; FAO, 2003; Ayinde, 2008; Ayinde *et al.,* 2016).

Mathematical programming as an optimization tool for studying the economic aspects of farm management has contributed immensely to agricultural development as its techniques such as the deterministic linear programming model has been used to study the problems of resource allocation among farmers. It provides prudent solutions to whole farm planning problems (Reddy *et al.,* 2004). Other mathematical programming tools such as the quadratic programming (QP) and linear programming with minimization of total absolute deviation (LP/MOTAD) models as seen in the works of Umoh (2008), Salimonu *et al.* (2008), Udo *et al.* (2015a) and Udo *et al.* (2015b) are the most recent and common techniques applied to risk-return analysis in the agricultural economics literature particularly in Nigeria. In the present stage of development, the focus is on incorporating risk into farm planning model to derive integrated optimum farm enterprise combinations that will offer more realistic solutions and increase farm income for the smallholder crop, livestock and fishery farmers in Kwara State, Nigeria.

1.2 Statement of the Research Problem

Smallholder farmers characterised with low literacy levels and technical competence are faced with a major challenge of identifying the combinations of farm enterprises that will produce maximum profit considering the amount of resources available to them (Tanko and Baba, 2013; Adewumi *et al.,* 2018). They are faced with the decision of which farm enterprise to undertake, how far they can go in integrating the enterprises or replacing an enterprise, which is partly dependent on the interrelationships between the enterprises as well as the prices of inputs and their corresponding outputs as argued by Adejobi *et al.* (2003). Farmers who engage in mixed crop and livestock farming mostly on a couple of hectares rely on meagre resources to undertake these enterprises. However, questions remain about how best to intensify production in these integrated systems so as to increase food yields and do so profitably and sustainably.

Udo *et al.* (2015a) argued that agriculture has recently experienced successive and concurring severe shocks often as a direct consequence of extreme weather events, raising concerns about greater uncertainties in agricultural production to a higher profile in the international community. Agricultural enterprises including crops, livestock and fisheries among others are indeed risk inherent at all levels due to variability in yields and prices. Udo *et al.* (2015b) opined that smallholder farmers have multiple farming objectives other than profit maximization which may include attaining household food security, limited extent of post-harvest losses and minimum variability in yield among others. These smallholder farmers who produce about 90% of the food output in Nigeria as pointed out by Bamiro *et al.* (2015) often take the decisions of integrated farm enterprise that will offer them the desired results by trial and error method. Unfortunately, this gives rise to uncertain outcomes. They suffer from a dearth of valuable optimum farm enterprise guides and are striving to optimize production goal(s) under their resource constraints and risk conditions.

There is a relatively abundant body of literature on how the deterministic linear programming models have been applied to analyse the potentialities of improving agricultural productivity and income among farmers through efficient utilisation of limited resources only under conditions of certainty. In Kwara State, few studies such as those of Babatunde *et al.* (2007), Ibrahim and Omotesho (2011) and Adewumi (2017) have attempted to derive optimum farm plans for the smallholder crop farmers under the embodied assumption that all coefficients are determined with perfect knowledge. There is however a huge knowledge gap in literature on the application of mathematical programming models to determine optimum farm plans under the conditions of limited resource, risk and uncertainty. Only a little evidence of research efforts aimed to inquire into the possibilities of maximising farm production and income under the conditions of risk and uncertainty particularly in Kwara State and Nigeria as a whole is available. Udo *et al.* (2015a) also argued that formulating farm plans in a risky environment with condition of certainty is inappropriate. More so, most of the research efforts to determine optimum farm plans for farmers under the conditions of risk and uncertainty in Nigeria such as those of Adubi (1992), Umoh and Adeyeye (2000), Olarinde (2004), Umoh (2008), Salimonu *et al.* (2008), Udo *et al.* (2015a) and Udo *et al.* (2015b) has focused only on the cropping enterprises. No effort has been made to consider other farm enterprises such as the livestock and fisheries in the risk programming models. To fill this gap, the study considered the combination of livestock and fishery enterprises along with crop enterprises in the risk programming model. The results will provide basis for similar future studies and a valuable guide to existing and intending smallholder farmers towards optimum farm enterprise combinations and diversification.

Nigeria is currently the seventh most populated country in the world and with a growth rate of 2.61% now has an estimated population of about 196 million (World Population Review (WPR), 2018). It has also been projected that by 2050, Nigeria will be the third most populous nation in the world with projected figure of 402 million people. With this alarming increasing population, there is a great threat to food security particularly to food production planning if feeding the many mouths could not be realized. It is against these backdrop that this study sought to answer the following research questions:

1. What are the socio-economic characteristics of the smallholder farmers in the study area?
2. What are the existing farm enterprise combinations undertaken by the farmers?
3. What are the costs and returns associated with farm enterprises undertaken?
4. What combinations of farm enterprises will maximize the profit of the farmers under risk and limited resource conditions?
5. What are the production constraints faced by the smallholder farmers?

1.3 Aim and Objectives of the Study

The aim of this study was to analyse farm enterprise combinations under risk and limited resource conditions among smallholder farmers in Kwara State, Nigeria using mathematical programming approach. The specific objectives were to:

i. describe the socio-economic characteristics of the smallholder farmers in the study area,

ii. identify the existing farm enterprise combinations undertaken by the smallholder farmers,

iii. estimate the costs and returns associated with the various farm enterprises undertaken by the farmers,

iv. determine optimum combinations of farm enterprise plans that will maximize the profit of the farmers under risk and limited resource conditions, and

v. describe the production constraints faced by the smallholder farmers.

1.4 Justification of the Study

Most smallholder farmers in Nigeria predominantly arable crop enterprise producers which is subjected to a high degree of uncertainty in yield (income) and employment due to variability in weather and prices among others (Jirgi, 2013; Ibrahim *et al.,* 2019). There is need for these farmers to also consider the livestock and fishery enterprises as suitable strategies for augmenting farm incomes and in all intent, enterprise diversification. Also, taking into cognisance the need to tackle the challenge of food insecurity given the alarming growing population, smallholder farmers in Nigeria need to efficiently allocate the limited resources available to them as Olayemi and Onyenweaku (1999) stated that rationing scarce resources among the intended competing activities is a challenge the farmers are faced with. Formulating integrated optimum farm plans that include crop, livestock and fishery enterprises for these smallholder farmers therefore cannot be overemphasised.

Maximising farm enterprise returns under limited resources and risk conditions by prescribing an efficient enterprise system is germane to improving the growth prospects of farm families particularly in terms of increased farm income and food security. Risk efficient farm enterprise plans will provide a valuable guide to existing and intending smallholder farmers and will be a huge step towards increased food production and income generation which will in the long run enhance food security and improve the farmers' standard of living.

Although, the works of Tanko (2004), Hassan *et al.* (2005), Igwe *et al.* (2011), Igwe (2012), Bamiro *et al.* (2015) and Adewumi (2017) among others have shown that the mathematical programming approach has been successfully applied in studies on optimum combination of farm enterprises and resource requirements in Nigeria, not many studies in Nigeria have adequately addressed the problem of what the optimum farm plan is under risk and limited resource conditions using risk programming models. Focusing on the smallholder farmers in Kwara State, it is hoped that the findings of this study will help to fill the knowledge gap in literature and extend the frontiers of knowledge particularly in the area of incorporating risk into farm planning models. Agricultural researchers and students will benefit from this study as it will serve as a foundation for future research on the subject matter in the area.

Agricultural project administrators, policy makers and extension agents both in the public and private sectors will also benefit from this study as its output will help to foster their work. Relevant information emanating from the outcome of this study will be useful for formulating effective policy that will stimulate increased food production and income generation among the smallholder farmers in the area and in Nigeria as a whole. It also could form part of the extension teaching content to guide the smallholder farmers on farm enterprise combinations that would maximize their farm returns and on efficient allocation of the limited resources available to them under the risk conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 Theory of production in agriculture

Production is a process in which inputs or resources are transformed into products or outputs. Durba (2017) also defined production as a process by which variable inputs and fixed factors are combined to produce output. In agriculture, the production inputs employed traditionally are land, labour, capital, management, and of recent, water resources. These resources can be coordinated into a farm-firm or a producing unit whose goal might be to maximize profit, maximize output, minimize cost, maximize utility, or a combination of all these motives of enterprise (Nwojo, 2017). In any production process, these resources are channelled into the farm with the aim of achieving maximum output at a minimum cost or to maximize profit.

The plain jostle of economics of agriculture production at the micro level, is to assist a single farmer or a group of farmers in achieving specified goals through efficient intra-farm resource allocation over a period of time. These resources are allocated as input mix which are managed to produce a specific level of output of the undertaken enterprise. Since there are alternative means of attaining the production goals or objectives, the theory of production offers a theoretical and empirical basis for making proper decisions among alternatives in order to achieve some combination of the farmer's goals. Economics of agricultural production is achieved either by measuring output from limited resources or reducing the quantity of resources required to produce a given level of output as posited by Olayide and Heady (1982) in Oni *et al.* (2009).

2.1.2 The theory of linear programming (LP)

Dantzig (2002) and Taha (2007) defined linear programming (LP) as a mathematical procedure for determining optimal allocation of scarce resources and has found practical application in almost all facets of business, from advertising to production planning. It is a mathematical programming model that belongs to the general class of allocation models used to determine optimal resource allocation decisions and patterns (Olayemi and Onyenweaku, 1999). Lucey (2002) stated that linear programming is an important practical technique with a wide variety of applications. It is a resource allocation problem which is occasioned when the objective function to be optimized is known, competing (but not equally efficient) courses of action are available and resources for attaining the objectives are limited (Olayemi and Onyenweaku 1999; Lucey, 2002). Igwe *et al.* (2013) and Jirgi *et al.* (2018) has noted that LP model has been used by agricultural economists to analyse a wide range of farm problems over the years.

Formulation of LP is the mathematical representation of a problem situation with well-defined decision variables, an objective function, and a set of constraints (Mishra and Jaisankar, 2007). Expression of an LP problem in a standardized manner according to Lucey (2002) is the key to solving the problem because it does not only help the calculation required for a solution but also ensures that no important element of the problem is over-looked. In formulating an LP problem for farm-planning and decision-making in agriculture, the activities involved include the listing of all the possible activities which are to be programmed, calculation of the net revenue for each of the activities, determination and/or enumeration of the resource restrictions and other limitations which are to be imposed upon the activities and the detailing of the requirements of the activities for these resources in a programming matrix (Olayide and Heady, 1982).

The information needed to develop a LP matrix for a farm plan is similar to that needed in budgeting except that the LP methods require a more rigorous specification of planning activities, restrictions, input-output coefficients, net revenues and production alternatives. The objective function once decided must be stated in mathematical form so that the elements involved in achieving this can be understood. The existing circumstances otherwise called limitations or constraints which govern the achievement and objective must be clearly identified, quantified and expressed mathematically (Lucey, 2002). A typical maximization linear programming problem can be stated mathematically as follows:

Maximize $Z = p_1x_1 + p_2x_2 + p_3x_3 + \ldots . + p_nx_n$ (2.1)

Subject to:

$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots . + a_{1n}x_n \leq b_1$ (2.2)

$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots . + a_{2n}x_n \leq b_2$ (2.3)

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$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots . + a_{mn}x_n \leq b_m$ (2.4)

and

$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, \ldots ., x_n \geq 0$ (2.5)

Where;

$x_1, x_2, x_3, \ldots x_n$ = the decision variable to be maximized which are also equivalent to the activities or enterprise to be engaged in,

$p_1, p_2, p_3, \ldots p_n$ = the price coefficients or unit process of the different activities,

a_{ij}'s = the input-output coefficients or the quantity of a resource i required to produce a unit of an activity j. For example, if it takes 0.4 tonnes of fertilizers to produce one tonne of rice, the a_{ij} in this case is 0.4,

b_1, b_2, b_3 ... b_m = quantities of resources or other restrictions available where i = 1, 2, 3…, m, and

Z = the objective function to be maximized. The maximization of Z is carried out so that the *m* constraints are satisfied (Olayemi and Onyenweaku, 1999).

The LP problem can be rewritten in a condensed form as;

Maximize $Z = \sum_{j=1}^{n} p_j x_j$ (2.6)

Subject to:

$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$ (2.7)

and $x_j \geq 0$ (2.8)

Where;

i = 1, 2, ..., m,

j = 1, 2, ..., n, and

p_j, x_j, a_{ij} and b_i's are as defined earlier.

Depending on the nature of the restraints, constraints set in equation (2.7) can also be in the form of a maximum constraint (≥) or an equality constraint (=). Restraint (2.8) simply requires decisions variables to be non-negative (non-negativity assumption). A substantial saving of space can be achieved by expressing linear program in ∑ notation as in equation (2.6) and (2.7). Equations 2.1 to 2.5 are the longhand form of presenting LP. Analogously, a minimization programme may be written in compact from as follows:

Minimize C = $\sum_{j=1}^{n} C_j X_j$ (2.9)

Subject to:

C = $\sum_{j=1}^{n} a_{ij} x_j \geq b_i$ (2.10)

and $x_j \geq 0$ (2.11)

Where;

i = 1, 2, …, m

j = 1, 2, …, m

Although the C-symbol served as a symbol for the minimand (the object to be minimized), the objective in many contexts may not be a cost function. The c_j in the objective function represent a set of given constant coefficients as are i's in the constraints. In this context, i signify requirements rather than restrictions (Tanko, 2004).

2.2 Conceptual Framework

2.2.1 Concept of farm enterprise combinations

A typical farm anywhere in the world is often confronted with the problem as to what enterprise to undertake, the level at which each enterprise should be taken up and the optimal combination of enterprises to adopt. According to Egbodion and Ada-Okungbonwa (2012), farm enterprise combination is an essential relationship in agricultural production economics involving the allotment of available resources among two or more enterprises. Senaratne and Hemantha (2007) opined that integrated activities of crop production, livestock rearing and use of organic manure still plays fundamental function in the subsistence farming system. Integrated farming systems comprising of crops and livestock has much influence on the world's food production, producing about half the world's food on 2.5 billion hectares. Mixed crop-livestock systems constitute the spine of agriculture in the tropics providing the most common form of animal traction in developing countries (Thornton and Herrero, 2001). Shamim *et al.* (2011) argued that the integration is done to recycle resources efficiently. Many countries have developed different ways to accomplish this, hitherto a common feature of the system is the integration of crop and livestock enterprises and other forms of integrated farming which include aquaculture. This system of farming according to Ponnusamy and Gupta (2007) can guarantee the farmer's food security provided the farm is operated under an optimum plan which is within the capability of the farmer.

Adejobi *et al.* (2003) stated that the degree to which one enterprise can be combined with another or substituted for another is informed by the inter-relationships between them as well as the value of their outputs and inputs. According to the authors, farm enterprises may have any or more of the following relationships: independent enterprises, competitive enterprises, supplementary enterprises, complementary enterprises and/or joint enterprises.

The integrated farming systems approach initiates a revolution in the farming technique for maximizing production in the cropping pattern and takes care of optimal utilization of resources. Egbodion and Ada-Okkungbowa (2012) argued that in Nigeria, farm enterprise combination has become an essential choice for most smallholder farmers due to human population explosion which has instigated increasing demand for land development for construction of social infrastructure. Farm enterprises combination has the potentials of economic use of land, increased production through diversification at the smallholder farm level and the possible attractive alternative to generate output without automatically increasing available land.

Livestock and crop production are essential parts of one another, as one of the common features of most integrated agricultural system is that livestock and fisheries waste are used as fertilizers to improve soil productivity and; livestock waste is also used to fertile the growth of various natural planktons in the pond as fish feed (Ugwumba *et al.*, 2010). They also provide animal power for farm operations and transport. Gupta *et al.* (2012) also stated that the sale of animals supplies cash for farm labour and agricultural inputs, crop residues serve as fodder for livestock consumption while intermittently; grains are part of supplementary feed for prolific animals.

Crop-livestock integrated farming systems have long been regarded as a poverty-relieving safety net for rural farmers who are resource-poor in developing countries and are unable to afford conventional fertilizers to sustain soil fertility (Omolehin *et al.*, 2007). Food and Agriculture Organization (FAO), (2015) stated that crop-livestock integration respond to different supply and demand pattern in factor and product markets, agro environment and population growth. The process of incorporating livestock into crop systems begins when two independent complementary systems interact through the exchange of by products, and as the population grows, competition for the primary production factor which is land also begins. Hence, prices of land increases and land use intensifies through decrease in the fallow period to increase cropping frequency. Where fertilizers are not readily available, croplands are enhanced by conveying manure from pad dock animals and demand for power promotes integration of animals in farming systems.

2.2.2 Risks and traditional agriculture

Adubi (1992) stated that risk is a pervasive phenomenon in any economic activity, particularly in traditional agriculture where it affects production decisions and adoption of technology among others. Agricultural risks seem to be predominant all through the world, but they are particularly burdensome to smallholder farmers in developing economies. Production inputs for these farmers consist of land and family labour; capital investment is negligible; modern biological inputs such as fertilizers and chemicals are seldom used (Adubi, 1992). The production of the small farmers is mainly for subsistence (family food requirements) while little surplus is taken to the market as marketable surplus. Many factors including climate, pest and diseases, insect infestations, general economic conditions, technological innovation design and adoption, and public and private institutional policies all combine to construct an exclusive decision making framework for the agricultural producer. Smallholder farmers production decisions are generally made under this environment of risks and uncertainties. Risks in agriculture according to Kobza *et al.* (2002) include production risk, price and market risks, institutional risk, human or personal risk, business risk and financial risk. Product prices, yield and to a smaller extent, input prices and quantities are rarely known with certainty when investment decisions are taken.

Jirgi (2013) stated that production risk relates to the unpredictability of the production process of a farm-firm. The predominant sources of this production risk according to Hardaker *et al.* (2004) and Drollete (2009) includes climate, diseases and pest infestations among others which causes variation in crop yields as well as livestock and poultry production. Other sources of production risk according to Sonka and Patrick (1984), include fire, wind, theft, and casualties.

Organisation for Economic Co-operation and Development (OECD) (2009) stated that price/market risk is attributed to fluctuations in product prices and marketable quantities. Price or market risk may arise as a result of insufficient knowledge of the prices of input and output (LeBel, 2003; Drollete, 2009). When a farmer has to determine the level of the inputs to use and how much of which products to produce, prices of farm outputs are rarely fully known (Hardaker *et al.,* 1997).

Hardaker *et al*. (2004) opined that changes in the rules that influence farm production decisions which might have far-reaching consequences for profitability are referred to as institutional risk. The government is the primary source of institutional risk (LeBel, 2003).

Human resource risk according to Musser and Patrick (2002) refers to the threat that owners, family members, and/or staff may be unavailable for farm labour and management. Farm business owners, according to Hardaker *et al.* (2004), may also be a source of risk for the farm's profitability. Major life predicaments, such as the owner's death, a long-term illness of one of the principals, or carelessness on the part of the farmer or farm workers while handling livestock or operating machinery can all result in major losses in the farm enterprise (Drollete, 2009).

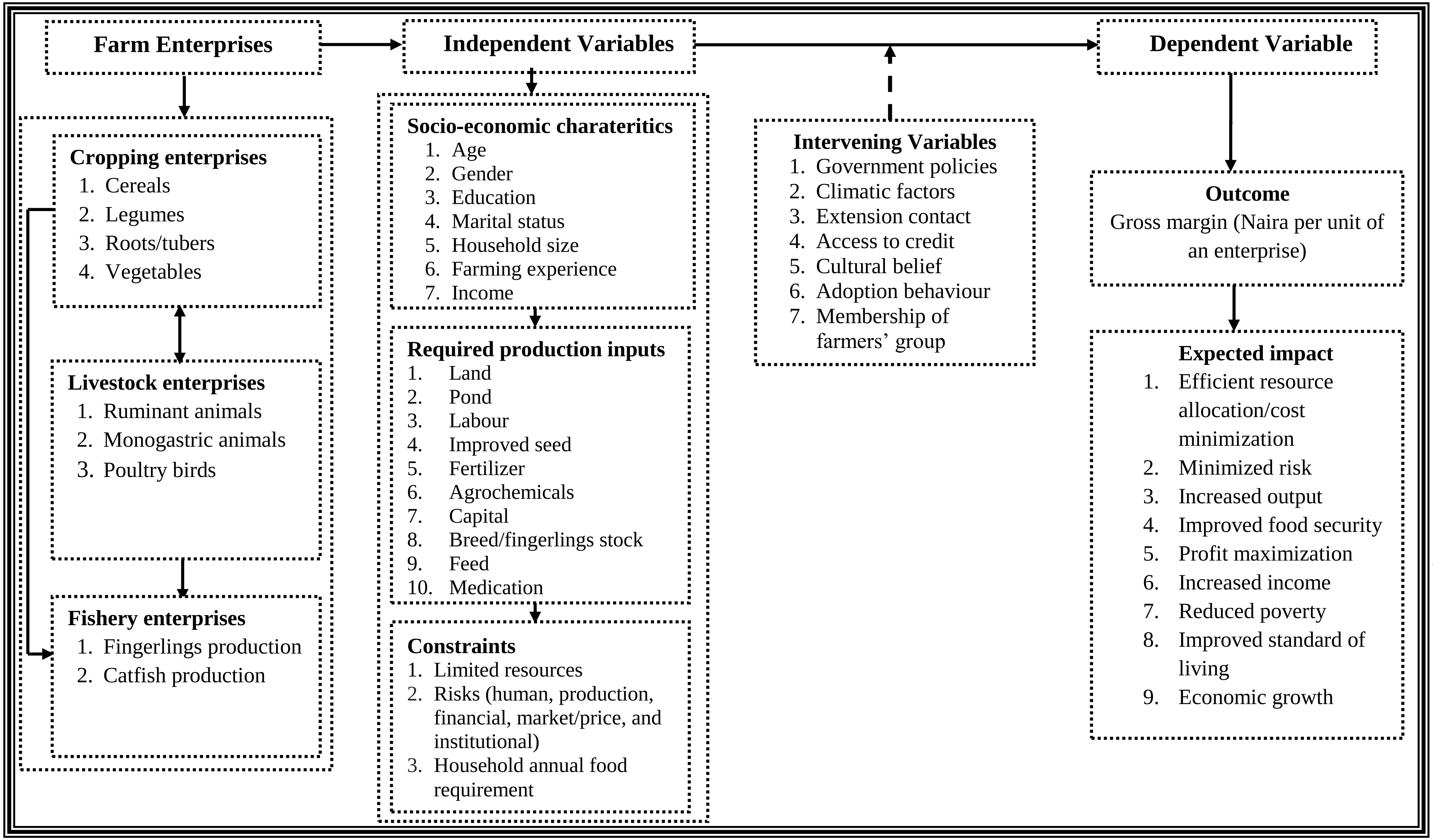
According to Drollete (2009), financial risk is the risk of abrupt interest rate increases on borrowed funds or the inability to receive loans from financial institutions. Farmers are exposed to financial risk as they use external funding to fund their farm enterprises (Jirgi, 2013). When an enterprise's profitability (rate of return) is less than the cost of capital, financial risk is evidenced. It is inversely related to profitability and multiplies with financial leverage ratio (debt/equity ratio) (Hardaker *et al.*, 2004).

Different variables contribute to the risk in agriculture, for example, the gestation lag, organic nature of farming and the farmers. Dercon (2002) and Patrick *et al.* (2007) reported farmers have recorded harvest failures, policy shocks, livestock death and illness, high yield fluctuations (in monetary terms) per unit of enterprise, yield instability, price of output and inputs, diseases and insect infestations.

2.2.3 Conceptual framework of farm enterprise combinations under limited resource and risk conditions among smallholder farmers

Figure 2.1 shows the conceptual framework of farm enterprise combinations under limited resource and risk conditions among smallholder farmers. The framework is designed to show the interrelationship between the different farm enterprises; the independent and dependent variables as well as the expected impact of combination of farm enterprises on the smallholder farmers. Combined crop and livestock production systems are highly efficient; potentially crop residues are used as livestock feed while the waste products form livestock activities such as the feces and urine can be decomposed and used as manure on the crop field and also to fertilize ponds for aquatic plant/algae production in the fishery enterprises. The logic is that, if the farmers combine farm enterprises subject to their limited resource and risk conditions, there will be efficient/maximum resource utilization and minimization of cost of production and the associated risks. This will result to profit maximization which in the long run will improve the farmers' welfare.

The framework further recognizes that farmers operate under limited resource and risk conditions which tend to impact on their output (gross margin). The outcome of the smallholder farmers' production activities depend on certain factors which include the farmers' socio-economic variables (age, gender, education, marital status, household size and farming experience, income); required production inputs (land, pond, labour, improved seeds, fertilizer, agrochemicals, capital, breed/fingerlings stock, feed and medications); constraints (limited resources, risks and household annual food requirement) and intervening variables (government policies, climatic factors, extension contact, access to credit, cultural belief, adoption behaviour and membership of farmers' group).



Source: Researcher's construct

Figure 2.1: Conceptual framework of farm enterprise combinations under limited resource and risk conditions among smallholder farmers

2.3 Analytical Framework

2.3.1 Some approaches to incorporating risk into farm planning models

Mathematical programming (MP) methods are very well adapted for farm optimisation models. Linear programming (LP) is a widely applied MP method used for farm planning. It may be used to maximise expected profit subject to the farm resource constraints and other restrictions without taking into account risk factors. In the past, when accurate non-linear computer codes were hard to obtain, the advantages of linear risk programming models over non-linear ones were crucial (Kobza *et al.,* 2002).

One of the often used ways of MP is to define the incorporating risk (different types of risks and their influence of each other). More secure plans might include producing less risky enterprises, diversifying into a larger number of enterprises to spread risks, sticking to existing technologies rather than trying out new ones, and, in the case of small-scale farmers, producing a larger portion of the family's food requirement. When risk-averse behaviour is ignored in farm planning models, the outcomes are often unsatisfactory to the farmer or have no connection to the decisions he actually makes. Several techniques for integrating risk-averse behaviour into mathematical programming models have been developed in recent years to solve this problem. Mean – variance analysis based on Markowitz portfolio decision theory which is the conventional framework for most risk – return analysis in agriculture has been used by researchers in several risk–return analyses in agriculture (Udo *et al.,* 2015b). In the agricultural economics literature on risk – return analysis, risk programming models such as Quadratic programming (QP) and Linear Programming/Minimization of Total Absolute Deviation (LP/MOTAD) are the most common mathematical programming methods.

2.3.1.1 Quadratic risk programming (QRP)

To establish the product mix, Stovall (1968) used the variance-covariance quadratic equation of enterprises to describe the total variance of incomes. The sign of covariance of a particular enterprise defines whether it will complement or minimize the difference in net incomes according to the author. If the covariance of a seemingly risky enterprise was negative and high, it would ultimately minimize the overall variation of incomes. The author went on to claim that income variance was a crucial variable in farmers' decision making process when it came to selection of farm enterprise mix.

The efficiency frontier set of expected value and the variance of outcomes of farm can be derived by means of quadratic programming developed by Hazel and Norton (1986). In this case the coefficients used in the model could be non-stochastic, the costs are constant and income distribution of farm plan is totally specified be the total gross margin distribution. Based on the farm activities the variance - covariance matrix has to be denoted in equation (2.12) as:

$$V = \sum_j \sum_k X_j X_k \sigma_{jk} \tag{2.12}$$

Where:

V = Income variance,

X_j and X_k = The level of j or k activity, and

σ_{jk} = The covariance of these activities.

Equation (2.12) shows that the variance of total gross margin is an aggregate of the variability of individual enterprise returns, and of the covariance relationship between them. Covariances are essential for efficient diversification of farm enterprises as a risk management strategy (Markowitz, 1959). The net return from a mixture of activities with negatively covariate gross margins is typically more stable than the return from more specialized strategies. Also, a crop that is risky in terms of its own variance of returns may still prove attractive if its returns are negatively covariated with other enterprises in the farm plan. To obtain the efficient set of expected value and the variance of outcomes it is required to minimise variance - covariance set for each possible level of expected income, while retaining feasibility with respect to the available resource constraints.

2.3.1.2 Minimization of total absolute deviation (MOTAD) programming

When quadratic programming (QP) failed to produce desired results on computational facilities, Kobzar *et al.* (2002) developed the minimisation of total absolute deviations (MOTAD) model. The model's main advantage over quadratic programming was the ability to convert functions to linearity and solve them using traditional linear programming computed codes. As compared to quadratic programming, the model's results had intended statistical properties and were on par with the recognised model of farm planning under risk and uncertainty. Hazell (1971) developed the MOTAD model which could be solved on the traditional normative linear programming codes with parameteric options while maintaining most of the desired attributes of the quadratic programming. The application of the MOTAD approach entails use of the same technical input-output tableau as for the LP and QRP models, but augmented with additional constraints (like absolute deviation of revenue, income deviation or probabilities) for the calculation of deviations for each state together with an additional constraint to calculate the mean absolute deviation. The deviations of the activity net revenues by state are calculated from the adjusted gross margins by deducting the corresponding expected gross margin from each. Also added to the tableau are further activities to calculate the negative deviations for each state. The model is then solved with mean absolute deviation set to an arbitrarily high value which is then progressively reduced until no further solutions of interest are found.

In matrix notation, the MOTAD model is specified in equation (2.13).

$$M = \frac{1}{N}(/\sum_{j=1}^{n}(C_{tj} - \bar{C}_j)/) \tag{2.13}$$

Where;

M = Mean Absolute Deviation that can be minimized for a level of expected profit,

N = Number of years,

C_{tj} = Gross margin per unit of j^{th} crop or livestock activity in the t^{th} year,

$\bar{C}_j$ = Sample mean gross margin per unit of j^{th} crop or livestock activity,

j = Refers to j^{th} activity (j = 1 to n activities),

t = Refers to t^{th} year (t = 1 to s years), and

// = Modulus denotes absolute value of the figures, that is, ignoring the signs within the two vertical bars.

2.3.1.3 Target minimization of total absolute deviation (T-MOTAD)

The Target MOTAD model is a modification of MOTAD in that it involves a constraint on income deviations, this time from a target level of income. Target MOTAD involves three parameters: expected profit, deviation from the target and target income. Efficient set of solutions is obtained for a given value of the target income. The key benefit is that the solutions are second-degree stochastically dominant (regardless of income distribution), making them efficient for risk-averse decision makers. The model usually is solved maximising profit for a relatively large number of combinations of target income and deviation from the target (Kobzar *et al.*, 2002).

In the target MOTAD model, Udo *et al.* (2015b) stated that a measure of risk of gross margin or profit which is given in the modulus is incorporated into LP model of a whole farm-planning problem. The Mean Absolute Deviation, (M) is minimized for a given level of expected gross margin or profit E(Z) which varies parametrically over zero to some desired range (M). The computational procedure of the model involves two steps-first a conventional linear programming maximization problem is formulated and solved to determine the maximum return without risk constraints. This gives the highest point on the efficiency frontier. Second, the element of risk is formulated as a matrix of gross margin or net returns deviations from expected returns. Points on the risk efficiency frontier are obtained by parametrically decreasing the value of (M) along the efficiency frontier in arbitrary amounts. The Target-MOTAD model minimizes the Mean Absolute Deviation for any given expected return (Ayinde *et al.*, 2010). The formulation of T-MOTAD model is as follows in equation (2.14).

$$Max\ E(Z) = \sum C_j X_j \quad (2.14)$$

Subject to:

$$\sum C_{ij} X_j \leq \beta_i \quad (2.15)$$

$$\sum C_{rj} X_j + y_r \geq T_r \quad (2.16)$$

$$\sum P_r Y_r = \lambda \quad (2.17)$$

Where:

$E(Z)$, x, y > 0, (2.18)

$E(Z)$ = Expected return per unit enterprise of the plan (₦),

C_j = Expected return per unit enterprise (₦),

X_j = level of enterprise j,

C_{ij} = Technical resource i requirement of enterprise j,

β_i = Level of resource i,

C_{rj} = Return of enterprise j for state of nature r,

Y_r = Negative deviation below T_r for state of nature r,

T_r = Target level of return (₦),

P_r = Probability that state of nature r will occur, and

λ = A constant parameterised from M to 0

The utilization of this model to build risk efficient farm plans in agriculture and other related fields have continued to increase.

2.3.1.4 Synopsis to risk programming approaches

Kakhki *et al.* (2009) in investigating the substitution capabilities of oilseeds in cropping patterns under risk conditions in Iran compared the quadratic programming and MOTAD models. Although the authors reported that the result of both approaches suggested that the farmers should increase the cultivated area of oilseed crops, the result of the MOTAD model however prescribed more feasible optimal solutions than the quadratic programming model.

Kobzar *et al.* (2002) had stated that quadratic programming failed to produce desired results on computational facilities which led to the development of the MOTAD model which allow for functions to be transformed to linearity and solved on traditional linear programming computed codes. The MOTAD model involves the dual requirement of minimizing the variance of net return as well as maximizing the net return as introduced by Hazell (1971).

In spite of this advantage of the MOTAD model over the quadratic programming model, Tauer (1983) argued that MOTAD solutions are not necessarily second degree stochastic dominance efficient. Stochastic dominance techniques are appealing in application because they need only a few restrictive assumptions about the utility function of the decision maker. According to Berbel (1990), it is rational to conclude that utility is a decreasing function of risk and an increasing function of income.

Tauer (1983) modified the MOTAD model developed a target – MOTAD (also called T-MOTAD) model approach. The author asserted that all solutions generated with a target

MOTAD model (with the exception of the very rare case of plans with equal means and deviations) belong to the second degree stochastic dominance efficient set, thus implying that target MOTAD techniques are better than MOTAD. Watts *et al.* (1984) also compared MOTAD and target MOTAD models and concluded that the target MOTAD is better than MOTAD for risk analysis in farm planning models.

The target MOTAD model has been successfully used in a number of studies and its use in the study of the Nigerian agricultural system is the most recent. Taking into cognizance the aforementioned advantage of the T-MOTAD techniques over other approaches in incorporating risk into farm planning models, it will therefore be adopted for this study.

2.4 Review of Empirical Literature

2.4.1 Socio-economic characteristics of smallholder farmers in Nigeria

Small scale farming is often characterised by small farm size, subsistence and low use of resources. According to Arene (2008), resource poor farmers are those who lack access to land, average income per farmer, credit, and other resources. In general, a number of factors incapacitates the smallholder farmers in the country as they attempt to produce food and fibres for human consumption. Smallholder farmers, according to Adubi (2000), are a type of farmer who exists on the periphery of the modern market, neither fully integrated into the economy nor completely insulated from its pressures, that is, they have one foot in the market economy and the other in the subsistence economy. Ibeawuchi *et al.* (2010) stated that in Nigeria, about 70 – 75% of the populations were farmers where members of the farm family participate in cultivating piecemeal family lands while the affluent ones engage in outright purchase of farmland from others or rent to produce food and fibre. Generally, the people were poor and most of them were smallholder farmers who produced majority of the food. They were said to be resource poor and practiced small scale farming (0.1 – 2ha). Afolabi (2010) also noted that over 80 percent of the farming population in Nigeria are smallholders who produce a substantial portion of the food requirements.

Ayinde (2008) in a study on small-scale farmers in Kwara State found that most farming household (70%) have large household size of more than 5 persons and cultivated farmland below 1.5 hectare which critically does not commensurate each other. The author also reported that 50% of the respondents are of the age group 21 to 40 years and over 50% having more than 19 years farming experience in the area. Oluwasola (2012) in a study on integrating smallholder crop farmers into the policies aimed to enhance commercialization and agriculture production on a large scale in Ekiti State, Nigeria reported that 94% of the respondents were male, the average farm size in the area was 2.5ha with 71% of the farmers farming less than 5ha and 72% having an educational level of only primary school. The above study also reveal that the mean age of the sampled farmers was 49years with a mean farming experience of 20years,the research concluded that these set of farms might finds it difficult to take risk in terms of adapting new innovations as well as acquiring loans for farm capitalization.

Osundare and Adekunmi (2014) reported that majority of crop farmers in Kwara State Nigeria were between the ages of 20 and 50 years with a mean of 38 years signifying that they were still in their productive years and are capable of adopting effective measures for mitigating the effect of environmental problems associated with crop production. The researchers further found that majority (72%) of the farmers were male which could be attributed to the tedious nature of farming activities, while 67.5% had above 5 years of farming experience.

Nwaiwu (2015) who studied the socio-economic variables that affects the decision of arable crop farmers to adopt environmental conservation measures in South Eastern Nigeria found that the female farmers were dominant (70.5%) in arable crop production and associated this to the fact that women were those who usually carry out most farming activities such as planting, bush clearing, cultivation and weeding in the area. The researcher further reported that most (62%) of the farmers had farming as their major occupation, 35.38% of them were within the ages of 50 to 60years, 81.29% of them were married with an average of 5 persons per farm household.

Adewumi (2017) in a study on optimum production patterns for cassava-based crop farmers in Kwara State reported that a typical farmer in the area was 49 years old, had household size of 7 persons, cultivated 1.01ha of land, had 15 years farming experience. The author further reported that majority (89.63%) of the farmers were males, 81.10% of them married, and 76.50% had formal education, but only 17.68% had access to agricultural credit.

Kayouli (2007) argued that livestock production is predominantly practiced by the resource poor smallholder farmers who are mostly rural dwellers with no easy access to technical extension services. In the analysis of cost and returns to goat production in the tropics, Baruwa (2013) reported that most (65%) of the sampled goat farmers were female, 98.3% of them were married and about 50% had family size of between 6 to 10 members. Most of the respondents (81.6%) were educated and with an average experience of 16 years in goat production. Ogunniyi and Ganiyu (2014) in a study on efficiency of livestock production in Oyo State, Nigeria reported that majority of the livestock farmers who are male are of middle age (45-52 years) with low educational level and large household sizes; and do not produce optimally based on the existing allocation of available resource.

Adewuyi *et al.* (2010) studied the profitability of fish farming in Ogun State and revealed that most of the fish farmers in the area were male constituting about 87.7% and about 63.7% were married. Large proportion (68%) had formal education and respondents whose age ranges between 31 to 40 years were the majority with 96.3% constituting those of the active age of between 20 to50 years. The average size of the fish pond operated in the area was found to be 355m^2 and it was revealed that extension services were quite poor.

Olasunkanmi (2012) carried out an economic analysis of fish farming in Osun State and reported that most of the fish farmers (58.3%) in the area were male, about 91.7% were married and that majority of the farmers were between ages 31 to 50 years. The study also showed that about 86.1% of the respondents owned the land they operated on, while others either operated on leased or rented land. Majority about 75% got their capital from personal savings and only 5.6% could access bank loan. It was also found that about 52.8% were regularly visited by extension workers and 16.7% were occasionally visited.

A study on fish farming in Oyo State by Olaoye *et al.* (2013) revealed that that the middle aged (41-50years) being the economic active age are those involved in fish farming in the area. The report also indicated that about 81% of the fish farmers had an experience of over 15 years, 84.2% were male, 46.1% were married and 87.3% had tertiary education which the researcher attributed to the fact that fish farming requires a lot of technicality for a successful and profitable venture.

According to Ibemere and Ezeamo (2014), fish farmers in River State Nigeria were still young, productive and innovative with about 74.4% of them below age 50 years. Results also revealed that 64.4% were male respondents, 61.1% were married and 42.2% of the fish farmers had a household size of between 6 to 10 persons while 30% had less than 5 persons. Nwachi and Begho (2014) reported from a study conducted on fish farmers in Delta State that male respondents were majority constituting 66%, 90% married with an average household size of 7persons. The authors' result further revealed that most of the respondents were between ages 31 and 40 years having a high level of literacy with 51% having tertiary education and only 3% had no form of formal education. Majority (72.5%) had experience in fish farming for between 1 to 10 years.

2.4.2 Estimating cost and returns in agricultural production

Smallholder farm profitability has significant implications for development policies in most developing countries where the agricultural production sector remains dominant. An improved understanding of its profitability will significantly assist policy makers in developing better policies and assessing the effectiveness of current and previous reforms (Sadiq *et al.*, 2013). According to Pandey (2002), profitability refers to the capacity of a company, an organization, enterprise or firm to benefit from the entirety of its business undertakings. It demonstrates how efficiently the management can benefit from using all available production and market resources. The farm budgeting technique has been widely used to carry out costs and returns analysis in various studies especially in agricultural production. Umoh (2006) used this method to calculate the profitability of urban farming and discovered that urban farming is not profitable enough to sustain a typical farmer in the area. Sanusi and Salimonu (2006), from their study in Oyo State reported that yam production enterprise is profitable with a positive gross margin and net profit and with the benefit cost ratio of 1.94.

Yusuf *et al.* (2008) used net farm income analysis to assess the profitability of *'Egusi'* melon production in the Okehi Local Government Area of Kogi State, and discovered that *'Egusi'* melon under mixed cropping had the highest gross margin. Haruna (2008) conducted a study in Jama'a Local Government Area of Kaduna State using gross margin analysis to evaluate the profitability of cassava-based crop farmers and reported that sole cassava generated the highest revenue but the lowest gross margin when compared to mixed cropping systems. Likewise, Yusuf *et al.* (2010) in a study conducted to figure out how profitable it is to produce improved maize varieties in Sabon Gari Local Government Area of Kaduna State used the same method and found farming of improved maize variety to be profitable. Jabo *et al.* (2010) used this approach to compare the profitability of chemical and non-chemical cowpea storage and found that those who used chemical storage made more profit than those who used non-chemical storage, though, both cowpea storage methods were found to be profitable. Akinola and Owombo (2011) in a study on economic analysis of adoption of mulching technology in yam production in Osun state, Nigeria reported that yam is a profitable enterprise. The result of the budgetary analysis used revealed gross margin and net farm income of ₦344,645.04 and ₦326,865.02 respectively from a total cost/ha of ₦86,106.67 and revenue/ha of ₦412,971.69.

Baruwa (2013) in a study on goat production under tropical condition employed the farm budgeting technique. The researcher found that goat production is a profitable livestock enterprise with the cost and return to goat production estimated been ₦244,182 and ₦560,000 respectively. The study further revealed a profit margin of 56.4% and a benefit cost ratio of 2.3. Bamiro *et al.* (2015) revealed in a study on enterprise combination in livestock sector in South-western Nigeria reported that cost of feed constitute greater percentage of the total cost in livestock production with 54.62% followed by the cost of stock with 21% of the total cost. The study also showed that total fixed cost was 11.91%

of the total cost and variable cost was 88.09%. A gross margin of ₦561,402.40 and net farm income of ₦505,999.16 proved that livestock production is a profitable enterprise in the area.

FAO (2011) acknowledged that small scale fish farming generates considerable profit, prove flexibility in terms of shock and crisis; and make significant contributions to poverty alleviation (income) and food security. This is in conformity with the findings of many researchers in various fish production studies in Nigeria.

Kareem *et al.* (2008) in a study on technical, allocative and economic efficiency of different pond systems in Ogun State, Nigeria revealed returns to every Naira invested on earthen pond system of fish farming to be ₦8.00 while that of concrete pond was ₦6.50. Result further revealed that the total variable cost constituted 98.7% of the total cost for concrete pond and 98% for earthen pond system. Kudi *et al.* (2008) in a study on fish production in Kaduna State reported that the variable cost constituted about 97% of the total cost among which the major cost incurred are those of fingerlings (42.82%), feed (34.70%) and hired labour (16.19%) whereas fixed cost constituted about 3%. It was further revealed that cost of production was ₦571,321.76, total revenue was ₦5,853,625.64 and net income was ₦5,282,393.85 which indicated that fish production is a profitable venture in the area.

Adewuyi *et al.* (2010) in their studies on profitability of fish farming in Ogun State showed that sampled fish farmers in the study obtained a profit of ₦320,650 with a rate of return of 1.55 which implied a profit of ₦0.55 on each naira invested. Oluwemimo and Damilola (2013) in a research carried out to determine the socio-economic and policy issues affecting sustainable fish farming in Nigeria obtained an average variable cost of

₦480,755.55 representing 78 percent of the total production cost which was ₦610,442.55. The average revenue of the farmers was ₦938,083.30 with a gross margin of ₦457,327.75 and a benefit-cost ratio of 1.51 indicating a profitable venture as every ₦1 earns ₦0.51. Olasunkanmi and Yusuf (2014) also in a study on small-scale fish farming in Osun State reported a return of ₦1.67 to investment which indicated that every Naira invested yielded ₦0.69 as profit showing that the enterprise is profitable.

2.4.3 Application of mathematical programming model to farm planning

Several mathematical programming models such as QP, LP, MOTAD and T-MOTAD have been developed and applied to solve farm resource allocation problems. There is a relatively abundant body of literature on the application of the models to farm planning among farmers. This section presents a review of the application of the LP and T-MOTAD models to farm planning.

2.4.3.1 Application of linear programming model to farm planning

Linear programming models have effectively been developed and utilized under various situations to model various types of economic and planning complexities. Its technique according to Hassan (2004) has been widely used both in the agricultural and industrial sectors all over the world, although the degree of its use has varied among countries particularly in agriculture. Although the tool has been used by agricultural researchers and scientists in analysis since many decades now, the LP technique has not gained much prominence among the farming communities in Nigeria and Africa as a whole as much as among farming communities in other countries of the world.

During the 2004 farming season, Babatunde *et al.* (2007) used the LP model to investigate the best farm plan in sweet potato cropping systems in Kwara State. The best crop combination prescribed was sweet potato/cassava on 0.91ha, with an average gross margin of ₦14,766/ha. Although capital was a finite input, human labour and land were not, with 0.06 hectare of unutilized land and 3.13man-days of unemployed labour. For increased crop production, increased capital investment was suggested.

Ibrahim *et al.* (2009) used LP technique to decide the best farm plan for gauging the food security among the farming households in North Central Nigeria, recommending that cassava, maize/cowpea, benniseed, and groundnut/yam enterprises be planted on 0.64ha, 0.34ha, 0.35ha, and 0.22ha respectively, to produce a net return of ₦141,692.89. The study also indicated that maize, cassava, and yam were the food security crops, and that effective resource allocation for increased production, as well as the implementation of participatory family planning techniques among food insecure households, were recommended. Ohajianya and Oguoma (2009) analysed the patterns of resource allocation among 120 food crops farmers in Imo State, Nigeria applying the LP techniques for resource optimization. Under limited and borrowed capital situations, the findings indicated a discrepancy between existing and optimum farm plans. The formulated optimum plans were subjected to sensitivity analysis to allow for the selection of a specific optimum solution that is consistent with the farm's output characteristics and resource constraints. Farm resources were not allocated optimally, and by optimizing them, farm income and labour employment could be expanded. Results also indicated that under the limited and borrowed capital scenarios, expanding the land under cultivation by 2 hectares could increase optimum farm income by ₦80,994.00/ha and ₦67,521.60/ha representing 87.94 percent and 54.18 percent respectively.

Abdelaziz *et al.* (2010) used the linear programming technique to analyze data obtained in a study on optimizing the cropping pattern in North Darfur State of Sudan. The study revealed that the models suggest a cropping pattern that differed from the current farmers' production plan. The farmers' plan resulted in a loss, while the outcomes of linear programming models returned a profit. In order to preserve groundwater usage in Punjab, Kaur *et al.* (2010) used the LP technique to recommend the best crop production pattern for optimizing net returns and ensuring substantial groundwater savings.

Ibrahim and Omotesho (2011) reported an optimum farm enterprise mix for vegetable farmers involved in *Fadama* in North Central region of Nigeria. In a composite objective function, their linear programming model considered both economic and environmental objectives at the same time. The best plan researchers claimed that the optimal plan attained 88 percent of the goals considered. In another study using farm data from 2009/2010 in Abia State, Nigeria, Igwe *et al.* (2011) developed a linear programming model to decide the best enterprise combination. Constraints such as calorie consumption were included in the LP model. The model's objective was to optimize the gross margin of farmers who were engaged in a mix of arable crops and fisheries enterprises. However, out of the twelve production activities identified in the existing plan comprising of ten crop and two fish enterprises, only two were prescribed in the optimum plan to attain a gross margin of ₦342,763.30. The authors also argued that the enterprises in prescribed plans are relevant to achieving food security among the rural farmers in Abia State and Nigeria as a whole.

Igwe and Onyenweaku (2013) applied LP technique to data obtained from 30 arable crop farmers in Aba agric zone of Abia State, Nigeria during 2010 farming season to optimize gross margin from various combination of arable crops and livestock enterprises. The result of optimum plan was significantly different from the existing plan. The gross margin obtained was 61.35 percent higher than that of the existing plan. Igwe, *et al.* (2013) in another research applied the LP model to the resource allocation problem of thirty farmers who cultivate arable crops in farming mix with rearing of monogastric farm animals and fish in Ohafia agric zone of Abia State, Nigeria. Their investigation solved a gross margin maximization objective function among the existing enterprises undertaken by this class of farmers. From the LP optimum result, sweet potato on 0.29ha, cassava on 0.02ha and cassava/maize/cocoyam on 0.13ha, broiler I (August – December) with 70.00 birds, fish I with 220.00 fish stock and layers with 205.00 birds enterprises were prescribed for a typical farmer in Ohafia zone to maximize gross margin given the available inputs.

Tsoho (2013) applied LP technique to ascertain the possibilities of cultivating a mix of onion/tomato and pepper/onion/tomato by small-scale irrigation farmers in Sokoto State, Nigeria to determine which yield optimum returns. The author based on the result of the findings prescribed that the farmers should undertake a mix of onion/tomato on 0.62 hectare and pepper/onion/tomato on 0.39 hectare of land respectively to achieve an optimal return to labour and management of ₦31,806.15. Labour was the most constraining input in the area.

Ismail (2013) used LP approach to develop a prototype optimum cropping pattern for *Fadama* farms in Niger State. The LP solution revealed that only rice enterprise should be undertaken by the farmers on 0.66 hectare of land to obtain an optimal return of ₦437,734.47 per hectare. LP result found capital to be the most constraining resource.

Majeke *et al*. (2013) carried out a study in Zimbabwe in which a linear programming model was used to decide the optimum cropping patterns and number of breeding sows. The optimization outcomes obtained using LP model were contrasted with those from the existing plans of the farmer. The patterns obtained by utilizing linear programming procedures yields more farm incomes than patterns from existing plans. Majeke (2013) in another investigation developed a LP model for farmers in Marondera, Zimbabwe. The goal of the investigation was to obtain optimum net incomes optimum combination of farm enterprises subject to input constraints. The outcomes showed that linear programming model solutions are worth adopting by the farmers.

Bamiro *et al.* (2015) in a study on enterprise combination in livestock sector in South-western Nigeria applied LP model in data analysis. The authors reported that the optimal enterprise combinations solution prescribed integrated poultry/fishery and poultry/piggery as the most efficient livestock enterprises in South-western Nigeria for the farmers to adopt.

Adewumi (2017) employed a LP model in a study conducted in Kwara State, Nigeria among cassava-based crop farmers to derive optimum cropping plans. The study identified 15 crop production activities with 34.15% and 65.85% of the farmers practising sole and mixed cropping enterprises respectively. The LP solution prescribed cassava/melon, cassava/yam/maize and cassava/sorghum/groundnut on 0.1434ha, 0.7505ha and 0.2261ha respectively for the farmers in the optimum farm plan to give a net return of ₦242,548.10/ha compared to the ₦165,913.85/ha in the existing plan.

2.4.4 Application of linear programming/T-MOTAD models to incorporate risk in farm planning

Zimet and Spreen (1986) developed and applied a T- MOTAD model to account for risk in a decision framework for the analysis of a typical crop and livestock farm in Jefferson County of North Florida. The authors included the complementarities and potential competition among beef cattle and crop enterprises. The results of the deterministic linear programming model prescribed stocker cattle, watermelon and peanuts enterprises in the optimal solution. The optimal solution for the T- MOTAD model includes soybeans under irrigation, stocker cattle, peanuts, cow-calf and watermelon.

Maleka (1993) used the T-MOTAD model to determine the optimum cropping patterns in Gwembe Valley of Zambia. The researcher reported that the results of the T- MOTAD model prescribed an optimal cropping pattern of growing soybeans, rice and sorghum which is in contrast to the existing crop plan comprising of maize, sunflower, cotton and sorghum.

Gajanana and Sharma (1994) used the MOTAD approach to formulate risk-efficient farm plans for drought-prone farmers in the Tumkur district of Karnataka who were struggling with weather-induced risk. The research used input-output data from 130 farmers for the years 1987-88 and time series data from 1969 to 1986. In the existing plans, the findings showed that there was a high risk associated with low returns. Crops, sericulture, and the dairy enterprise system were found to be more suitable in the risk efficient plans in terms of adding stability to farm returns while also offering more employment opportunities.

Alam *et al.* (1997) employed the parametric linear programming model, a modified form of the MOTAD model to small farm planning under risk in Jessore District of Bangladesh. The researchers reported that the risk programming result uncovered that higher gross margin, human labour hiring and farm tractor/power tiller usage were related with higher risk, while land usage and capital investment expanded alongside the gross margin-risk frontier. The solution likewise showed direction of efficient input use for risk minimization at different degrees of gross margins for the small farms.

Kehkha *et al.* (2005) applied a MOTAD risk-programming model to examine the impacts of risk on cropping pattern and farmers' incomes in Ramjerd and Sarpaniran Districts in

Fars Province of Iran. The authors reported that variability of farm gross margins significantly affects cropping patterns, yet it changes with various farmers and regions with different climatic conditions. It was likewise revealed that farm plans with higher number of crops have lower returns but with higher level of certainty.

In a study on risk preference and differentials in resource allocation among food crop farmers in Osun State, Nigeria, Salimonu and Falusi (2007) employed the LP and T-MOTAD models for data analysis. The researchers reported that the level of return from 13 crop enterprises in the existing plan was ₦31, 959.81/ha. The result of the normative optimum plan revealed a return of ₦36, 776.05/ha from six prescribed crop enterprises while the risk efficient plan prescribed five crop enterprises and a return of has ₦35,812.14/ha for the farmers.

Derakhshan *et al.* (2007) applied the conventional linear programming and the MOTAD and T-MOTAD models in an effort to develop a risk-including optimal cropping pattern of agricultural and horticultural crops in Neyriz, Fars Province of Iran. The researchers reported that in MOTAD model outcome, the minimized risk increased with rising anticipated farm incomes, prompting the substitution of low income yielding crops with high ones. Orange and tangerine because of high income yielding condition were better than apple, cotton and watermelon in more significant levels of expected income. The results of the T-MOTAD model uncovered a reduction in the cropping area for cotton and watermelon showing the impact of risky condition on these crops. The area of land under cultivation for orange and tangerine were expanded given that they were high income yielding crops.

Umoh (2008) applied the T-MOTAD model in an investigation to develop the optimum farm plans under risk conditions in floodplains farming in Akwa Ibom State, Nigeria. The researcher reported that the main risk factors in floodplains farming are flood and dry season and that these risks were managed by the farmers through cropping in a sequential pattern, planting early germinating and flood resistant crop varieties. The outcome of the target MOTAD model indicated that farmers are not producing at optimal level of production and a crop mix comprising of cocoyam, maize, cassava and fluted pumpkin was discovered to be less risky and the most beneficial in terms of farm profit while all vegetables crop combinations were the most risky.

Salimonu *et al.* (2008) applied T-MOTAD analysis to model efficient resource allocation patterns for food crop farmers in Nigeria. Their result revealed that the optimal value of profit maximization plan of ₦98,861.24/ha and the risk minimized plans of ₦54,919.73/ha and ₦36,776.05/ha respectively were higher than the net return value of the farmers' existing plan. The authors further argued that the alternative efficient resource allocation plans recommended have higher expected returns than the farmers' plan and, in this way, fulfilling the increased income goal and that the normative profit maximization solution was more risky than the prescribed efficient plans.

In a research aimed at optimizing agricultural production under financial risk of water constraint in the Jordan Valley by Haddad and Shahwan (2012), the target MOTAD model was utilized to assess three levels of water accessibility. These are: current and normal circumstance and 50 percent and 30 percent water decrease levels. The researchers reported that the response of the crops under risk condition in Jordan Valley varies with the associated risk in the production process, both for season and volume of water accessible for irrigation farming where the effect of water loss was an issue in the winter (spring) farming season.

Udo *et al.* (2015a) developed optimum farm plans aimed at reducing child farm labour utilization under risk scenarios for arable crop farmers in Akwa Ibom State using the LP and T-MOTAD models. Eleven cropping enterprises were ascertained in the existing plans in the area with a mean net return of ₦275,247.03/ha for the State. The estimation of the normative optimum (single objective optimum net return) for a typical farmer recommended the cultivation of four crop enterprises, that is, 0.10ha of cassava/melon, 1.11 ha of cassava/melon/cocoyam, 0.61ha of sweet-potato/maize/pumpkin and 0.34ha of sweet-potato/maize/cocoyam to give an average return of ₦514,110.40/ha, implying an increase of 86.78 percent, over the existing plans. The researchers further explained that the net returns in the risk efficient plan was ₦467,506.20/ha which showed an improvement representing 69.84 percent over the existing plan but a decrease of 16.94 percent below the profit maximizing plan. The alternative risk efficient farm plan recommended cassava/melon/cocoyam on 0.52ha, cassava/melon on 0.11 ha, cassava/maize/pumpkin on 0.83ha, sweet potato/maize/pumpkin on 0.23ha, and sweet potato/maize/cocoyam on 0.33ha.

Udo *et al.* (2015b) additionally utilized the LP and T-MOTAD models to prescribed an alternative farm plan with risk constraint for arable crop farmers in Etinan, Abak and Eket agric zones of Akwa Ibom State employing both primary and secondary farm data. The investigation identified eleven enterprises in the existing plans with yearly net returns of ₦317,723.59/ha, ₦245,969.12/ha and ₦262,048.39/ha for Etinan Abak and Eket zones. The normative optimum net returns for a typical farmer were ₦559,028.50/ha in Etinan zone, ₦537,089.00/ha in Abak zone and ₦595,018.30/ha in Eket zone which indicates an increment of 75.94 percent, 118.35 percent and 127.06 percent over the existing plans in the three zones respectively. The net returns of the risk efficient plans were ₦415,884.10/ha in Etinan zone, ₦430,569.10/ha in Abak zone and ₦456,200.80/ha in

Eket zone respectively which were higher than those of the farmer's plan in each of the zones respectively but were lower than what was obtained in the single objective profit maximization plan. The researchers opined that the normative profit maximizing plans with higher returns have higher variability of returns (risk) than the recommended efficient plans. The authors concluded that capital was the lone restricting resource in the area and that the existing level of returns were not optimal.

Fathelrahman *et al.* (2017) applied the target MOTAD model to determine the optimum gross margin of greenhouse vegetable production under quality of water and risk constraints in the United Arab Emirates. The authors examined the trade-offs between gross margin of choice vegetables which were tomato, pepper, and cucumber, the mean deviation from gross margin and water saltiness utilizing a unique target MOTAD modelling to help the farmers solve resource allocation problems. The outcomes affirmed that enterprise diversification decreases associated risks. The optimal vegetable production mix uncovered that decrease in the production of tomato should to be balanced by an increment in the production of cucumber while the level of pepper production remains constant. The authors implied that risk is discounted as the production of cucumber rises dues to higher degree of tomato and lettuce price unpredictability as the option to cucumber. The reported solution was profoundly sensitive to variations in the constraining crop water saltiness. The investigation concluded from the results obtained that the target MOTAD modelling approach is an appropriate optimization technique under risk conditions.

The present study differed from the reviewed empirical studies in that it focused on incorporating risk into whole farm planning model and also considered what the optimum farm plan is under limited resource condition for crop, livestock and fishery smallholder farmers particularly in Kwara State. These types of enterprises represent the bulk of the farming systems by the smallholder farmers. Although, in Kwara States, there are more registered crop-based farmers than those practicing mixed farming (Kwara State Ministry of Agriculture and Natural Resources (KWSMANR), 2010), the livestock and fishery farmers could not be neglected in farm planning. In addition, LP problems were solved bearing in mind the agro ecological situation of the area in question. Some of the regions/areas where the LP technique was applied in previous studies were areas that have a different agro ecological condition from that of Kwara State. Besides, no study has been done in the area on the application of LP/T-MOTAD models to farm planning.

2.4.5 Production constraints encountered by smallholder farmers

Smallholder farmers are faced with many production constraints which limits the attainment of the production objectives. There is a relatively abundant body of literature on the production constraints encountered by arable crop, fish and livestock farmers in Nigeria and other parts of the world. This section presents a review of some of the previous studies on farmers production constraints.

Muriithi (2007) in a study on resource usage in small-scale food crop production among farmers in Kenya found inadequate money, seasonal labour shortages, weak marketing infrastructure, low farm profits are the major challenges to the farmers. The researcher argued further that most of these farmers lack the financial means to invest in other forms of production. According to Ayinde (2008), small-scale farmers' development operation is characterized by dispersed small land holdings with little prospect of expansion.

In a study conducted by Muzari *et al.* (2012), unreliable and poorly distributed rainfall patterns, low and unattractive prices, lack of small-scale irrigation facilities and were identified as severe limitations to agricultural productivity among smallholder farmers in sub-Saharan Africa. Other constraints identified were infestation of pests and diseases, large post-harvest losses, weak research-extension links, inadequate input supply (especially improved seed varieties and fertilizer), infertile soils and smallholder farmers' failure to adjust to changing environmental conditions and improved technologies.

The production constraints identified by Onojah *et al.* (2013) in a study conducted among maize farmers in Nigeria were inadequate funding, high labour costs, poor transportation amenities, inadequate access to extension services and lack of available market. Onumadu *et al.* (2014) also reported inadequate credit availability, land scarcity, high labour costs, inadequate supply and high cost of improved varieties as major constraints to farmers in Anambra State. Other constraints included pests and diseases, inadequate infrastructure and transportation facilities and a shortage of storage and processing facilities.

Adewumi (2017) found that conflicts with Fulani herdsmen, high cost of credit and farm inputs and poor access road, inadequate extension and farm advisory services and inadequate market information among others were the major constraints faced by crop farmers in Kwara State. Durba *et al.* (2019) in a study carried out in Kaduna State reported high cost of acquiring credit facilities, poor access road and transport facility, inadequate market information, high cost of farm inputs, inadequate storage facility and inadequate extension and farm advisory services as severe production constraints to crop farmers. The authors argued that these constraints pose a great threat to farmers' potential of achieving improved productivity and food security.

Akpabio and Inyang (2007) identified poor access to credit facilities, inadequate supply of fingerlings, high cost of fish pond establishment, high cost of feed, lack of affordable land, lack of equipment for different production phases, low selling price of produce, taxation, unavailability of improved species, predation of fish by animals and activity of fish poachers among others as major constraints to fish production in Akwa Ibom State, Nigeria. Kudi *et al.* (2008) also reported that the constraints faced by fish farmers in Kaduna State are lack of capital, lack of good demand, diseases and short water supply.

According to Abiona *et al.* (2011), inadequate capital, limited access to credit, market price risk, output risk, exploitation by middlemen, insufficient motivation for water infrastructure maintenance, inadequate capital assets and social attitude are major among the constraints faced by small fish farmers in Nigeria. In addition, Hossian and Islam (2014) reported that fish farmers in Mymensingh, Bangladesh are faced with a lack of credit, high input and operational costs and a lack of scientific knowledge.

Shitote *et al.* (2012) investigated the challenges faced in the development of fish farming in Kenya and discovered that high feed costs, water scarcity during the drought and flooding were major constraints. The authors further identified shortage of fingerlings, poor protection/security, siltation of ponds and pond maintenance were problems for fish farmers.

In a study conducted by Olaoye *et al.* (2013), land disputes, lack of funds, gap between the farmers and the extension officers, non-availability and/or high cost of fingerlings, lack of preservation and processing facilities, market price fluctuations, high cost of feed, poaching, high cost of construction materials, water shortage, disease and pest infestation and lack of technical skills were constraints faced by the fish farmers in Oyo State.

In separate studies, Ibemere and Ezeano (2014) and Sadiq and Kolo (2015) examined the problems and prospects of small-scale fish farming in Niger State and found that the major constraints faced by fish farmers in the region are lack of good breed stock, lack of resources, and high cost of feed. Other constraints reported were high labour costs, inadequate and weak storage facilities, insufficient water supply and disease-related mortality. Issa *et al.* (2014) reported limited capital, marketing issues diseases, high input costs and lack of government support as constraints decried by fish farmers in Kaduna State.

As revealed in a study conducted by Nwachi and Begho (2014) in Delta State, Nigeria, catfish production has been hampered by a lack of resources, shortage of skilled labourers, water poisoning, lack of power, high cost of feed and a lack of necessary equipment for fish farming. In another survey James *et al.* (2014), respondents identified lack of funds, market price fluctuations, high input prices, seasonality of fish availability, a lack of technical expertise, and fish spoilage due to post-harvest handling as a limitation to fish production in Delta State. Olasunkanmi and Yusuf (2014) also reported high cost of feed, price fluctuation and flooding during the rainy season as constraints to fish farmers in Osun State.

Dambata *et al.* (2016) in a study in Kano State reported that the constraints of the fishery enterprises were inadequate capital, high cost of inputs, poor sale, poor road linkages, inadequate processing facilities and aquatic vegetation menace. Ibeun *et al.* (2019) also reported that fish production constraints in Kainji Lake Basin, Nigeria are inadequate improved fingerlings, inadequate extension agents, land/pond acquisition problem, low dissemination of research findings, high cost of feed, unavailability of production inputs, flooding, adverse climatic condition, incidence of pest and diseases, poor remunerative process and inadequate access to credit.

Many studies also revealed the challenges that livestock farmers face. According to Sathyanarayan *et al.* (2010), lack of fodder, lack of room, middlemen exploitation, inadequate funds, unskilled labour and the presence of predators are major setback in livestock production in Narasapura, India. Mutibvu *et al.* (2012) investigated the constraints and opportunities for increased livestock production in Zimbabwe and reported that diseases, feed shortage, water shortage, poor extension service among other issues as constraints to the farmers.

According to Le *et al.* (2013), livestock disease, limited access to credit, high and rapid increases in feed price, high volatility of output prices and insufficiency of market information are major constraints to livestock production in Vietnam. Belay *et al.* (2013) also reported poor-quality animal feed, animal diseases, decrease in water quantity during the dry season, as well as poor water quality are major hindrances to livestock production in Ginchi, Ethiopia.

Inadequate access to credit facilities, disease outbreaks, high mortality rates, difficulty in getting good breed stock, low profits, feed shortage, poor market pricing policy, inadequate knowledge of livestock production and inadequate livestock capacity according to Baruwa (2013) are constraints to livestock production in Nigeria. The most serious constraints faced by livestock farmers in Nigeria according to Umunna *et al.* (2014) are a lack of veterinary facilities, insufficient resources, scarcity of fodder and lack of expertise and training.

Jacob (2019) in a study on optimum combination of crop, livestock and fishery enterprises in Niger State reported inadequate finance, high cost of inputs and labour, lack of machineries, soil infertility, poor extension services, changes in rainfall pattern, scarcity of land, lack of storage facilities, large post-harvest losses and flood as constraints of the crop farmers. Lack of sufficient capital shortage of veterinary services, pest and diseases, poor extension services, scarcity of fodder, middle men exploitation, poor water quality, insufficient space were the constraints identified in livestock production. The researcher also identified inadequate finance, lack of credit facilities, high cost of inputs, difficulty in getting quality breed and quality fingerlings among others as the major constraints faced by the fisheries farmers.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Area of Study

The study was conducted in Kwara State, Nigeria. The State is comprised of sixteen (16) Local Government Areas (LGAs) which are grouped into four agricultural zones namely; Kaiama (zone A), Patigi (zone B), Shao (zone C) and Igbaja (zone D). The State has a total land area of 32,500 square kilometres, 75.3% of which is cultivable (Kwara State Ministry of Agriculture and Natural Resources (KWSMANR), 2010). The State has a total population of 2,371,089 persons (KWSMANR, 2010) and with an annual growth rate of 2.8% (Gannicott, 2008), the total population is estimated to be 3,395,145 as at 2019.

Kwara State is located in North Central Nigeria between Latitudes 7°45′N to 9°30′N and Longitudes 2°30′E to 6°25′E and shares boundaries with Niger State in the North, Osun and Oyo States in the South, Kogi State in the East and Benin Republic in the West. The mean annual rainfall ranges between 1000mm and 1500mm. The rainy season in the State falls between March and October with a short break in August while the dry season is between November and February. The average temperature ranges between 30°C and 35°C. The topography of the State which is mainly plain to slightly gentle rolling lands and the climatic condition favours the cultivation of various arable crops including cassava, yam, cowpea, maize, millet, rice, groundnut, sorghum and vegetables as well as rearing of livestock such as cattle, goat, sheep, and poultry birds among others (KWSMANR, 2010).

Besides employment in the civil service, farming and trading are the major occupations of the people of the State. It has a total of 99,695 and 3,274 registered crop and non-crop farmers respectively giving a sum total of 102,969 farmers, while a total of 1,094,232 of the population are engaged in direct farming (KWSMANR, 2010). The major tribes in the State are Yoruba, Nupe and Baruba. Other tribes present include Fulani, Igbo and Hausa. The Map of Nigeria showing the study area is presented in Figure 3.1.

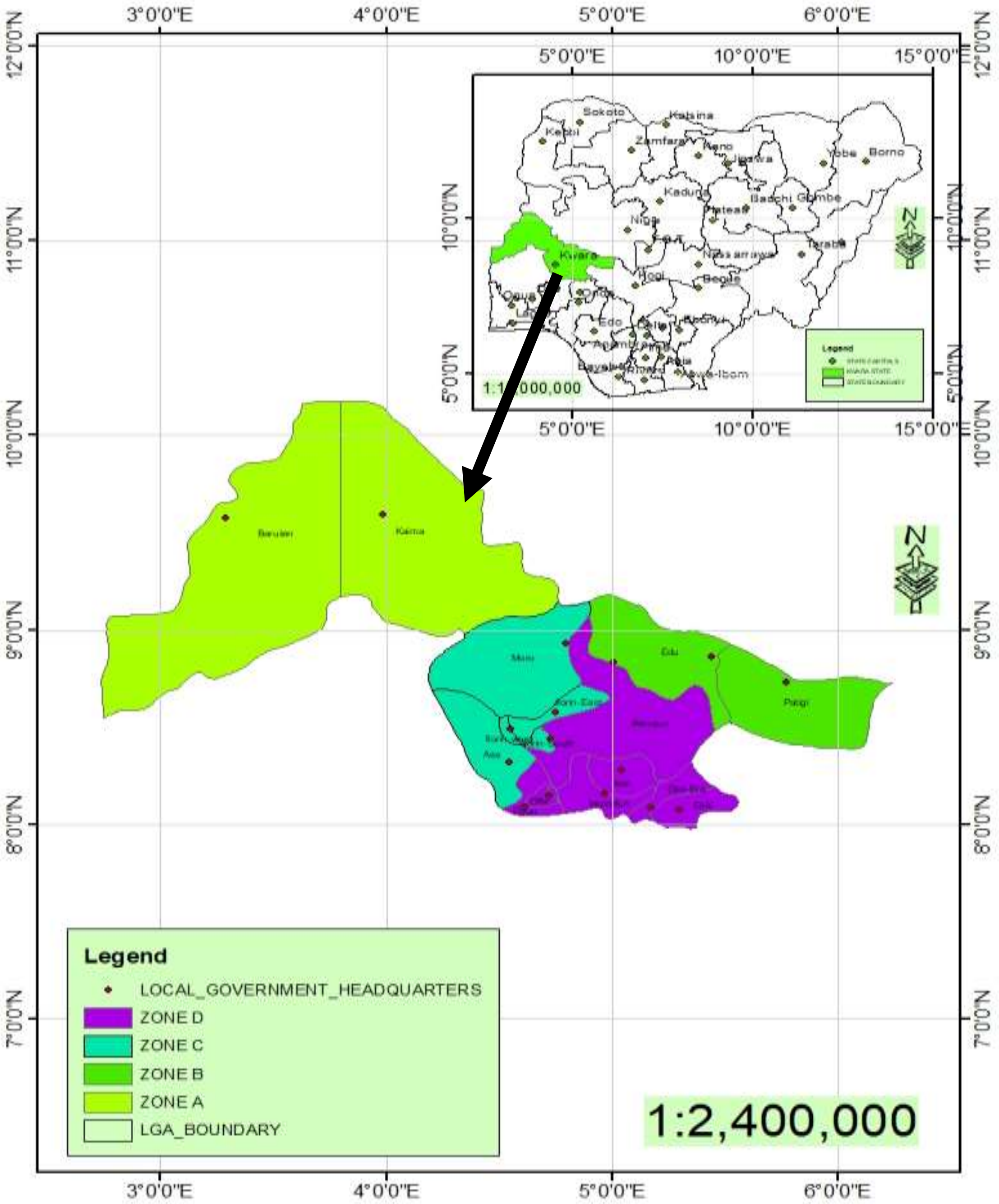


Figure 3.1: Map of Nigeria showing the study area

3.2 Sampling Procedure

A multi-stage sampling procedure was employed for this study. Kwara State is divided into four agricultural zones (A, B, C and D). All smallholder farmers operating crop, livestock and fishery enterprises in the four agricultural zones of Kwara State constituted the population of study. At the first stage, 50% of the Local Government Areas (LGAs) in each zone were randomly sampled. This gave a total pf eight LGAs for the study. The second stage involved the random selection of 25% of the districts from each of the selected LGAs. LGAs that have less than four districts, one of the districts was randomly selected. This gave a total of eight districts for the study. The third stage involved the random selection of 5% of the communities from each of the selected districts which gave a total of 29 communities. Following Israel (1992), Cochran's formula for representative sample determination specified in equation (3.1) was used to determine the sample size for the study. This study considered crop, livestock and fisheries production enterprises. The smallholder farmers who are engaged in crop, livestock or fisheries production enterprises were identified and selected with the assistance of the village heads and the resident extension agents. The sampling design is presented in Table 3.1.

$$n = \frac{Z^2 p(1-p)}{e^2} \tag{3.1}$$

Where;

n = sample size,

Z = desired confidence level at 95% (1.96),

p = degree of variability in the population attributes (50% adopted for this study), and

e = desired level of precision (α = 0.05 for this study).

Table 3.1: Sampling design for the study

Agricultural zone	LGA	District	Community	Sample frame	Sample size
Kaiama (A) (2*)	Kaiama (2**)	Kaiama (82***)	Frenaba	71	8
			Mamman Buran	138	15
			Onipako	101	11
			Woro	87	9
Patigi (B) (2*)	Patigi (3**)	Patigi (41***)	Esungi	134	14

			Rifun	165	18
Shao (C) (5*)	Asa (3**)	Owode (164***)	Alagbede	122	13
			Budo Ajokode	86	9
			Budo Aribi	91	10
			Budo Eleran	106	11
			Budo Inda	115	12
			Budo Ogbin	134	14
			Budo Temidire	144	16
			Eleyele	138	15
	Moro (5**)	Malete (110***)	Adanduro	140	15
			Alaya	96	10
			Gaa Aiyekale	116	13
			Igbo-Onishin	106	11
			Okete	162	17
			Panbo	121	13
Igbaja (D) (7*)	Irepodun (4**)	Ajase (39***)	Buari	94	10
			Ajase-Ipo	237	26
	Oyun (2**)	Odo-Ogun (69***)	Ajoko	109	12
			Kajola	85	9
			Igosun	143	15
			Ago Balomi	135	15
	Isin (2**)	Isin (36***)	Edidi	139	15
			Owu-Isin	152	16
	Ekiti (2**)	Osi (18***)	Idera-Opin	107	12
Total				**3,574**	**384**

Source: Kwara State Agricultural Development Programme (2014).
*, ** and *** imply number of LGAs, districts and communities respectively.

3.3 Method of Data Collection

Primary data were used for this study. The cross-sectional data for 2019 production season were collected from the farmers through the limited cost-route approach in the study area with the aid of a structured questionnaire. Given that farmers rarely keep farm records, the limited cost-route approach was used to track the activities carried out by the farmers on their farms especially the arable crop farmers from land preparation to harvest during the year 2019 farming season in order to obtain accurate data. Data on household demographic characteristics were obtained once while production data were collected on a monthly basis. The structured questionnaire was complimented with interview schedules. The researcher was assisted by trained resident extension agents and enumerators during the data collection process. The choice of this category of extension agents and enumerators was to facilitate access given that they were conversant with the study locations and are familiar with the target populations.

Data were collected on the household characteristics of the farmers such as age, sex, marital status, household size, level of education, years of farming experience, membership of farmers' group and access to credit and extension services as well as the constraints encountered in the production activities of their farm enterprises. Information on the crop, fisheries and livestock farm enterprise inputs and prevailing costs of inputs, corresponding outputs and prevailing market price of the outputs were also collected and used to estimate potential gross returns. Data on farm size were also obtained with the use of measuring tape and Google Earth software. The outputs from farms where crops have not been completely harvested were measured using the yield plot method adopted by Tanko (2004) and Igwe (2012). Where livestock or fishery enterprises were involved, measurements were taken using weighing balance. These were done in addition to the information obtained from the farmers.

3.4 Analytical Techniques

Data analysis was done with the use of descriptive statistics, farm budgeting model, linear programming model, target-minimization of total absolute deviation (T-MOTAD) model and Kendall's non-parametric test statistics.

3.4.1 Descriptive statistics

Descriptive statistics were employed to analyse objectives (i), (ii) and (v). This involved the use of charts, tables, frequency distribution, percentages and means. For objective (v), a five-point Likert type rating scale was used to measure farmers' perception on the severity of production constraints to aid analysis which guided drawing of inferences and deductions on implications to policy culminating into appropriate recommendations.

3.4.2 Farm budgeting model

A farm budgeting model was used to estimate the costs and returns associated with the farm enterprises namely, namely crop, livestock and fisheries undertaken by the smallholder farmers (objective iii). It involved the estimation of the gross margin (GM) as well as the net farm incomes (NFI). The farm budgeting model adopted from Adewumi (2017) and specified in equations (3.2) and (3.3) were used.

$$GM = \sum_{i=1}^{m} P_{yi}Y_i - \sum_{j=1}^{n} P_{xj}X_j \tag{3.2}$$

$$NFI = \sum_{i=1}^{m} P_{yi}Y_i - \sum_{j=1}^{n} P_{xj}X_j - \sum_{k=1}^{o} F_k \tag{3.3}$$

Where;

GM = Gross Margin,

NFI = Net farm income,

Y_i = Output per unit enterprise (where i = 1, 2, 3, …, m products),

P_{yi} = Unit price of the product,

X_j = Quantity of the variable inputs per unit enterprise (where j =, 1, 2, 3, …, n variable inputs),

P_{xj} = Price per unit of variable inputs, and

F_k = Cost of fixed inputs per unit enterprise (where k =, 1, 2, 3, …, o fixed inputs).

The depreciation on farm tools which was computed with the straight-line method of depreciation.

3.4.3 Mathematical programming models

3.4.3.1 Linear programming (LP) model

A linear programming (LP) model was used to derive optimum farm plans for the smallholder farmers in the study area. The LP model adapted from Igwe (2012) and Adewumi (2017) is expressed mathematically in an expanded form following Reddy *et al.* (2004) as specified in equations (3.4) to (3.15).

The objective function of the model was to maximize the gross margins. For crop enterprises, it is defined as total farm income minus the total costs of labour, seed, agrochemical, fertilizer, tractor hiring, transportation, processing and storage. In the case of fisheries enterprise, the objective function which was to maximize gross margins is defined as gross income less costs of feed, fingerlings, breed stock, medication, labour, transportation and storage, while for the livestock enterprises, it is gross income minus costs of breed stock, feed, veterinary services (consultancy fee), vaccination and medications, labour, commission fees and transportation. The farm budgeting model also adopted from Adewumi (2017) as specified in equation (3.2) was used to compute the farmers' gross margin for each farm enterprise undertaken. For this study, the unit of activity was one hectare, one Tropical Livestock Unit (TLU) and one metre square for crop, livestock and fishery enterprises respectively. The conversion equivalents of sub-Saharan African livestock into TLU adapted from Njuki *et al.* (2011) was used for this study. The Table is presented in Appendix H.

Owned (limited) and borrowed capital scenarios:

Crop enterprises;

The objective function was to:

$$\text{Maximize } Z_c = P_1X_1 + P_2X_2 + P_3X_3 + \ ....+P_nX_n \qquad (3.4)$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + \ ... + \ A_{1n}X_n \ \leq L_S \text{ (Land in hectare)} \qquad (3.5)$$

$$A_{21}X_1 + A_{22}X_2 + \ ... + \ A_{2n}X_n - L_t \ \leq HL_t \text{ (Hired labour in mandays)} \qquad (3.6)$$

$$A_{31}X_1 + A_{32}X_2 + \ ... + \ A_{3n}X_n - L_t \ \leq FL_t \text{ (Family labour in mandays)} \qquad (3.7)$$

$$A_{41}X_1 + A_{42}X_2 + \ ... + \ A_{4n}X_n - M_t \ \leq C_t \text{ (Capital inputs in Naira)} \qquad (3.8)$$

$$A_{51}X_1 + A_{52}X_2 + \cdots + \ A_{5n}X_n - E_t \ \leq S_t \text{ (Seed in kilograms)} \qquad (3.9)$$

$$A_{61}X_1 + A_{62}X_2 + \cdots + \ A_{6n}X_n - B_t \ \leq F_t \text{ (Fertilizer in kilograms)} \qquad (3.10)$$

$$A_{71}X_1 + A_{72}X_2 + \ ... + \ A_{7n}X_n \ - K_t \ \leq A_t \text{ (Agrochemical in litres)} \qquad (3.11)$$

$$A_{81}X_1 + A_{82}X_2 + \ ... + \ A_{8n}X_n - L_t \ \leq T_t \text{ (tractor/power tiller in machine hours)} \qquad (3.12)$$

$$A_{91}X_1 + A_{92}X_2 + \ ... + \ A_{9n}X_n - L_t \ \leq M_t \text{ (Marketing expenses in Naira)} \qquad (3.13)$$

$$CF_{10n}X_n \geq F_c \text{ (Min)(Minimum farm family food crop requirement)} \qquad (3.14)$$

and,

$$X_1 \geq 0, X_2 \geq 0, ..., X_n \geq 0 \ \text{ (non} - \text{negativity assumption)} \qquad (3.15)$$

Where;

Z_c = Gross Margin,

$X_1, X_2, X_3, ... X_n$ = Crop activities or enterprise(s) undertaken (decision variables),

$P_1, P_2, P_3, ... P_n$ = Output coefficients or net prices (gross margin/ha) of the different crop activities maximized,

A_{ij} (Equations (3.5) – (3.13)) = Input-output coefficients, that is, quantity of i^{th} resource (land, hired labour, family labour, capital, seed, fertilizer, agrochemical, tractor/power tiller and marketing expenses) required to produce a unit output of j^{th} crop activity. The unit of crop activity for this study was one hectare,

CF_{10n} = Minimum farm family i^{th} food crop requirement for j^{th} crop enterprise,

L_s = Level of available land in hectare from owned and rented sources for crop activities with s restriction,

HL_t = Level of available hired labour in man-day,

FL_t = Level of available family labour in man-day,

C_t = Level of available working capital in Naira from owned and borrowed sources,

S_t = Level of available seed in kilograms,

F_t = Level of available fertilizer in kilograms,

A_t = Level of available agrochemical in litres,

T_t = Level of available tractor/power tiller in machine hours,

M_t = Level of marketing expenses incurred in Naira, and

F_c = Level of food crops consumed in kilograms.

Livestock (ruminant/poultry) enterprises;

The objective function was stated as:

$$\text{Maximize } Z_l = P_1X_1 + P_2X_2 + P_3X_3 + \ldots . + P_nX_n \quad (3.16)$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + \ldots + A_{1n}X_n \leq L_S \text{ (Livestock capacity in TLU)} \quad (3.17)$$

$$A_{21}X_1 + A_{22}X_2 + \ldots + A_{2n}X_n - L_t \leq HL_t \text{ (Hired labour in man} - \text{days)} \quad (3.18)$$

$$A_{31}X_1 + A_{32}X_2 + \ldots + A_{3n}X_n - L_t \leq FL_t \text{ (Family labour in man} - \text{days)} \quad (3.19)$$

$$A_{41}X_1 + A_{42}X_2 + \ldots + A_{4n}X_n - M_t \leq C_t \text{ (Capital inputs in Naira)} \quad (3.20)$$

$$A_{51}X_1 + A_{52}X_2 + \cdots + A_{5n}X_n \leq F_t \text{ (Feed in kilograms)} \quad (3.21)$$

$$A_{61}X_1 + A_{62}X_2 + \cdots + A_{6n}X_n \leq B_t \text{ (Breed stock in TLU)} \quad (3.22)$$

$$A_{71}X_1 + A_{72}X_2 + \ldots + A_{7n}X_n \leq M_t \text{ (Medications in Naira)} \quad (3.23)$$

$$A_{81}X_1 + A_{82}X_2 + \ldots + A_{8n}X_n \leq T_t \text{ (Marketing expenses in Naira)} \quad (3.24)$$

$$LF_{9n}X_n \geq F_l \text{ (Min)(Minimum farm family livestock (protein) requirement)} \quad (3.25)$$

and,

$$X_1 \geq 0, X_2 \geq 0, \ldots., X_n \geq 0 \ \text{(non - negativity assumption)} \qquad (3.26)$$

Where;

Z_l = Gross Margin,

$X_1, X_2, X_3, \ldots X_n$ = Livestock/poultry activities or enterprises undertaken (decision variables) such as rearing of cattle, goats, sheep, pigs, rabbit and poultry birds among others,

$P_1, P_2, P_3, \ldots P_n$ = Output coefficients (gross margin/TLU) of the different livestock activities maximized,

A_{ij} = Input-Output coefficients, that is, quantity of i^{th} resource (livestock capacity, hired labour, family labour, capital, feed, breed stock, medications and marketing expenses) required to produce a unit (one TLU) output of j^{th} livestock activity,

LF_{9n} = Minimum farm family t^{th} livestock (protein) requirement for j^{th} livestock enterprise,

L_s = Level of available livestock capacity in TLU,

HL_t = Level of available hired labour in man-day,

FL_t = Level of available family labour in man-day,

C_t = Level of available working capital from owned and borrowed sources in Naira,

F_t = Level of available feed in kilograms,

B_t = Level of available breed stock in TLU,

M_t = Level of available medications in Naira,

T_t = Level of marketing expenses incurred in Naira, and

F_1 = Level of food (livestock protein) consumed in kilograms/annum.

Fisheries enterprises;

The objective function:

$$\text{Maximize } Z_f = P_1X_1 + P_2X_2 + P_3X_3 + \ldots + P_nX_n \quad (3.27)$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + \ldots + A_{1n}X_n \leq P_S \text{ (Pond size in meter squared)} \quad (3.28)$$

$$A_{21}X_1 + A_{22}X_2 + \ldots + A_{2n}X_n - L_t \leq HL_t \text{ (Hired labour in man} - \text{days)} \quad (3.29)$$

$$A_{31}X_1 + A_{32}X_2 + \ldots + A_{3n}X_n - L_t \leq FL_t \text{ (Family labour in man} - \text{days)} \quad (3.30)$$

$$A_{41}X_1 + A_{42}X_2 + \ldots + A_{4n}X_n - M_t \leq C_t \text{ (Capital inputs in Naira)} \quad (3.31)$$

$$A_{51}X_1 + A_{52}X_2 + \cdots + A_{5n}X_n \leq F_t \text{ (Feed in kilograms)} \quad (3.32)$$

$$A_{61}X_1 + A_{62}X_2 + \cdots + A_{6n}X_n \leq FS_t \text{ (Fingerlings stock in number)} \quad (3.33)$$

$$A_{71}X_1 + A_{72}X_2 + \ldots + A_{7n}X_n \leq L_t \text{ (Lime in kilograms)} \quad (3.34)$$

$$A_{81}X_1 + A_{82}X_2 + \ldots + A_{8n}X_n \leq M_t \text{ (Medications in Naira)} \quad (3.35)$$

$$A_{91}X_1 + A_{92}X_2 + \ldots + A_{9n}X_n \leq T_t \text{ (Marketing expenses in Naira)} \quad (3.36)$$

$$F_{10n}X_n \geq F_f \text{ (Min)(Minimum farm family fish product (protein) requirement)} \quad (3.37)$$

and,

$$X_1 \geq 0, X_2 \geq 0, \ldots, X_n \geq 0 \text{ (non} - \text{negativity assumption)} \quad (3.38)$$

Where;

Z_f = Gross Margin,

$X_1, X_2, X_3, \ldots X_n$ = Fishery activities or enterprises undertaken (decision variables) such as fingerlings, tilapia, catfish and fish feed production among others,

$P_1, P_2, P_3, \ldots P_n$ = Output coefficients (gross margin per metre square) of the different fishery activities maximized,

A_{ij} = Input-output coefficients, that is, quantity of i^{th} resource (pond size, hired labour, family labour, capital, feed, fingerlings stock, lime, medications and marketing expenses) required to produce a unit output of j^{th} fishery activity,

F_{10n} = Minimum farm family i^{th} fish product (protein) requirement for j^{th} fishery enterprise,

P_s = Level of available pond size in meter squared from owned and rented sources,

HL_t = Level of available hired labour in man-day,

FL_t = Level of available family labour in man-day,

C_t = Level of available working capital in Naira from owned and borrowed sources,

F_t = Level of available feed in kilograms,

FS_t = Level of available fingerlings stock in kilograms,

L_t = Level of available lime in kilograms.

M_t = Level of available medications in Naira.

T_t = Level of marketing expenses incurred in Naira, and

F_f = Level of fish product (protein) consumed in kilograms/annum.

Combination of farm enterprises;

The objective function:

$$\text{Maximize } Z = P_1X_1 + P_2X_2 + P_3X_3 + \ ....+P_nX_n \tag{3.39}$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + \ ... + \ A_{1n}X_n \ \le L_S \text{ (Land in hectare)} \tag{3.40}$$

$$A_{21}X_1 + A_{22}X_2 + \ ... + \ A_{2n}X_n \ \le L_c \text{ (Livestock capacity in TLU measurement)} \tag{3.41}$$

$$A_{31}X_1 + A_{32}X_2 + \ ... + \ A_{3n}X_n \ \le P_S \text{ (Pond size in meter squared)} \tag{3.42}$$

$$A_{41}X_1 + A_{42}X_2 + \ ... + \ A_{4n}X_n - L_t \ \le HL_t \text{ (Hired labour in mandays)} \tag{3.43}$$

$$A_{51}X_1 + A_{52}X_2 + \cdots + \ A_{5n}X_n - L_t \ \le FL_t \text{ (Family labour in mandays)} \tag{3.44}$$

$$A_{61}X_1 + A_{62}X_2 + \cdots + \ A_{6n}X_n - M_t \ \le C_t \text{ (Capital inputs in Naira)} \tag{3.45}$$

$$A_{71}X_1 + A_{72}X_2 + \ ... + \ A_{7n}X_n - E_t \ \le S_t \text{ (Seed in kilograms)} \tag{3.46}$$

$$A_{81}X_1 + A_{82}X_2 + \ ... + \ A_{8n}X_n - B_t \ \le FT_t \text{ (Fertilizer in kilograms)} \tag{3.47}$$

$$A_{91}X_1 + A_{92}X_2 + \ ... + \ A_{9n}X_n \ - K_t \ \le A_t \text{ (Agrochemical in litres)} \tag{3.48}$$

$$A_{101}X_1 + A_{102}X_2 + \ ... + \ A_{10n}X_n - L_t \ \le T_t \text{ (tractor/power tiller in machine hours)} \tag{3.49}$$

$$A_{111}X_1 + A_{112}X_2 + \cdots + \ A_{11n}X_n \ \le F_t \text{ (Feed in kilograms)} \tag{3.50}$$

$$A_{121}X_1 + A_{122}X_2 + \cdots + A_{12n}X_n \le B_t \text{ (Breed stock in TLU measurement)} \quad (3.51)$$

$$A_{131}X_1 + A_{132}X_2 + \cdots + A_{13n}X_n \le FS_t \text{ (Fingerlings stock in number)} \quad (3.52)$$

$$A_{141}X_1 + A_{142}X_2 + \ldots + A_{14n}X_n \le L_t \text{ (Lime in kilograms)} \quad (3.53)$$

$$A_{151}X_1 + A_{152}X_2 + \ldots + A_{15n}X_n \le M_t \text{ (Medications in Naira)} \quad (3.54)$$

$$A_{161}X_1 + A_{162}X_2 + \ldots + A_{16n}X_n - L_t \le MK_t \text{ (Marketing expenses in Naira)} \quad (3.55)$$

$$CF_{17n}X_n \ge F_c \text{ (Min)(Minimum farm family food crop requirement)} \quad (3.56)$$

$$LF_{18n}X_n \ge F_l \text{ (Min)(Minimum farm family livestock (protein) requirement)} \quad (3.57)$$

$$F_{19n}X_n \ge F_f \text{ (Min)(Minimum farm family fish product (protein) requirement)} \quad (3.58)$$

and,

$$X_1 \ge 0, X_2 \ge 0, \ldots., X_n \ge 0 \text{ (non} - \text{negativity assumption)} \quad (3.59)$$

Where all variables are as previously defined.

Limited (owned capital) resource condition:

Crop enterprises;

The objective function was stated as:

$$\text{Maximize } Z_c = \sum P_j X_j \quad (3.60)$$

Subject to:

$$A_{ij}X_j \le \beta_i t \quad (3.61)$$

$$\sum CF_{ij}X_j \ge f_c \text{ (Min)(Minimum farm family food crop requirement)} \quad (3.62)$$

and

$$X_j \ge 0 \quad \text{(non} - \text{negativity assumption)} \quad (3.63)$$

Where;

Z_c = Gross Margin,

X_j = Crop activity or enterprise undertaken (decision variable),

P_j = Output coefficient or net price (gross margin/ha) of each crop activity maximized,

A_{ij} (Same as in equations (3.5) – (3.14)) = Input-output coefficients, that is, quantity of i^{th} resource (land, hired labour, family labour, capital, seed, fertilizer, agrochemical, tractor/power tiller and marketing expenses) required to produce a unit (one hectare) output of j^{th} crop activity.

$\beta_i t$ = Total level of available resources for crop activities/enterprises,

CF_{ij} = Minimum farm family i^{th} food crop requirement for j^{th} farm enterprise,

Livestock (ruminant/poultry) enterprises;

The objective function was stated as:

$$\text{Maximize } Z_l = \sum P_j X_j \qquad (3.64)$$

Subject to:

$$A_{ij} X_j \leq \beta_i t \qquad (3.65)$$

$$\sum L_{ij} X_j \geq f_l \text{ (Min)(Minimum farm family livestock product requirement)} \qquad (3.66)$$

and

$$X_j \geq 0 \quad \text{(non} - \text{negativity assumption)} \qquad (3.67)$$

Where;

Z_l = Gross Margin,

X_j = Livestock activity or enterprise undertaken (decision variable),

P_j = Output coefficient or net price (gross margin/TLU) of each livestock activity maximized,

A_{ij} (Same as in equations (3.17) – (3.24)) = Input-output coefficients, that is, quantity of i^{th} resource (livestock capacity, hired labour, family labour, capital, feed, breed stock, medications and marketing expenses) required to produce a unit (one TLU) output of j^{th} livestock activity.

$\beta_i t$ = Level of available resources for livestock activities/enterprises,

L_{ij} = Minimum farm family i^{th} livestock product requirement for j^{th} farm enterprise.

Fisheries enterprises;

The objective function was stated as:

$$\text{Maximize } Z_f = \sum P_j X_j \qquad (3.68)$$

Subject to:

$$A_{ij} X_j \leq \beta_i t \qquad (3.69)$$

$$\sum F_{ij} X_j \geq f_f \text{ (Min)(Minimum farm family fish product requirement)} \qquad (3.70)$$

and

$$X_j \geq 0 \quad \text{(non − negativity assumption)} \qquad (3.71)$$

Where;

Z_f = Gross Margin,

X_j = Fishery activity or enterprise undertaken (decision variable),

P_j = Output coefficient or net price (gross margin/ton) of each fishery activity maximized,

A_{ij} (Same as in equations (3.28) – (3.36)) = Input-output coefficients, that is, quantity of i^{th} resource (pond size, hired labour, family labour, capital, feed, fingerlings stock, lime, medications and marketing expenses) required to produce a unit (one ton) output of j^{th} fishery activity.

$\beta_i t$ = Level of available resources for fishery activities/enterprises, and

F_{ij} = Minimum farm family i^{th} fish product requirement for j^{th} farm enterprise.

Combination of farm enterprises;

The objective function was stated as:

$$\text{Maximize } Z = \sum P_j X_j \qquad (3.72)$$

Subject to:

$$A_{ij} X_j \leq \beta_i t \qquad (3.73)$$

$$\sum CF_{ij} X_j \geq f_c \text{ (Min)(Minimum farm family food crop requirement)} \qquad (3.74)$$

$\sum L_{ij} X_j \geq f_l$ (Min)(Minimum farm family livestock product requirement) (3.75)

$\sum F_{ij} X_j \geq f_f$ (Min)(Minimum farm family fish product requirement) (3.76)

an

$X_j \geq 0$ (non − negativity assumption) (3.77)

Where;

Z = Gross Margin,

X_j = Crop/livestock/fishery activity or enterprise undertaken (decision variable),

P_j = Output coefficient or net price (gross margin/unit activity) of crop/livestock/fishery activity maximized,

A_{ij} (Same as in equations (3.40) – (3.55)) = Input-output coefficients, that is, quantity of i^{th} resource (land, livestock capacity, pond size, hired labour, family labour, capital, seed, fertilizer, agrochemical, tractor/power tiller, feed, breed stock, fingerling stock, lime, medication and marketing expenses) required to produce a unit output of j^{th} crop/livestock/fishery activity.

$\beta_i t$ = Level of available resources for crop/livestock/fishery activities/enterprises,

CF_{ij} = Minimum farm family i^{th} food crop requirement for j^{th} farm enterprise,

L_{ij} = Minimum farm family i^{th} livestock product requirement for j^{th} farm enterprise, and

F_{ij} = Minimum farm family i^{th} fish product requirement for j^{th} farm enterprise.

3.4.3.2 Target minimization of total absolute deviation (T-MOTAD) model

To incorporate risk into the LP model, the T-MOTAD model adapted from Tauer, (1983), Zimet and Spreen (1986) and Udo *et al.* (2015b) was used. The optimum gross margins obtained from LP models for capital borrowing and limited (owned) resources conditions were used as the target returns (T_r) in this model.

Crop enterprises;

The objective function was specified as:

$$Max\ E(Z) = \sum P_j X_j \tag{3.78}$$

Subject to:

$\sum A_{ij} X_j \leq \beta_i$ (Technical resources requirement for crop activities), (3.79)

$\sum CF_{ij} X_j \geq \delta_i$ (Farm family food crop consumption requirement), (3.80)

$\sum C_{rj} X_j \geq T_r$ (Absolute deviations from T_r), (3.81)

$\sum P_r Y_r = \lambda$ (Risk: – ve deviations (₦)) (3.82)

and

$X_j \geq 0$ (3.83)

Where:

$E(Z)$ = Expected return per hectare of the plan (₦),

P_j = Output coefficients (gross margin) per hectare crop enterprise (₦),

X_j = Crop enterprise j undertaken (decision variables),

A_{ij} = Technical resource i requirement of crop enterprise j,

β_i = Level of available technical resource i,

CF_{ij} = Minimum farm family food i requirement of crop enterprise j,

δ_i = Level of food i consumed,

C_{rj} = Level of total absolute deviations from target returns of crop enterprise j for state of nature r in Naira,

T_r = Target level of return in Naira,

Y_r = Level of negative deviation below T_r for state of nature r in Naira,

P_r = Probability that state of nature r will occur, and

λ = A constant parameterised from M to 0

Livestock (ruminant/poultry) enterprises;

The objective function was specified as:

$$Max\ E(Z) = \sum P_j X_j \qquad (3.84)$$

Subject to:

$$\sum A_{ij} X_j \leq \beta_i \quad \text{(Technical resources requirement for livestock activities),} \qquad (3.85)$$

$$\sum L_{ij} X_j \geq \delta_i \quad \text{(Farm family livestock product requirement),} \qquad (3.86)$$

$$\sum C_{rj} X_j \geq T_r \quad \text{(Absolute deviations from } T_r \text{),} \qquad (3.87)$$

$$\sum P_r Y_r = \lambda \quad \text{(Risk: – ve deviations (₦))} \qquad (3.88)$$

and

$$X_j \geq 0 \qquad (3.89)$$

Where:

$E(Z)$ = Expected return per TLU of the plan (₦),

P_j = Output coefficients (gross margin) per TLU of livestock enterprise (₦),

X_j = Livestock enterprise j undertaken (decision variables),

A_{ij} = Technical resource i requirement of livestock enterprise j,

β_i = Level of available technical resource i,

L_{ij} = Minimum farm family livestock product i requirement of livestock enterprise j,

δ_i = Level of livestock product i consumed,

C_{rj} = Level of total absolute deviations from target returns of livestock enterprise j for state of nature r in Naira,

T_r = Target level of return in Naira,

Y_r = Level of negative deviation below T_r for state of nature r in Naira,

P_r = Probability that state of nature r will occur, and

λ = A constant parameterised from M to 0

Fisheries enterprises;

The objective function was specified as:

$$Max\ E(Z) = \sum P_j X_j \quad (3.90)$$

Subject to:

$$\sum A_{ij} X_j \leq \beta_i \ \text{(Technical resources requirement for fishery activities),} \quad (3.91)$$

$$\sum F_{ij} X_j \geq \delta_i \ \text{(Farm family fishery product requirement),} \quad (3.92)$$

$$\sum C_{rj} X_j \geq T_r \ \text{(Absolute deviations from } T_r \text{),} \quad (3.93)$$

$$\sum P_r Y_r = \lambda \ \text{(Risk: – ve deviations (₦))} \quad (3.94)$$

and

$$X_j \geq 0 \quad (3.95)$$

Where:

$E(Z)$ = Expected return per ton of the plan (₦),

P_j = Output coefficients (gross margin) per ton of fishery enterprise (₦),

X_j = Fishery enterprise j undertaken (decision variables),

A_{ij} = Technical resource i requirement of fishery enterprise j,

β_i = Level of available technical resource i,

F_{ij} = Minimum farm family fish product i requirement of fishery enterprise j,

δ_i = Level of fishery product i consumed,

C_{rj} = Level of total absolute deviations from target returns of fishery enterprise j for state of nature r in Naira,

T_r = Target level of return in Naira,

Y_r = Level of negative deviation below T_r for state of nature r in Naira,

P_r = Probability that state of nature r will occur, and

λ = A constant parameterised from M to 0

Combination of farm enterprises;

The objective function was specified as:

$$Max\ E(Z) = \sum P_j X_j \quad (3.96)$$

Subject to:

$$\sum A_{ij} X_j \leq \beta_i \text{ (Technical resources requirement for farm enterprise j),} \quad (3.97)$$

$$\sum CF_{ij} X_j \geq \delta_i \text{ (Farm family food crop consumption requirement),} \quad (3.98)$$

$$\sum L_{ij} X_j \geq \delta_i \text{ (Farm family livestock product requirement),} \quad (3.99)$$

$$\sum F_{ij} X_j \geq \delta_i \text{ (Farm family fishery product requirement),} \quad (3.100)$$

$$\sum C_{rj} X_j \geq T_r \text{ (Absolute deviations from } T_r\text{),} \quad (3.101)$$

$$\sum P_r Y_r = \lambda \text{ (Risk: – ve deviations (₦))} \quad (3.102)$$

and

$$X_j \geq 0 \quad (3.103)$$

Where:

$E(Z)$ = Expected return per unit enterprise of the plan (₦),

P_j = Output coefficients (gross margin) per unit enterprise (₦),

X_j = Enterprise j (crop/livestock/fisheries) undertaken (decision variables),

A_{ij} = Technical resource i requirement of farm enterprise j (crop/livestock/fisheries),

β_i = Level of available technical resource i,

CF_{ij} = Minimum farm family food i requirement of crop enterprise j

L_{ij} = Minimum farm family livestock product i requirement of livestock enterprise j,

F_{ij} = Minimum farm family fish product i requirement of fishery enterprise j,

δ_i = Level of food i consumed,

C_{rj} = Level of total absolute deviations from target returns of enterprise j (crop/livestock/fisheries) for state of nature r in Naira,

T_r = Target level of return in Naira,

Y_r = Level of negative deviation below T_r for state of nature r in Naira,

P_r = Probability that state of nature r will occur, and

λ = A constant parameterised from M to 0

Determination of probability that risk will occur;

To determine the probability of risk occurrence in an enterprise, z-scores were calculated with the formula adapted from Bauer and Bushe (2003) and specified in equation (3.104). The calculated z-scores were then used to check the probability values in the statistical tables presented in Appendix I.

$$Z = \frac{X - \bar{X}}{S} \tag{3.104}$$

Where;

Z = Calculated Z-Score

X = Expected farm returns

$\bar{X}$ = Mean of expected farm returns

S = calculated standard deviation

3.4.4 Kendall's non-parametric test statistics

For objective (v), a five-point Likert type rating scale was employed to measure the perception of the smallholder farmers on the severity of the production constraints they face in their production activities. The 5-point Likert type rating scale was allotted as follows: Not a constraint = 1, Not Severe = 2, Undecided = 3, Severe = 4 and Very Severe = 5. This was then subjected to Kendall's non-parametric test adopted from Legendre (2005) to generate mean scores for each constraint and a coefficient of concordance (*W)* which is a measure of the extent of agreement or disagreement among respondents based on mean ranking. The value of W is positive and ranges from zero to one. Zero implies perfect disagreement while one implies perfect agreement among the respondents based on ranking. The constraints were ranked according to their severity based on the mean scores generated from Kendall's non-parametric test. The Kendall's test is mathematically expressed in equation (3.105) as:

$$W = \frac{12S}{m^2(n^3 - n)} \quad (3.106)$$

S was computed as specified in equation (3.107):

$$S = \sum_{i=1}^{n}(R_i - \bar{R})^2 \quad (3.107)$$

$\bar{R}$ was computed as specified in equation (3.108):

$$\bar{R} = \frac{1}{n}\sum_{i=1}^{n} R_i \quad (3.108)$$

R_i was computed as specified in equation (3.109):

$$R_i = \sum_{j=i}^{m} r_{ij} \quad (3.109)$$

Where;

W = Kendall's coefficient of concordance,

S = Sum of squared deviations,

m = Number of respondents,

n = Number of objects (farmers' constraints) considered,

$\bar{R}$ = Mean value of the total ranks

R_i = Total rank given to the i^{th} object (farmers' constraint) considered,

r_{ij} = Rank given to the i^{th} object (farmers' constraint) by the j^{th} respondent,

i = i^{th} object (farmers' constraint) considered, and

j = j^{th} respondent.

3.5 Measurement of Variables

3.5.1 Measurement of socio-economic and institutional variables

1. **Age**: This was measured as the number of years from birth of the respondent up to the time of data collection.
2. **Gender**: This was measured as a qualitative binary variable and recorded as either a male or a female.
3. **Marital status**: This was also measured as a qualitative variable, it indicated as whether the respondent is married, single, divorced or widowed.
4. **Household size**: This was measured as the total number of household members which includes the wife(s), children and other dependants of the respondents.
5. **Farming experience**: This is the number of years the smallholder farmer has been actively engaged in farming activities.
6. **Educational status**: This was measured as the number of years spent in formal schooling, which is related to the qualification held.
7. **Access to extension services**: This was measured as the number of times the farmers have contact with agricultural extension agents for farm education/training.
8. **Access to credit**: This is the amount of capital the farmers borrowed from formal and informal credit institutions for their production activities. It was measured in Naira.
9. **Membership of cooperative/farmers' group**: This was measured as a qualitative binary variable and will be recorded as either a farmer is a member of cooperative/farmers' group or not a member.

3.5.2 Input-output coefficients

The input-output coefficients refer to the actual quantities (averages) of the different resources required to produce a unit output of each farm activity that was investigated. This was measured on per hectare basis for crop activities, per TLU for livestock activities and per meter square for fishery activities. For example, the input-output coefficient for human labour denoted by $a_{jt's}$ refers to the amount of human labour in man-days required to produce a unit output of the j^{th} farm activity. The input-output coefficient for capital represents the amount in Naira of capital (owned and borrowed) required to produce a unit output of the j^{th} farm activity. The input-output coefficients for agrochemicals in litres, for fertilizer, feed and seeds in kilograms, breed stock in numbers, fingerling stock in kilograms and tractor/power tiller in hours are the actual quantities required to produce a unit of the j^{th} farm activity. For seeds, grain equivalent table was used to convert and aggregate all the crop seeds into one.

3.5.3 Price coefficients

The price coefficient "P_j" of a production activity in the model denotes the gross margin per unit output of all the activities. For human labour and tractor/power tiller hiring activities, the price coefficient was the prevailing wage rate per man-day and wage rate per machine-hours respectively. For a capital borrowing activity, the price coefficient was the prevailing market rate of interest. While the price coefficient for a selling activity was the marketing expense per unit of the product sold.

3.5.4 Resource constraints

Resource constraints refer to the resources which were considered to be in limited supply at levels which are likely to restrict the attainment of the objective of the smallholder farmers in the study area. This implies that the total amount of a resource required to produce the 'n' product activities are not to exceed availability. The constraints in the model however, are land, human (family and hired) labour, tractor/power tiller, seed, fertilizer, agrochemicals, feed, breed stock, fingerlings, lime, capital, pond size, livestock capacity and market expenses. For labour constraint, the availability and requirement in respect to machine labour, hired human labour and family labour were incorporated in the programming models as separate restrictions. In the same manner, the different time periods for labour were also considered as separate restrictions. For crop activities, human labour restriction was categorized for land preparation, planting, weeding, fertilizer/agrochemical application and harvesting periods. For livestock and fishery activities, labour restriction was for pond preparation (for fishery), cleaning, feeding, sorting and harvesting.

Following Igwe (2012) and Udo *et al.* (2015b) who in their separate studies incorporated household food requirement in their farm planning model as a constraint, the minimum crop/livestock/fishery product requirement was also incorporated into the model to account for the minimum farm family food consumption requirement. This is because, one of the smallholder farmers' farm objectives is to meet their annual household food requirement. For this study, the minimum farm family food requirement was estimated on the basis of information collected from the farmers which was in form of bulk weight of the crop/livestock/fish produced and consumed by the smallholder farmer.

3.5.5 Activities in the model

The activities in the models basically include crop/livestock/fishery production activities, human labour and tractor/power tiller hiring activities, capital borrowing and product selling activities. The unit of activity for crop enterprises is one hectare, one TLU for livestock enterprises and one ton for fishery enterprises.

The selling activities facilitate the sale of the final output realized from the various farm activities. Some production activities had more than one selling activity depending on whether such activities were sole or mixed cropping, livestock or fishery. The net price of a selling activity was in Naira per unit output of each the crop/livestock/fishery activities.

Transfer activities (rows) provide the means whereby the services or output of one activity may be transferred in the model to another activity to curtail redundancy. Therefore, to guarantee adequate utilization of resources particularly capital and labour, transfer activities were incorporated in the model. These transfer activities ensured the transfer of capital and labour from one period/enterprise to another period/enterprise provided it was profitable.

CHAPTER FOUR

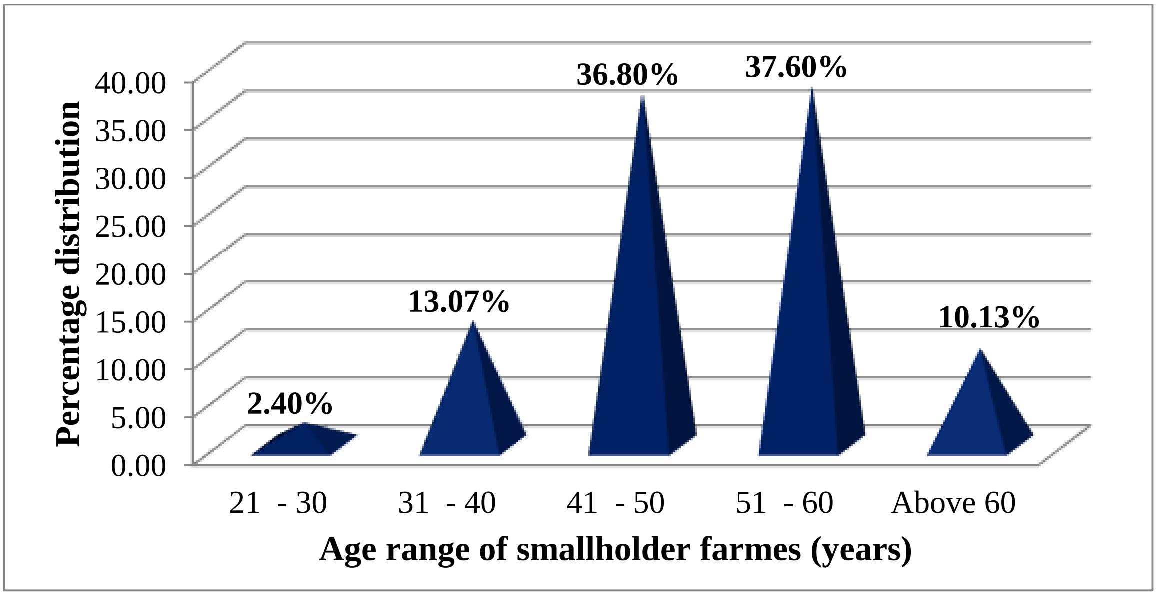
4.0 RESULTS AND DISCUSSION

4.1 Household Characteristics

This section presents the results and discussion on the household characteristics of the smallholder farmers in the study area. A total of 384 smallholder farmers who undertook crop, livestock and/or fisheries enterprises were sampled. The farmers' household characteristics described in this section include age, sex, marital status, household size, level of education, years of farming experience, membership of farmers' group, access to credit and extension services.

4.1.1 Age distribution

Age is the number of years of life of an individual and it is a key factor in agriculture and other socio-economic related activities. Results presented in Figure 4.1 show the age distribution of the smallholder farmers in Kwara State. It revealed that 36.80% and 37.60% of the farmers sampled were between the age ranges of 41 – 50 and 51 – 60 years respectively. It further revealed that 13.07% of the farmers were between 31 – 40 years old while only 10.13% of them were above the age of 60 years. The computed mean age revealed that a typical farmer in the area was 50 years old. This distribution and mean age suggest that majority of the smallholder farmers were still in their productive and economically active age and are likely to adopt optimum farm enterprises combinations if disseminated. Younger farmers are more enthusiastic, mentally alert, adventurous and have greater flexibility in adopting innovations in agriculture that will improve their productivity if appropriate technology is disseminated. They are also more likely to cope with complexities associated with agricultural innovation, adoption and more likely able to handle a combination farm enterprise. This view is supported by the argument of Yisa (2019) that older farmers always regard farming as a way of life inherited from their forefathers whereas the young farmers have the disposition to consider farming as a business venture that is germane to meeting the food and financial requirements of their families. These results are also similar to the findings of Igwe *et al.* (2013) and Jirgi (2013) who reported that farmers in Abia and Kebbi States respectively were in their economically active age bracket.



$Mean\ (\bar{X}) = 50.00$ years

Figure 4.1: Age distribution of smallholder farmers

Source: Computed from Field Survey Data, 2019

4.1.2 Sex distribution

The results presented in Figure 4.2 show the distribution of the farmers according to sex. It shows that majority of the farmers representing 90.67% were males while females represented only 9.33%. This is an indication that the males are the dominant farmer category in the study area. This result is similar to the findings of Oluwasola (2012) and Osundare and Adekunmi (2014) who reported that males are the dominant farmers in Ekiti and Kwara States respectively. The dominant nature of males in agriculture in the area implies that men play important roles in meeting the farm family livelihood and food requirements. This may be due to the cultural background of the farming communities in the area that still limit the women to domestic activities such as nurturing of children and performance of house chores and other tasks within the agricultural value chain such as processing and marketing of farm produce. The dominance of the males in agricultural activities could also be due to the high level of physical energy required especially for production activities. This finding gives credence to the argument of Adewumi (2017) that most agricultural production activities are rigorous and require a lot of energy which most women do not have and cannot cope with.

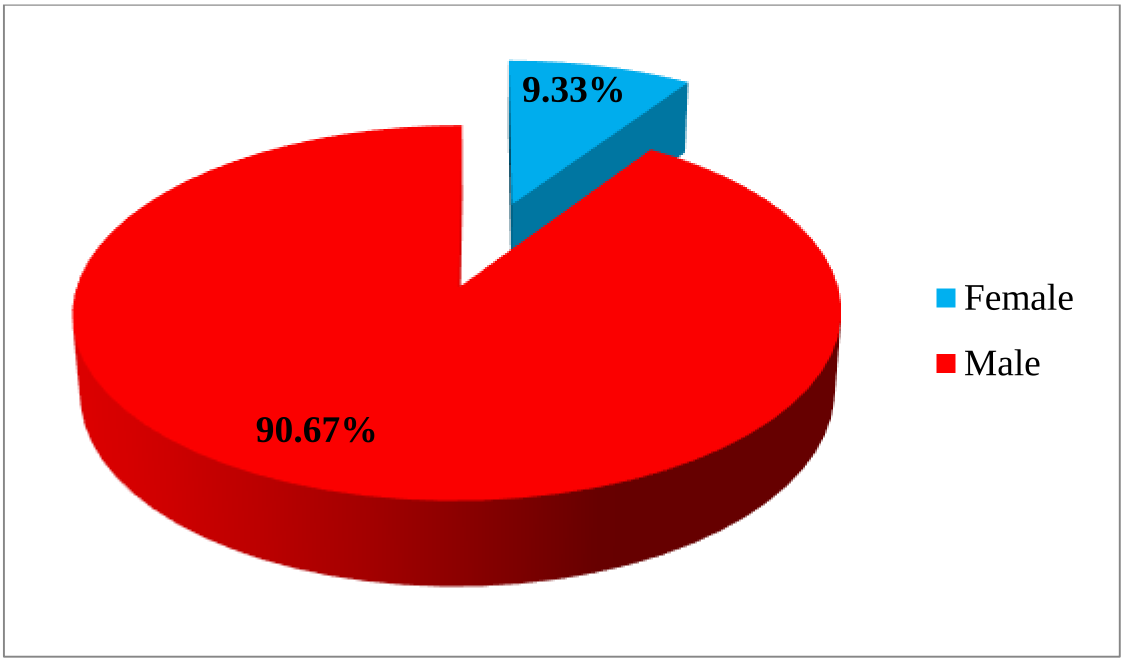


Figure 4.2: Distribution of farmers according to their sex
Source: Computed from Field Survey Data, 2019.

4.1.3 Marital status

Results of the analysis of the farmers' marital status is presented in Figure 4.3. It revealed that majority (89.33%) were married, while only 2.13%, 4.01% and 4.53% of the farmers are divorced, single and widowed respectively. This result is similar to the findings of Olaoye *et al.* (2013) and Jacob (2019) who found that majority of farmers in Oyo and Niger States respectively were married. The larger percentage of the married farmers could imply that they will be committed to high level of responsibilities especially in meeting household food requirement. In another sense, the household sizes of married farmers will probably be larger thereby enhancing the provision of cheap family labour through the spouse(s) and children for the accomplishment of farm operations during critical periods of labour requirement. This could reduce the cost of production in their respective farm enterprises in terms of labour hiring and thereby facilitate the attainment of profit maximization objectives.

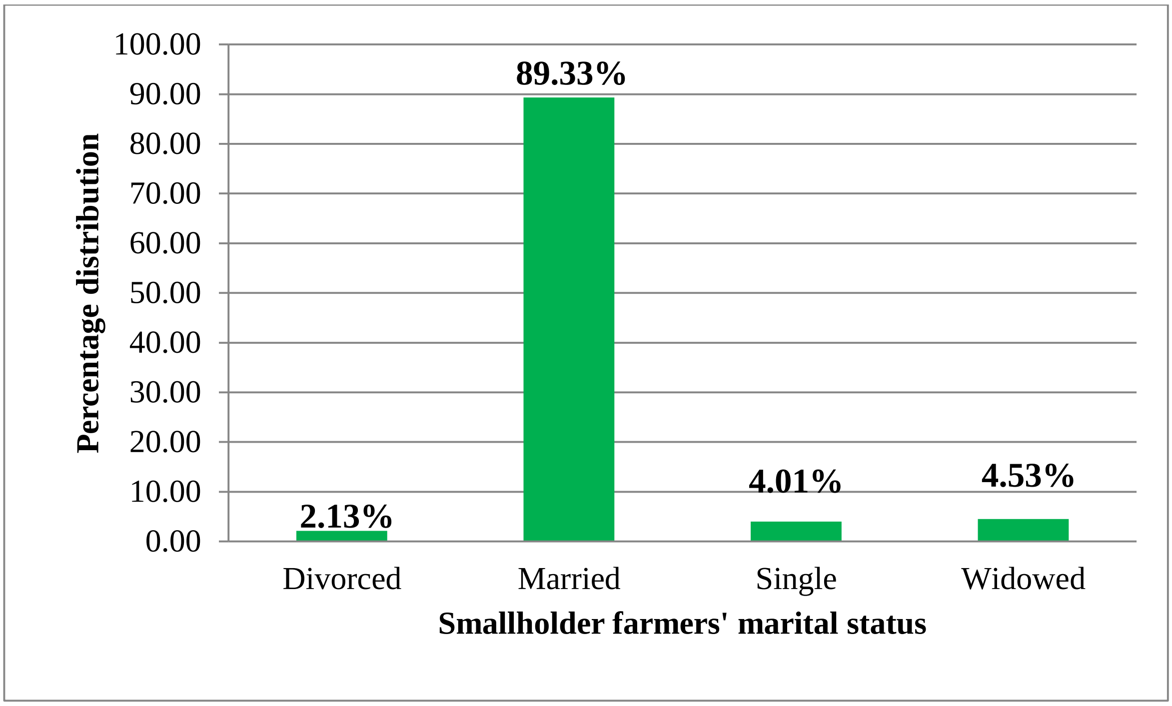
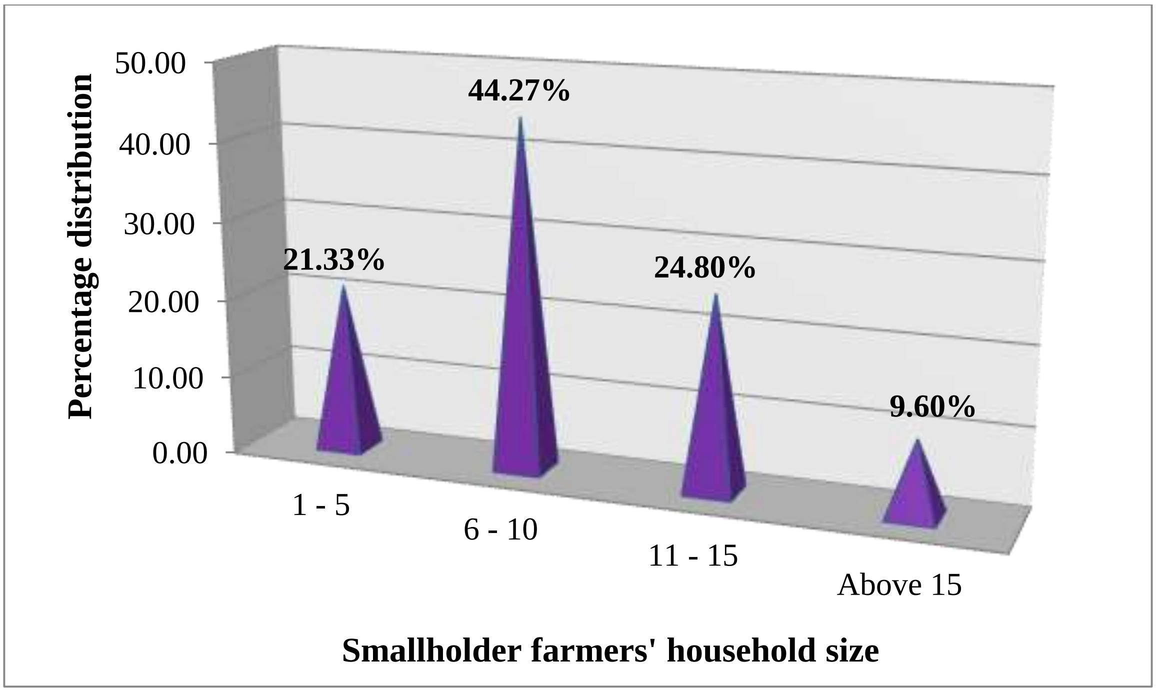


Figure 4.3: Distribution of farmers according to their marital status
Source: Computed from Field Survey Data, 2019.

4.1.4 Household size

This section described the household size of the farmers in the study area. Results in Figure 4.4 show that most (44.27%) of the farmers have household sizes of 6 – 10 persons while 21.33 % and 24.80% of the farmers have household sizes of 1 – 5 and 11 – 15 persons respectively. It further revealed that a typical farmer in the study area have household size of nine persons. This result is similar to those of Nwachi and Begho (2014) and Pelemo (2016) who reported a household size of eight persons per farmer in Delta and Kogi States respectively. The household size is important as it could determine the level of family labour available for farming activities. This lends credence to the argument of Yisa (2019) that larger household size gives farm households the flexibility to pool resources and minimize risks by taking advantage of household returns to scale and labour supply required during peak demand season. However, the farmers do not have very large household size like the average of 14 persons per household as reported by Yisa *et al*. (2020) for farmers in Niger State and may have to augment their family labour with hired labour to efficiently undertake farm enterprise combinations.



$Mean\ (\bar{X}) = 9.00$

Figure 4.4: Household size distribution of smallholder farmers

Source: Computed from Field Survey Data, 2019.

4.1.5 Level of Education

Results presented in Figure 4.5 show the distribution of the farmers according to their levels of education. It revealed that only 21.60% of the farmers had no formal education while 13.60%, 23.73% and 29.62% had attained up to primary, secondary and tertiary levels of education respectively in the study area. This implies that most of the farmers had one form of formal education or the other. This is contrary to the widely held assumption that the level of education among farmers could be low. This finding is similar to those of Adewumi (2017) and Jacob (2019) who reported that a reasonable proportion of farmers in Kwara and Niger States respectively were literate. It is however in contrast to the findings of Jirgi (2013) who found that majority of the farmers in Kebbi State have not attended school. Formal education is a vital requirement as it can enhance the farmers' technical skills and enables him/her to cope with complexities associated with modern ways of agricultural production. It could also go a long way at enhancing improved extension services delivery among farmers with less difficulty.

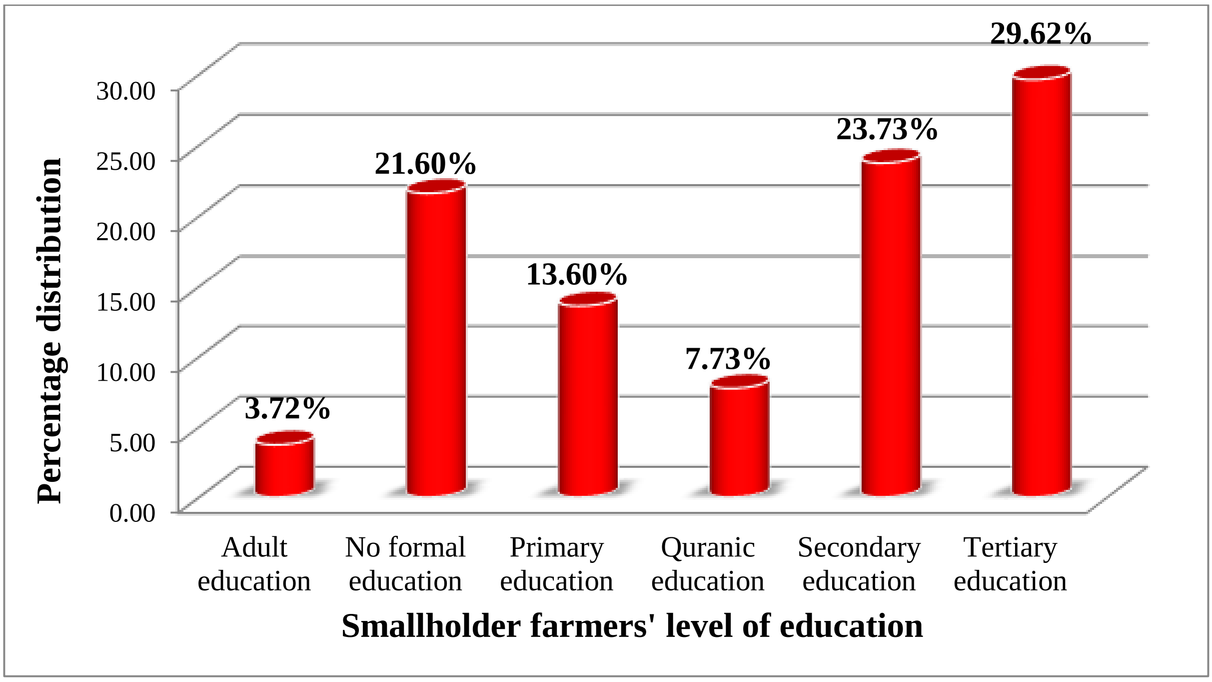
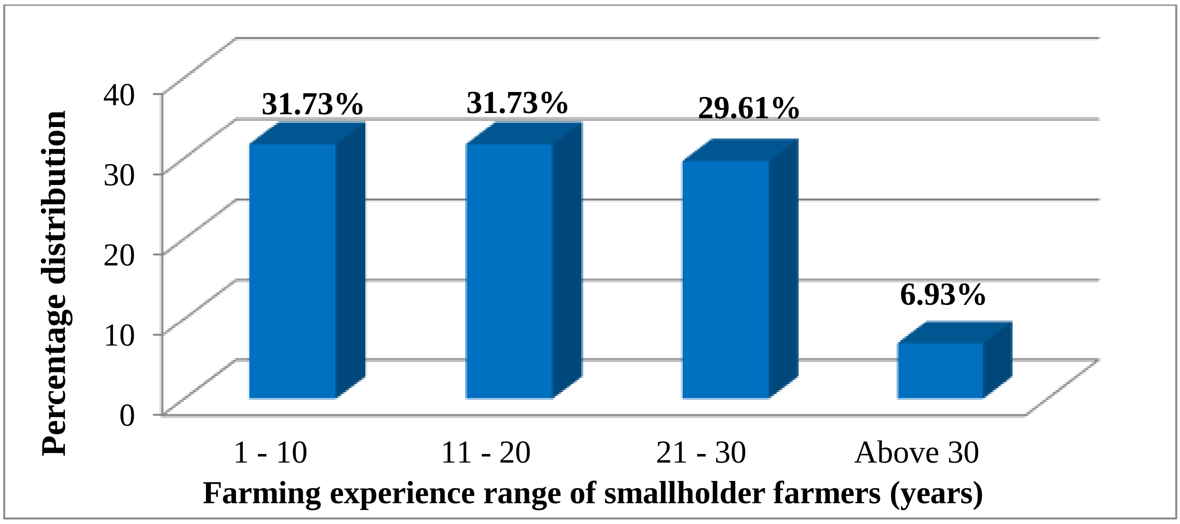


Figure 4.5: Distribution of farmers according to level of education
Source: Computed from Field Survey Data, 2019

4.1.6 Farming experience

Farming experience refers to the number of years spent in farming activities and it may be either full-time or part-time. It may also affect adoption of innovation. The results presented in Figure 4.6 show the distribution of the smallholder farmers according to their years of farming experience. It revealed that 31.73%, 31.73% and 29.61% of the farmers had farming experiences of 1 – 10, 11 – 20 and 20 – 30 years respectively. Only 9.93% had more than 30 years of farming experience. A typical farmer in the area had a farm enterprise experience of 18 years which is an indication of the length of the practical knowledge and skills acquired by the farmers in the various farm enterprises. It implies that the farmers are relatively experienced in their farming activities. The average years of farming experience in the study area is similar to the 19 and 20 years reported by Ayinde (2008) and Oluwsola (2012) for Kwara and Ekiti States respectively. Tanko (2015) opined that experience enables the farmers to set realistic targets while Sadiq and Kolo (2015) asserted that experience reduces management risk. This implies that the farmers in Kwara State would probably not be confused on the concept of optimum combination of farm enterprises. They will also be able to have a plan to cope with inherent risk and uncertainty associated with traditional agriculture.



$Mean\ (\bar{X}) = 18.00$ years

Figure 4.6: Distribution of farmers according to years of farming experience

Source: Computed from Field Survey Data, 2019

4.1.7 Membership of association

Results in Figure 4.7 show the distribution of the farmers according to their membership of farmer associations. It indicated that majority (67.47%) of the farmers belonged to one farmer association/cooperative society or the other. Farmers that belonged to an association had access to more information and innovations that will enhance their productivity, income and livelihood than those that do not belong. It could also increase farmers' timely access to credit facilities and other production inputs that will help them successfully implement optimum combination of farm enterprises under risk and uncertainty. Farmers cooperatives usually provide benefits to members at a cost. This finding is similar to that of Durba *et al.* (2019) who reported that 67.81% of farmers in Kaduna State belonged to farmer groups.

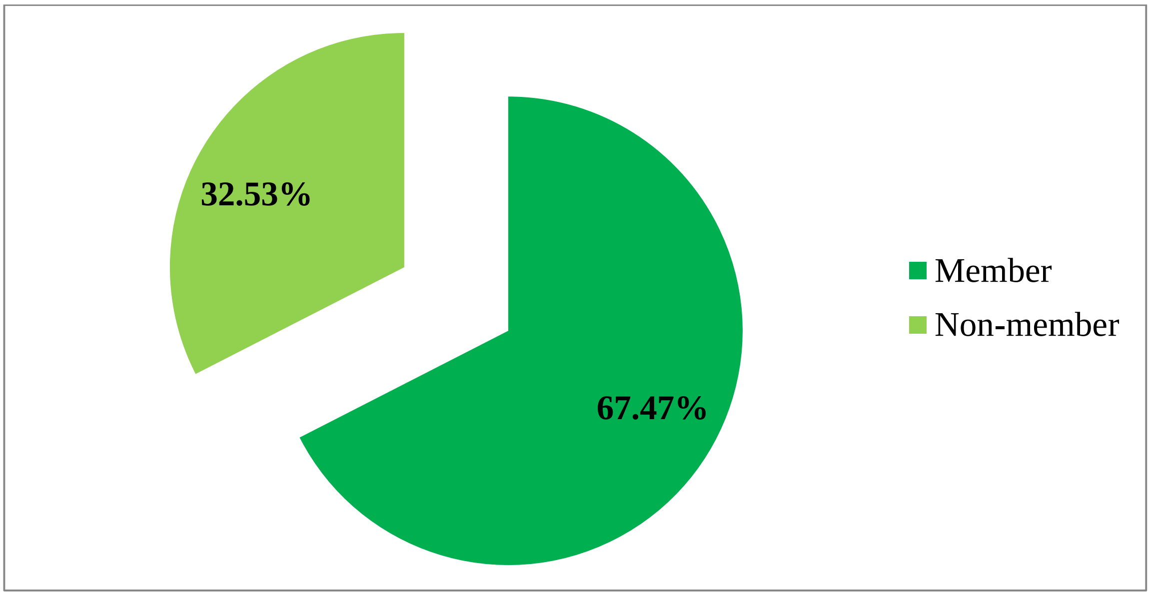


Figure 4.7: Distribution of farmers according to group membership status
Source: Computed from Field Survey Data, 2019

4.1.8 Access to credit

Access to agricultural credit enables farmers especially the smallholder households to procure additional production inputs such as fertilizers, agrochemicals and to hire additional labour so as to expand production. The results shown in Figure 4.8 revealed that majority (85.60%) of the smallholder farmers in the study area had no access to credit. The implication of this finding is that they are faced with the problem of inadequate capital to expand their scale of operation. This further implies that they over rely on their personal income or proceeds from previous farming season/production cycle to finance their production activities. Oladejo and Adetunji (2012) observed that personal financing of small farms often leads to farmer's inability to expand scale of production and attain greater efficiency. The poor access to credit could be as a result of bureaucratic procedures, high interest rates and limited grace period associated with obtaining credit in Nigeria. This finding is similar to the findings of Jirgi (2013), Sallawu (2014) and Adewumi (2017) who reported that majority of farm households in Kebbi, Niger and Kwara States respectively do not have access to agricultural credit.

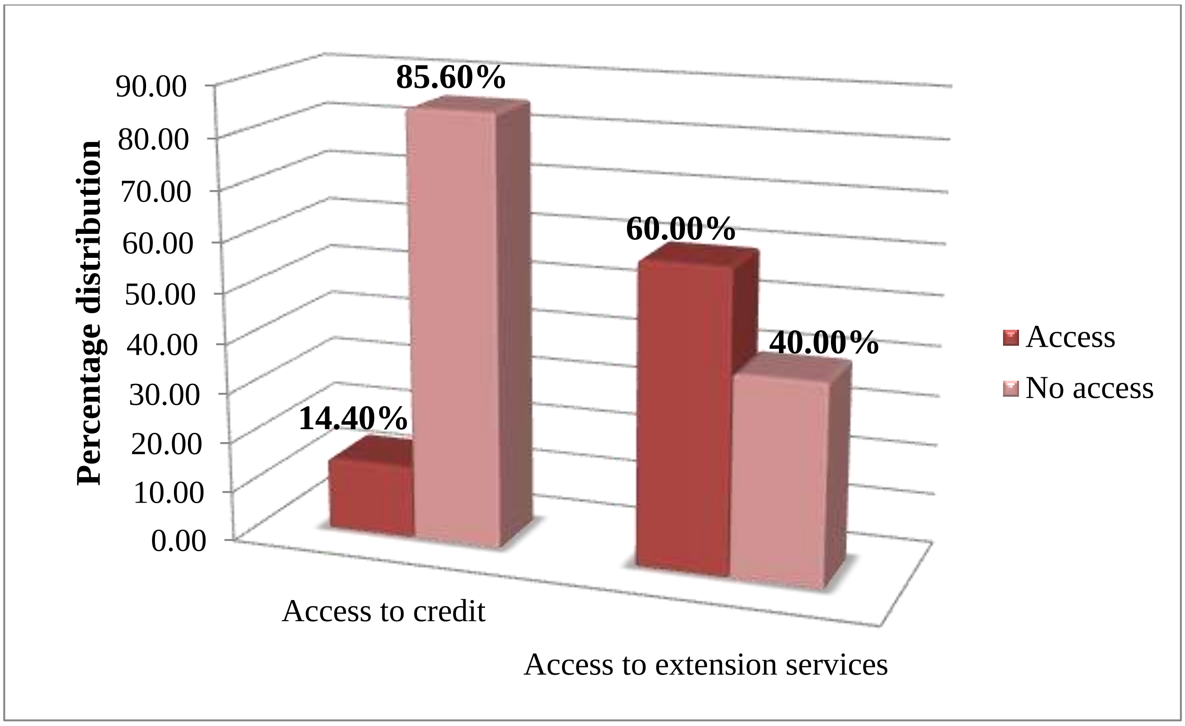


Figure 4.8: Distribution of farmers according to access to credit and extension services

Source: Computed from Field Survey Data, 2019

4.1.9 Farmers' access to extension services

Results in Figure 4.8 show the distribution of farmers according to their access to extension services. It revealed that 60% of the smallholder farmers in the study area had access to extension services. Perhaps, this is because at least 60% of the farmers are members of farmers association/cooperative society as presented in Figure 4.7. This implies that most of the farmers have considerable level awareness of new technologies that will enhance improved and efficient production in their various farm enterprises in the study area. Extension contact is a potent variable that can enhance the likelihood of farmers' adoption of innovations in agriculture especially optimum farm enterprise plans under risk and limited resources conditions. This finding is similar to the findings of Durba *et al.* (2019) who reported that majority of the smallholder farmers in Kaduna State had access to extension services which provide them access to more information and innovations that could help improve their productivity. It is however contrary to that of Adewuyi *et al.* (2010) who reported that farmers in Ogun State had poor access to extension services.

4.2 Existing Farm Enterprise Combinations

This section identified the existing farm enterprise combinations undertaken by the smallholder farmers in the study area. Results are presented in Table 4.1. The farmers were engaged in crop, fisheries and livestock enterprises. Thirty-one crop enterprises, three fishery enterprises and fourteen livestock enterprises were identified giving a total of forty-eight farm enterprises. The results showed that both sole and mixed crop, fishery and livestock enterprises were undertaken by the farmers. Multiple responses were recorded as there were farmers who were engaged in more than one farm enterprise at a time. This could be a strategy adopted by the farmers to mitigate the effect of risk on their farm incomes. This gives credence to the argument of Gupta *et al.* (2012) that most smallholder farmers integrate crop and livestock enterprises primarily to minimize risk.

Also, there was a noticeable variation in the type of farm enterprises undertaken by the farmers across the four agricultural zones in the state. This may be attributed to the ecological differences from one zone to another in the area. In Kaiama zone, yam, maize/cowpea, maize/groundnut, sorghum/soybean, maize/soybean and sorghum/yam were the dominant farm enterprises undertaken by the farmers. This could be attributed to the fact that yam, maize, cowpea, soybean and groundnut are commercial crops in the area that yield more returns for the farmers compared to other crops. Similarly, it was observed that rice, maize/groundnut, cassava/maize, sorghum and sorghum/groundnut exercised dominance over other enterprises in Patigi zone. These are also commercial crops and Patigi zone is predominantly known for rice production in the state. On the contrary, cassava/maize represents the dominant farm enterprise in Shao and Igbaja zones.

However, it was glaring from the result that Shao and Igbaja zones are more diversified in their farm enterprises compared to other zones, and while Kaiama zone specializes in root and leguminous crops, Patigi zone specializes majorly in cereal crops. Nonetheless, the crop enterprises in the study area comprised of tubers, cereals, legumes and vegetables; fishery enterprises were basically catfish and fingerlings production while the livestock enterprises include ruminant animals and poultry birds. The crop enterprises identified in this study are similar to those previously reported by Igwe (2012), Udo *et al.* (2015a), Jirgi *et al.* (2018) and Jacob (2019) among others in studies on optimum combination of farm enterprises in Nigeria. Similarly, the fishery and livestock enterprises undertaken by the farmers are also not completely different from those reported by Igwe and Onyenweaku (2013), Bamiro *et al.* (2015) and Jacob (2019) in studies carried on livestock enterprises in Nigeria.

Table 4.1 Distribution of smallholder farmers according the farm enterprises undertaken

Farm enterprise	*** Frequency distribution**				
	Kaiama zone	**Patigi zone**	**Shao zone**	**Igbaja zone**	**Pooled result**
Cassava	-	6 (18.75)	20 (11.17)	15 (11.54)	41 (10.68)
Maize	7 (16.28)	4 (12.50)	11 (6.15)	13 (10.00)	35 (9.11)
Melon	3 (6.98)	6 (18.75)	3 (1.68)	1 (0.77)	13 (3.39)
Millet	6 (13.95)	5 (15.63)	-	-	11 (2.86)
Rice	-	17 (53.13)	-	-	14 (3.65)
Sorghum	8 (18.60)	10 (31.25)	4 (2.23)	2 (1.54)	24 (6.25)
Soybean	12 (27.91)	-	5 (2.79)	2 (1.54)	19 (4.95)
Yam	28 (65.12)	-	10 (5.59)	-	38 (9.90)
Cassava/Groundnut	-	2 (6.25)	4 (2.23)	2 (1.54)	8 (2.08)

Cassava/Maize	-	11 (34.38)	38 (21.23)	29 (22.31)	81 (21.09)
Cassava/Melon	-	8 (25.00)	4 (2.23)	1 (0.77)	13 (3.39)
Cassava/Sorghum	-	4 (12.50)	6 (3.35)	2 (1.54)	12 (3.13)
Cassava/Soybean	-	-	5 (2.79)	3 (2.31)	8 (2.08)
Maize/Cowpea	26 (60.47)	6 (18.75)	15 (8.38)	9 (6.92)	56 (14.58)
Maize/Groundnut	18 (41.86)	12 (37.50)	6 (3.35)	8 (6.15)	44 (11.46)
Maize/Melon	4 (9.30)	8 (25.00)	5 (2.79)	2 (1.54)	19 (4.95)
Maize/Sorghum	10 (23.26)	7 (21.88)	12 (6.70)	8 (6.15)	37 (9.64)
Maize/Soybean	15 (34.88)	3 (9.38)	8 (4.47)	4 (3.08)	30 (7.81)
Maize/Yam	18 (41.86)	-	10 (5.59)	4 (3.08)	32 (8.33)
Melon/Millet	4 (9.30)	6 (18.75)	2 (1.12)	-	12 (3.13)
Sorghum/Groundnut	6 (13.95)	8 (25.00)	2 (1.12)	2 (1.54)	18 (4.69)
Sorghum/Okra	-	-	-	5 (3.85)	5 (1.30)
Sorghum/Soybean	16 (37.21)	10 (31.25)	4 (2.23)	1 (0.77)	31 (8.07)
Sorghum/Yam	14 (32.56)	-	4 (2.23)	5 (3.85)	23 (5.99)
Cassava/Sorghum/Groundnut	-	3 (9.38)	9 (5.03)	5 (3.85)	17 (4.43)
Cassava/Maize/Cowpea	-	-	8 (4.47)	3 (2.31)	11 (2.86)
Cassava/Maize/Groundnut	-	-	7 (3.91)	9 (6.92)	16 (4.17)
Cassava/Maize/Melon	-	-	4 (2.23)	2 (1.54)	6 (1.56)
Cassava/Maize/Okra	-	-	-	4 (3.08)	4 (1.04)
Cassava/Maize/Soybean	-	-	11 (6.15)	7 (5.38)	18 (4.69)
Maize/Sorghum/Soybean	9 (20.93)	4 (12.50)	8 (4.47)	5 (3.85)	26 (6.77)
Catfish	3 (6.98)	2 (6.25)	11 (6.15)	7 (5.38)	23 (5.99)
Fingerlings	-	-	3 (1.68)	1 (0.77)	4 (1.04)
Catfish/Fingerlings	-	-	2 (1.12)	-	2 (0.52)
Broiler	3 (6.98)	2 (6.25)	25 (13.97)	10 (7.69)	40 (10.42)
Layer	2 (4.65)	1 (3.13)	14 (7.82)	8 (6.15)	25 (6.51)
Cockerel	5 (11.63)	3 (9.38)	20 (11.17)	19 (14.62)	47 (12.24)
Layer/Cockerel	1 (2.33)	2 (6.25)	7 (3.91)	7 (5.38)	17 (4.43)
Broiler/Cockerel	2 (4.65)	2 (6.25)	13 (7.26)	7 (5.38)	24 (6.25)
Broiler/Layer	3 (6.98)	1 (3.13)	9 (5.03)	6 (4.62)	19 (4.95)
Broiler/Layer/Cockerel	1 (2.33)	2 (6.25)	7 (3.91)	3 (2.31)	13 (3.39)
Cattle	1 (2.33)	-	1 (0.56)	-	2 (0.52)
Goat	3 (6.98)	3 (9.38)	5 (2.79)	3 (2.31)	14 (3.65)
Sheep	2 (4.65)	1 (3.13)	6 (3.35)	3 (2.31)	12 (3.13)
Cattle/Goat	1 (2.33)	-	1 (0.56)	-	2 (0.52)
Cattle/Sheep	1 (2.33)	1 (3.13)	3 (1.68)	-	5 (1.30)
Goat/Sheep	3 (6.98)	2 (6.25)	9 (5.03)	4 (3.08)	18 (4.69)
Cattle/Goat/Sheep	1 (2.33)	-	1 (0.56)	-	2 (0.52)
Total	**236**	**162**	**362**	**231**	**991**

Source; computed from field survey data, 2019

* implies multiple responses recorded for enterprises: Figures in parentheses are percentages

4.3 Costs and Returns Analysis of Farm Enterprises

In order to the determine the profitability of the various farm enterprises undertaken by the farmers, the associated costs and returns were computed. The results of the costs and returns analysis for each farm enterprises undertaken is presented in Tables 4.2 and 4.3. The variable and fixed costs of production, revenue, gross margin and net farm income per unit farm enterprise and gross ratio were computed.

4.3.1 Costs and returns analysis of crop enterprises

For the arable crop enterprises, the values estimated were on the basis of Naira per hectare. The variable cost items include cost expended on labour, seed, fertilizer, agrochemical, tractor hiring, transportation, processing and storage while fixed cost items were depreciation on farm tools and machinery, farmland rent and interest on borrowed capital. The results show that all the crop enterprises undertaken by the small holder farmers were profitable given that the computed respective gross margins and net farm incomes were positive and the computed gross ratios were less than one. Gross ratio was computed as a ratio of total cost to total revenue. According to Olukosi and Erhabor (2008), a less than one gross ratio is desirable for any farm enterprise. The lower the ratio, the higher the return per Naira invested. Based on this, cassava/maize/okra enterprise is the most profitable with a gross ratio of 0.20. This is closely followed by cassava/sorghum/groundnut and cassava/maize/soybean enterprises with gross ratios of 0.21 each respectively. On the other hand, yam enterprise was the least profitable crop enterprise with gross ratio of 0.40, and closely followed by cassava and maize enterprises with gross ratios of 0.36 each respectively. Interestingly, the least profitable crop enterprises were the sole crop enterprises.

Table 4.2 Costs and Return Analysis of Arable Crop Enterprises

Farm Enterprises	TVC	TFC	TC	TR	GM	NFI	GR
Crop enterprises			**Average amount (Naira per hectare)**				
Cassava	58,389.97	3,708.37	62,098.34	173,232.14	114,842.17	111,133.80	0.36
Maize	53,575.09	1,649.82	55,224.91	155,137.52	101,562.43	99,912.61	0.36
Melon	32,205.88	5,036.92	37,242.81	168,585.71	136,379.83	131,342.91	0.22
Millet	60,353.54	1,309.09	61,662.63	164,705.88	104,352.35	103,043.26	0.37
Rice	89,630.65	8,350.00	97,980.65	363,975.81	274,345.16	265,995.16	0.27
Sorghum	52,074.12	780.74	52,854.87	170,670.08	118,595.96	117,815.21	0.31
Soybean	56,728.71	732.50	57,461.21	181,772.28	125,043.56	124,311.06	0.32
Yam	135,058.25	2,833.22	137,891.47	342,813.67	207,755.42	204,922.20	0.40
Cassava/Groundnut	75,858.59	5,288.89	81,147.47	289,575.00	213,716.41	208,427.53	0.28
Cassava/Maize	84,416.11	1,823.81	86,239.92	295,259.84	210,843.73	209,019.92	0.29
Cassava/Melon	75,661.61	6,141.05	81,802.66	298,661.14	222,999.53	216,858.48	0.27
Cassava/Sorghum	74,776.60	3,914.56	78,691.16	294,659.84	219,883.24	215,968.68	0.27
Cassava/Soybean	73,058.82	15,372.20	88,431.02	309,917.07	236,858.25	221,486.05	0.29
Maize/Cowpea	80,093.02	4,214.34	84,307.36	293,194.63	213,101.61	208,887.27	0.29
Maize/Groundnut	80,648.15	2,305.93	82,954.07	305,645.57	224,997.42	222,691.50	0.27
Maize/Melon	70,746.67	7,111.01	77,857.68	299,712.60	228,965.94	221,854.93	0.26
Maize/Sorghum	87,207.79	1,703.86	88,911.65	303,563.72	216,355.93	214,652.07	0.29
Maize/Soybean	80,189.19	917.33	81,106.52	312,617.28	232,428.09	231,510.76	0.26
Maize/Yam	150,443.41	5,691.76	156,135.17	473,622.25	323,178.84	317,487.07	0.33
Melon/Millet	78,773.99	7,459.55	86,233.54	318,504.52	239,730.53	232,270.98	0.27
Sorghum/Groundnut	79,052.92	1,368.00	80,420.92	320,579.71	241,526.79	240,158.79	0.25
Sorghum/Okra	78,994.97	1,036.73	80,031.71	280,351.44	201,356.46	200,319.73	0.29
Sorghum/Soybean	76,385.54	5,114.78	81,500.32	307,571.43	231,185.89	226,071.10	0.26
Sorghum/Yam	144,795.92	7,067.94	151,863.86	467,463.24	322,667.32	315,599.38	0.32
Cassava/Sorghum/Groundnut	89,473.68	1,222.22	90,695.91	436,323.53	346,849.85	345,627.62	0.21
Cassava/Maize/Cowpea	92,053.57	1,346.67	93,400.24	425,133.33	333,079.76	331,733.10	0.22
Cassava/Maize/Groundnut	77,466.22	16,108.11	93,574.32	431,246.67	353,780.45	337,672.34	0.22
Cassava/Maize/Melon	88,894.74	6,688.42	95,583.16	427,881.58	338,986.84	332,298.42	0.22
Cassava/Maize/Okra	79,634.21	1,030.00	80,664.21	404,004.52	324,370.31	323,340.31	0.20
Cassava/Maize/Soybean	90,940.59	679.21	91,619.80	435,117.65	344,177.05	343,497.85	0.21

Source: Computed from Field Survey Data, 2019.

Note: TVC = Total variable Cost; TFC = Total Fixed Cost; TC = Total Cost; TR = Total Revenue; GM = Gross Margin; NFI = Net Farm Income and GR = Gross Ratio

A further look at the gross margins and net farm incomes also show that mixed crop enterprises were slightly more profitable than the sole crop enterprises in the study area. This gives credence to the argument of Adewumi (2017), Jirgi *et al.* (2018) and Jacob (2019) that crop mixtures have the potentiality to improve productivity per unit land area and time, and judicious exploitation of land resources and farm inputs including labour.

4.3.2 Costs and returns analysis of fishery enterprises

Costs and returns were also calculated for the fisheries enterprises and the results are presented in Table 4.3. The estimated average values were in Naira per square meter. The variable cost incurred were on feed, fingerlings, breeding stock, medications, labour, transportation, and storage while fixed cost items were depreciation on tools and ponds, pond rent and interest on borrowed capital. The estimated gross margins, net farm incomes and gross ratios all proved that fishery enterprise is profitable in Kwara State. The fingerlings production enterprise was found to be more profitable based on the estimated gross ratio of 0.47 compared to 0.48 obtained for catfish enterprise. This finding is similar to that of Ibeun *et al.* (2018) who reported that fishery enterprise is a profitable farm enterprise in Kainji Lake Basin, Nigeria.

4.3.3 Costs and returns analysis of livestock enterprises

The analysis of the livestock enterprises was done based on one tropical livestock unit (TLU). Costs incurred on breed stock, feed, veterinary services, vaccination and medications, labour, commission fee and transportation constituted the variable costs of production in the livestock enterprise. The fixed cost items were depreciation on tools, rent, tax and interest on borrowed capital.

Table 4.3 Costs and Returns Analysis of Fishery and Livestock Enterprises

Farm Enterprises	TVC	TFC	TC	TR	GM	NFI	GR
Fishery enterprises			**Average amount (Naira per square meter)**				
Catfish	3,529.52	517.15	4,046.66	8,369.46	4,839.94	4,322.80	0.48
Fingerlings	4,956.45	411.29	5,367.73	11,466.16	6,509.71	6,098.42	0.47
Catfish/Fingerlings	4,226.89	656.77	4,883.66	13,759.39	9,532.50	8,875.73	0.35
Livestock enterprises			**Average amount (Naira per tropical livestock unit (TLU))**				
Cattle	97,457.97	16,770.79	114,228.77	307,896.06	210,438.09	193,667.30	0.37
Goat	70,643.71	11,365.31	82,009.02	254,054.20	183,410.49	172,045.18	0.32
Sheep	74,389.20	13,780.57	88,169.77	286,758.24	212,369.04	198,588.48	0.31
Cattle/Goat	76,971.91	12,233.09	89,204.99	279,760.51	202,788.60	190,555.51	0.32
Cattle/Sheep	77,920.85	13,552.06	91,472.90	292,867.25	214,946.40	201,394.34	0.31
Goat/Sheep	80,525.24	10,057.45	90,582.68	265,543.94	185,018.70	174,961.25	0.34
Cattle/Goat/Sheep	79,399.15	14,350.87	93,750.01	294,811.45	215,412.30	201,061.43	0.32
Broiler	102,189.33	16,426.62	118,615.95	302,647.59	200,458.25	184,031.64	0.39
Layer	142,355.42	19,386.37	161,741.79	440,372.87	298,017.45	278,631.08	0.37
Cockerel	62,118.33	11,063.14	73,181.47	195,701.75	133,583.42	122,520.29	0.37
Layer/Cockerel	116,558.07	16,037.07	132,595.14	375,372.87	258,814.80	242,777.73	0.35
Broiler/Cockerel	93,977.31	19,280.57	113,257.87	287,515.21	193,537.90	174,257.33	0.39
Broiler/Layer	126,097.54	20,034.23	146,131.77	414,956.73	288,859.19	268,824.96	0.35
Broiler/Layer/Cockerel	104,291.32	21,958.71	126,250.03	351,027.22	246,735.90	224,777.19	0.36

Source: Computed from Field Survey Data, 2019.

Note: TVC = Total variable Cost; TFC = Total Fixed Cost; TC = Total Cost; TR = Total Revenue; GM = Gross Margin; NFI = Net Farm Income and GR = Gross Ratio

The estimated gross margins, net farm incomes and the gross ratios indicated that all the livestock enterprises in the area were profitable. Sheep and cattle/sheep enterprises were the most profitable which both had a gross ratio of 0.31. This was is closely goat, cattle/goat and cattle/goat/sheep enterprises with similar gross ratio of 0.32. On the other hand, broiler and broiler/cockerel enterprises were the least profitable livestock enterprises with similar gross ration value of 0.39. However, the computed gross ratios which were all less than one suggests that all the livestock enterprises were profitable. The profitability of livestock enterprises in the study area is similar to the findings of Bamiro *et al.* (2015) and Jacob (2019) who in their separate investigations found that livestock enterprise is a profitable farm enterprise in Southwest and Niger State Nigeria, respectively.

4.4 Optimum Farm Enterprise Combinations under Risk and Limited Resource Conditions

This section presents results of optimum combinations of farm enterprises that will maximize the gross margins of the farmers under risk and limited resource conditions in the study area. Traditionally, farmers are basically concerned with farming objectives such as the attainment of a minimum level of self-sufficiency in family food supply asides maximum farm income or farm profit. The programming was therefore constrained so as to satisfy the farm family minimum food requirements.

Optimum plans I and II were obtained using the LP model aimed at gross margin maximization alone under owned and borrowed capital and limited resource (only owned capital) conditions respectively. Given that there are inherent elements of risk in farming and since farmers differ in the degree to which they accept risk, risk attitudes are generally classified as: risk-averse (farmers who try to avoid taking risks); risk-takers (farmers who are open to more risky enterprise options); and risk-neutrals (farmers who lie between the risk-averse and risk-taking position). Ayinde *et al.* (2016) reported that about 86% of farmers in a study conducted in Kwara State are risk averse. Among the sampled farmers, the risk neutrals and risk takers are most likely to adopt optimum plans I and II. This because these plans have higher gross margins which could be attractive to the farmers. However, they are prone to the inherent risks associated with agricultural production. A set of feasible risk efficient farm plans (I, II and III) were also obtained with the T-MOTAD model by parametrizing and varying the total absolute deviation (TAD) at 100%, 50% and 0% respectively. The risk averse farmers would most likely adopt these plans over the risk prone gross margin maximizing optimum plans.

4.4.1 Crop enterprise combinations under risk and limited resource conditions

4.4.1.1 Cropping pattern in the existing, optimum and risk efficient plans

The results presented in Table 4.4 show the identified crop enterprises in the existing, normative optimum and risk efficient farm plans. The study identified eight sole and twenty-three mixed crop enterprises giving a total of thirty-one crop enterprises undertaken by the farmers in the area. Only six of the 31 crop enterprises namely rice, maize/cowpea, maize/soybean, maize/yam, cassava/sorghum/groundnut and maize/sorghum/soybean were included in the optimum plan I (owned plus borrowed capital). The LP result prescribed 1.00ha for rice, 0.73ha for maize/cowpea, 0.31ha for maize/soybean, 1.05ha for maize/yam, 0.67ha for cassava/sorghum/groundnut and 0.14ha for maize/sorghum/soybean respectively as optimal for the smallholder famers to maximize their gross incomes. In the second scenario, that is, optimum cropping plans under limited resource condition, only four crop enterprises were included in the plan. The optimum plan for the smallholder farmers under this condition is to cultivate 1.00ha of rice, 0.47ha of maize/soybean, 1.05ha of maize/yam and 0.11ha of maize/sorghum/soybean respectively. It is noteworthy that plan I had more crop enterprises than plan II. The scale of operation, that is, the farm size for plan I was 3.90ha while plan II was only 2.63ha. The difference in the two optimum plans could be attributed to the limited resource condition (exclusion of borrowed capital) in plan II in which the scale of operation reduced by 1.27ha. This also resulted in the exclusion of two enterprises from the plan. This could be to ensure efficient allocation of the limited resources at the disposal of the farmers.

Table 4.4: Existing, optimum and risk efficient cropping plans (in hectares)

Crop enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Rice	1.24	1.00	1.00	1.10	1.53	1.00
Cassava/Melon	1.00	-	-	-	0.29	-
Maize/Cowpea	1.51	0.73	-	-	-	0.46
Maize/Soybean	0.75	0.31	0.47	-	-	0.83
Maize/Yam	1.34	1.05	1.05	0.83	0.79	0.32
Sorghum/Yam	1.13	-	-	0.21	-	-
Cassava/Sorghum/Groundnut	0.70	0.67	-	-	-	-
Maize/Sorghum/Soybean	1.20	0.14	0.11	0.54	-	-

Source; Computed from Field Survey Data, 2019.

The results revealed that only four enterprises were prescribed in the risk efficient plan I. These are rice on 1.10ha, maize/yam on 0.83ha and sorghum/yam on 0.21ha respectively. The risk efficient plan II also recommended only three crop activities namely, 1.53ha for rice, 0.29ha for cassava/melon and 0.79ha for maize/yam. For risk efficient plan III, the T-MOTAD result prescribed rice on 1.00ha, maize/cowpea on 0.46ha, maize/soybean on 0.83ha and maize/yam on 0.32ha respectively. Two to three enterprises were excluded from the risk efficient plans indicating that their production carries a high margin of risk compared to those enterprises that were included in the optimum plans.

Interestingly, rice and maize/yam crop enterprises were prescribed in all the plans. This could be attributable to the fact that rice, maize and yam are staple in the diets of many farm households in the study area. Also, rice and yam are commercial crops that could attract more farm income for the farmers which may be a reason for their inclusion in all the plans in the quest to maximize farm incomes. It is noteworthy that apart from rice enterprise, all the crop enterprises in the optimum plan were crop mixtures. This implies that mixed crop enterprises are in better competitive position to yield more returns for the farmers and could be a better strategy to enhance the mitigation of associated risk in farming than the sole crop enterprises. This finding is similar to those of Babatunde *et al.* (2007), Igwe *et al.* (2011), Tsoho (2013) and Adewumi *et al.* (2018) who in separate studies reported that mixed crop enterprises were better off in terms of productivity and profit maximization than sole crop enterprises for farmers in Nigeria.

4.4.1.2 Marginal opportunity cost (MOC) of excluded cropping activities

In a maximization LP problem, marginal opportunity costs (MOC) also known as shadow prices for activities are the income penalties that would be experienced by a farmer who forcefully introduce or undertake any such activity that has been excluded by the optimized farm plans. In essence, it indicates the amount by which farm returns would be reduced if an excluded activity was undertaken or forced into the production plan by the smallholder farmers. The higher the value of the marginal opportunity cost of an excluded activity the lower its chances of being prescribed in the optimum plan and vice versa. The marginal opportunity costs of the excluded cropping activities for this study as obtained from the LP and T-MOTAD solutions are presented in Table 4.5. It shows that 25, 27, 27, 28 and 27 crop enterprises were excluded in optimum plans I and II, risk efficient plans I, II and III respectively for the farmers to maximize their gross margins and minimize the associated risk.

It further revealed that crop enterprises sorghum/soybean with MOC of ₦761.61 in optimum plan I, cassava/melon with MOC of ₦5,263.50 in optimum plan II, maize/cowpea with MOC of ₦7,099.06 in risk efficient plan I, sorghum/yam with MOC of ₦1,518.98 in risk efficient plan II and sorghum/yam with MOC of ₦4,998.06 in risk efficient plan III had the least MOC values in their respective optimized plans. This implies that these crop enterprises are in better competitive positions to fit into the various derived plans respectively compared to the other excluded enterprises. In other words, they would have been the next enterprises to be considered for inclusion in the optimum plans.

Table 4.5: Marginal opportunity cost of excluded cropping enterprises

Excluded cropping enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	100,032.00	131,806.40	123,232.00	129,194.60	117,827.90
Maize	76,624.33	80,010.52	94,211.97	101,767.00	79,005.34
Melon	116,639.40	24,476.99	161,502.90	35,969.27	139,046.10
Millet	15,580.90	82,488.94	79,074.50	57,393.61	78,038.71
Sorghum	44,448.07	43,756.11	57,342.52	68,217.96	42,493.34
Soybean	90,574.53	92,806.09	76,759.38	87,339.58	75,717.95
Yam	26,906.15	38,516.39	50,256.07	47,831.18	28,979.64
Cassava/Groundnut	10,960.26	47,744.52	48,432.49	32,818.18	47,544.41
Cassava/Maize	51,421.59	70,948.77	86,726.81	90,776.45	68,663.00
Cassava/Melon	53,876.68	5,263.50	105,551.60	-	90,292.37
Cassava/Sorghum	59,271.61	87,345.02	93,169.96	94,968.54	81,179.47
Cassava/Soybean	41,465.13	121,360.20	179,811.30	167,857.50	140,663.60
Maize/Cowpea	-	53,871.60	7,099.06	28,100.00	-
Maize/Groundnut	49,546.46	58,473.29	36,051.51	28,157.11	45,051.64
Maize/Melon	101,482.00	44,249.84	167,495.00	63,742.04	138,026.70
Maize/Sorghum	47,781.80	50,953.03	70,698.82	75,682.76	51,348.48
Maize/Soybean	-	-	16,586.89	23,268.01	-
Melon/Millet	14,350.03	19,135.16	72,827.60	52,859.50	128,122.40
Sorghum/Groundnut	68,710.96	75,239.07	32,326.40	29,517.24	74,004.84
Sorghum/Okra	82,183.43	46,610.00	81,911.05	85,454.70	49,359.60
Sorghum/Soybean	761.61	21,177.46	26,045.88	25,268.59	15,223.40
Sorghum/Yam	2,997.49	8,830.38	-	1,518.98	4,998.06
Cassava/Sorghum/Groundnut	-	17,646.76	45,537.50	35,565.90	53,197.54
Cassava/Maize/Cowpea	56,142.16	56,889.90	38,735.75	29,674.81	85,718.61
Cassava/Maize/Groundnut	58,903.80	97,580.96	113,903.00	98,573.72	114,656.10
Cassava/Maize/Melon	61,094.27	6,151.10	127,185.40	11,678.68	143,221.40
Cassava/Maize/Okra	113,014.60	44,909.95	143,901.90	82,337.81	47,559.30
Cassava/Maize/Soybean	101,059.40	117,632.10	106,022.20	127,546.50	142,089.40
Maize/Sorghum/Soybean	-	-	-	14,049.81	130,606.90

Source: Computed from Field Survey Data, 2019.

Conversely, the crop enterprises with the highest MOC values were melon in optimum plan I with MOC of ₦116,639.40, cassava in optimum plan II with MOC of ₦131,806.40, cassava/soybean in risk efficient plans I and II with MOC values of ₦179,811.30 and ₦167,857.50 respectively and cassava/maize/melon in risk efficient plan III with MOC of ₦143,221.40. The implication of this is that these enterprises have the worst competitive positions to fit into the various derived plans respectively among all the other excluded crop enterprises,

4.4.1.3 Marginal value product (MVP) of resources under crop enterprises

The resources limiting the achievement of the smallholder farmers' objective and those in excess supply of the requirements as obtained from the LP and T-MOTAD models' output are presented in Table 4.6. Results show the MVP of resources also referred to as shadow prices as obtained from the LP and T-MOTAD optimal solutions. In mathematical programming models such as the LP in which the problem is to maximize the objective function, any resource that is completely utilized by the programme and has positive MVP greater than zero is limiting. Any additional unit usage of the resource will lead to increase in the value of the objective solution by its corresponding MVP. This is in agreement with the finding of Hassan *et al.* (2005) that asserted that complete usages of resources in a LP solution induce maximization of the objective function. Conversely, any resource that is not completely utilized by the programme is in excess of what is required and has zero MVP and is therefore non-limiting. Olayemi and Onyenweaku (1999) affirmed that resources not used up were not limiting in fulfilling the attainment of programme's goal and vice versa.

Results presented in Table 4.6 for optimum plan I revealed that farm size, borrowed capital, human labour for land preparation, planting, fertilizer application, harvesting and fertilizer application had MVP of ₦78,570.92, ₦1.55, ₦1,674.56, ₦999.93, ₦1000.01, ₦1,200.00 and ₦150.00 respectively. This implies that these resources were completely utilized by the programme and therefore limit the gross margin maximization goal of the smallholder farmers. An increase in the use of these resources by a unit will lead to increase in the gross margin of the farmers by their corresponding MVP. For example, the MVP for farm size was ₦78,570.92 which implies that if the farm holding in increased by 1ha, it would lead to increase in gross margin by ₦78,570.92.

Table 4.6: Marginal value product of resources under cropping enterprises

Resource	**Marginal value product of resources (₦/Unit)**				
	Optimum plan I	**Optimum plan II**	**Risk efficient plan I**	**Risk efficient plan II**	**Risk efficient plan III**
Farm size	78,570.92 (0)	73,318.91 (0)	96,410.21 (0)	110,326.90 (0)	79,970.63 (0)
Owned capital	0 (2,857.98)	0 (1,518.89)	28.22 (0)	0 (3,485.15)	0 (2.24)
Borrowed capital	1.55 (0)	-	12.5 (0)	12.5 (0)	12.5 (0)
HL for land preparation	1674.56 (0)	1,874.30 (0)	0 (10.41)	0 (4.89)	897.06 (0)
HL for planting	999.93 (0)	1,000 (0)	999.98 (0)	1,000.01 (0)	999.98 (0)
HL for weeding	0 (55.94)	0 (65.03)	0 (55.12)	212.53 (0)	0 (15.80)
HL for fertilizer application	1,000.01 (0)	1,000.01 (0)	999.75 (0)	0 (1.47)	999.98 (0)
HL for harvesting	1,200 (0)	1,200 (0)	1,200 (0)	1,200 (0)	1,200 (0)
Seed	0 (162.59)	0 (0)	0 (46.71)	0 (170.71)	0 (955.54)
Fertilizer	150 (0)	150 (0)	150 (0)	150 (0)	150 (0)
Agrochemical	0 (0.18)	0 (6.80)	0 (7.68)	0 (6.61)	0 (8.03)
Tractor/power tiller	0 (1.54)	0 (1.02)	0 (2.54)	0 (2.45)	0 (0.62)

Source: Computed from Field Survey Data, 2019
*Figures in parentheses are slack/surplus values; HL = Human labour

Result also revealed that owned capital, labour for weeding, seed, agrochemical and tractor/power tiller were found to be surplus across the plans as they were not completely utilized in the programme. These resources equally had zero MVPs and imply that they were in excess of the actual requirements to maximize the profit of the smallholder farmers; therefore, an increase in the usage of any of these resources for the production of the activities will reduce the gross margin. This result is in line with the arguments of Igwe *et al.* (2013), Adewumi *et al.* (2018) and Jacob (2019) in studies among arable crop farmers in Nigeria that increased usage of any farm resource in excess of what is required in an optimization problem will lead to a decrease in the value of the objective function. It is also similar to the findings of Abdelaziz *et al.* (2010), Kaur *et al.* (2010) and Majeke *et al.* (2013) in other countries.

4.4.1.4 Gross margin in existing, optimum and risk efficient cropping plans

The average gross margins in Naira per hectare obtained from the smallholder farmers' existing, optimum and risk efficient plans are presented in Figure 4.9. It revealed that the average gross margin in the existing plan for crop enterprises was estimated to be ₦242,760.98/ha. The average obtainable gross margins from the LP solutions were ₦465,968.30/ha and ₦438,192.10/ha for income maximization plans in optimum plan I and II respectively. The lower gross margin in optimum plan II compared to plan I could be attributed to the fact that farmers are limited to their resource base without borrowing. Howbeit, the results imply that there is an average increase of ₦223,207.32/ha and ₦195,431.12/ha representing 91.95% and 80.50% change respectively in the optimum plans over the farmers' existing plan. This further implies that an average smallholder arable crop farmer has the potential to maximize gross margin by reallocating the existing resources in a more optimal manner. These results are similar to those obtained from the studies carried out by Tanko and Baba (2013) and Jacob (2019) in Niger State and Jirgi *et al.* (2018) in Kwara State respectively. The researchers all reported higher farm returns in optimum plans as compared to existing plans.

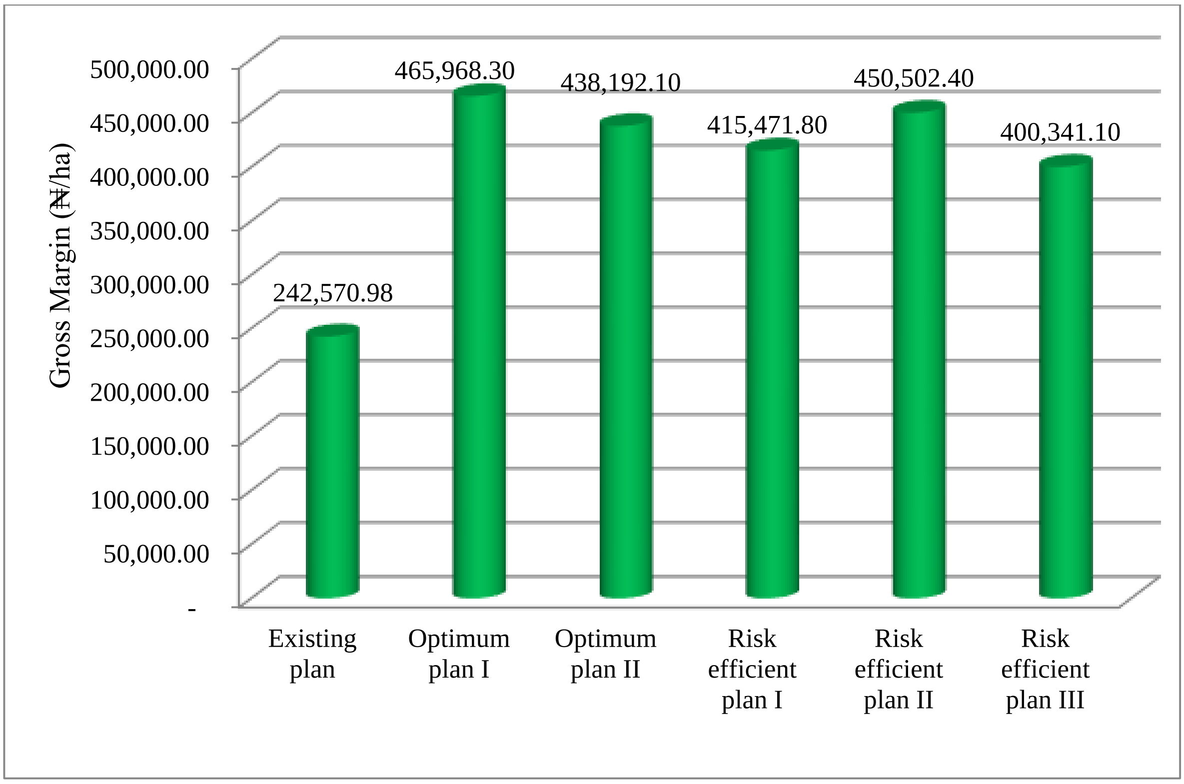


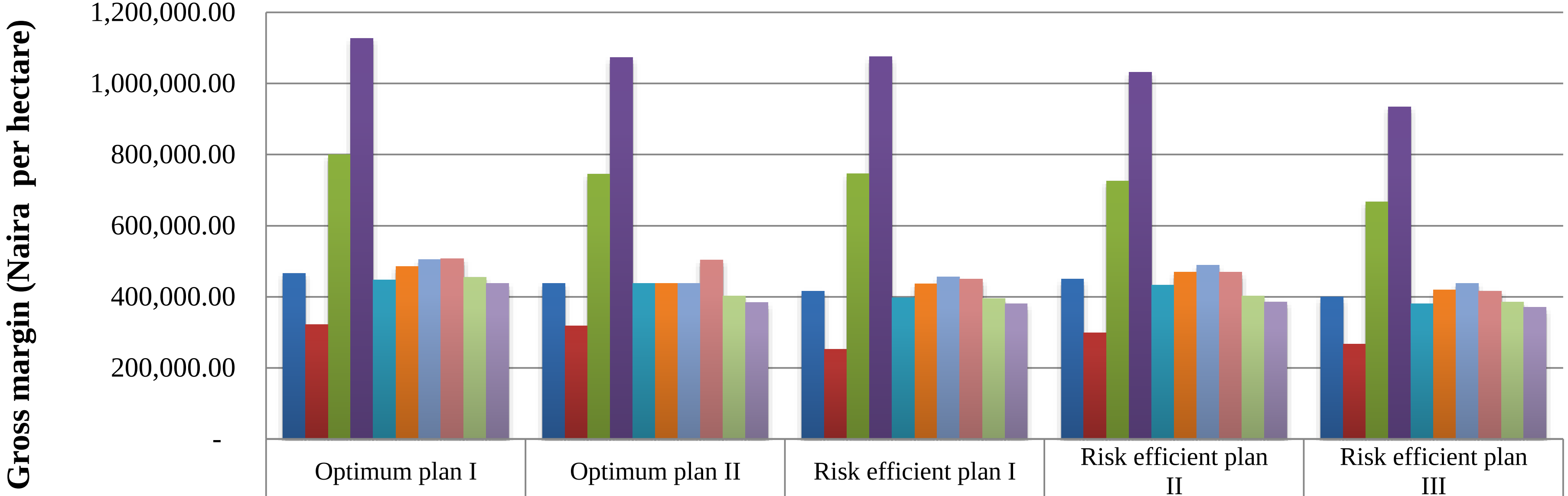
Figure 4.9: Gross margins in the existing, optimum and risk efficient cropping plans
Source: Computed from Field Survey Data, 2019

The average gross margins obtained from the T-MOTAD solutions for risk efficient plans were ₦415,471.80/ha, ₦450,502.40/ha and ₦400,341.10/ha in plan I, plan II and plan III respectively. These also indicated that there is an average increase of ₦172,900.82/ha, ₦207,741.42/ha and ₦157,580.12/ha respectively in the risk efficient plans over the existing plan. These represent 71.22%, 85.57% and 64.91% proportionate increase over the existing plans. The average gross margins obtained in the risk efficient plans are relatively lower than those obtained in optimum plans I and II, especially for risk efficient plans I and III. The differences in these gross margins could be regarded as the risk premium payable by the smallholder farmers for forgoing more risky optimum plans and adopting a plan with a minimized risk. This finding is similar to those of Umoh (2008), Salimonu *et al.* (2008), Udo *et al.* (2015a) and Udo *et al.* (2015b) in various studies carried out on optimum crop combinations in Nigeria.

4.4.1.5 Sensitivity analysis of gross margin for crop enterprises

Sensitivity analysis was carried out to examine the effect of varying selected variables on the gross margins of the smallholder arable crop farmers in the derived plans. The results are presented in Figure 4.10. Variables considered are price of output, capital and labour wage rate given their potentiality to induce or inhibit the level of farmers' gross margin. These variables among others are considered germane to the achievement of the gross margin maximization and risk minimization objectives of the farmers in the study area and were all varied at -50%, +50% and +100% respectively following Igwe (2012) and Jacob (2019). The selection of prices of output is justifiable with the fact that price risk according to Drollete (2009) usually occurs due to the imperfect knowledge about input and output prices. Also, the instability of prices of output can be attributed to factors such as vagaries of weather and climate change phenomena which could affect crop production and government policies.

It was observed that variation in the prices of farm outputs significantly affected the gross margin across all the obtained plans. Decrease in output price by 50.00% marginally reduced the gross margin obtainable by the smallholder arable crop farmers by 30.76%, 27.42%, 39.10%, 33.88% and 33.37% in optimum plans I and II and risk efficient plans I, II and III respectively. Whereas, varying the output price by +50% resulted to marginal increases in the gross margin across all plans by more than 40% except in risk efficient plan II. Similarly, variation in price of product at +100% resulted in more than 100% increases in the gross margin across all plans. These results are similar to the findings of Jacob (2019) who also reported that the value of the objective function for arable crop farmers increased by 21% with increased variation in the prices of farm output by 10% in Niger State. This result is a clear indication that price of farm produce is a significant determinant of farm revenue.



	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Previous value	465,968.30	438,192.10	415,471.80	450,502.40	400,341.10
Output price (-50%)	322,656.70	318,040.40	252,999.90	297,870.70	266,753.90
Output price (+50%)	799,887.70	745,873.90	746,504.60	726,165.40	667,901.70
Output price (+100%)	1,127,671.00	1,073,713.00	1,076,156.00	1,031,546.00	934,867.90
Capital (-50%)	447,632.00	438,192.10	397,620.70	433,347.00	381,213.60
Capital (+50%)	485,108.60	438,192.10	436,159.30	469,657.80	419,635.00
Capital (+100%)	504,264.00	438,192.10	455,570.20	488,813.20	438,062.40
Labour (-50%)	507,288.60	503,633.10	450,039.50	469,379.60	415,751.80
Labour (+50%)	455,258.70	402,283.60	395,362.10	402,247.20	385,039.40
Labour (+100%)	437,862.50	384,081.80	380,770.90	385,657.20	370,546.50

Figure 4.10: Sensitivity analysis of gross margin to variation in output price, capital and labour wage rate for arable crop enterprises
Source: Computed from Field Survey Data, 2019.

Also, inadequate capital has been identified as a major source of financial risk as reported by Jirgi (2013). When capital was varied by -50.00%, gross margins decreased marginally by less than 5.00% across all the plans except in optimum plan II where there was no change. When capital was varied by +50% and +100%, the gross margins increased by just about 4.00% and 9.00% respectively across all the plans. However, gross margin in optimum plan II remained unchanged with variation in capital.

Labour wage rate has also been reported to constitute a large proportion of production cost among smallholder farmers as reported by Adewumi (2017), Durba *et al.* (2019), Yisa (2019) and Jacob (2019) among others. For -50% variation in labour wage rate, it was observed that gross margins increased marginally by 8.87% in optimum plan I, 14.93% in optimum plan II, 8.32% in risk efficient plan I, 4.19% in risk efficient plan II and 3.85% in risk efficient plan III. On the contrary, at +50% variations, gross margins reduced marginally by 2.30% and 8.19% in optimum plans I and II, and by 4.84%, 10.71% and 3.82% in risk efficient plans I, II and III respectively. Gross margins also reduced marginally by 6.03% and 12.35% in optimum plans I and II, and by 8.35%, 14.39% and 7.44% in risk efficient plans I, II and III respectively when labour wage rate was increased by +100%. This suggests that labour wage rate have significant influence of the gross margin of the farmers. This is similar to what was reported by Adewumi (2017) and Jacob (2019) for arable crop farmers in Kwara and Niger States respectively. It is also in consonance with the argument of Igwe (2012) that higher wage paid on labour depresses the farmers' revenue.

4.4.2 Fishery enterprise combinations under risk and limited resource conditions

4.4.2.1 Existing, optimum and risk efficient fishery enterprise plans

The results presented in Table 4.7 show the outlook of the fishery enterprises in the existing plan, optimum farm plans I and II and the risk efficient plans I, II and III respectively. The study identified three fishery enterprises undertaken by the smallholder farmers in the area. These are catfish, fingerlings and catfish/fingerlings enterprises. Interestingly, the LP solution for optimum plan I and the T-MOTAD solutions for risk efficient plans I, II and III respectively included the three enterprises in their various recommended plans. This implies that under these derived plans, all the fishery enterprises have competitive potentialities to yield more returns for the fishery farmers. Only in optimum plan II was catfish/fingerlings enterprise excluded from the prescribed solution and this may not be unconnected with the fact that, farmers were constrained by resources under this scenario. This finding is similar to that of Igwe (2012), Bamiro *et al.* (2015) and Jacob (2019) who all reported that fishery enterprises were prescribed in optimum farm solutions in various studies carried out in Nigeria. This underscores the critical roles these enterprises play in improving livelihoods by raising farm incomes and the need to further exploit fish value chains.

Table 4.7: Existing, optimum and risk efficient fishery enterprise plans

Fishery enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Catfish	1.0450	0.7100	1.0000	0.4588	0.5092	0.6546
Fingerlings	0.7084	0.8600	1.0000	0.7294	0.7546	0.8273
Catfish/Fingerlings	1.3070	0.1400	-	0.2706	0.2454	0.1727

Source; computed from field survey data, 2019
Note: 1 unit = 14 fishes/meter square

The LP results prescribed 0.7100 units of catfish, 0.8600 units of fingerlings and 0.1400 units of catfish/fingerlings in optimum plan I, while in optimum plan II, 1 unit of catfish and 1 unit of fingerlings were prescribed respectively. For the risk efficient plans, the T-MOTAD prescribed 0.4588 units of catfish, 0.7294 units of fingerlings and 0.2706 units of catfish/fingerlings in plan I, while for plan II, 0.5092 units of catfish, 0.7546 units of fingerlings and 0.2454 units of catfish/fingerlings were recommended. Lastly, 0.6546 units of catfish, 0.8273 units of fingerlings and 0.1727 units of catfish/fingerlings were prescribed in plan III. It is noteworthy that the levels of activities prescribed in the various risk efficient plans were relatively lower than the level of activities prescribed in the gross margin maximization optimum plans. This suggests that the production level of the enterprises in the optimum plans carries a high margin of risk compared to those in the risk efficient plans.

4.4.2.2 Marginal opportunity cost of excluded fishery activities

As earlier mentioned, marginal opportunity costs for activities are the income penalties that would be experienced by a farmer who forcefully undertakes any activity that has been excluded by the optimum solution. The MOC of the excluded fishery activity is presented in Table 4.8. It revealed that only catfish/fingerlings enterprise was excluded in optimum plan II for the farmers to maximize their gross margins. This excluded enterprise had a MOC value of ₦701.88. This implies that catfish/fingerlings enterprise was not prescribed in the optimum plan and should not be undertaken by any fish famer because of the income penalty associated with undertaking the enterprise which will depress the value of the objective function.

Table 4.8: Marginal opportunity cost of excluded fishery enterprises

Excluded fishery enterprises	Marginal opportunity cost (₦/meter square)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Catfish/Fingerlings	-	701.88	-	-	-

Source: Computed from Field Survey Data, 2019.

4.4.2.3 Marginal value product (MVP) of resources under fishery enterprises

The results presented in Table 4.9 show the MVP of resources also known as shadow prices obtained from the LP and T-MOTAD solutions. It revealed that all the resources except pond size had positive MVP (greater than zero) in optimum plans I and II respectively. This implies that all these resources were completely utilized by the programme and were therefore limiting the gross margin maximization goal of the smallholder fishery farmers. A unit increase in the usage of these resources will lead to increase in the gross margin of the farmers by their corresponding MVPs. Example, the MVP of feed in risk efficient plan I was ₦350.00 which implies that if feed is increased by 1kg, the value of the objective function will increase by ₦350.00. This gives credence to the findings of Hassan *et al.* (2005) who found that complete usages of resources in a LP solution induce maximization of the objective function.

Table 4.9: Marginal value product of resources under fishery enterprises

Resource	**Marginal value product of resources (₦/Unit)**				
	Optimum plan I	**Optimum plan II**	**Risk efficient plan I**	**Risk efficient plan II**	**Risk efficient plan III**
Pond size	0 (78.29)	0 (78.00)	0 (78.54)	0 (78.49)	0 (78.35)
HL for pond preparation	1,000 (0)	1,000.03 (0)	1,000 (0)	999.9998 (0)	999.98 (0)
HL for cleaning	500 (0)	500.05 (0)	500 (0)	500 (0)	500.05 (0)
HL for feeding	500 (0)	500.09 (0)	500 (0)	500 (0)	499.99 (0)
HL for sorting	500 (0)	499.98 (0)	500.0004 (0)	499.99 (0)	499.98 (0)
HL for harvesting	1,000 (0)	999.95 (0)	1,000 (0)	1,000.02 (0)	1,000.07 (0)
Owned capital	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Borrowed capital	1.2 (0)	-	1.2 (0)	1.2 (0)	1.2 (0)
Feed	350 (0)	350.02 (0)	350 (0)	350 (0)	350 (0)
Fingerlings stock	24.3 (0)	26.5 (0)	0 (2.68)	0 (2.15)	0 (0.63)
Breed stock	1,727.73 (0)	2327.73 (0)	1,479.56 (0)	1,479.56 (0)	1,479.56 (0)
Lime	134.94 (0)	134.94 (0)	134.94 (0)	134.94 (0)	134.94 (0)

Source: Computed from Field Survey Data, 2019.
*Figures in parentheses are slack/surplus values; HL = Human labour

Similarly, for the risk efficient plans I, II and III, the result also revealed that only pond size and fingerling stock were surplus as they were not completely utilized in the programme. All the other resources were completely utilized by the programme and had positive MVP greater than zero indicating that they were limiting in the attainment of the goal of maximizing gross margins. Interestingly, space for pond (pond size) was found to be in excess of the actual requirements to maximize the gross margins of the fishe farmers, whereas other vital inputs such as capital were limiting. This further buttressed the arguments of Ohajianya and Oguoma (2009) and Igwe *et al.* (2015) that smallholder farmers have limited resources at their disposal to maximize their production objectives.

4.4.2.4 Gross margin in existing, optimum and risk efficient fisheries plans

The GMs obtained in the existing, optimum and risk efficient plans are presented in Figure 4.11. Results show the average gross margins in Naira per meter square obtained from the existing plan and in the LP and T-MOTAD solutions for optimum plans I and II and risk efficient plans I, II and III respectively. It shows that the gross margin in the existing plan was estimated to be ₦6,960.72/m^2. The gross margins of ₦9,894.64/m^2 and ₦9,251.45/m^2 obtained in the optimum plans I and II respectively was higher than the GM in the existing plan. This implies that there is an average increase of ₦2,933.92/m^2 and ₦2,290.73/m^2 representing 42.15% and 32.91% change respectively in the optimum plans I and II over the existing plan. These results are similar to that of Bamiro *et al.* (2015) who also reported higher returns in optimum plans than existing plan for fish farmers in Southwest Nigeria. The average gross margins obtained from the T-MOTAD solutions for risk efficient plans were ₦7,009.71/m^2 in plan I, ₦7,225.39/m^2 in plan II and ₦7,846.58/m^2 in plan III respectively. Although, the average gross margins obtained in the risk efficient plans are lower than those obtained in optimums plan I and II, they were still slightly higher than the farmers' existing gross margin. This further implies that an average smallholder fish farmer has the potential to maximize gross margin in the area by adopting the optimum plans or the risk minimized plans prescribed.

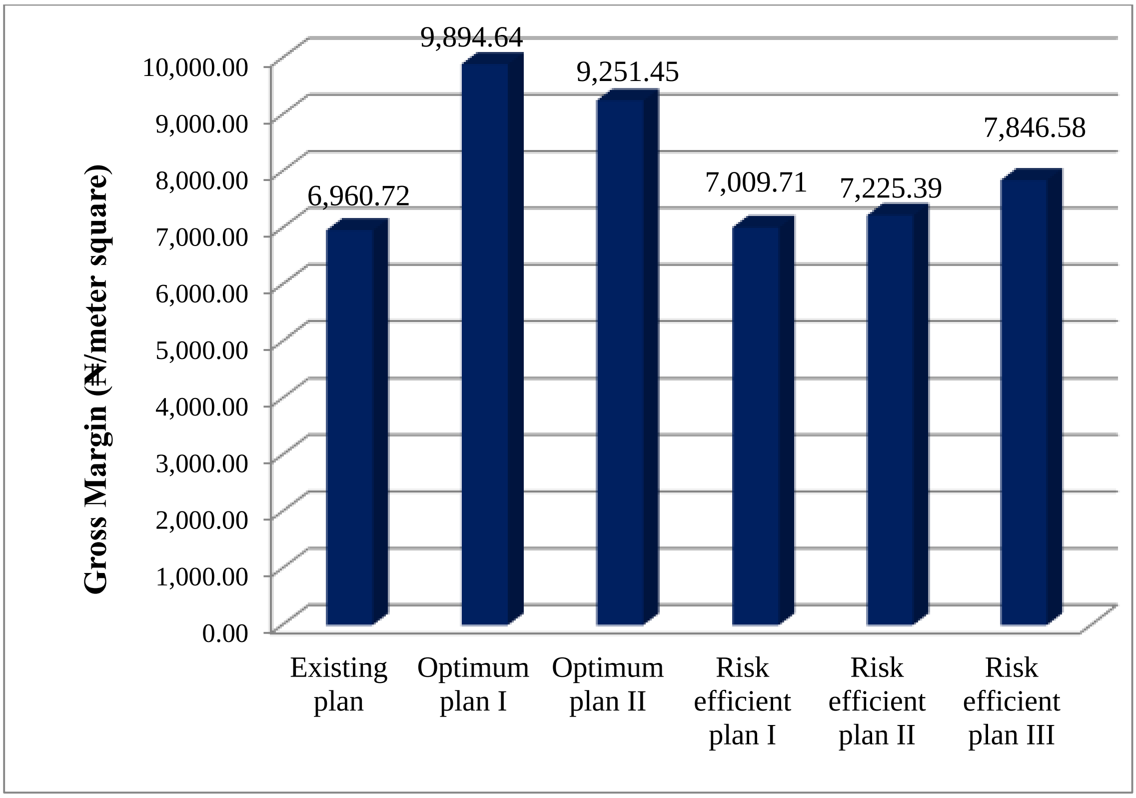
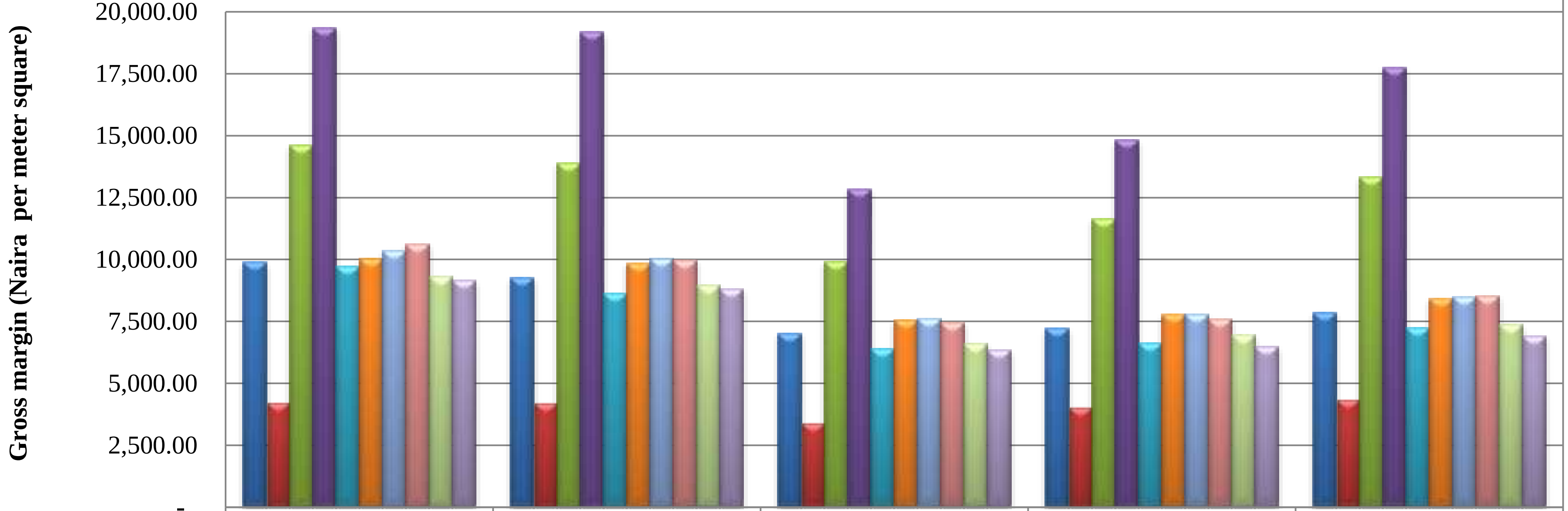


Figure 4.11: Gross margin in the existing, optimum and risk efficient fishery plans
Source: Computed from Field Survey Data, 2019.

4.4.2.5 Sensitivity analysis of gross margin for fishery enterprises

Sensitivity analyses were performed to gauge the responsiveness of the objective function to changes in some predetermined variables. The effects of varying prices of output, capital and labour wage rate on the gross margins of the fisheries farmers were parameterized. The results are presented in Figure 4.12. Results indicated that gross margin decreased marginally by 57.16% in optimum plan I, 54.23% in optimum plan II, 51.17% in risk efficient plan I, 43.80% in risk efficient plan II and 44.37% in risk efficient plan III respectively at -50.00% variations in prices of the output. However, at +50.00% variations, gross margin marginally increased by 47.79%, 50.05%, 41.58%, 61.04% and 69.81% in optimum plans I, II, risk efficient plans I, II and III respectively. Gross margins also increased by 95.58%, 107.30%, 83.17%, 105.28% and 126.11% respectively when prices of output were varied by +100.00%.



	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Previous value	9,894.64	9,251.45	7,009.71	7,225.39	7,846.58
Output price (-50%)	4,239.01	4,234.39	3,422.87	4,060.37	4,364.82
Output price (+50%)	14,623.14	13,882.26	9,924.69	11,635.43	13,324.33
Output price (+100%)	19,351.64	19,178.18	12,839.67	14,832.10	17,742.05
Capital (-50%)	9,731.71	8,639.70	6,398.87	6,614.55	7,235.74
Capital (+50%)	10,046.33	9,842.57	7,553.27	7,774.68	8,410.78
Capital (+100%)	10,364.73	10,046.33	7,605.20	7,793.17	8,484.16
Labour (-50%)	10,619.63	9,967.95	7,442.32	7,594.59	8,521.18
Labour (+50%)	9,323.32	8,963.98	6,607.11	6,956.19	7,371.99
Labour (+100%)	9,159.74	8,800.40	6,344.50	6,487.00	6,897.39

Figure 4.12: Sensitivity analysis of gross margin to variation in output price, capital and labour wage rate for fishery enterprises

Source: Computed from Field Survey Data, 2019.

When capital was reduced by 50.00%, gross margin decreased marginally by an average of 6.64% in all the optimized plans, whereas, when capital was varied by +50% and +100%, the gross margins increased marginally by 6.09% and 7.56% respectively across all the plans. For variation in labour wage rate, it was observed that variation in labour wage rate by -50% marginally increased the gross margin obtainable by 7.33%, 7.74%, 6.17%, 5.11% and 8.60% in optimum plans I and II and risk efficient plans I, II and III respectively, whereas, varying the wage rate of labour by +50.00% and +100.00% resulted to marginal decrease in the gross margin across all plans by an average of 4.88% and 8.82% respectively.

From these results, it is glaring that variation in prices of outputs had the greatest effect on the gross margin of the fish farmers. This implies that gross margins of agricultural enterprises such as fisheries largely depends on output prices. However, other factors such as capital and labour wage rate among others should not be overlooked.

4.4.3 Livestock enterprise combinations under risk and limited resource conditions

4.4.3.1 Existing, optimum and risk efficient livestock enterprise plans

The results of the LP and T-MOTAD models for livestock enterprises is presented in Table 4.10. It shows the existing, the optimum and risk efficient farm plans. It identified fourteen livestock enterprises undertaken by the smallholder farmers in the area. Only three of the fourteen enterprises were included in the optimum plans. Interestingly, the LP solution recommended the same enterprises in both optimum plans I and II. These are namely cattle/goat/sheep, broiler and broiler/layer livestock enterprises. These represent the livestock enterprises that are in better competitive position to yield more returns for the farmers. The LP results prescribed 0.25TLU for cattle/goat/sheep, 0.37TLU for broiler and 0.47TLU for broiler/layer to maximize their net returns in optimum plan I. Meanwhile, in optimum plan II, 0.29TLU, 0.37TLU and 0.47TLU were recommended for cattle/goat/sheep, broiler and broiler/layer livestock enterprises respectively. This finding is similar to that of Bamiro *et al.* (2015) who found that broiler and layer combinations are optimum livestock enterprises in Southwest Nigeria. It also corroborates the finding of Jacob (2019) that goat and sheep in enterprise combination is optimum for farmers in Niger State, Nigeria.

Table 4.10: Existing, optimum and risk efficient livestock enterprise plans

Livestock enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cattle/Goat/Sheep	1.20	0.25	0.29	0.25	0.07	0.36
Broiler	1.07	0.37	0.37	0.37	0.28	0.05
Cockerel	1.25	-	-	-	-	0.48
Broiler/Layer	0.99	0.47	0.47	0.47	0.79	0.23

Source; computed from field survey data, 2019

A cursory look at the results of the T-MOTAD model for risk efficient farm plans for the smallholder famers, it was revealed that three, three and four enterprises were prescribed in plans I, II and III respectively for the risk adverse farmers. Again, just as in optimum plans I and II, cattle/goat/sheep, broiler and broiler/layer enterprises were also prescribed in the risk efficient plans I and II. These same enterprises were also recommended in risk efficient plan III with the addition of cockerel enterprise. This is a strong indication that for livestock enterprises in Kwara State, cattle/goat/sheep, broiler and broiler/layer enterprises are in better competitive positions to yield more returns for the smallholder farmers. They aid in meeting farm family nutritional protein requirements under the risk and limited resource conditions in the area. Specifically, 0.25TLU of cattle/goat/sheep, 0.37TLU of broiler and 0.47TLU of broiler/layer were prescribed in risk efficient plan I; 0.07TLU of cattle/goat/sheep, 0.28TLU of broiler and 0.79TLU of broiler/layer were prescribed in risk efficient plan II; and in risk efficient plan III, 0.36TLU of cattle/goat/sheep, 0.05TLU of broiler, 0.48TLU of cockerel and 0.23TLU of broiler/layer were recommended for the farmers.

4.4.3.2 Marginal opportunity cost of excluded livestock activities

The marginal opportunity costs also known as shadow prices of the excluded livestock enterprises in the optimized plans are presented in Table 4.11. It shows that 10 enterprises each were excluded in the optimum plans I and II and risk efficient plans I and II respectively while nine enterprises were excluded from risk efficient plan III to necessitate the attainment of gross margin maximization and/or risk minimization in the area. It further revealed that sole cockerel with MOCs of ₦21,975.18 and ₦21,975.00 in optimum plan I and risk efficient plan I respectively, sole cattle with MOCs of ₦12,311.04 and ₦9,918.08 in optimum plan II and risk efficient plan II respectively and mixed layer/cockerel with MOC of ₦8,987.66 in risk efficient plan III had the least MOC values in their respective derived plans. This implies that these livestock enterprises are in better competitive positions to fit into the optimum plans compared to the other excluded enterprises.

Amazingly, in all the derived plans, sole goat enterprise had the highest MOC value. Results indicate that sole goat had MOC values of ₦146,269.50, ₦154,071.50, ₦146,283.80, ₦156,428.60, and ₦113,513.40 in optimum plans I and II and risk efficient plans I, II and III respectively. The implication of this is that sole goat enterprise was in the worst competitive position among all the other excluded enterprises. This is a strong indication that the farmers should not undertake sole goat enterprise if they aim to maximize gross margins and minimize the associated risks in livestock enterprise.

Table 4.11: Marginal opportunity cost of excluded livestock enterprises

Excluded livestock enterprises	Marginal opportunity cost (₦/TLU)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cattle	26,923.88	12,311.04	26,948.84	9,918.08	46,558.34
Goat	146,269.5	154,071.5	146,283.8	156,428.6	113,513.4
Sheep	77,323.45	82,311.93	77,339.16	76,464.38	58,458.68
Cattle/Goat	52,966.76	46,390.64	52,963.66	66,000.11	10,687.03
Cattle/Sheep	58,130.90	60,316.98	58,182.19	71,864.56	30,273.28
Goat/Sheep	69,350.21	75,484.36	69,405.48	78,219.93	57,649.02
Layer	50,034.94	52,185.66	50,033.91	22,495.22	65,782.32
Cockerel	21,975.18	38,866.57	21,975.00	15,948.80	-
Layer/Cockerel	57,741.55	69,672.36	57,734.46	52,819.40	8,987.66
Broiler/Cockerel	51,014.87	45,345.65	51,009.09	42,263.80	21,067.05
Broiler/Layer/Cockerel	117,544.80	130,303.3	117,539.8	117,900.50	83,694.53

Source; computed from field survey data, 2019

4.4.3.3 Marginal value product (MVP) of resources under livestock enterprises

Results of the LP and T-MOTAD for livestock enterprises showing the marginal value product of resources also known as shadow prices is presented in Table 4.12. For all the derived plans, the results revealed that livestock capacity, human labour for feeding, and all breed stocks (except broiler stock) in risk efficient plan II and capital and cockerel stock in risk efficient plan III had zero MVPs. This implies that these resources were in excess of the actual requirements to maximize gross margins of the smallholder livestock farmers under risk and limited resource conditions. Consequently, because they are non-limiting, they should not be used in production of the activities beyond their current levels. This is also consistent with the assertion of Olayemi and Onyenweaku (1999) who asserted that resources not used up were not limiting in fulfilling the attainment of the programme's goal.

Table 4.12: Marginal value product of resources under livestock enterprises

Resource	Marginal value product of resources (₦/Unit)				
	Optimum plan I	**Optimum plan II**	**Risk efficient plan I**	**Risk efficient plan II**	**Risk efficient plan III**
Livestock capacity	0 (205.33)	0 (205.33)	0 (205.33)	0 (205.28)	0 (205.29)
HL for pen preparation	1000 (0)	1000 (0)	1000 (0)	1000 (0)	1000 (0)
HL for cleaning	500 (0)	500 (0)	500 (0)	500 (0)	500 (0)
HL for feeding	0 (0.61)	0 (0.62)	0 (0.61)	0 (2.51)	0 (0.05)
HL for sorting	500 (0)	500 (0)	500 (0)	500 (0)	500 (0)
HL for harvesting	1000 (0)	1000 (0)	1000 (0)	1000 (0)	0 (0.04)
Owned capital	1 (0)	1 (0)	1 (0)	1 (0)	0 (599.78)
Borrowed capital	2.1 (0)	-	2.1 (0)	2.1 (0)	0 (1832.7)
Feed	350 (0)	350 (0)	350 (0)	350 (0)	350 (0)
Breed stock (cattle)	0 (1)	0 (1)	0 (1)	0 (1.18)	0 (0.89)
Breed stock (goat)	0 (7.75)	0 (7.75)	0 (7.75)	0 (8.12)	0 (7.52)
Breed stock (sheep)	0 (5.49)	0 (5.50)	0 (5.49)	0 (6.23)	0 (5.04)
Breed stock (broiler)	0 (4.15)	0 (4.11)	0 (4.16)	300 (0)	0 (48.90)
Breed stock (layer)	0 (39.48)	0 (39.45)	0 (39.49)	0 (22.15)	0 (52.37)
Breed stock (cockerel)	0 (60.50)	0 (60.50)	0 (60.50)	0 (60.50)	94.28 (0)

Source: Computed from Field Survey Data, 2019.
*Figures in parentheses are slack/surplus values; HL = Human labour

However, on the contrary, labour for pen preparation, cleaning, sorting, harvesting, owned and borrowed capital and feed had positive MVPs. This implies that all these resources were completely utilized by the programme and were therefore limiting the attainment of the objective function which is to maximize gross margins. The implication is that a unit increase in their usage will lead to increase in the gross margins of the farmers by their corresponding MVPs. For example, labour for cleaning had MVP of ₦500.00 in risk efficient plan III. This implies that if labour for cleaning is increased by 1 man-day, the value of the objective function will increase by ₦500.00. This finding is similar to those of Sathyanarayan *et al.* (2010), Baruwa (2013) and Bamiro *et al.* (2015) who reported that human labour and feed were factors limiting the profit maximization objective of livestock farmers. It also corroborates the report of Jacob (2019) that labour and capital were limiting the gross margin maximization objective of livestock farmers in Niger State.

4.4.3.4 Gross margin in existing, optimum and risk efficient livestock plans

The gross margins obtained in Naira per TLU in the existing plan, optimum plans I and II and the risk efficient plans I, II and II for livestock enterprises are presented in Figure 4.13. Estimated gross margin in the existing farm plan was ₦218,170.75/TLU, whereas, gross margins of ₦242,662.30/TLU and ₦247,676.00/TLU obtained in optimum plans I and II were higher. This implies that there was an increase of ₦24,491.55/TLU and ₦29,505.25/TLU representing 11.23% and 13.52% proportionate change in the optimum plans respectively over the existing plan. These results are similar to those obtained from the study carried out by Bamiro *et al.* (2015) and Jacob (2019) on optimum livestock production among farmers in the Southwest and Niger State Nigeria respectively.

The average gross margins obtained from the T-MOTAD solutions for risk efficient plans were ₦242,670.60/TLU in plan I, ₦235,065.60/TLU in plan II and ₦222,897.90/TLU in plan III respectively. These indicate that there is an increase of ₦24,499.85/TLU, ₦16,894.85/TLU and ₦4,727.15/TLU respectively in the risk efficient plans representing 11.23%, 7.74% and 2.17% proportionate increase in these plans over the farmers' existing plan. Results further show that gross margins obtained in the risk efficient plans are slightly lower than those obtained in optimum plans I and II, especially for risk efficient plans II and III. The differences in the gross margins could be attributable to the risk premium payable by the smallholder farmers for forgoing more risky optimum plans and adopting a plan with a minimized risk.

It is worthy of note that the average gross margin of the farmers increased across the optimum and risk efficient plans. It however increased proportionately higher in optimum plan II and least in risk efficient plan III. The implication of these increments and disparity in the optimum and risk efficient plans is that, an average smallholder livestock farmer in the study area has the potential to increase and maximize net profit under risk and limited resource conditions.

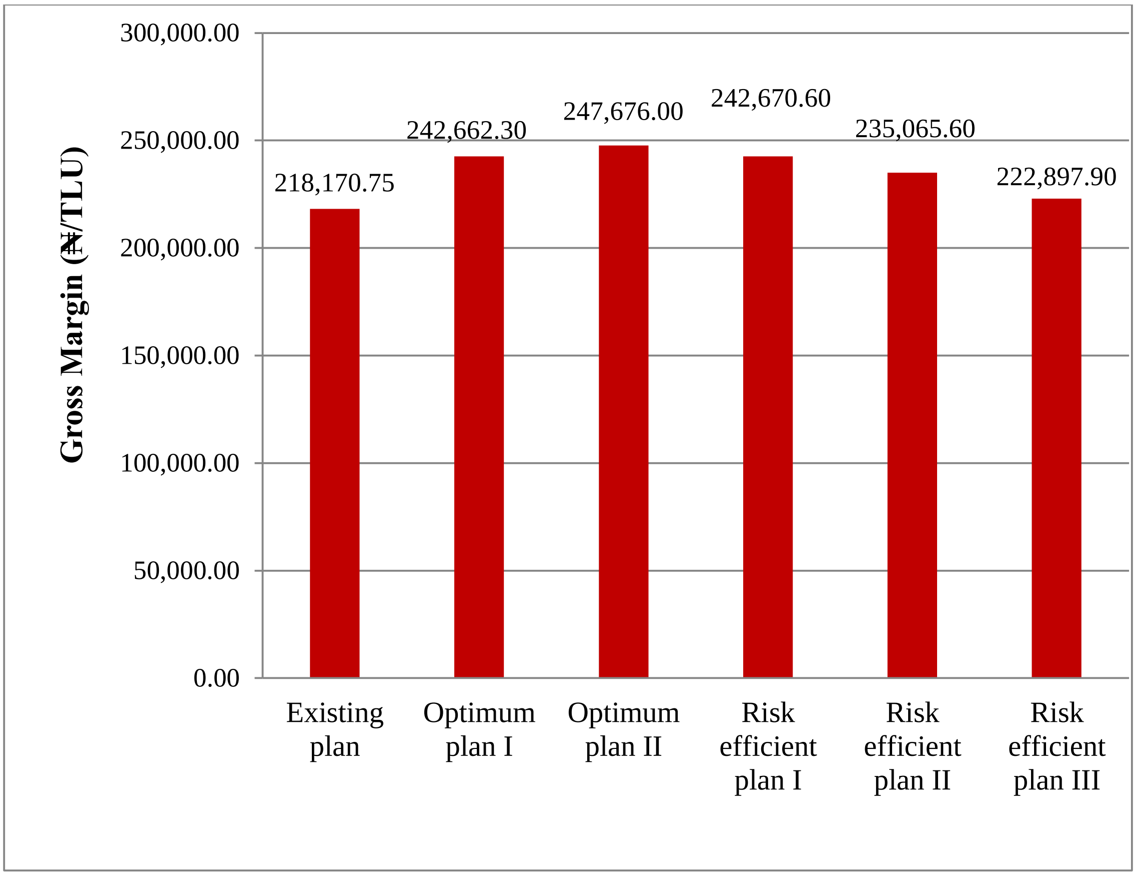
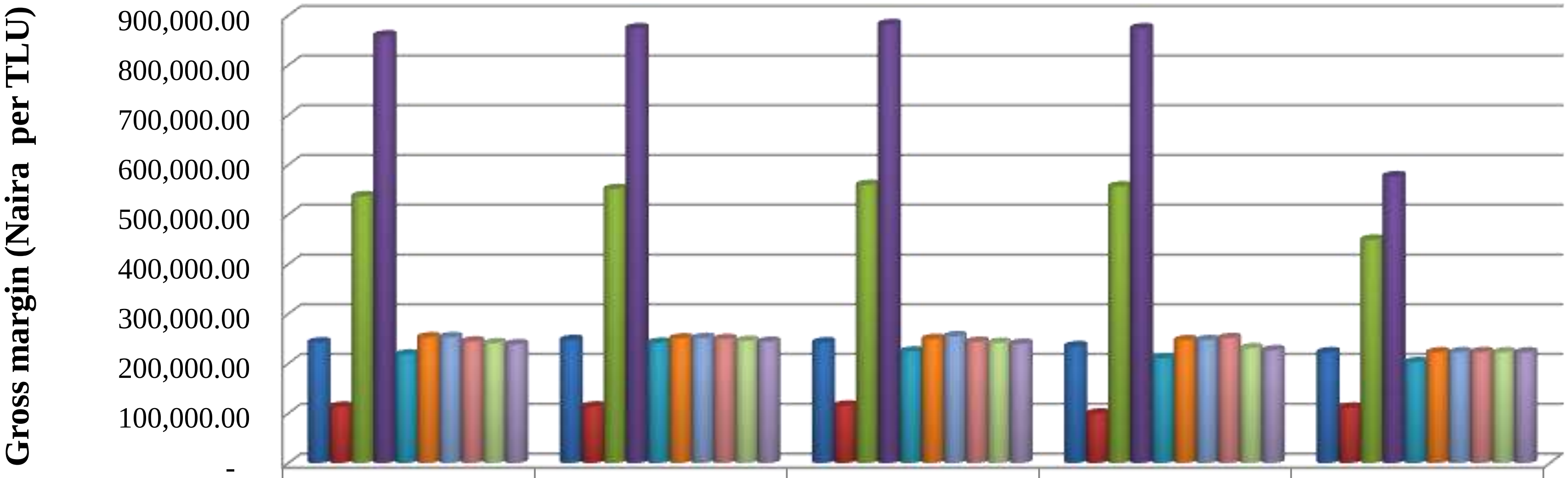


Figure 4.13: Gross margin in the existing, optimum and risk efficient livestock plans
Source: Computed from Field Survey Data, 2019.

4.4.3.5 Sensitivity analysis of gross margin for livestock enterprises

For livestock enterprises, the results of the sensitivity analysis performed are presented in Figure 4.14. When prices of output were varied at -50.00% connoting a reduction, it was observed that gross margins marginally decreased by 53.23% in optimum plan I, 54.00% in optimum plan II, 52.34% in risk efficient plan I, 57.58% in risk efficient plan II and 49.90% in risk efficient plan III respectively. Interestingly, at +50.00% variations, gross margins increased by more than 100.00% across all the plans. Also, gross margin increased by more than 200.00% across all the plans except in risk efficient plan III wherein it increased by 158.83% when prices of output were doubled, that is, increased by +100.00%. This is clear indication that gross margin in livestock enterprises is very sensitive to changes in prices of output. Livestock play very critical roles at enhancing livelihoods of farm households. They also seem to command higher market prices as compared to outputs of crop enterprises.

The sensitivity analysis of gross margins to variations in amount of capital revealed that when capital was reduced by 50%, gross margin decreased marginally by 10.02%, 2.30%, 7.52%, 10.36% and 8.88% in optimum plans I and II and risk efficient plans I, II and III respectively. On the other hand, when capital was increased by +50%, gross margins increased slightly by 4.27%, 1.28%, 2.88%, and 5.18% in all the plans respectively except in risk efficient plan III. Similar results were recorded when capital was doubled, that is, increased by +100%. However, the gross margins increased slightly except in risk efficient plan III.



	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Previous value	242,662.30	247,676.00	242,670.60	235,065.60	222,897.90
Output price (-50%)	113,494.90	113,939.40	115,646.90	99,709.34	111,678.40
Output price (+50%)	536,649.40	551,085.30	559,348.10	556,388.20	449,288.40
Output price (+100%)	859,922.80	874,400.40	882,740.40	874,409.70	576,937.40
Capital (-50%)	218,344.30	241,981.30	224,429.60	210,724.20	203,095.60
Capital (+50%)	253,014.50	250,835.30	249,658.30	247,234.30	222,897.90
Capital (+100%)	253,372.00	251,543.60	255,200.40	247,435.20	222,897.90
Labour (-50%)	244,527.00	249,534.80	243,958.80	251,503.50	223,260.70
Labour (+50%)	240,814.20	245,857.40	241,742.40	230,997.30	222,735.10
Labour (+100%)	238,957.80	243,996.00	239,886.00	226,929.10	222,572.30

Figure 4.14: Sensitivity analysis of gross margin to variation in output price, capital and labour wage rate for livestock enterprises

Source: Computed from Field Survey Data, 2019.

For variation in human labour wage rate, when wage rate was reduced by 50%, it led to marginal increase of 0.77% in optimum plan I, 0.75% in optimum plan II, 0.53% in risk efficient plan I, 6.99% in risk efficient plan II and 0.16% in risk efficient plan III respectively. When the wage rate of labour was increased by half, that is, +50.00%, it was observed that gross margins declined by just 0.76%, 0.73%, 0.38%, 1.73% and 0.07% in optimum plans I and II and risk efficient plans I, II and III respectively. When labour wage rate was doubled, that is, increased by +100%, marginal decrease in the gross margin across all plans by 1.55%. This result is similar to that of Bamiro *et al.* (2015) who reported that farm returns in livestock enterprises was sensitive to variation in labour wage in Southwest Nigeria. This suggests that farmers will be willing to hire more labour to necessitate the accomplishment of livestock operations during critical periods of labour requirement.

4.4.4 Farm enterprise combinations under risk and limited resource conditions

This section presents results of analysis of pooled farm enterprise combinations in crop, livestock and fishery enterprises.

4.4.4.1 Existing, optimum and risk efficient farm enterprise plans

Results in Table 4.13 show the various farm enterprises in the existing, normative optimum and risk efficient farm plans. A total of forty-eight different farm enterprises undertaken by the smallholder farmers in the area were identified. It also revealed that only ten, seven, ten, eleven and ten farm enterprises were included in optimum plans I, II, risk efficient plans I, II and III respectively for the farmers to maximize their gross margins under risk and limited resource conditions in the study area. These recommended enterprises consist of both sole and mixed enterprises.

The LP results prescribed enterprise combination of millet on 1.1420ha, maize/cowpea on 0.1587ha, maize/groundnut on 0.0718ha, maize/soybean on 0.3331ha, cassava/sorghum/groundnut on 1.1957ha, maize/sorghum/soybean on 0.8317ha, 0.6037TLU of broiler, 0.0137TLU of cockerel, 0.0064TLU of broiler/layer and 0.2782TLU of goat respectively as optimal for the smallholder famers to maximize their gross margins. In optimum plan II, the farm enterprises recommended for combination under limited resource condition are 1.1420ha of millet, 0.2406ha of maize/groundnut, 0.0613ha of sorghum/groundnut, 1.0000ha of maize/sorghum/soybean, 0.6028TLU of broiler, 0.3121TLU of cockerel and 0.1282TLU of cattle respectively.

For farm enterprise combinations under risk condition, the prescribed enterprises in the T-MOTAD results for plan I were millet on 1.1288ha, rice on 0.2969ha, maize/cowpea on 0.0010ha, cassava/sorghum/groundnut on 0.1241ha, maize/sorghum/soybean on 1.0097ha, 0.0555units of catfish, 0.0983units of catfish/fingerlings, 0.1266TLU of layers, 0.5029TLU of cockerel and 0.2597TLU of cattle respectively.

Table 4.13: Existing, optimum and risk efficient farm enterprise plans (pooled)

Farm enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Millet	1.7000	1.1420	1.1420	1.1288	1.0980	1.1420
Rice	1.2400	-	-	0.2969	0.0408	0.0719
Maize/Cowpea	1.5100	0.1587	-	0.0010	0.1014	-
Maize/Groundnut	0.6800	0.0718	0.2406	-	-	0.6545
Maize/Soybean	0.7500	0.3331	-	-	-	-
Sorghum/Groundnut	0.9500	-	0.0613	-	-	-
Sorghum/Yam	1.1300	-	-	-	0.0619	-
Cassava/Sorghum/Groundnut	0.7000	1.1957	-	0.1241	0.1927	-
Maize/Sorghum/Soybean	1.2000	0.8317	1.0000	1.0097	0.4267	0.2436
Catfish	1.0000	-	-	0.0555	-	0.0013
Catfish/Fingerlings	1.0000	-	-	0.0893	-	-
Broiler	1.0700	0.6037	0.6028	-	0.5998	0.6025
Layer	1.1000	-	-	0.1266	-	0.0004
Cockerel	1.2500	0.0137	0.3121	0.5029	0.4838	0.5482
broiler/layer	0.9900	0.0064	-	-	-	-
Broiler/Layer/Cockerel	1.0500	-	-	-	-	-
Cattle	1.2000	-	0.1282	0.2597	0.0353	0.0005
Goat	1.5000	0.2782	-	-	0.0296	-
Sheep	1.3000	-	-	-	0.0121	0.0020

Source: Computed from Field Survey Data, 2019.

The risk efficient plan II recommended the highest number of farm enterprise combinations consisting of 1.0980ha of millet, 0.0408ha of rice, 0.1014ha of maize/cowpea, 0.0619ha of sorghum/yam, 0.1927ha of cassava/sorghum/groundnut, 0.4267ha of maize/sorghum/soybean, 0.5998TLU of broilers, 0.4838TLU of cockerel, 0.0353TLU of cattle, 0.0296TLU of goat and 0.0121TLU of sheep respectively. It is noteworthy that all the derived plans covered a wide range of available choice options for the smallholder farmers on the basis of enterprise combination and resource allocation. The T-MOTAD results prescribed millet on 1.1420ha, rice on 0.0719ha, maize/groundnut on 0.6545ha, maize/sorghum/soybean on 0.2436ha, 0.0013units of catfish, 0.6025TLU of sole broiler, 0.0004TLU of sole layer, 0.5482TLU of sole cockerel,0.0005TLU of sole cattle and 0.0020TLU of sole sheep respectively for risk efficient enterprise combination plan III.

Interestingly, millet, maize/sorghum/soybean and cockerel enterprises were prescribed in all the plans. The implication of this could be that millet and maize/sorghum/soybean together with cockerel enterprise are in better competitive positions to yield more returns for the farmers even under limited resource condition and meet their household's dietary requirements. Although, these crops may not be cash crops, yet, they are dietary staples that are very necessary in meeting the annual farm family food requirements. These could also provide a better strategy to enhance the mitigation of associated risk in farming than the other farm enterprises recommended by the LP and T-MOTAD solutions for the farm households in the study area. It is noteworthy that all farm enterprises prescribed in the LP and T-MOTAD solutions consists of both crop and livestock enterprises as combinations. These crop-livestock enterprise interactions could serve as the poverty and food insecurity safety net for these resource poor smallholder farmers. This finding is similar to that of Igwe and Onyenweaku (2013) and Jacob (2019) who both reported optimum combination of crop and livestock enterprises for farmers in Abia and Niger States Nigeria respectively. Crop and livestock are indispensable in smallholder agriculture. The crop meets the starch while livestock the protein requirements respectively.

4.4.4.2 Marginal opportunity cost of excluded farm enterprises (pooled)

The marginal opportunity costs of the excluded farm enterprises for this study as obtained from the LP and T-MOTAD solutions are presented in Table 4.14. It revealed that thirty-eight, forty-one, thirty-eight, thirty-seven, and thirty-eight farm enterprises were excluded in optimum plans I, II, risk efficient plans I, II and III respectively for the farmers to maximize their gross margins and minimize the associated risk.

Results in Table 4.14 further revealed that sorghum/groundnut with MOC of ₦3,437.89 in optimum plan I, catfish/fingerlings with MOC of ₦16,049.82 in optimum plan II, cattle/goat/sheep with MOC of ₦15,418.81 in risk efficient plan I, maize/groundnut with MOC of ₦2,984.45 in risk efficient plan II and maize/soybean with MOC of ₦2,187.56 in risk efficient plan III had the least MOC values in their respective derived plans. The implication of this is that these enterprises have a better chance to be included into the various derived plans respectively compared to the other excluded enterprises. Whereas, the enterprises with the highest MOC values were melon in optimum plan I with MOC of ₦116,639.40, cassava in optimum plan II with MOC of ₦131,806.40, cassava/soybean in risk efficient plans I and II with MOC values of ₦179,811.30 and ₦167,857.50 respectively and cassava/maize/melon in risk efficient plan III with MOC of ₦143,221.40. The implication of this is that these enterprises have the worst competitive advantage to fit into the various derived plans respectively among all the other excluded farm enterprises.

Table 4.14: Marginal opportunity cost of excluded farm enterprises (pooled)

Excluded farm enterprises	Marginal opportunity cost (₦/unit enterprise)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	279,465.50	124,657.30	374,145.40	191,077.10	178,180.30
Maize	145,245.90	96,495.06	339,444.60	120,015.70	128,902.40
Melon	130,850.30	215,764.00	317,024.50	208,813.30	5,085.10
Rice	158,168.10	42,736.57	-	-	-
Sorghum	85,203.80	32,352.11	311,412.80	64,954.26	77,454.24
Soybean	135,064.60	138,219.70	342,030.60	113,041.40	64,500.50
Yam	199,265.30	354,331.20	228,794.00	272,981.10	348,343.80
Cassava/Groundnut	225,834.40	39,502.00	281,195.30	111,511.40	115,986.80
Cassava/Maize	175,532.80	144,980.90	228,182.90	286,018.40	329,618.40
Cassava/Melon	199,577.30	151,278.00	324,880.00	204,141.00	28,842.90
Cassava/Sorghum	286,650.00	76,500.00	306,297.30	134,722.50	130,847.90
Cassava/Soybean	249,092.20	220,452.40	323,370.10	251,238.80	222,319.70
Maize/Cowpea	-	27,412.39	-	-	7,728.20
Maize/Groundnut	-	-	250,965.80	2,984.45	-
Maize/Melon	200,006.60	290,917.20	209,040.10	300,185.00	168,485.60
Maize/Sorghum	95,945.95	57,846.91	103,097.20	93,853.34	114,222.80
Maize/Soybean	-	44,915.73	62,604.60	27,263.15	2,187.56
Maize/Yam	89,861.70	59,037.63	237,986.80	121,152.60	182,225.00
Melon/Millet	115,148.40	168,051.20	95,316.39	151,435.70	15,522.86
Sorghum/Groundnut	3,437.89	-	47,836.70	51,039.36	55,220.71
Sorghum/Okra	137,716.60	68,586.27	360,680.70	96,163.44	80,143.63
Sorghum/Soybean	37,537.30	146,853.50	45,173.30	176,774.10	114,155.30
Sorghum/Yam	139,138.60	165,941.70	182,592.50	-	377,994.10
Cassava/Sorghum/Groundnut	-	216,813.70	-	-	132,559.00
Cassava/Maize/Cowpea	90,783.60	24,632.00	141,871.00	161,989.40	209,115.00
Cassava/Maize/Groundnut	212,994.00	24,511.73	184,175.00	202,676.00	116,395.30
Cassava/Maize/Melon	180,538.10	222,148.70	220,330.40	401,402.90	313,438.10
Cassava/Maize/Okra	211,079.30	115,583.40	239,272.00	281,137.20	312,373.60
Cassava/Maize/Soybean	115,507.00	70,471.80	183,196.80	204,745.80	251,859.50
Catfish	24,395.89	27,541.46	-	31,905.70	-
Fingerlings	26,882.22	30,348.75	17,977.11	35,157.79	42,196.30
Catfish/Fingerlings	14,216.56	16,049.82	-	18,593.06	22,315.35
Broiler	-	-	41,118.81	-	-
Layer	52,933.68	152,075.70	-	262,437.30	-
Layer/Cockerel	254,640.30	288,046.50	115,895.50	436,929.90	161,792.90
Broiler/Cockerel	332,926.30	258,405.30	88,947.57	217,956.30	232,659.60
broiler/layer	-	224,271.30	46,395.90	114,742.20	81,691.23
Broiler/Layer/Cockerel	271,221.30	358,071.60	175,672.90	226,519.30	173,158.00
Cattle	60,889.13	-	-	-	-
Goat	-	186,303.40	125,201.10	-	59,511.07
Sheep	194,340.40	176,622.20	78,570.68	-	-
Cattle/Goat	207,936.00	132,669.30	70,384.11	112,536.20	154,618.40
Cattle/Sheep	254,830.10	222,132.20	91,066.44	125,797.30	139,606.30
Goat/Sheep	186,754.30	186,303.30	77,949.97	73,688.20	138,966.30
Cattle/Goat/Sheep	185,965.30	164,969.60	15,418.81	72,649.18	106,025.30

Source: Computed from Field Survey Data, 2019.

4.4.4.3 Marginal value product (MVP) of resources of pooled farm enterprises

The results presented in Table 4.15 show the MVP of resources for crop, livestock and fishery farm enterprise combinations obtained from the LP and T-MOTAD solutions for optimum plans I and II and risk efficient plans I, II and III respectively. It shows the optimal pattern of resource use and allocation pattern, depicting the surplus and the shadow prices. From the result, owned and borrowed capital, human labour for fertilizer/agrochemical application, harvesting of crops, pen/pond preparation, cleaning and harvesting of livestock, feed and broiler stock across the various derived plans were fully utilized in the programme and all had positive MVP greater than zero. This implies that, if any of these resources is increased by one percent or one unit, the optimal profit will increase by same corresponding MVPs respectively.

On the contrary, farm size except in optimum plan I; pond size; livestock capacity; human labour for planting, weeding, feeding except in risk efficient plan I, human labour for harvesting fish and livestock; seed; fertilizer; agrochemical; tractor/power tiller; lime except in risk efficient I; fingerling stock; breed stock for fish, cattle, goat, sheep, layer, and cockerel except in the risk efficient plans all had zero MVPs. This implies that these resources were not fully utilized in the programme and were in excess of the actual quantity required by the smallholder farmers to maximize the farm gross margin under risk and limited resource conditions in Kwara State. It further implies that they should not be in further use for the production of the activities to abate wastage.

Table 4.15: Marginal value product of resources of farm enterprises

Resource	Marginal value product of resources (₦/Unit)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Farm size (ha)	145,780.40 (0)	0 (0.18)	0 (0.06)	0 (0.70)	0 (0.51)
Pond size (m^2)	0 (2.77)	0 (2.77)	0 (2.63)	0 (2.77)	0 (2.77)
Livestock capacity (number)	0 (205.52)	0 (205.38)	0 (205.53)	0 (205.26)	0 (205.27)
Owned capital (₦)	4.72 (0)	8.51 (0)	7.93 (0)	5.95 (0)	0.90 (0)
Borrowed capital (₦)	2.50 (0)	-	2.36 (0)	0 (106.60)	0 (282.12)
HL for land preparation (man-day)	0 (20.83)	982.50 (0)	1,205.08 (0)	1,296.19 (0)	0 (9.63)
HL for planting (man-day)	0 (5.08)	0 (3.19)	0 (0.87)	0 (5.73)	0 (5.73)
HL for weeding (man-day)	0 (41.95)	0 (76.93)	0 (72.82)	0 (82.82)	0 (84.94)
HL for fertilizer/agrochemical application (man-day)	469.97 (0)	899.01 (0)	1000.02 (0)	700.09 (0)	0 (3.21)
HL for harvesting of crops (man-day)	780.10 (0)	919.48 (0)	599.39 (0)	809.99 (0)	847.26 (0)
HL for pen/pond preparation (man-day)	347.71 (0)	603.98 (0)	780.18 (0)	928.93 (0)	1,000.04 (0)
HL for cleaning (man-day)	0 (0.09)	489.06 (0)	304.96 (0)	419.70 (0)	444.98 (0)
HL for feeding (man-day)	0 (3.01)	0 (2.56)	500.07 (0)	0 (3.37)	0 (4.52)
HL for sorting (man-day)	400.09 (0)	490.46 (0)	0 (0.25)	347.93 (0)	499.39 (0)
HL for harvesting of fish (man-day)	0 (29.37)	0 (20.90)	0 (26.51)	0 (21.17)	0 (17.02)
HL for harvesting of livestock (man-day)	0 (34.88)	0 (26.04)	0 (31.84)	0 (26.02)	0 (21.81)
Seed (kg)	0 (284.57)	0 (456.39)	0 (408.10)	0 (318.90)	0 (477.10)
Fertilizer (kg)	0 (56.77)	0 (76.92)	0 (55.74)	0 (73.95)	0 (56.98)
Agrochemical (litres)	0 (3.25)	0 (10.05)	0 (9.99)	0 (11.66)	0 (9.17)
Tractor/Power tiller (hours)	0 (1.80)	0 (2.56)	0 (3.50)	0 (3.16)	0 (1.31)
Feed (kg)	1,585.49 (0)	1,201.66 (0)	0 (14.92)	909.47 (0)	903.16 (0)
Lime (kg)	0 (0.29)	0 (0.29)	6,364.99 (0)	0 (0.29)	0 (0.29)
Fingerling stock (number)	0 (12)	0 (12)	0 (10.36)	0 (12)	0 (11.98)
Breed stock (fish) (number)	0 (2)	0 (2)	0 (1.82)	0 (2)	0 (2)
Breed stock (cattle) (number)	0 (1.25)	0 (0.99)	0 (0.73)	0 (1.18)	0 (1.25)
Breed stock (goat) (number)	0 (4.08)	0 (8.25)	0 (8.25)	0 (7.81)	0 (8.25)
Breed stock (sheep) (number)	0 (6.50)	0 (6.50)	0 (6.50)	0 (6.34)	0 (6.47)
Breed stock (broiler) (number)	4,593.06 (0)	3,788.84 (0)	0 (64.50)	3,179.03 (0)	3,701.34 (0)
Breed stock (layer) (number)	0 (64.41)	0 (64.75)	0 (50.82)	0 (64.75)	0 (64.70)
Breed stock (cockerel) (number)	0 (58.79)	0 (21.49)	1,594.42 (0)	1,230.70 (0)	1,500.03 (0)

Source: Computed from Field Survey Data, 2019.
*Figures in parentheses are slack/surplus values; HL = Human Labour

For example, in optimum plan I, farm size, owned capital, borrowed capital, human labour for fertilizer/agrochemical application, for harvesting of crops, for pen/pond preparation, for sorting, feed and broiler stock had MVP of ₦145,780.40, ₦4.72, ₦2.50, ₦469.97, ₦780.10, ₦347.71, ₦400.09, ₦1,585.49 and ₦4,593.06 respectively which means they were completely utilized by the programme. This further implies that an increase in the use of these resources by a unit will lead to increase in the gross margin of the farmers by their corresponding MVPs. On the other hand, all other resources in the plan were found to be surplus and were not limiting the achievement of the farmers' objective. Similarly, in risk efficient plan I, owned capital, borrowed capital, human labour for land preparation, fertilizer/agrochemical application, harvesting of crops, pen/pond preparation, cleaning, and feeding, lime and cockerel stock had MVP of ₦7.93, ₦2.36, ₦1,205.08, ₦1,000.02, ₦599.39, ₦780.18, ₦304.96, ₦500.07, ₦6,364.99 and ₦1,594.42 respectively. This implies that these resources were completely utilized by the programme and were therefore limiting the gross margin maximization goal of the smallholder farmers.

4.4.4.4 Gross margin in existing, optimum and risk efficient farm plans (pooled)

The estimated average gross margin in Naira in the smallholder farmers' existing plan and the gross margins obtained from the LP and T-MOTAD solutions for pooled enterprises are presented in Figure 4.15. In the existing plan, the gross margin was estimated to be ₦228,597.90. Looking at the results from the LP solutions for farm profit maximization objective, the average maximum obtainable gross margins were ₦582,711.40 and ₦516,863.10 in optimum plans I and II respectively. Given that the gross margin obtained in optimum plan II is lower than that obtained in plan I, this could be traced to the constraining (limited) resource condition of the farmers. Nevertheless, the result implies that there is an average increase of ₦354,113.50 in plan I and

₦288,265.20 in plan II representing 154.91% and 126.10% change respectively in the optimum plans over the farmers' existing plan. It is noteworthy that these gross margins and their corresponding increase over the existing plan are considerably higher than those obtained from those where only crop or fisheries or livestock enterprises were optimized. This suggests that these relatively higher optimum values could be attributed to the combination of crop, fishery and livestock enterprises in the programming. The implication of this is that, the smallholder farmers have the prospects to not only increase their gross margins, but double it even under the limited resource condition. This result is similar to those of Igwe (2012), Igwe *et al.* (2013) and Jacob (2019) who reported that the optimum gross margins of combined farm enterprises were relatively higher than the optimum values of those where only crop or livestock enterprises were evaluated in Nigeria.

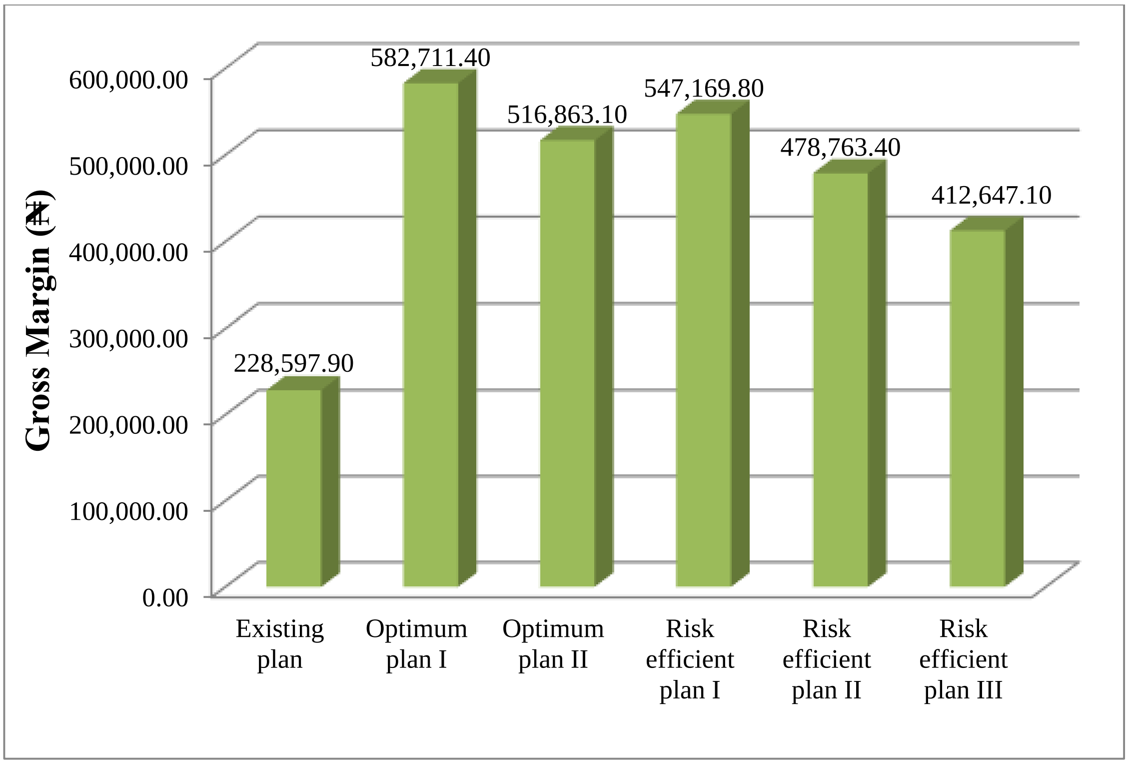


Figure 4.15: Gross margin in the existing, optimum and risk efficient pooled farm enterprise plans

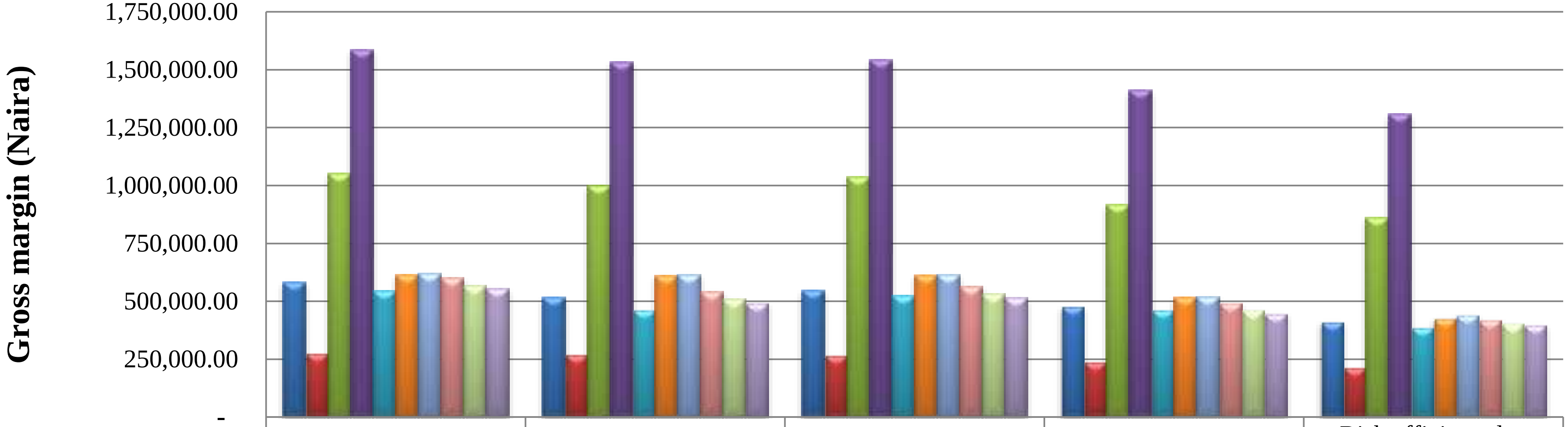
Source: Computed from Field Survey Data, 2019.

Similarly, the gross margins obtained from the T-MOTAD solutions for risk efficient plans were also relatively higher than that of the existing plan. The gross margin was ₦547,169.80 in plan I, ₦478,763.40 in plan II and ₦412,647.10 in plan III respectively. These shows that the gross margins in the risk efficient farm plans increased by ₦318,571.90 in plan I, ₦250,165.50 in plan II and ₦184,049.20 in plan III which represents a 139.36%, 109.43% and 80.51% proportionate increase respectively in these plans over the existing plan. Again, the differences in the gross margins obtained from the risk efficient plans I, II and III and those of the optimum plans I and II represents the risk premium the farmers have to pay for forgoing more risky optimum plans and adopting plans reflective of minimized risk. This finding is similar to those reported by Umoh (2008), Salimonu *et al.* (2008), Udo *et al.* (2015a) and Udo *et al.* (2015b) in various studies carried out on optimum enterprise combinations in Nigeria using the LP and T-MOTAD programming models.

The gross margins in all the optimized plans are higher than that of the existing plan. This further implies that an average smallholder farmer has the possibility to maximize gross margin in the area by adopting any of the risk minimized plans or gross margin maximizing optimum plans even under limited resource conditions.

4.4.4.5 Sensitivity analysis of gross margin for farm enterprise combinations

The results of the sensitivity analysis carried out to examine the effects of varying prices of output, capital and labour wage rates on the gross margins of the smallholder farmers is presented in Figure 4.16. When prices of output were varied at -50.00%, the results indicated that gross margin declined by an average of 49.93% in the deterministic gross margin maximization optimum plan. Similarly, gross margin also declined by an average of 49.56% in the risk efficient plans.



	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Previous value	582,711.40	516,863.10	547,169.80	478,763.40	412,647.10
Output price (-50%)	276,559.10	272,231.30	267,360.50	239,950.70	215,930.60
Output price (+50%)	1,052,525.00	999,031.80	1,038,047.00	917,566.40	860,405.70
Output price (+100%)	1,585,825.00	1,534,179.80	1,543,959.00	1,411,596.30	1,308,167.80
Capital (-50%)	544,106.70	463,253.90	524,817.60	463,336.00	388,430.90
Capital (+50%)	613,042.10	610,672.70	612,401.40	516,718.70	427,425.70
Capital (+100%)	620,442.40	613,856.70	614,938.90	518,662.00	442,055.80
Labour (-50%)	599,995.40	539,770.10	563,136.20	495,300.10	420,062.40
Labour (+50%)	567,636.60	508,896.80	531,423.80	463,587.70	406,231.60
Labour (+100%)	553,095.30	494,721.20	515,677.80	447,841.70	398,785.60

Figure 4.16: Sensitivity analysis of gross margin to variation in output price, capital and labour wage rate for pooled farm enterprises
Source: Computed from Field Survey Data, 2019.

For +50.00% variations, it was observed that gross margin increased by an average of 86.96% and 96.62% in the optimum and risk efficient plans respectively. Increases of 184.49% and 198.01% was recorded in the optimum and risk efficient plans respectively over the previously obtained gross margin when prices of output were doubled, that is, +100.00%. This implies that farm enterprise gross margins were highly sensitive to changes in the prices of output. These results are similar to what was reported by Jacob (2019) on the sensitivity of gross margins of farm enterprises to variation in prices of output in Niger State.

For the sensitivity analysis on amount of capital, variation at -50.00% revealed that gross margins decreased by 6.63%, 10.37%, 4.09%, 3.22% and 5.87% in optimum plans I and II and risk efficient plans I, II and III respectively. Whereas, when capital was varied by +50%, gross margins increased by 5.21%, 18.15%, 11.92%, 7.93%, and 3.58% in all the plans respectively. Similarly, 6.48%, 18.77%, 12.39%, 8.33%, and 7.13% proportionate increase in all the plans respectively were recorded when capital was varied by +100.00%. The implication of this is that, gross margin is also sensitive to variation in the amount of capital available to the smallholder farmers in the various farm enterprises. This finding corroborates those of Igwe (2012), Adewumi (2017) and Jacob (2019) who reported similar sensitivity of gross margin to variation in capital in studies carried on farm enterprise combinations in Nigeria.

The sensitivity analysis on changes in human labour wage rates indicated increases of 2.97% in optimum plan I, 4.43% in optimum plan II, 2.92% in risk efficient plan I, 3.45% in risk efficient plan II and 1.80% in risk efficient plan III when wage rates were reduced by 50.00%. Conversely, when the wage rate of labour was increased by +50.00%, it was observed that gross margins declined by 2.59%, 1.54%, 2.88%, 3.17% and 1.55% in optimum plans I and II and risk efficient plans I, II and III respectively.

Variation of wage rates by doubling it, that is, +100.00% resulted in a marginal decrease of 4.68% and 5.19% in the gross margins in the optimum and risk efficient plans respectively. These results are in agreement with the findings of Igwe (2012) and Jacob (2019) who found that optimal values are sensitive to changes in the labour wage rates in Abia and Niger States respectively.

It is also noteworthy that the increase/decrease in the value of the programme with variation in prices of output is significantly higher compared to increase/decrease with variation in the amount of capital and human labour wage rates. This implies that farm enterprise gross margin is more sensitive to changes in the prices of output than other variables in the study area.

4.5 Constraints Encountered in Farm Enterprises

This section presents the constraints encountered by the farmers in crop, livestock and fishery enterprises. The results were summarized and presented in Tables 4.16 to 4.18.

4.5.1 Arable crop farmers' production constraints in Kwara State

The results presented in Table 4.16 revealed that the Kendall's coefficient of concordance obtained in the analysis was 0.558 and significant at $p \leq 0.01$ probability level, suggesting that 55.80% of the smallholder farmers agreed on the outcome of the ranking of their production constraints. It shows the outcome of the mean ranking of the production constraints associated with arable crop production among the smallholder farmers in the study area. These constraints are economical, socio-cultural, institutional, environmental and infrastructures related constraints and demands urgent attention form the government and other relevant agencies.

From the results presented in Table 4.16 and in decreasing magnitude of importance, conflict with herdsmen ($\bar{X}$ = 11.89) ranked first among crop production constraints. The implication of this is that the most severe constraint faced by the crop farmers was conflicts with herdsmen. This is a very serious problem as it can affect both the life of the farmers and the optimum production of their crops. It could lead to farmers' inability to access their farms and thereby reduce farmers' crop yield and farm incomes. This result confirms the earlier findings of Adewumi (2017) and Sadiq *et al.* (2018) who both reported that conflict with herdsmen is a severe production constraint among crop farmers in Kwara State.

Table 4.16: Analysis of crop enterprise production constraints in Kwara State

Constraints	Mean Score	Rank
Conflict with herdsmen	11.89	1st
High cost of acquiring credit facilities	11.03	2nd
Poor access road and transport facilities	10.14	3rd
High cost of farm inputs	10.13	4th
Low and unattractive prices for farm produce	9.31	5th
Pilfering/theft	9.12	6th
Inadequate storage facilities	8.70	7th
Large post-harvest losses	8.35	8th
Inadequate market information	8.19	9th
Inadequate extension and farm advisory services	7.91	10th
Impoverished farmland	7.65	11th
Limited farmland	7.55	12th
High incidence of pests and diseases	7.18	13th
Weak/poor cooperative or farmers' association support	7.06	14th
Insufficient rainfall	5.99	15th
Flood problem	5.79	16th
Diagnostic Statistics		
Kendall's Coefficient of Concordance (W)	0.558	
Chi-Square	641.287***	

Source: Computed from Field Survey, 2019.

Next is the high cost of acquiring credit facilities ($\bar{X}$ = 11.03) which ranked second among the constraints. Credit facilities serve a great purpose of enabling farmers' access to required inputs towards optimum productivity and improved standard of living. High cost of acquiring credit could inhibit their productivity as well as their livelihood. This finding is similar to those of Pelomo (2016) and Jacob (2019) who reported high cost of credit facilities as a problem faced by farmers in Kogi and Niger States. It also lends credence to the findings of Phillip and Adetimirin (2001) who reported that inadequate amounts of loan, banks' requirements of collateral, and high rates of interest charged on loans by the banks among others are major constraints to accessing agricultural credit in Nigeria.

Poor access road and transport facilities ($\bar{X}$ = 10.14) was found to be the third most severe constraints faced by the smallholder crop farmers. This constraint is capable of hindering the smooth movement of farm produce to the market. The implication of this is that, farmers are not able to sell their produce in good time. This could reduce the quality of the farm produce and thereby negatively affect their market prices resulting in low farm income.

High cost of farm inputs ($\bar{X}$ = 10.13) was the fourth ranked constraint which poses a barrier to farmers' access to adequate resources required for improved crop productivity. In spite of several attempts by government to subsidize the prices of some of the farm inputs, these inputs do not reach the farmers as and when required. The available subsidized inputs rarely get to the practicing farmers thereby leaving them to battle with the limited resource condition. This result conforms to the findings of Jacob (2019) who also reported the problem of high cost of farm inputs in Niger State. The fifth ranked constraint was low and unattractive market prices ($\bar{X}$ = 9.31). This could limit the profit maximization objective of the farmers and could discourage them from intensifying production.

Pilfering/theft ($\bar{X}$ = 9.12) ranked sixth among the constraints encountered by the farmers. This constraint has the potential to reduce farmers' crop yield and farm incomes. This finding is similar to that of Sadiq *et al.* (2018) who reported that theft of farm produce is a challenge to farmers in Kwara State.

Inadequate storage facilities ($\bar{X}$ = 8.70) and large post-harvest losses ($\bar{X}$ = 8.35) were also among the highly ranked constraints in the area. Agricultural products are highly perishable and cannot be preserved for a long time. In the absence of adequate storage facilities, farmers could suffer post-harvest losses which will reduce their farm incomes. This finding is in line with the argument of Adewumi (2017) and Pelemo (2019) that inadequate storage facilities contribute to post-harvest farm losses and negatively affect the income and livelihood of farmers.

The farmers were faced with the problems of inadequate market information ($\bar{X}$ = 8.19) and extension and farm advisory services ($\bar{X}$ = 7.91). This implies that they no access to improved technologies and Research Institutes. This could be due to the fact that extension agents were not enough in terms of number and perhaps are not also well equipped with extension facilities that will foster appropriate dissemination of information and service delivery to the farmers. This lends credence to the arguments of Adewumi (2017) and Jacob (2019) that inadequate transfer of information to farmers by extension agents could hamper their awareness and knowledge of innovations in agriculture. Information and extension services in agriculture are indispensable avenues to assist farmers to improve methods and techniques of agricultural production and marketing of farm produce.

Other constraints faced by the smallholder crop farmers in the study area include impoverished farmland ($\bar{X}$ = 7.65) and limited farm land ($\bar{X}$ = 7.55). This means that fertile arable farmland is not readily available to the farmers in required size. This could be due to land tenure system, land use conflicts or land degradation among others. This is line with the earlier position of Andohol (2012) that inadequate farmland brought about land tenure system, insecurity, land dispute, land degradation and low agricultural productivity. Consequently, smallholder farmers' output will be drastically reduced due to low productivity upon fragmented lands. The farmers also had environmental problem of high incidence of pest and disease ($\bar{X}$ = 7.18). It is possible that the farmers are using seeds that are not pest and disease resistant. This problem poses great threat to crop yield and farmers' productivity in the study area.

Inadequate cooperative or farmers' association support ($\bar{X}$ = 7.06) was also identified as a constraint among the farmers. This could limit farmers access to adequate and timely information and innovations that will enhance their productivity, incomes and livelihood. It could also limit their access to credit facilities and other production inputs that will help them successfully implement optimum combination of farm enterprises under risk and uncertainty.

Insufficient rainfall ($\bar{X}$ = 5.99) and flood problem ($\bar{X}$ = 5.79) were the least ranked constraints respectively with relatively low mean values compared to other constraints. This implies that insufficient rainfall and flood are not severe constraints to the farmer in the area. However, it was obvious form the results presented that the smallholder crop farmers are faced with several challenges in the study area which require attention for improved and optimum production.

4.5.2 Livestock enterprises' production constraints

The perception of the smallholder livestock farmers on the production constraints they face was analysed using the that Kendall's coefficient of concordance. The constraints were ranked in a hierarchical order according to their severity and the result presented in Table 4.17. The result of the analysis shows that the significance of the estimated value of Kendall's coefficient of concordance (0.636) at $p \leq 0.01$ probability level indicates that there is a 63.60% concordance or agreement among the smallholder farmers with respect to the ranking of the constraints affecting livestock enterprises in the area.

The mean ranking shows that the farmers viewed high cost of acquiring credit facilities ($\bar{X}$ = 15.62) as the most severe production constraint they face in the area. Credit facilities are hardly available to smallholder farmers and where they are available there are lots of bottle-necks and constraints to accessing such. Many of the smallholder farmers involved in livestock enterprise production depends on other sources of finance for their farming activities. This result is in line with the findings of Baruwa (2013) and Ogah *et al.* (2014) who all identified difficult access to credit facilities as a limitation to livestock enterprise production in Nigeria.

Feed is essential for increased productivity of livestock enterprises. The farmers ranked high cost of feed ($\bar{X}$ = 13.22) as the second most severe constraints in the area. This implies that nutritious animal feeds are not readily available and easily affordable for the smallholder livestock farmers. Since farmers venture into animal production for profit, they need to obtain feed at a price will ensure they break-even as well as make significant profit. Many livestock and poultry farmers have resulted to compounding their own animal feeds but are also faced with the challenge very expensive or unavailable raw materials. This finding is similar to that of Bamaiyi (2013) in a study on factors militating against animal production in Nigeria.

Table 4.17: Analysis of livestock enterprise production constraints

Constraints	Mean Score	Rank
High cost of acquiring credit facilities	15.62	1st
High cost of feeds	13.22	2nd
High incidence of diseases	13.14	3rd
Poor/shortage of veterinary services	12.98	4th
Limited capital	12.83	5th
High cost of acquiring breed stock	12.77	6th
Inadequate processing storage facilities	12.15	7th
High cost of medications	11.86	8th
High mortality rate	11.80	9th
Low and unattractive prices for produce	10.97	10th
Difficulty in getting good quality breed	9.99	11th
Middlemen exploitation	9.98	12th
Inadequate market information	9.32	13th
Scarcity of fodder	8.59	14th
Limited livestock capacity space	8.30	15th
Weak/poor cooperative or farmers' association support	8.26	16th
Pilfering/theft	7.98	17th
Poor feed quality	7.78	18th
Inadequate access to quality water	6.81	19th
Inadequate extension and farm advisory services	5.64	20th
Diagnostic Statistics		
Kendall's Coefficient of Concordance (W)	0.636	
Chi-Square	255.620***	

Source: Computed from Field Survey, 2019.

High incidence of diseases ($\bar{X}$ = 13.14) is also a major constraint to the smallholder farmers as it was ranked third on the list. This is similar to the finding of Adesehinwa *et al.* (2004), Maass *et al.* (2012) and Jacob (2019) who all reported that high incidence of diseases poses a major challenge to livestock farmers. Bamaiyi (2013) also argued that livestock diseases remain a veritable threat which inhibits the productivity of the livestock production industry. The spread of diseases among livestock is capable of wiping out the whole stock and thereby limiting the attainment of optimum plan by the farmers.

Next to this is the poor/shortage of veterinary services constraint ($\bar{X}$ = 12.98) ranked fourth by the farmers. Veterinary services are needed by livestock producers in order to curtail infections and its spread of diseases among the animals..

Limited capital ($\bar{X}$ = 12.83) ranked sixth among the livestock farmers' production constraints. This implies that the smallholder farmers are not able to afford the required inputs and other facilities that they need for maximum productivity. Capital is one of the most essential resources of production known to man. It is highly required to make investment in farm business such as the livestock enterprises and to sustain its productivity. Capital is one of the major constraining factors to the growth of the livestock sector especially in developing economies like Nigeria. Financial inadequacies have led to the slow growth and the contribution of the sector to the nations GDP. Smallholder farmers who are characterized by low income earnings dominates the livestock industry and as such, they are not able to handle the huge financial investment demands of the industry towards optimum productivity. This result is in line with the findings of Bamaiyi (2013), Baruwa (2013), Ogah *et al.* (2014) and Jacob (2019) who all identified that financial limitations as a major setback to livestock enterprise production in Nigeria.

Mores so, high cost of acquiring breed stock ($\bar{X}$ = 12.77), inadequate processing and storage facilities ($\bar{X}$ = 12.15) were among the severe constraints faced by the smallholder livestock farmers as they were ranked sixth and seventh respectively. There is generally a lack of proper modern infrastructure required for processing and storage of farm produce such as the livestock produce in developing countries like Nigeria. This is a major setback for the livestock industry towards achieving optimum productivity especially among the smallholder farmers.

The farmers also claimed that high cost of medications ($\bar{X}$ = 11.86) and high mortality rate ($\bar{X}$ = 11.80) are among the major constraints to livestock production is the area. These are closely related to poor/shortage of veterinary services and their combination could cause a devastation havoc to the output of the smallholder farmers. These findings are in agreement with argument of Lawal-Adebowale (2012), Bamaiyi (2013) and Jacob (2019) who that the maintenance and sustenance of wellbeing of farm animals in terms of their health constitute a major challenge to efficient livestock production among Nigeria livestock producers.

Another severe constraint faced by the farmers is low and unattractive prices for produce ($\bar{X}$ = 10.97). This is capable of discouraging the farmers from intensifying production towards achieving their profit maximization objective as they don't get the appropriate value for their produce. This may not be unconnected to the exploitative activities of the middlemen in livestock enterprises in the area.

In hierarchical order, a further perusal of the result in Table 4.17 revealed that the other production constraints faced by the smallholder farmers with mild to low severity includes difficulty in getting good quality breed ($\bar{X}$ = 9.99), middlemen exploitation ($\bar{X}$ = 9.98), inadequate market information ($\bar{X}$ = 9.32), scarcity of fodder ($\bar{X}$ = 8.59), limited livestock capacity/space ($\bar{X}$ = 8.30), weak/poor cooperative/farmers' association support ($\bar{X}$ = 8.26), pilfering/theft ($\bar{X}$ = 7.98), poor feed quality ($\bar{X}$ = 7.78), inadequate access to quality water ($\bar{X}$ = 6.81) and inadequate extension and farm advisory services ($\bar{X}$ = 5.64). These results are in line those of Adesehinwa *et al.* (2004), Bamaiyi (2013) and Jacob (2019) for livestock farmers in Nigeria.

4.5.3 Constraints associated with fish farming

The result presented in Table 4.18 shows the smallholder fish farmers' constraints ranked in order of their perceived severity. It revealed that the Kendall's coefficient of concordance obtained in the analysis was 0.743 and significant at $p \leq 0.01$ probability level, suggesting that a majority of the fish farmers representing 74.30% agreed with the outcome of the ranking of their production constraints.

Limited capital ($\bar{X}$ = 17.13) ranked first as the most severe constraints faced by the fish farmers. Smallholder fish farmers usually did not have sufficient funds for investment in their fisheries enterprise. This implies that they rarely meet the requirement of operational expenditure in fish farming and cannot expand their production. This is similar to the findings of Ibeun *et al.* (2019) and Jacob (2019) who reported limited capital as a major constraint to fisheries enterprises in Kainji Lake Basin and Niger State respectively.

High cost of feeds ($\bar{X}$ = 16.88), low and unattractive prices for produce ($\bar{X}$ = 16.19), high cost of acquiring credit facilities ($\bar{X}$ = 15.78) and middlemen exploitation ($\bar{X}$ = 15.13) ranked second, third, fourth and fifth respectively among the farmers' constraints. The high cost of feeds has the potential to suppress the profit of the farmers as the cost incurred of fish feed usually account for more than 50% of the operating cost in fish farming as reported by Ibeun *et al.* (2018). High cost of acquiring credit facilities could also impede the farmers' increased productivity and profit maximization objective. This result is in line with the findings of Dambatta *et al.* (2016) for fisheries enterprises in Kano State. More so, low and unattractive prices for produce and middlemen exploitation which are marketing related altogether have the ability to reduce the smallholder fish farmers' return on investment.

Table 4.18: Analysis of fisheries enterprise production constraints

Constraints	Mean Score	Rank
Limited capital	17.13	1st
High cost of feeds	16.88	2nd
Low and unattractive prices for produce	16.19	3rd
High cost of acquiring credit facilities	15.78	4th
Middlemen exploitation	15.13	5th
Inadequate storage facilities	14.36	6th
Pilfering/theft	14.13	7th
Predators	13.68	8th
Inadequate market information	12.11	9th
Poor/shortage of veterinary services	10.86	10th
Inadequate cooperative or farmers' association support	9.81	11th
Inadequate extension and farm advisory services	9.73	12th
Market distance	9.52	13th
Flood problem	9.29	14th
High cost of acquiring fingerlings	9.28	15th
Difficulty in getting quality fingerlings	8.87	16th
High cost of medications	8.83	17th
Limited livestock capacity space	8.55	18th
High incidence of diseases	8.34	19th
High mortality rate	8.08	20th
Poor feed quality	7.26	21st
Inadequate access to quality water	5.47	22nd
Diagnostic Statistics		
Kendall's Coefficient of Concordance (W)	0.743	
Chi-Square	387.675***	

Source: Computed from Field Survey, 2019.

The farmers also decried pilfering/theft ($\bar{X}$ = 14.13) and predators ($\bar{X}$ = 13.68) as severe constraints to fisheries enterprises in the study area. This is a great threat to farmers achievement of optimum harvest and returns. This is in line with the findings of Akpabio and Inyang (2007) in Akwa Ibom State.

Market distance ($\bar{X}$ = 13.25), inadequate market information ($\bar{X}$ = 12.11), poor/shortage of veterinary services ($\bar{X}$ = 10.86), weak/poor cooperative or farmers' association support

($\bar{X}$ = 9.81) and inadequate extension and farm advisory services ($\bar{X}$ = 9.73) are institutional related challenges perceived by the farmers to severely affect fishery enterprises in Kwara State. Extension services are vital in disseminating information and introducing new innovations to farmers as argued by Adesehinwa *et al.* (2004) and Jacob (2019). Veterinary services are needed by fish producers in order to keep in check infections and mortality of the fish. Shortage of veterinary services could easily enhance the spread of diseases and infections which could reduce the productivity of the farmers significantly. Whereas, inadequate cooperative support among the farmers could significantly inhibit extension service delivery and access to information and current trends in agriculture towards improved production. Thus, for farmers to have sufficient access to knowledge such as the optimum combination of farm enterprises and market information, the aforementioned institutional variables must work.

Other constraints to fisheries enterprises in Kwara State decried by the farmers in order of importance are market distance, flood, high cost of acquiring fingerlings, difficulty in getting quality fingerlings, high cost of medications, limited space, high incidence of diseases, high mortality rate, poor feed quality and inadequate access to quality water. A critical assessment of these constraints and how they interplay and influence the fish farmers' production activities calls for concern. These constraints combined together if not alleviated are a great threat to the productivity and livelihood of the fish farmers in the study area.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study attempted to determine optimum combination of farm enterprises that will maximize the profit of the farmers under risk and limited resource conditions. Based on the findings of this study, it was concluded that all the farm enterprises considered were profitable in the study area. Howbeit, resources were not optimally allocated in the existing farm plans. The mixed farm enterprises were in better competitive positions than sole farm enterprises in the optimum and risk minimized plans. Both crop, livestock and fishery enterprises were included in the LP and T-MOTAD solutions prescribed for the smallholder farmers. The farm enterprise plans prescribed are optimum and efficient and suggested optimal combinations of enterprises, optimal gross margins, minimized risk and optimal utilization of farm resources under limited resource conditions. The study revealed that when risk is not included in subsistence farm models, farm income would be overestimated. Consequently, optimal combination of farm enterprises among smallholder farmers not only helps to increase farm incomes, but also to make efficient use of available resources.

A typical smallholder farmer in the study area has the potential to increase gross margins by reallocating resources on enterprises with higher returns as reflected in the optimum and risk efficient farm plans. The gross margins were sensitive to variations in prices of output, amount of capital available and labour wage rate. Limited capital, facilities, high cost of credit and farm inputs, low and unattractive prices for farm produce, weak/poor cooperative support among others were identified as the major constraints faced by the smallholder farmers in Kwara State.

5.2 Recommendations

On the basis of the results of this study, the following recommendations were made:

i. Smallholder farmers in Kwara State should take advantage of the outcome of this study by reallocating their farm resources to include high value enterprises in the prescribed plans, that is, undertake the various farm enterprise mixtures that fit into the optimum and risk efficient plans. This would help them to achieve food security, increased farm incomes, reduced cost of production and risk minimization. In essence, the optimum and risk efficient plans should be incorporated in to extension education content of the Kwara State ADP.

ii. Given that farm incomes would be overestimated when risk is not included in subsistence farm models, it is therefore contingent to integrate risk into modelling farm plans for smallholder farmers in tropical agriculture. Researchers in academic institutions and agricultural extension workers in the state should work in synergy to achieve this.

iii. Farmers should ensure they reallocate those resources identified as surplus in the existing plan such as seed, tractor/power tiller hours, agrochemicals and fertilizer to optimal enterprises that will generate additional incomes and minimize risk.

iv. Government in collaboration with security agencies and community leaders should make efforts to curb farmer-herder conflicts and pilfering/theft on the farm.

v. Given that prices of products played critical roles as shown in the sensitivity analysis, government through its agencies such as the Ministry of Agriculture should work at stabilizing prices or reducing price volatility for agricultural produce through the market-led price stabilization mechanisms such as commodity exchanges, negotiated off-take agreements, extended farm-gate price under value chains coordination mechanisms and agricultural insurance among others as given in the Federal Government's Agriculture Promotion Policy (2016 – 2020).

vi. The optimum plans are suggestive of commercialization drive especially with cash crops such as rice, yam and maize which are part of the priority crops in the Nigerian Agriculture Promotion Policy. Farmers should be encouraged by extension service support to include these crops in their farm plan.

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APPENDIX A

RESEARCH QUESTIONNAIRE FOR ARABLE CROP FARMERS

Dear Respondent,

I ADEWUMI, Adeoluwa am a postgraduate (PhD) student of the above named institution with registration number PhD/SAAT/2017/933. I am currently carrying out an academic research on the topic **'*Analysis of farm enterprise combinations under risk conditions among smallholder farmers in Kwara State, Nigeria.*'**

This questionnaire is to help me collect vital data on the topic. I hereby solicit your kind cooperation to fill in the questionnaire and tick where appropriate. All information shall be treated with strict confidentiality and used for this research only.

Thank you for your anticipated cooperation.

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

1. Name of Town/Village...
2. Local Government Area...
3. Sex: A. Male ( ) B. Female ( )
4. Age ....(years)
5. Education: A. No formal education ( ) B. Quranic education ( ) C. Primary education ( ) D. Adult education ( ) E. Secondary education ( ) F. Tertiary education ( )
6. How many years did you spent in schooling?..................................
7. Marital status: A. Single ( ) B. Married ( ) C. Divorced ( ) D. Widowed ( )
8. How many children and dependants are living with you?
   i. Under 8 years of age: Male.............. Female.................
   ii. Between 8 and 15 years of age: Male.............. Female.................
   iii. Over 15 years of age: Male.............. Female.................
9. How many wives do you have? ....
10. Major occupation: A. Farming ( ) B. Trading ( ) C. Civil servant ( ) D. Others (specify)...
11. If you undertake other occupations, how much do you earn from this off-farm occupation/activity per month? ₦……............................
12. What is your source of capital? A. Personal Savings ( ) B. Friends and relatives ( ) C. Commercial banks ( ) D. Cooperative society ( ) E. Money lenders ( ) F. Others (specify)..
13. Do you belong to any farmers' association/cooperative? A. Yes ( ) B. No ( )
14. Did you have access to agricultural credit in the last cropping season? A. Yes ( ) B. No ( )
15. If yes, how much did you received for the last cropping season ₦ ....……
16. At what interest rate did you obtain the credit? ……….%
17. Do you have access to extension services? A. Yes ( ) B. No ( )
18. If yes, how many times were visited in the last cropping season? ……….

SECTION B: FARMING INFORMATION

19. For how long have you been into crop farming? .... (years)
20. How many plots of land do you have? ....
21. What is the size of your farmland? ....(hectares)

22. Do you own land that was not cultivated in last cropping season? A. Yes (   ) B. No (   )
23. If yes, what is the size of this uncultivated land you own in hectares? ....(hectares)
24. How did you acquire the land you use for farming? A. Purchase (   ) B. Inheritance (   ) C. Rent (   ) D. Borrowing (   ) E. Pledge (   ) Others (specify).......................................
25. If rented, how much did you pay as rent during the last cropping season? ₦……......................…
19. Do you practice sole or mixed cropping? A. Sole cropping (   ) B. Mixed cropping (   )
20. Please indicate the crops you grow and the farm size cultivated for each in the last cropping season:

Sole crops	**Land allocated (ha)**	**Mixed crops**	**Land allocated (ha)**

21. Please fill in as appropriate the detail of labour used during the last cropping season.
Name of sole crop 1..

Operation/Activity	**Family Labour**			**Hired Labour**			
	No. of people	**No. of days used**	**No. of hours per day**	**No. of people**	**No. of days used**	**No. of hours per day**	**Total Amount Paid (₦)**
Land preparation							
Ridge/mound making							
Planting							
First weeding							
Second weeding							
Third weeding							
Fertilizer application							
Staking (for yam)							
Harvesting							
Winnowing							
Others...........................							

Name of sole crop 2..

Operation/Activity	**Family Labour**	**Hired Labour**

	No. of people	No. of days used	No. of hours per day	No. of people	No. of days used	No. of hours per day	Total Amount Paid (₦)
Land preparation							
Ridge/mound making							
Planting							
First weeding							
Second weeding							
Third weeding							
Fertilizer application							
Staking (for yam)							
Harvesting							
Winnowing							
Others............................							

Name of mixed crops 1...

Operation/Activity	**Family Labour**			**Hired Labour**			
	No. of people	**No. of days used**	**No. of hours per day**	**No. of people**	**No. of days used**	**No. of hours per day**	**Total Amount Paid (₦)**
Land preparation							
Ridge/mound making							
Planting							
First weeding							
Second weeding							
Third weeding							
Fertilizer application							
Staking (for yam)							
Harvesting							
Winnowing							
Others............................							

Name of mixed crops 2...

Operation/Activity	**Family Labour**			**Hired Labour**			
	No. of people	**No. of days used**	**No. of hours per day**	**No. of people**	**No. of days used**	**No. of hours per day**	**Total Amount Paid (₦)**
Land preparation							
Ridge/mound making							
Planting							
First weeding							
Second weeding							
Third weeding							
Fertilizer application							
Staking (for yam)							

Harvesting							
Winnowing							
Others............................							

22. How many people actively participate in farming activities in your household?
    Adult male............ Adult female............... Children...............
23. How many days in a week do you use for farm work in your household? ....
24. For how many hours do you normally work on your farm in a day? ....
25. How much do you pay the following category of people for a day job in your farm when hired?
    Adult male (₦).............. Adult female (₦).............. Children (₦)..............
26. Do you own or hire tractor? A. Own ( ) B. Hire ( ) C. None of the above ( )
27. Please give the detail of your expenses on tractor hiring/maintenance in the last cropping season?

Farm operations	**Sole cropping**			**Mixed cropping**		
	No. of days used	**No of hours used per day**	**Total cost incurred (₦)**	**No. of days used**	**No of hours used per day**	**Total cost incurred (₦)**
Ploughing & Harrowing						
Ridging						

28. Please provide information on the following farm inputs you bought and used during the last cropping season?

Farm inputs	**Sole cropping**			**Mixed cropping**		
	Quantity bought	**Cost per unit (₦)**	**Total amount (₦)**	**Quantity bought**	**Cost per unit (₦)**	**Total amount (₦)**
Herbicide (litre)						
Insecticide (litre)						
Fertilizer (kg)						
Manure (kg)						
Cassava stem (bundles)						
Yam sett						
Seeds (kg)						

	Sole cropping	**Mixed cropping**	

Farm tools/implements	Number bought	Cost per unit (₦)	Total amount (₦)	Number bought	Cost per unit (₦)	Total amount (₦)	Life span (years)
Hoe							
Cutlass							
Knife							
Sickle							
File							
Axe							
Basket							
Sprayer							
Wheelbarrow							
Tractor drawn plough							
Ridger							
Harrow							
Farm boot							

29. How much did you spend on the following activities in the last cropping season?

Activity	**Total amount spent (₦)**
Transportation	
Processing	
Storage	

30. What is the estimated food required by your family for consumption per month? Please provide the information in the following table:

Food crop item	**Quantity required/consumed from your farm (mudus/tubers per month)**
Rice	
Maize	
Sorghum	
Millet	
Cowpea/beans	
Soybean	
Melon	
Groundnut	
Cassava	
Others..........................	

31. What is the total output, quantity sold and cash income realized from the sale of the crop(s) you produced? Please specify the number of kg in a bag. ....kg/bag.

Name of crop(s)	**Total crop output (kg/bags/tubers/pick-up)**	**Quantity of output sold (kg/bags/tubers/pick-up)**	**Price per kg/bag/tuber /pick-up (₦)**	**Total income from sales of**

				your crop (₦)
Sole crops				
Mixed crops				

32. Please provide the information on your cost and income in the last four (4) production seasons.

Name of crop(s)	2015		2016		2017		2018	
	Cost	Income	Cost	Income	Cost	Income	Cost	Income
Sole crops								
Mixed crops								

33. Please tick where appropriate the problems you do face in your crop production activities.

Problems	Very severe	Severe	Undecided	Not severe	Not a constraint
Limited farm land					
Impoverished farm land					
Poor road access and transport facilities					
High cost of acquiring credit facilities					
High cost of farm inputs					
Inadequate market information					
Low and unattractive prices for farm produce					
Insufficient rainfall					
High incidence of pests and diseases					
Inadequate storage facilities					
Large post-harvest losses					
Flood problem					
Inadequate extension and farm advisory services					
Weak co-operative or farm association support					
Pilfering/theft					
Conflict with Fulani herdsmen					

APPENDIX B

RESEARCH QUESTIONNAIRE FOR LIVESTOCK FARMERS

Dear Respondent,

I ADEWUMI, Adeoluwa am a postgraduate (PhD) student of the above named institution with registration number PhD/SAAT/2017/933. I am currently carrying out an academic research on the topic ***'Analysis of farm enterprise combinations under risk conditions among smallholder farmers in Kwara State, Nigeria.'***

This questionnaire is to help me collect vital data on the topic. I hereby solicit your kind cooperation to fill in the questionnaire and tick where appropriate. All information shall be treated with strict confidentiality and used for this research only.

Thank you for your anticipated cooperation.

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

1. Name of Town/Village..
2. Local Government Area..
3. Sex: A. Male ( ) B. Female ( )
4. Age ....(years)
5. Education: A. No formal education ( ) B. Quranic education ( ) C. Primary education ( ) D. Adult education ( ) E. Secondary education ( ) F. Tertiary education ( )
6. How many years did you spent in schooling?..................................
7. Marital status: A. Single ( ) B. Married ( ) C. Divorced ( ) D. Widowed ( )
8. How many children and dependants are living with you?
   i. Under 8 years of age: Male.............. Female.................
   ii. Between 8 and 15 years of age: Male.............. Female.................
   iii. Over 15 years of age: Male.............. Female.................
9. How many wives do you have? ....
10. Major occupation: A. Farming ( ) B. Trading ( ) C. Civil servant ( ) D. Others (specify)..
11. If you undertake other occupations, how much do you earn from this off-farm occupation/activity per month? ₦……............................
12. Do you belong to any farmers' association/cooperative? A. Yes ( ) B. No ( )
13. What is your source of capital? A. Personal Savings ( ) B. Friends and relatives ( ) C. Commercial banks ( ) D. Cooperative society ( ) E. Money lenders ( ) F. Others (specify)...
14. Did you have access to agricultural credit in the last production year? A. Yes ( ) B. No ( )
15. If yes, how much did you received for the last production year? ₦ ....……
16. At what interest rate did you obtain the credit? ……….%
17. Do you have access to extension services? A. Yes ( ) B. No ( )
18. If yes, how many times were visited in the last production year? ……….

SECTION B: FARMING INFORMATION

19. For how long have you been into livestock (ruminant/poultry) farming? .... (years)

20. What is the size of your farmland? ....(hectares)
21. How did you acquire the land you use for farming? A. Purchase ( ) B. Inheritance ( ) C. Rent ( ) D. Borrowing ( ) E. Pledge ( ) F. Others (specify)..
22. If rented, how much did you pay as rent during the last production year? ₦……........................…
23. What system of management do you practice? A. Intensive ( ) B. Semi-intensive ( ) C. Extensive ( )
24. What is your livestock capacity? Please indicate below.

Ruminant/Monogastric animals	**Installed capacity (number)**	**Actual capacity (number)**	**Poultry birds**	**Installed capacity (number)**	**Actual capacity (number)**
Cattle			Broiler		
Goat			Layer		
Sheep			Cockerel		
Pig			Turkey		
Rabbit			Quail		
Others..........................			Duck		
			Goose		
			Guinea fowl		
			Others..........		

25. Please fill in as appropriate the detail of labour used during the last production year.

Operation/Activity	**Family Labour**			**Hired Labour**			
	No. of people	**No. of days used**	**No. of hours per day**	**No. of people**	**No. of days used**	**No. of hours per day**	**Total Amount Paid (₦)**
Feeding/watering							
Cleaning							
Medication/vaccination							
Feed milling/compounding							
Harvesting (poultry eggs)							
Grazing (ruminant animals)							
Others............................							

26. Please fill in as appropriate the detail of inputs used during the last production year.

Fixed inputs	**Year of purchase**	**Expected life span**	**Price per unit (₦)**	**Quantity**	**Amount (₦)**

		(number of years)			
House					
Feeders					
Drinkers					
Boots					
Buckets					
Rent payment					
Drum					

Variable inputs	**Price per unit (₦)**	**Quantity**	**Total Amount (₦)**
Breed stock			
Feeds(kg)			
Cost of supplements			
Veterinary services			
Vaccines & medication			
Water			
Wages of workers			
Cost of repairs			
Fence			
Cost of transportation			
Commission & tax			

27. Please fill in as appropriate the detail of produce/harvest during the last production year

Type of livestock product	**Quantity consumed (number)**	**Quantity given out as gift (number)**	**Quantity sold (number)**	**Price per unit (₦)**
Cattle				
Goat				
Sheep				
Pig				
Rabbit				
Broiler				
Spent Layer				
Crates of eggs				
Cockerel				
Turkey				
Quail				
Duck				
Goose				
Guinea fowl				
Manure (bag)				
Others...............................				
....				
....				
....				
....				
....				

28. Please provide the information on your cost and income in the last four (4) production years.

Type of livestock product	**2015**		**2016**		**2017**		**2018**	
	Cost	**Income**	**Cost**	**Income**	**Cost**	**Income**	**Cost**	**Income**
Cattle								
Goat								
Sheep								
Pig								
Rabbit								
Broiler								
Layer/eggs								
Cockerel								
Turkey								
Quail								
Duck								
Goose								
Guinea fowl								

29. Please tick where appropriate the problems you do face in your livestock production activities.

Problems	**Very severe**	**Severe**	**Undecided**	**Not severe**	**Not a constraint**
Limited livestock capacity (space)					
Limited capital					
High cost of acquiring credit facilities					
High cost of acquiring breed stock					
High cost of feeds					
High cost of medications					
Difficulty in getting good quality breed					
Poor feed quality					
Scarcity of fodder					
Inadequate access to quality water					
Inadequate market information					
Low and unattractive prices for produce					
Middlemen exploitation					
Inadequate processing/storage facilities					
High incidence of diseases					
High mortality rate					
Poor/shortage of veterinary services					
Inadequate extension and farm advisory services					
Weak co-operative or farmer association support					

Pilfering/theft					

APPENDIX C

RESEARCH QUESTIONNAIRE FOR FISHERY FARMERS

Dear Respondent,

I ADEWUMI, Adeoluwa am a postgraduate (PhD) student of the above named institution with registration number PhD/SAAT/2017/933. I am currently carrying out an academic research on the topic '***Analysis of farm enterprise combinations under risk conditions among smallholder farmers in Kwara State, Nigeria.'***

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Thank you for your anticipated cooperation.

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

1. Name of Town/Village..
2. Local Government Area..
3. Sex: A. Male ( ) B. Female ( )
4. Age ....(years)
5. Education: A. No formal education ( ) B. Quranic education ( ) C. Primary education ( ) D. Adult education ( ) E. Secondary education ( ) F. Tertiary education ( )
6. How many years did you spent in schooling?..................................
7. Marital status: A. Single ( ) B. Married ( ) C. Divorced ( ) D. Widowed ( )
8. How many children and dependants are living with you?
   i. Under 8 years of age: Male............... Female..................
   ii. Between 8 and 15 years of age: Male............... Female..................
   iii. Over 15 years of age: Male............... Female..................
9. How many wives do you have? ....
10. Major occupation: A. Farming ( ) B. Trading ( ) C. Civil servant ( ) D. Others (specify)..
11. If you undertake other occupations, how much do you earn from this off-farm occupation/activity per month? ₦……..............................
12. Do you belong to any farmers' association/cooperative? A. Yes ( ) B. No ( )
13. What is your source of capital? A. Personal Savings ( ) B. Friends and relatives ( ) C. Commercial banks ( ) D. Cooperative society ( ) E. Money lenders ( ) F. Others (specify)...
14. Did you have access to agricultural credit in the last production cycle? A. Yes ( ) B. No ( )
15. If yes, how much did you received for the last production cycle? ₦ ....……
16. At what interest rate did you obtain the credit? ……….%
17. Do you have access to extension services? A. Yes ( ) B. No ( )

18. If yes, how many times were visited in the last production cycle? ……….

SECTION B: FARMING INFORMATION

19. For how long have you been into fish farming? .... (years)
20. How many ponds do you have?.............................
21. What is the size of your pond(s)? Pond 1 ....(m^2) Pond 2 ....(m^2) Pond 3 ....(m^2) Pond 4 ....(m^2) Pond 5 ....(m^2) Pond 6 ....(m^2) Pond 7 ....(m^2) Pond 8 ....(m^2) Pond 9 ....(m^2) Pond 10 ....(m^2)
22. What type of pond do you use? A. Earthen ( ) B. Concrete ( ) C. Plastic container ( ) D. Earthen/Concrete ( ) E. Earthen/Plastic ( ) F. Concrete/Plastic ( ) G. Earthen/Concrete/Plastic ( )
23. How did you acquire the land/pond you use for fish farming? A. Purchase ( ) B. Inheritance ( ) C. Rent ( ) D. Borrowing ( ) E. Pledge ( ) F. Others (specify).......................................
24. If rented, how much did you pay as rent during the last production cycle? ₦……….......................…
25. What is the stock capacity of your pond(s)?

Ponds	**Installed stock capacity (number of fish)**	**Actual stock capacity (number of fish)**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

26. What is your source of water? A. River ( ) B. Well ( ) C. Bore-hole ( )
27. Please fill in as appropriate the detail of labour used during the last production cycle.

Operation/Activity	**Family Labour**			**Hired Labour**			
	No. of people	**No. of days used**	**No. of hours per day**	**No. of people**	**No. of days used**	**No. of hours per day**	**Total Amount Paid (₦)**
Pond preparation							
Pond stocking (fingerling supply)							
Medication							
Lime application							
Fertilizer application							
Feeding							
Water supply/application							
Feed milling/compounding							
Harvesting							

Others..................................							

28. Please provide the necessary information in the following table:

Input	**Quantity**	**Unit price**	**Amount spent (₦)**
Fingerlings			
Feed			
Drugs/chemicals			
Lime			
Transportation			
Pond construction			
Water			
Repairs or cleaning the pond			
Generator			
Fuel			
Pumping machine			

29. How much did you spend on the following activities in the last production cycle?

Activity	**Total amount spent (₦)**
Processing	
Storage	

30. Please fill in as appropriate the detail of your fish harvest during the last production cycle

Enterprise	**Quantity harvested (number)**	**Quantity consumed (number)**	**Quantity given out as gift (number)**	**Quantity sold (number)**	**Price per unit (₦)**
Catfish					
Fingerlings					

31. Please provide the information on your cost and income in the last four (4) production years/cycles.

Enterprise	**2015**		**2016**		**2017**		**2018**	
	Cost	**Income**	**Cost**	**Income**	**Cost**	**Income**	**Cost**	**Income**
Catfish								
Fingerlings								

32. Please tick where appropriate the problems you do face in your fishery production activities.

Problems	**Very severe**	**Severe**	**Undecided**	**Not severe**	**Not a constraint**
Limited pond capacity					
Limited capital					
High cost of acquiring credit facilities					
High cost of acquiring fingerlings					
High cost of feeds					
High cost of medications					
Difficulty in getting quality fingerlings					
Poor feed quality					
Inadequate access to quality water					
Inadequate market information					
Low and unattractive prices for produce					
Market distance					
Middlemen exploitation					
Inadequate storage facilities					
High incidence of diseases					
High mortality rate					
Flood problem					
Poor/shortage of veterinary services					
Inadequate extension and farm advisory services					
Weak co-operative or farmers association support					
Pilfering/theft					
Predators					

APPENDIX D

Results of Farm enterprise combinations for Kaiama Agricultural Zone

Crop enterprises:

Table 1: Existing, normative optimum and risk efficient cropping plans

Crop enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Maize	0.85	-	-	-	-	-
Melon	0.70	-	-	1.00	1.00	1.00
Millet	0.80	-	-	-	-	-
Sorghum	1.87	-	-	-	-	-
Soybean	0.82	-	-	-	-	-
Yam	1.03	-	-	-	-	0.47
Maize/Cowpea	1.61	0.75	0.75	-	-	0.43
Maize/Groundnut	0.78	-	-	-	-	-
Maize/Melon	0.60	-	-	-	-	-
Maize/Sorghum	1.37	-	-	-	-	-
Maize/Soybean	2.04	0.64	-	-	-	-
Maize/Yam	1.44	0.40	0.61	0.52	0.56	-
Melon/Millet	0.50	-	-	-	-	-
Sorghum/Groundnut	1.05	-	-	-	-	-
Sorghum/Soybean	0.87	0.70	0.95	0.64	0.97	0.65
Sorghum/Yam	1.23	-	-	-	-	-
Maize/Sorghum/Soybean	1.30	-	-	0.40	0.04	-

Table 2: Marginal opportunity cost of excluded cropping enterprises

Excluded cropping enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Maize	83,718.91	86,238.82	114,691.80	114,691.80	88279.87
Melon	-	104,739.80	-	-	-
Millet	27,438.62	-	115,003.60	86,527.63	94540.92
Sorghum	33,683.86	64,334.07	67,113.13	67,113.19	39033.50
Soybean	63,782.70	69,323.72	83,358.71	83,358.77	52792.41
Yam	21,232.04	22,888.51	64,694.07	64,694.07	-
Maize/Cowpea	-	-	-	2,970.19	-
Maize/Groundnut	95,450.33	-	118,540.10	80,547.80	109122.80
Maize/Melon	71,136.61	113,005.30	67,855.44	67,855.38	69510.73
Maize/Sorghum	54,389.05	80,651.97	84,877.93	84,877.94	60578.06
Maize/Soybean	-	10,463.36	8,363.32	8,363.32	704.65
Maize/Yam	-	-	-	-	51890.30
Melon/Millet	-	20,784.22	67,641.80	-	75894.27
Sorghum/Groundnut	134,669.60	104,309.40	158,523.20	-	146923.60
Sorghum/Yam	43,749.21	25,665.86	34,603.13	34,603.11	111230.80
Maize/Sorghum/Soybean	79,134.63	107,208.10	-	-	193478.60

Table 3: Marginal value product of resources under cropping enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	0	0.0795	19138.25	0	23672.67	0	23672.79	0	29730.44	0
Owned capital	0	0	0	0	0	0	0	0	0	0
Borrowed capital	11.4555	0			12	0	12	0	12	0
HL for land preparation	2000	0	2000	0	2000	0	2000	0	2000	0
HL for planting	1000.001	0	1000	0	999.9998	0	1000	0	1000	0
HL for weeding	176.3192	0	209.9327	0	0	80.7426	0	83.6751	0	36.5355
HL for fertilizer application	999.9998	0	0	0.4674	1000.016	0	999.9988	0	0	1.7749
HL for harvesting	1200	0	1200.001	0	1200	0	1200.001	0	1200	0
Seed	0	844.524	0	534.8546	0	683.8815	0	633.5737	0	765.2499
Fertilizer	0	98.399	0	112.48	0	113.6103	0	108.6919	0	136.1
Agrochemical	1200.004	0	0	0.1452	1199.998	0	1200.001	0	1200	0
Tractor/power tiller	0	0.4399	0	2.0188	0	1.6112	0	1.518	0	0.492

HL = Human labour

Table 4: Gross margin in the existing, optimum and risk efficient cropping plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦/ha)	216,940.81	418,749.20	409,911.60	339,804.20	365,735.80	358,067.00

Livestock enterprises:

Table 5: Existing, normative optimum and risk efficient livestock plans

Livestock enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cattle	1.4300	-	-	-	-	-
Goat	1.2300	-	-	-	-	-
Sheep	0.9700	-	-	-	-	-
Cattle/Goat	0.8900	-	-	-	-	-
Cattle/Sheep	1.2500	-	-	-	-	-
Goat/Sheep	1.0800	-	-	-	0.1854	-
Cattle/Goat/Sheep	1.1700	0.1066	0.1083	0.3510	0.1805	0.4399
Broiler	1.3200	0.2999	0.3010	-	-	-
Layer	0.9300	-	-	-	-	-
Cockerel	1.0800	0.0006	0.0010	0.4755	0.2256	0.3985
Layer/Cockerel	1.3200	-	-	-	-	-
Broiler/Cockerel	0.8000	-	-	-	-	-
Broiler/Layer	1.4400	0.7203	0.7177	0.3206	0.8886	0.1796
Broiler/Layer/Cockerel	1.3000	-	-	-	-	-

Table 6: Marginal opportunity cost of excluded livestock enterprises

Excluded livestock enterprises	Marginal opportunity cost (₦/TLU)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cattle	18,959.82	4,572.84	59,860.59	59,114.64	60,987.83
Goat	131,698.40	134,491.60	142,201.90	85,663.37	117,374.40
Sheep	73,069.11	69,084.19	44,336.01	272,505.30	34,281.90
Cattle/Goat	57,759.56	48,938.02	49,562.91	39,404.68	23,432.13
Cattle/Sheep	66,869.74	68,796.95	48,884.78	201,291.80	44,974.48
Goat/Sheep	52,036.11	59,975.60	57,931.62	-	45,136.83
Broiler	-	-	31,972.25	148,083.60	75,983.14
Layer	20,586.78	3,212.88	24,294.52	29,266.53	67,835.44
Layer/Cockerel	41,806.46	30,517.36	14,839.38	188,783.80	31,330.87
Broiler/Cockerel	44,255.18	28,813.76	52,977.34	216,627.80	81,252.71
Broiler/Layer/Cockerel	124,674.60	125,234.20	104,207.80	224,150.60	103,689.90

Table 7: Gross margin in the existing, optimum and risk efficient livestock plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross margin (₦/TLU)	218,813.43	239,285.90	235,262.10	229,700.50	255,561.60	233,235.60

Table 8: Marginal value product of resources under livestock enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Livestock capacity size	0	25.2926	0	205.292	0	205.273	0	204.9399	0	205.402
HL for pen preparation	999.9828	0	999.9713	0	999.9739	0	1000.001	0	1000	0
HL for cleaning	500.0332	0	500.0638	0	500.0101	0	500.0047	0	0	0.0074
HL for feeding	0	2.1105	0	2.0856	750.0022	0	0	3.6145	750.0002	0
HL for sorting	500.0104	0	499.8308	0	499.8767	0	499.9969	0	0	0.3797
HL for harvesting	999.999	0	999.998	0	1000	0	1000.004	0	0	0.8098
Owned capital	1	0	1	0	1	0	1	0	0	1342.548
Borrowed capital	2.1	0			0	1413.423	2.1	0	0	2757.277
Feed	350	0	350	0	350	0	349.9999	0	9.2655	0
Breed stock (cattle)	0	1.1434	0	1.1417	0	0.899	0	1.0695	0	0.8101
Breed stock (goat)	0	8.0368	0	8.0335	0	7.548	0	6.4059	0	7.3702
Breed stock (sheep)	0	6.0736	0	6.067	0	5.096	0	5.2218	0	4.7404
Breed stock (broiler)	4.4509	0	245.1219	0	0	50.0749	0	24.5149	0	56.4171
Breed stock (layer)	0	25.8537	0	25.9937	0	47.4399	0	16.7679	0	55.0505
Breed stock (cockerel)	0	60.4228	0	60.3689	0	1.0644	0	32.2959	0	10.6917

Combined farm enterprises:

Table 9: Existing, normative optimum and risk efficient farm plans

Farm enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Maize	0.85	-	-	-	-	-
Melon	0.70	-	-	-	-	-
Millet	0.80	-	-	-	-	-
Sorghum	1.87	-	-	-	-	-
Soybean	0.82	-	-	-	-	-
Yam	1.03	-	-	-	-	-
Maize/Cowpea	1.61	-	-	-	0.14	0.84
Maize/Groundnut	0.78	-	-	-	-	-
Maize/Melon	0.60	-	-	-	-	-
Maize/Sorghum	1.37	-	-	-	-	-
Maize/Soybean	2.04	-	-	-	-	0.21
Maize/Yam	1.44	0.33	0.33	0.33	0.73	-
Melon/Millet	0.50	-	-	-	-	-
Sorghum/Groundnut	1.05	-	-	-	-	-
Sorghum/Soybean	0.87	-	-	-	0.35	0.26
Sorghum/Yam	1.23	0.30	0.23	0.38	-	-
Maize/Sorghum/Soybean	1.30	1.00	1.00	1.00	0.69	0.43
Catfish	0.78	0.15	0.15	0.15	0.15	-
Broiler	1.43	-	-	0.44	0.35	-
Layer	1.23	-	-	-	-	-
Cockerel	0.97	0.76	0.41	0.6	0.71	1.35
Layer/Cockerel	0.89	-	-	-	-	-
Broiler/Cockerel	1.25	-	-	-	-	-
broiler/layer	1.08	-	-	-	-	-
Broiler/Layer/Cockerel	1.17	-	-	-	-	-
Cattle	1.32	0.54	0.38	-	-	-
Goat	0.93	-	-	-	-	-
Sheep	1.08	-	-	-	-	-
Cattle/Goat	1.32	-	-	-	-	-
Cattle/Sheep	0.80	-	-	-	-	-
Goat/Sheep	1.44	-	-	-	0.10	0.31
Cattle/Goat/Sheep	1.30	0.41	0.49	0.08	-	-

Table 10: Gross margin in the existing, optimum and risk efficient farm plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦)	259,869.97	525,611.30	439,819.60	406,553.10	398,170.90	432,007.10

Table 11: Marginal opportunity cost of excluded farm enterprises

Excluded farm enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Maize	154,376.30	158,343.40	157,201.10	142,917.30	140,194.30
Melon	90,841.67	84,866.23	86,586.84	73,448.24	83,150.61
Millet	227,170.00	229,373.10	228,738.80	225,369.70	247,545.20
Sorghum	40,765.66	45,735.32	44,304.35	43,389.95	54,214.48
Soybean	80,003.74	80,298.67	80,213.63	72,414.09	95,886.37
Yam	414,144.40	424,175.30	421,287.00	429,298.20	471,735.30
Maize/Cowpea	89,109.70	92,955.80	91,808.30	-	-
Maize/Groundnut	191,422.20	191,361.70	191,001.70	99,629.84	53,563.00
Maize/Melon	271,978.70	204,089.20	203,758.00	170,549.80	178,888.00
Maize/Sorghum	163,069.00	171,351.70	168,966.80	132,781.10	84,381.62
Maize/Soybean	143,482.30	149,145.50	147,514.80	94,093.31	-
Maize/Yam	-	-	-	-	32,307.44
Melon/Millet	264,200.00	181,026.80	181,957.60	187,782.30	279,436.90
Sorghum/Groundnut	1,282.93	187,268.50	6,825.80	97,498.80	52,417.33
Sorghum/Soybean	21,263.53	10,253.05	13,423.42	-	-
Sorghum/Yam	-	-	-	64,319.64	221,438.30
Catfish	-	-	-	-	95.46
Broiler	23,823.20	1,130.73	-	-	5,869.50
Layer	24,865.20	19,230.70	7,050.15	535.64	1,870.27
Layer/Cockerel	24,230.30	17,493.24	38,460.94	17,771.45	1,411.10
Broiler/Cockerel	80,116.23	64,549.97	71,338.19	58,271.25	46,679.30
broiler/layer	16,074.86	763.00	4,557.80	346.30	3,960.51
Broiler/Layer/Cockerel	170,138.60	147,743.00	151,099.60	156,276.50	174,210.10
Cattle	-	-	30,754.92	24,367.29	59,498.84
Goat	92,470.69	117,725.40	52,249.45	63,481.61	79,512.38
Sheep	73,807.16	86,789.40	20,549.38	22,324.00	33,227.39
Cattle/Goat	42,300.39	44,515.20	49,727.88	44,790.48	73,814.34
Cattle/Sheep	41,812.77	38,298.28	53,666.52	49,753.01	86,386.32
Goat/Sheep	63,025.13	69,108.21	5,062.24	-	-
Cattle/Goat/Sheep	-	-	-	17,405.20	40,688.29

Table 12: Marginal value product of resources under combined farm enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	0	0.99	0	1.05	0	0.91	0	0.71	0	0.88
Pond size	0	2.63	0	2.63	0	2.63	0	2.63	0	2.77
Livestock capacity size	0	205.21	0	205.14	0	205.3	0	205.27	0	204.76
Owned capital	16.62	0	12.5	0	13.9	0	9.25	0	4.07	0
Borrowed capital	0.58	0	-	-	0	311.46	0	420.12	0	52.95
HL for land preparation	0	5.62	0	7.5	0	3.55	0	0.38	1301.79	0
HL for planting	0	4.05	0	4.48	0	3.57	0	1.45	0	2.73
HL for weeding	0	88.73	0	90.88	0	86.36	0	72.84	873	0
HL for fertilizer application	1000	0	1000	0	1000	0	1000	0	0	1.38
HL for harvesting (crops)	1000	0	1000	0	1000	0	1000	0	1000	0
HL for pen/pond preparation	1000	0	1000	0	1000	0	1000	0	1000	0
HL for cleaning	500	0	500	0	500	0	500	0	500	0
HL for feeding	500	0	500	0	0	3.26	0	3.73	500	0
HL for sorting	0	0.15	0	0.4	500	0	500	0	500	0
HL for harvesting (fish)	0	10.01	0	8.58	0	11.85	0	14.55	0	9.26
HL for harvesting (livestock)	0	15.65	0	14.48	0	16.96	0	19.74	0	14.01
Seed	0	509.39	0	613.67	0	394.83	0	364.38	0	1456
Fertilizer	0	100.37	0	112.86	0	86.66	0	56.03	0	174.87
Agrochemical	0	12.55	0	12.77	0	12.3	0	10.95	0	13.03
Tractor/power tiller	0	3.53	0	3.72	0	3.32	0	3.08	0	2.7
Feed	350	0	350	0	144.32	0	261.89	0	350	0
Fingerling stock	0	9.83	0	9.83	0	9.83	0	9.83	0	12
Breed stock (cattle)	0	0.77	1267.52	0	0	1.17	0	1.25	0	1.25
Breed stock (goat)	0	7.44	0	7.28	0	8.1	0	7.49	0	5.75
Breed stock (sheep)	0	4.87	0	4.55	0	6.19	0	6.21	0	5.56
Breed stock (broiler)	0	64.5	0	64.5	0	17.3	0	27.33	0	64.5
Breed stock (layer)	0	64.75	0	64.75	0	64.75	0	64.75	0	64.75
Breed stock (cockerel)	150	0	0	9.66	150	0	150	0	150	0
Lime	21633.65	0	17886.18	0	12673.6	0	8358.08	0	0	0.29

APPENDIX E

Results of Farm enterprise combinations for Patigi Agricultural Zone

Crop enterprises:

Table 13: Existing, normative optimum and risk efficient cropping plans

Crop enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	1.3500	-	-	-	-	-
Maize	1.0700	-	-	-	-	-
Melon	1.2800	-	-	-	-	-
Millet	0.8700	-	-	-	-	0.9265
Rice	1.6200	1.0000	0.7654	0.9615	0.8949	0.9976
Sorghum	1.0300	-	-	-	-	-
Cassava/Groundnut	0.8100	-	-	-	-	-
Cassava/Maize	0.7800	-	-	-	-	-
Cassava/Melon	0.9000	-	-	-	-	-
Cassava/Sorghum	1.0500	-	-	-	-	-
Maize/Cowpea	1.1000	-	0.0546	-	-	-
Maize/Groundnut	1.2400	-	-	0.0082	-	0.7236
Maize/Melon	1.1500	0.3534	-	-	-	-
Maize/Sorghum	1.0500	-	-	-	-	-
Maize/Soybean	0.8700	-	-	-	-	-
Melon/Millet	1.2300	-	-	1.0104	1.0000	0.2352
Sorghum/Groundnut	1.3000	1.0000	1.0000	-	0.3434	0.0096
Sorghum/Soybean	0.9700	0.0966	-	0.0655	-	-
Cassava/Sorghum/Groundnut	1.2300	-	-	0.0072	0.076	-
Maize/Sorghum/Soybean	1.4300	-	-	0.478	0.1356	-

Table 14: Gross margin in the existing, optimum and risk efficient cropping plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦/ha)	231520.2	429724.2	360664.1	326866.4	327210.8	317790.9

Table 15: Marginal opportunity cost of excluded cropping enterprises

Excluded cropping enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	112,531.30	103,420.20	160,681.30	203,496.90	132,631.40
Maize	71,969.37	104,219.10	126,963.10	159,089.00	90,050.30
Melon	92,606.30	137,387.20	127,931.00	139,059.00	5,513.23
Millet	3,303.00	12,839.23	31,973.82	17,187.00	-
Sorghum	30,843.78	83,384.33	83,462.89	128,162.20	45,613.45
Cassava/Groundnut	69,896.62	61,336.89	110,046.80	142,008.30	90,325.23
Cassava/Maize	42,688.08	75,278.12	104,758.40	204,790.50	181,386.30
Cassava/Melon	71,886.58	52,723.53	98,446.01	134,688.40	60,285.00
Cassava/Sorghum	78,809.95	86,868.95	109,039.60	157,105.80	101,239.60
Maize/Cowpea	3,367.80	-	54,652.09	122,735.40	77,453.10
Maize/Groundnut	25,750.83	12,346.07	-	38,028.10	-
Maize/Melon	-	21,574.98	44,007.90	108,813.10	25,249.40
Maize/Sorghum	18,759.53	61,595.04	66,098.04	131,863.40	69,609.68
Maize/Soybean	11,028.76	30,268.20	56,916.55	110,811.70	73,179.02
Melon/Millet	3,126.28	12,152.40	-	-	-
Sorghum/Groundnut	-	-	1,894.81	-	-
Sorghum/Soybean	-	13,167.91	-	55,506.07	113,968.00
Cassava/Sorghum/Groundnut	93,616.55	117,343.40	-	-	29,613.60
Maize/Sorghum/Soybean	69,351.53	90,450.41	-	-	27,436.00

Table 16: Marginal value product of resources under cropping enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	71652.92	0	135873.6	0	93176.1	0	92420.2	0	0	0.4425
Owned capital	0	0	0	0	0	91.6039	0	0.0991	0	102.1111
Borrowed capital	12.5	0	-	-	12.5	0	12.5	0	12.5	0
HL for land preparation	2000	0	667.3004	0	2000	0	2000	0	2000	0
HL for planting	999.9998	0	0	0.7778	0	0.7026	0	1.0879	0	0.1486
HL for weeding	1500	0	1500	0	1500	0	1500	0	1500	0
HL for fertilizer application	0	3.292	0	4.0398	0	2.7772	0	3.777	0	5.3001
HL for harvesting	0	0.9559	0	7.407	1200	0	524.4471	0	1200	0
Seed	0	332.1272	0	349.0117	0	314.1797	0	298.3968	0	334.7385
Fertilizer	0	50.4236	0	99.0646	0	2.0908	150	0	0	12.141
Agrochemical	0	1.1133	0	3.3809	0	2.9496	0	1.5804	0	0.1821
tractor/power tiller	0	6	0	5.8831	0	6	0	6	0	4.6102

HL = Human labour

Livestock enterprises:

Table 17: Existing, normative optimum and risk efficient livestock plans

Livestock enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Goat	0.8700	-	-	-	-	-
Sheep	1.2100	-	0.0010	-	-	0.0893
Cattle/Sheep	1.4300	-	-	-	-	0.1670
Goat/Sheep	1.1500	0.0003	-	0.1063	0.1063	-
Broiler	0.9400	0.2687	0.5525	0.3402	0.3402	-
Layer	0.6500	-	-	-	-	-
Cockerel	1.0400	0.3266	-	0.3050	0.3050	0.7374
Layer/Cockerel	0.8900	-	-	-	-	-
Broiler/Cockerel	0.6700	-	-	-	-	-
Broiler/Layer	1.3200	0.7944	0.7803	0.6208	0.6208	0.4062
Broiler/Layer/Cockerel	0.9500	-	-	-	-	-

Table 18: Marginal opportunity cost of excluded livestock enterprises

Excluded livestock enterprises	Marginal opportunity cost (₦/TLU)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Goat	110,038.90	109,361.20	103,814.30	103,814.30	92,062.17
Sheep	1,632.20	-	9,596.79	9,596.79	-
Cattle/Sheep	14,525.96	12,658.50	6,151.60	6,151.60	-
Goat/Sheep	-	109,361.20	-	-	92,062.20
Broiler	-	-	-	-	189,088.00
Layer	22,383.38	17,816.69	35,050.96	35,050.96	39,830.61
Cockerel	-	123,434.40	-	-	-
Layer/Cockerel	48,059.03	47,510.71	45,982.13	45,982.13	38,911.59
Broiler/Cockerel	43,888.18	31,649.82	43,831.86	43,831.86	1,667.84
Broiler/Layer/Cockerel	126,266.70	130,458.90	116,574.70	116,574.70	110,767.00

Table 19: Gross margin in the existing, optimum and risk efficient livestock plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross margin (₦/TLU)	221,249.91	281,116.50	252,055.10	230,873.10	230,873.10	235,999.70

Table 20: Marginal value product of resources under livestock enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Livestock capacity size	0	205.0299	0	205.0862	0	205.0477	0	205.0477	0	205.0201
HL for pen preparation	1000.003	0	999.9948	0	1000.003	0	1000.003	0	1000.105	0
HL for cleaning	500.0651	0	500.0087	0	500.0651	0	500.0651	0	500.0186	0
HL for feeding	0	2.6194	0	2.3999	0	2.3028	0	2.3028	0	0.5237
HL for sorting	500.0299	0	500.0768	0	500.0572	0	500.0572	0	499.991	0
HL for harvesting	999.9984	0	1000.001	0	999.9984	0	999.9984	0	1000.001	0
Owned capital	1	0	1	0	1	0	1	0	1	0
Borrowed capital	2.1	0			2.1	0	2.1	0	0	117.791
Feed	350	0	350	0	350	0	350	0	350	0
Breed stock (cattle)	0	1.25	0	1.25	0	1.25	0	1.25	0	1.083
Breed stock (goat)	0	8.2475	0	8.25	0	7.3998	0	7.3998	0	8.25
Breed stock (sheep)	0	6.499	0	6.4864	0	6.1812	0	6.1812	0	4.3366
Breed stock (broiler)	220.1799	0	300	0	181.9817	0	181.9817	0	0	46.2228
Breed stock (layer)	0	21.8525	0	22.6153	0	31.2282	0	31.2282	0	42.8173
Breed stock (cockerel)	0	19.6711	0	60.4997	0	22.3782	0	22.3782	150	0

HL = Human labour

Combined farm enterprises:

Table 21: Existing, normative optimum and risk efficient farm plans

Farm enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	1.35	-	-	-	-	-
Maize	1.07	-	-	-	-	-
Melon	1.28	-	-	-	-	-
Millet	0.87	-	-	-	-	-
Rice	1.62	1.00	1.00	1.00	1.00	1.00
Sorghum	1.03	-	-	-	-	-
Cassava/Groundnut	0.81	-	-	-	-	-
Cassava/Maize	0.78	-	-	-	-	-
Cassava/Melon	0.90	-	-	-	-	-
Cassava/Sorghum	1.05	-	-	-	-	-
Maize/Cowpea	1.10	0.23	0.22	0.16	0.25	0.61
Maize/Groundnut	1.24	-	-	-	-	-
Maize/Melon	1.15	-	-	-	-	-
Maize/Sorghum	1.05	-	-	-	-	-
Maize/Soybean	0.87	0.06	-	0.15	0.13	0.25
Melon/Millet	1.23	-	-	-	-	-
Sorghum/Groundnut	1.30	-	-	-	-	-
Sorghum/Soybean	0.97	-	-	-	-	-
Cassava/Sorghum/Groundnut	1.23	0.36	0.33	0.40	0.31	-
Maize/Sorghum/Soybean	1.43	0.96	1.00	0.91	0.92	0.43
Catfish	1.03	0.15	-	0.15	0.11	-
Broiler	0.87	-	-	-	-	-
Layer	1.21	-	-	-	-	-
Cockerel	1.43	-	-	1.00	1.03	1.12
Layer/Cockerel	1.15	-	-	-	-	-
Broiler/Cockerel	0.94	-	-	-	-	-
Broiler/Layer	0.65	-	0.50	-	-	-
Broiler/Layer/Cockerel	1.04	-	-	-	-	-
Goat	0.89	-	-	-	-	-
Sheep	0.67	-	-	-	-	-
Cattle/Sheep	1.32	-	-	-	-	-
Goat/Sheep	0.95	0.48	0.27	0.15	0.13	0.08

Table 22: Gross margin in the existing, optimum and risk efficient farm plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦)	238,501.09	493,485.90	401,236.00	461,614.50	448,660.00	387,026.10

Table 23: Marginal opportunity cost of excluded farm enterprises

Excluded farm enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	192,448.20	192,187.10	191,988.20	167,755.50	141,594.40
Maize	130,157.60	143,719.50	126,863.40	119,164.10	123,032.00
Melon	97,924.10	74,415.70	98,355.30	58,052.50	57,346.60
Millet	151,047.40	141,664.80	145,797.90	119,935.80	122,559.70
Sorghum	65,705.51	88,147.02	61,999.23	36,651.46	44,509.06
Cassava/Groundnut	70,538.15	75,392.65	73,177.59	48,985.82	15,552.93
Cassava/Maize	189,063.80	253,656.00	195,312.90	274,461.90	272,036.10
Cassava/Melon	167,147.60	152,822.90	170,093.10	138,175.20	107,988.80
Cassava/Sorghum	145,185.70	165,722.70	151,382.70	74,968.39	52,770.91
Maize/Groundnut	1,666.39	32,961.84	270.38	22,678.85	33,070.40
Maize/Melon	197,926.00	237,356.20	205,726.10	216,799.70	219,584.60
Maize/Sorghum	104,078.10	169,707.50	105,940.10	66,345.77	70,965.52
Maize/Soybean	-	74,688.80	-	-	-
Melon/Millet	106,798.90	122,242.00	113,916.80	105,253.70	119,457.80
Sorghum/Groundnut	134,876.80	145,648.50	142,193.70	27,223.65	49,958.73
Sorghum/Soybean	111,568.40	91,748.70	124,856.00	28,749.93	44,724.60
Cassava/Sorghum/Groundnut	-	-	-	-	15,629.70
Catfish	-	1,925.85	-	-	1,667.29
Broiler	3,020.30	29,261.72	32,165.64	36,078.02	122,153.90
Layer	89,818.09	37,968.96	26,952.40	30,638.70	176,655.30
Cockerel	266,957.60	137,716.30	-	-	-
Layer/Cockerel	109,773.70	71,111.70	48,320.10	44,992.75	160,526.30
Broiler/Cockerel	99,074.85	94,866.24	124,462.20	112,933.60	92,486.85
Broiler/Layer	2,038.00	-	21,703.90	24,343.80	82,424.25
Broiler/Layer/Cockerel	123,599.50	115,357.50	131,168.40	140,427.90	167,280.30
Goat	43,348.66	60,836.84	20,158.15	34,673.98	52,019.86
Sheep	37,807.10	27,638.20	24,786.74	28,741.56	33,998.09
Cattle/Sheep	22,821.43	29,999.51	18,633.31	43,976.60	64,477.90

Table 24: Marginal value product of resources under combined farm enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	91674.18	0	0	0.06	79000.4	0	20422.36	0	0	0.33
Pond size	0	2.63	0	2.77	0	2.63	0	2.66	0	2.77
Livestock capacity size	0	205.94	0	205.65	0	205.27	0	205.26	0	205.22
Owned capital	19.43	0	12.5	0	23.47	0	17.56	0	12.29	0
Borrowed capital	0	3028.29	-	-	0	373.55	0	272	2.89	0
HL for land preparation	2000	0	2000	0	2000	0	2000	0	2000	0
HL for planting	1000	0	1000	0	1000	0	1000	0	1000	0
HL for weeding	0	32.79	0	34.55	0	42.38	0	31.06	227.73	0
HL for fertilizer application	1000	0	1000	0	1000	0	1000	0	1000	0
HL for harvesting (crops)	1000	0	1000	0	1000	0	1000	0	1000	0
HL for pen/pond preparation	0	0.33	1000	0	1000	0	1000	0	1000	0
HL for cleaning	0	0.14	500	0	500	0	500	0	500	0
HL for feeding	0	3.3	0	1.85	0	3.77	0	4.01	0	4.64
Sorting HL	0	1.03	500	0	0	0.3	0	0.29	0	0.26
HL for harvesting (fish)	0	34.91	0	39.62	0	36.62	0	36.25	0	29.28
HL for harvesting (livestock)	0	42.23	0	41.57	0	42.22	0	41.8	0	34.67
Seed	0	1291.39	0	1302.95	0	1276.87	0	1309.31	0	1441.25
Fertilizer	0	96.25	0	100.67	0	94.03	0	89.91	0	63.86
Agrochemical	0	6.73	0	7.23	0	6.22	0	7.01	0	10.67
tractor/power tiller	0	4.5	0	4.72	0	4.38	0	4.22	0	3.06
Feed	0	85.64	24.84	0	0	5.96	0	6.74	0	6.7
fingerlings stock	0	9.83	0	12	0	9.83	0	10.28	0	12
Breed stock (cattle)	0	1.25	0	1.25	0	1.25	0	1.25	0	1.25
Breed stock (goat)	0	4.38	0	6.11	0	7.04	0	7.2	0	7.62
Breed stock (sheep)	0	5.05	0	5.7	0	6.05	0	6.1	0	6.26
Breed stock (broiler)	0	64.5	0	41.87	0	64.5	0	64.5	0	64.5
Breed stock (layer)	0	64.75	0	37.59	0	64.75	0	64.75	0	64.75
Breed stock (cockerel)	0	60.5	0	60.5	150	0	150	0	150	0
Lime	158.29	0	0	0.29	10266.01	0	0	0.06	0	0.29

APPENDIX F

Results of Farm enterprise combinations for Shao Agricultural Zone

Crop enterprises:

Table 25: Existing, normative optimum and risk efficient cropping plans

Crop enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	0.9100	-	-	-	-	-
Maize	1.7000	-	-	-	-	-
Melon	1.0800	-	-	0.2770	0.1989	0.1972
Sorghum	0.8500	-	-	-	-	-
Soybean	0.8200	-	-	-	-	-
Yam	0.9500	0.3229	-	0.3924	0.3234	0.6069
Cassava/Groundnut	1.1000	0.3168	0.6130	-	-	-
Cassava/Maize	1.1600	-	-	-	-	-
Cassava/Melon	1.3000	-	-	0.3575	1.0504	1.0527
Cassava/Sorghum	1.2100	-	-	-	-	-
Cassava/Soybean	1.1000	0.5178	-	-	-	-
Maize/Cowpea	0.9100	0.3212	0.6370	-	-	0.1426
Maize/Groundnut	1.2900	-	-	-	-	-
Maize/Melon	1.3700	-	-	-	-	-
Maize/Sorghum	1.0200	-	-	-	-	-
Maize/Soybean	1.2900	0.6194	-	-	0.2847	-
Maize/Yam	1.5000	-	-	-	-	-
Melon/Millet	1.0800	-	-	-	-	-
Sorghum/Groundnut	0.9100	-	-	-	-	-
Sorghum/Soybean	1.2700	-	-	-	-	-
Sorghum/Yam	1.5000	-	-	-	-	-
Cassava/Sorghum/Groundnut	1.2100	-	-	-	0.0007	-
Cassava/Maize/Cowpea	0.9900	-	-	-	-	-
Cassava/Maize/Groundnut	0.6800	-	-	0.4586	-	-
Cassava/Maize/Melon	1.0900	-	-	0.1437	-	-
Cassava/Maize/Soybean	0.9300	0.2432	0.4800	-	-	-
Maize/Sorghum/Soybean	0.7000	-	-	0.5393	0.7073	0.1558

Table 26: Gross margin in the existing, optimum and risk efficient cropping plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦/ha)	259,757.02	411,165.10	383,254.40	307,862.20	318,801.60	327,973.10

Table 27: Marginal opportunity cost of excluded cropping enterprises

Excluded cropping enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	77,935.35	60,264.79	121,716.50	106,294.10	111,874.10
Maize	77,012.39	111,754.90	111,663.10	77,314.80	82,951.87
Melon	104,134.90	4,288.20	-	-	-
Sorghum	32,359.97	93,694.82	81,536.55	39,473.35	46,209.61
Soybean	84,364.00	102,494.50	110,074.80	87,339.84	85,771.63
Yam	-	13,131.42	-	-	-
Cassava/Groundnut	-	-	70,207.46	10,335.74	12,831.42
Cassava/Maize	37,275.59	39,556.82	87,943.59	57,703.45	60,322.70
Cassava/Melon	64,085.70	3,473.43	-	-	-
Cassava/Sorghum	31,013.92	60,798.56	112,648.90	64,078.13	62,900.25
Cassava/Soybean	-	8,745.29	89,011.63	33,966.00	25,346.92
Maize/Cowpea	-	-	24,184.30	3,272.94	-
Maize/Groundnut	53,885.84	70,953.84	77,482.17	36,198.41	35,725.87
Maize/Melon	60,129.74	74,914.27	44,634.74	34,336.13	34,034.92
Maize/Sorghum	32,974.80	85,974.10	87,900.84	40,061.32	41,135.23
Maize/Soybean	-	48,473.55	45,009.40	-	587.40
Maize/Yam	12,431.80	5,669.78	12,210.39	1,949.92	5,726.68
Melon/Millet	49,326.20	23,385.90	89,142.70	77,074.90	78,048.30
Sorghum/Groundnut	69,616.03	78,800.61	87,322.46	61,751.31	55,251.20
Sorghum/Soybean	13,840.61	30,869.22	67,102.77	24,522.47	16,456.27
Sorghum/Yam	58,920.36	5,592.30	28,982.13	52,115.43	55,520.01
Cassava/Sorghum/Groundnut	12,534.00	68,590.30	48,758.64	-	11,353.60
Cassava/Maize/Cowpea	59,078.45	42,645.06	50,889.88	72,202.80	70,489.46
Cassava/Maize/Groundnut	89,602.64	83,275.78	-	79,927.63	79,926.98
Cassava/Maize/Melon	65,810.20	64,826.06	-	36,602.08	41,900.29
Cassava/Maize/Soybean	-	-	19,301.74	9,621.34	11,992.26
Maize/Sorghum/Soybean	14,623.21	56,375.25	-	-	-

Table 28: Marginal value product of resources under cropping enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	0	0.2287	144955.9	0	103730.3	0	0	0.0045	0	0.4148
Owned capital	0	0	0	0	0	259.8153	0	0.9353	0	1.0673
Borrowed capital	12.1398	0			12.5	0	12.5	0	12.5	0
HL for land preparation	1983.014	0	0	1.3948	284.9041	0	2000	0	1872.82	0
HL for planting	758.6756	0	0	5.1143	1000	0	999.9938	0	1000	0
HL for weeding	0	40.6164	0	14.7307	0	84.2977	0	82.0231	0	78.5246
HL for fertilizer application	1000.001	0	0	2.5388	999.9969	0	999.9999	0	0	2.4494
HL for harvesting	1200	0	1045.482	0	1200	0	1200	0	1200	0
Seed	0	612.5774	0	1095.272	0	537.4438	0	622.3528	0	224.2654
Fertilizer	0	49.673	0	78.2701	0	101.725	0	149.0367	0	146.1938
Agrochemical	0	6.0298	0	8.0064	0	7.6218	0	5.3446	0	7.3475
tractor/power tiller	8161.749	0	0	1.0796	0	2.3922	7724.708	0	10000	0

HL = Human labour

Fisheries enterprises:

Table 29: Existing, normative optimum and risk efficient livestock plans

Fishery enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Catfish	0.9588	1.0340	1.0000	0.3955	0.5251	0.6546
Fingerlings	1.0684	1.2142	1.0932	0.6977	0.7625	0.8273
Catfish/Fingerlings	0.7716	-	-	0.3019	0.2371	0.1727

Table 30: Marginal opportunity cost of excluded fishery enterprises

Excluded fishery enterprises	Marginal opportunity cost (₦/(₦/m^2))				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Catfish/Fingerlings	6,327.18	5,490.68	-	-	-

Table 31: Gross margin in the existing, optimum and risk efficient fishery plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross margin (₦/m^2)	6,957.48	13,402.45	12,336.73	11,398.05	11,843.59	12,293.19

Table 32: Marginal value product of resources under fishery enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	**Slack/Surplus**	**MVP**	**Slack/Surplus**	**MVP**	**Slack/Surplus**	**MVP**	**Slack/Surplus**	**MVP**	**Slack/Surplus**
Pond size	0	78	0	78	0	78.6048	0	78.4753	0	78.3454
HL for Pond preparation	1000.001	0	1000	0	999.9996	0	999.9996	0	999.9973	0
HL for cleaning	499.9992	0	500.0003	0	499.9998	0	499.9998	0	500.0003	0
HL for feeding	500.0001	0	499.9997	0	499.9999	0	499.9999	0	500.0007	0
HL for sorting	500	0	499.9999	0	499.9976	0	499.9976	0	500.0003	0
HL for harvesting	999.9919	0	1000.014	0	1000.002	0	1000.002	0	999.9963	0
Owned capital	1	0	1	0	1	0	1	0	1	0
Borrowed capital	1.2	0	-	-	1.2	0	1.2	0	1.2	0
Feed	350	0	350	0	350	0	350	0	350	0
Fingerlings stock	26.5	0	26.5	0	0	3.3504	0	1.9904	0	0.6265
Breed stock	2625.355	0	2545.353	0	2420.959	0	2420.959	0	2425.462	0
Lime	134.9395	0	134.9401	0	134.9401	0	134.9401	0	134.94	0

Livestock enterprises:

Table 33: Existing, normative optimum and risk efficient livestock plans

Livestock enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cattle	1.4175	-	0.0998	-	0.0067	-
Goat	1.1234	-	-	-	-	-
Sheep	1.3440	-	-	0.1314	-	-
Cattle/Goat	1.0920	0.2122	-	-	-	0.1714
Cattle/Sheep	0.9345	-	-	-	-	-
Goat/Sheep	0.7031	-	-	-	-	-
Cattle/Goat/Sheep	1.3860	-	-	-	-	0.1134
Broiler	0.9970	0.3474	0.4655	0.3953	0.4929	-
Layer	1.2917	-	-	-	-	-
Cockerel	1.3650	0.3425	-	0.0687	-	0.7046
Layer/Cockerel	1.0182	-	-	0.0544	-	-
Broiler/Cockerel	1.2918	-	-	-	-	-
Broiler/Layer	1.5013	0.1507	0.7085	-	0.7960	0.3766
Broiler/Layer/Cockerel	1.0810	-	-	-	-	-

Table 34: Gross margin in the existing, optimum and risk efficient livestock plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross margin (₦/TLU)	218,599.14	288,982.80	333,745.80	270,277.40	320,149.70	294,093.50

Table 35: Marginal opportunity cost of excluded livestock enterprises

Excluded livestock enterprises	Marginal opportunity cost (₦/TLU)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cattle	96,508.14	-	88,187.06	-	20,667.39
Goat	93,387.87	103,466.50	176,612.40	192,371.30	128,864.60
Sheep	140,225.10	89,839.31	-	93,660.66	59,064.31
Cattle/Goat	-	125.37	39,629.60	68,737.27	-
Cattle/Sheep	127,972.60	114,892.20	52,068.07	125,114.40	53,165.03
Goat/Sheep	65,957.50	22,835.47	87,041.20	106,939.20	54,968.54
Cattle/Goat/Sheep	54,687.08	68.40	12,455.80	30,298.31	-
Broiler	-	-	-	-	11,160.24
Layer	115,868.00	24,471.57	188,554.70	19,923.07	60,691.74
Cockerel	-	131,032.60	-	10,702.88	-
Layer/Cockerel	70,725.91	69,786.33	-	83,686.49	38,985.24
Broiler/Cockerel	32,115.98	33,598.11	31,071.32	48,507.37	53,666.23
Broiler/Layer	-	-	43,976.57	-	-
Broiler/Layer/Cockerel	56,207.22	147,342.60	64,073.21	152,451.00	117,517.80

Table 36: Marginal value product of resources under livestock enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Livestock capacity size	0	205.3672	0	205.1462	0	205.7701	0	205.1243	0	205.054
HL for Pen preparation	0	0.0805	1000.009	0	0	0.5286	1000.004	0	1000.02	0
HL for cleaning	500.0211	0	499.9981	0	0	0.9563	500.0001	0	500.0013	0
HL for feeding	0	4.1922	0	1.287	0	8.502	0	2.503	0	0.4429
HL for sorting	0	0.2305	500.0008	0	0	1.2781	499.9933	0	499.9995	0
HL for harvesting	0	0.4699	1000	0	0	2.2791	1000.004	0	1000.003	0
Owned capital	1	0	1	0	0	4639.508	1	0	1	0
Borrowed capital	2.1	0	-	-	2.1	0	2.1	0	2.1	0
Feed	350	0	350	0	350	0	350	0	350	0
Breed stock (cattle)	0	1.0378	0	1.0504	0	1.25	0	1.2365	0	0.9652
Breed stock (goat)	0	6.5521	0	8.25	0	8.25	0	8.25	0	6.6523
Breed stock (sheep)	2000	0	0	6.5	0	4.7914	0	6.5	0	6.0464
Breed stock (broiler)	0	20.5506	300	0	0	22.2001	300	0	0	47.5519
Breed stock (layer)	0	56.6108	0	26.4923	0	61.2152	0	21.765	0	44.4123
Breed stock (cockerel)	105.6467	0	0	60.5	42.1598	0	0	60.5	150	0

HL = Human labour

Combined farm enterprises:

Table 37: Existing, normative optimum and risk efficient farm plans

Farm enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	0.910	-	-	-	-	-
Maize	1.700	-	-	-	-	-
Melon	1.080	-	-	-	-	-
Sorghum	0.850	-	-	-	-	-
Soybean	0.820	-	-	-	-	-
Yam	0.950	-	-	-	-	-
Cassava/Groundnut	1.100	-	-	-	-	-
Cassava/Maize	1.160	-	-	-	-	-
Cassava/Melon	1.300	-	-	-	-	-
Cassava/Sorghum	1.210	-	-	-	-	-
Cassava/Soybean	1.100	-	-	-	-	-
Maize/Cowpea	0.910	0.480	0.310	0.480	0.810	0.830
Maize/Groundnut	1.290	-	-	-	-	0.630
Maize/Melon	1.370	-	-	-	-	-
Maize/Sorghum	1.020	-	-	-	-	-
Maize/Soybean	1.290	0.350	-	0.260	0.180	0.020
Maize/Yam	1.500	-	0.340	-	-	-
Melon/Millet	1.080	-	-	-	-	-
Sorghum/Groundnut	0.910	-	-	-	-	-
Sorghum/Soybean	1.270	-	-	-	-	-
Sorghum/Yam	1.500	-	-	-	-	-
Cassava/Sorghum/Groundnut	1.210	0.610	0.530	0.590	0.530	0.120
Cassava/Maize/Cowpea	0.990	-	-	-	-	-
Cassava/Maize/Groundnut	0.680	-	-	-	-	-
Cassava/Maize/Melon	1.090	-	-	-	-	-
Cassava/Maize/Soybean	0.930	-	-	-	-	-
Maize/Sorghum/Soybean	0.700	0.650	0.770	0.680	0.460	0.070
Catfish	0.959	-	-	-	-	0.150
Fingerlings	1.068	0.290	0.290	-	-	-
Catfish/Fingerlings	0.772	-	-	0.150	0.150	-
Broiler	1.418	-	-	-	-	-
Layer	1.123	-	-	-	-	-
Cockerel	1.344	-	-	0.230	0.280	0.360
Layer/Cockerel	1.092	-	-	-	-	-
Broiler/Cockerel	0.935	-	-	-	-	-
Broiler/Layer	0.703	0.470	1.410	-	-	-
Broiler/Layer/Cockerel	1.386	-	-	-	-	-
Cattle	0.997	0.260	-	0.180	0.170	0.150
Goat	1.292	-	-	-	-	-
Sheep	1.365	-	-	-	-	-
Cattle/Goat	1.018	-	-	-	-	-
Cattle/Sheep	1.292	-	-	-	-	-
Goat/Sheep	1.501	-	-	-	-	-
Cattle/Goat/Sheep	1.081	-	-	0.500	0.460	0.450

Table 38: Gross margin in the existing, optimum and risk efficient farm plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦)	232,330.59	489,917.60	477,617.30	429,537.40	483,142.60	432,502.90

Table 39: Marginal opportunity cost of excluded farm enterprises

Excluded farm enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	131,599.30	134,055.40	129,607.70	152,570.80	117,942.50
Maize	102,699.40	119,795.80	103,433.00	110,374.10	101,644.80
Melon	128,840.80	120,415.00	135,234.40	134,494.80	14,148.79
Sorghum	71,110.46	93,173.89	71,344.91	61,910.81	55,962.59
Soybean	74,150.53	92,689.59	69,984.69	91,519.09	61,046.90
Yam	358,726.70	421,139.30	366,655.90	406,387.60	336,808.30
Cassava/Groundnut	24,999.87	21,828.25	28,395.94	38,612.55	19,721.63
Cassava/Maize	283,240.30	336,285.80	282,261.80	293,322.20	292,749.00
Cassava/Melon	102,094.90	89,671.59	105,544.90	120,086.80	11,460.60
Cassava/Sorghum	252,056.10	243,502.70	257,459.80	86,999.95	58,655.30
Cassava/Soybean	137,053.50	82,238.97	156,884.30	166,739.20	130,197.70
Maize/Groundnut	27,929.63	45,349.64	26,549.76	21,688.12	-
Maize/Melon	204,721.70	201,713.10	214,885.50	210,596.90	118,961.50
Maize/Sorghum	164,263.00	187,939.20	167,599.50	92,756.37	89,555.28
Maize/Soybean	-	33,825.53	-	-	-
Maize/Yam	227,732.90	-	7,011.93	87,059.15	129,754.50
Melon/Millet	308,534.90	297,896.90	319,181.80	331,768.40	228,367.40
Sorghum/Groundnut	199,569.30	224,641.50	199,347.30	62,422.09	22,486.64
Sorghum/Soybean	189,049.10	186,819.00	197,235.70	44,513.10	12,841.63
Sorghum/Yam	227,938.60	244,331.30	239,533.50	219,941.30	129,871.70
Cassava/Maize/Cowpea	87,061.40	102,743.00	76,389.71	240,441.20	212,168.70
Cassava/Maize/Groundnut	20,417.53	10,220.28	25,570.64	180,421.20	193,607.20
Cassava/Maize/Melon	222,535.20	222,868.60	226,503.80	375,301.10	274,025.30
Cassava/Maize/Soybean	80,015.69	108,115.30	72,805.91	238,769.50	240,477.00
Catfish	2,407.73	4,839.94	23,554.30	1,028.58	-
Fingerlings	-	-	30,041.25	9,454.91	45.18
Catfish/Fingerlings	14,583.84	116,759.80	-	-	23.89
Broiler	84,288.38	175,243.90	43,677.86	49,990.81	35,375.70
Layer	96,123.26	185,158.50	50,578.79	59,359.18	142,089.30
Cockerel	359,341.50	32,191.40	-	-	-
Layer/Cockerel	107,495.30	177,160.80	62,573.57	56,564.87	116,502.00
Broiler/Cockerel	141,312.50	189,279.30	114,405.50	110,070.20	75,126.12
Broiler/Layer	-	-	36,009.40	42,260.60	23,870.00
Broiler/Layer/Cockerel	214,058.30	229,385.60	202,870.60	206,725.00	197,898.70
Cattle	-	64,775.63	-	-	-
Goat	112,041.80	166,750.90	93,416.76	97,683.80	99,236.77
Sheep	101,935.70	100,457.50	81,918.52	72,503.66	70,419.84
Cattle/Goat	41,224.30	77,413.33	40,117.96	41,026.09	41,406.81
Cattle/Sheep	51,748.82	86,323.32	38,365.45	41,538.33	42,587.72
Goat/Sheep	54,892.27	77,892.00	62,110.62	39,568.66	35,135.49
Cattle/Goat/Sheep	17,802.90	28,796.20	-	-	-

Table 40: Marginal value product of resources under combined farm enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	0	0.53	0	0.67	0	0.6	0	0.63	0	0.96
Pond size	0	2.48	0	2.48	0	2.63	0	2.63	0	2.63
Livestock capacity size	0	205.69	0	205.01	0	205.51	0	205.52	0	205.47
Owned capital	14.2	0	0.5	0	18.09	0	10.93	0	9.26	0
Borrowed capital	0	3154.68	-	-	0.24	0	1.72	0	2.09	0
HL for land preparation	1352.23	0	1282.23	0	1107.06	0	2000	0	281.74	0
HL for planting	0	1.26	0	2	0	1.64	0	1.8	0	4.87
HL for weeding	0	35.86	0	54.62	0	36.21	90.78	0	481.97	0
HL for fertilizer application	1000	0	1000	0	1000	0	1000	0	0	4.17
HL for harvesting (crops)	1000	0	1000	0	1000	0	1000	0	1000	0
HL for pen/pond preparation	1000	0	1000	0	1000	0	1000	0	1000	0
HL for cleaning	500	0	500	0	500	0	500	0	500	0
HL for feeding	500	0	500	0	500	0	500	0	500	0
HL for sorting	500	0	500	0	0	0.51	0	0.51	0	0.5
HL for harvesting (fish)	0	18.06	0	27.31	0	13.15	0	11.91	0	6.29
HL for harvesting (livestck)	0	20.39	0	19.51	0	19.61	0	18.34	0	12.57
Seed	0	1219.46	0	747.25	0	1228.47	0	1257.09	0	1420.5
Fertilizer	0	184.41	0	137.28	0	190.22	0	178.3	0	165.15
Agrochemical	0	6.45	0	7.31	0	6.97	0	7.88	0	9.26
tractor/power tiller	0	3.01	0	3.68	0	3.3	0	2.86	0	1.28
Feed	256.76	0	350	0	350	0	350	0	350	0
fingerlings stock	0	12	0	12	0	10.7	0	10.7	0	9.83
Breed stock (fish)	0	1.42	0	1.42	0	1.71	0	1.71	0	2
Breed stock (cattle)	0	0.73	0	1.25	0	0.4	0	0.46	0	0.51
Breed stock (goat)	0	8.25	0	8.25	0	7.26	0	7.33	0	7.36
Breed stock (sheep)	0	6.5	0	6.5	0	4.51	0	4.66	0	4.72
Breed stock (broiler)	0	43.47	0	0.99	0	64.5	0	64.5	0	64.5
Breed stock (layer)	0	39.52	400	0	0	64.75	0	64.75	0	64.75
Breed stock (cockerel)	0	60.5	0	60.5	0	31.33	0	25.86	0	14.98
Lime	164.35	0	2326.23	0	28640.71	0	8103.02	0	5650.73	0

APPENDIX G

Results of Farm enterprise combinations for Igbaja Agricultural Zone

Crop enterprises:

Table 41: Existing, normative optimum and risk efficient cropping plans

Crop enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	0.8500	-	-	-	-	-
Maize	0.8200	-	-	-	-	-
Melon	0.9500	-	-	-	-	-
Sorghum	1.1000	-	-	-	-	-
Soybean	1.1600	-	-	-	-	-
Cassava/Groundnut	1.3000	0.9778	0.7849	-	0.2049	-
Cassava/Maize	1.2100	-	-	-	-	-
Cassava/Melon	1.1000	-	-	-	-	0.6105
Cassava/Sorghum	0.9100	-	-	-	-	-
Cassava/Soybean	1.2900	-	-	-	-	-
Maize/Cowpea	1.3700	-	-	0.2405	0.4569	0.8621
Maize/Groundnut	1.0200	-	-	-	-	-
Maize/Melon	1.2900	-	-	-	-	-
Maize/Sorghum	1.5000	-	-	-	-	-
Maize/Soybean	1.0800	0.2006	-	-	0.5763	0.5239
Maize/Yam	0.9100	-	-	-	-	-
Sorghum/Groundnut	1.4200	-	-	-	-	-
Sorghum/Okra	1.1200	0.0448	-	-	0.2789	-
Sorghum/Soybean	1.3400	0.7856	0.7442	0.2853	-	0.1218
Sorghum/Yam	1.0900	-	-	0.2010	0.0464	-
Cassava/Sorghum/Groundnut	0.9300	-	-	-	-	-
Cassava/Maize/Cowpea	0.7000	0.1268	0.3210	1.1106	0.7957	0.2016
Cassava/Maize/Groundnut	1.3900	-	-	-	-	-
Cassava/Maize/Melon	1.0000	-	-	-	-	-
Cassava/Maize/Okra	1.2900	-	-	-	-	-
Cassava/Maize/Soybean	1.3700	-	-	-	-	-
Maize/Sorghum/Soybean	1.3000	0.1844	-	0.1969	-	-

Table 42: Gross margin in the existing, optimum and risk efficient cropping plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦/ha)	258,282.28	404,573.30	360,093.60	356,493.10	398,101.50	371,212.40

Table 43: Marginal opportunity cost of excluded cropping enterprises

Excluded cropping enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	83,327.48	56,232.11	147,737.10	79,843.48	114,059.40
Maize	112,717.60	119,686.50	112,471.60	113,967.30	129,657.00
Melon	76,693.60	78,776.01	23,147.60	67,101.63	130,966.70
Sorghum	66,066.08	87,970.38	55,859.43	51,742.27	67,733.98
Soybean	121,013.70	113,603.40	112,076.20	130,353.00	149,179.40
Cassava/Groundnut	-	-	84,242.55	-	89,879.60
Cassava/Maize	103,424.80	80,843.21	231,437.00	84,320.13	88,003.98
Cassava/Melon	991.97	37,966.70	28,689.22	33,204.90	-
Cassava/Sorghum	43,578.35	50,516.42	116,540.40	39,548.79	44,606.97
Cassava/Soybean	87,466.52	1,964,654.00	188,807.30	96,114.55	94,622.51
Maize/Cowpea	6,977.48	2,578.77	-	-	-
Maize/Groundnut	88,099.90	79,749.84	183,408.30	106,715.00	99,984.59
Maize/Melon	38,719.70	41,860.99	21,577.62	36,610.70	30,470.13
Maize/Sorghum	78,197.98	83,707.43	126,336.10	68,056.91	74,524.41
Maize/Soybean	-	12,420.13	61,797.27	-	-
Maize/Yam	20,933.65	103,335.40	15,464.65	28,871.71	85,902.06
Sorghum/Groundnut	70,122.81	74,609.88	61,906.79	76,563.86	71,903.66
Sorghum/Okra	-	13,547.39	224,346.40	-	252,959.30
Sorghum/Soybean	-	-	-	3,116.27	-
Sorghum/Yam	45,700.36	70,016.67	-	-	106,720.20
Cassava/Sorghum/Groundnut	74,255.26	130,851.90	37,487.65	71,811.38	150,857.50
Cassava/Maize/Groundnut	60,379.31	103,126.90	87,910.88	70,877.56	163,326.90
Cassava/Maize/Melon	117,596.80	110,302.30	128,062.10	106,313.30	197,401.10
Cassava/Maize/Okra	85,394.19	108,053.20	137,822.50	72,385.34	155,400.20
Cassava/Maize/Soybean	41,075.07	58,711.78	85,482.55	42,303.06	151,373.70
Maize/Sorghum/Soybean	-	18,872.84	-	611.31	112,161.60

Table 44: Marginal value product of resources under cropping enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	31222.15	0	146399.3	0	0	0.2857	73230.41	0	27685.98	0
Owned capital	0	0	0	0	0	0.2139	0	105.8944	0	0
Borrowed capital	12.5	0	-	-	12.5	0	12.5	0	12.5	0
HL for land preparation	2000	0	138.8747	0	2000	0	2000	0	2000	0
HL for planting	999.9999	0	0	0.4716	1000.001	0	1000	0	1000	0
HL for weeding	0	74.8355	0	80.8717	0	27.5796	0	9.6702	1500	0
HL for fertilizer application	626.4573	0	0	1.9144	1000.002	0	1000	0	0	0.8668
HL for harvesting	1200	0	1200	0	1200.001	0	1200	0	1200	0
Seed	0	1069.728	0	1079.639	0	741.4327	0	1013.987	0	1177.027
Fertilizer	0	95.5861	0	111.3369	0	35.5086	0	20.2985	0	103.8744
Agrochemical	0	4.789	0	4.5561	1200	0	1200	0	0	5.0201
tractor/power tiller	4300.841	0	0	1.6714	0	4.1296	0	0.4158	7773.544	0

HL = Human labour

Fisheries enterprises:

Table 45: Existing, normative optimum and risk efficient livestock plans

Fisheries enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Catfish	1.02	1.26	0.81	0.83	0.83	0.83
Fingerlings	1.38	1.62	1.07	0.76	0.76	0.76

Table 46: Gross margin in the existing, optimum and risk efficient fishery plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross margin (₦/m^2)	5,669.97	11,155.63	10,503.95	10,117.85	10,117.85	10,117.85

Table 47: Marginal value product of resources under fishery enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Pond size	0	78	0	78	0	78	0	78	0	78
HL for pond preparation	999.9999	0	1000	0	1000	0	1000	0	1000	0
HL for cleaning	500	0	500	0	500	0	500	0	500	0
HL for feeding	500	0	500	0	500	0	500	0	500	0
HL for sorting	500.0004	0	500.0007	0	500.0004	0	500.0004	0	500.0004	0
HL for harvesting	999.9995	0	999.9999	0	1000	0	1000	0	1000	0
Owned capital	1	0	1	0	1	0	1	0	1	0
Borrowed capital	1.2	0	-	-	1.2	0	1.2	0	1.2	0
Feed	350	0	350	0	350	0	350	0	350	0
Fingerling stock	26.5	0	26.5	0	26.5	0	26.5	0	26.5	0
Breed stock	1457.33	0	2057.33	0	1457.33	0	1457.33	0	1457.33	0
Lime	134.94	0	134.9399	0	134.94	0	134.94	0	134.94	0

Livestock enterprises:

Table 48: Existing, normative optimum and risk efficient livestock plans

Livestock enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Goat	1.3721	-	-	-	-	-
Sheep	1.6216	-	-	-	-	-
Goat/Sheep	1.3041	0.1793	-	-	-	0.3746
Broiler	1.0660	-	-	0.2511	-	0.0154
Layer	0.7371	-	-	-	-	-
Cockerel	1.1794	-	0.2640	-	0.2454	0.4840
Layer/Cockerel	1.0093	-	0.0367	-	-	-
Broiler/Cockerel	0.7598	-	-	-	0.0323	-
Broiler/Layer	1.4969	0.7663	0.8879	0.9068	0.9227	0.3338
Broiler/Layer/Cockerel	1.0773	-	-	-	-	-

Table 49: Gross margin in the existing, optimum and risk efficient livestock plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross margin (₦/TLU)	221,880.26	251,720.10	230,642.20	231,817.00	223,449.50	200,300.60

Table 50: Marginal opportunity cost of excluded livestock enterprises

Excluded livestock enterprises	Marginal opportunity cost (₦/TLU)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Goat	89,659.52	162,225.00	89,357.48	101,511.00	79,233.73
Sheep	93,542.04	100,355.20	40,226.56	98,117.30	22,817.44
Goat/Sheep	-	84,999.17	89,357.30	101,511.00	-
Broiler	79,363.46	26,591.75	-	189,639.00	-
Layer	80,488.50	57,788.57	28,813.05	21,978.46	64,600.05

Cockerel	69,179.52	-	3,009.24	-	-
Layer/Cockerel	74,323.45	-	46,320.10	60,185.58	21,006.61
Broiler/Cockerel	115,630.50	40,243.24	44,088.92	-	32,457.43
Broiler/Layer/Cockerel	136,298.20	72,698.39	116,470.20	113,010.70	97,724.81

Table 51: Marginal value product of resources under livestock enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Livestock capacity size	0	185.3844	0	185.1414	0	185.172	0	185.1297	0	185.1223
HL for pen preparation	1000.002	0	1000.001	0	1000.002	0	999.9838	0	999.999	0
HL for cleaning	0	0.1072	499.9997	0	500.0009	0	499.9934	0	0	0.0796
HL for feeding	0	3.4768	0	3.588	0	3.2003	0	3.3188	0	2.2705
HL for sorting	499.9998	0	500.0009	0	499.9545	0	499.9821	0	500.0025	0
HL for harvesting	1000	0	1000.001	0	1000.001	0	1000.005	0	1000	0
Owned capital	1	0	1	0	1	0	1	0	1	0
Borrowed capital	0	1382.783	-	-	2.1	0	2.1	0	0	2601.269
Feed	350	0	350	0	350	0	350	0	350	0
Breed stock (goat)	0	6.8154	0	8.25	0	8.25	0	8.25	0	5.2531
Breed stock (sheep)	0	5.962	0	6.5	0	6.5	0	6.5	0	5.3762
Breed stock (broiler)	0	30.0163	0	24.5461	300	0	0	20.6898	0	47.837
Breed stock (layer)	0	23.3695	0	14.4225	0	15.7802	0	14.9259	0	46.7264
Breed stock (cockerel)	0	60.5	0	26.0303	0	60.5	0	28.6306	34.756	0

HL = Human labour

Combined farm enterprises:

Table 52: Existing, normative optimum and risk efficient farm plans

Farm enterprise	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	0.850	-	-	-	-	-
Maize	0.820	-	-	-	-	-
Melon	0.950	-	-	-	-	-
Sorghum	1.100	-	-	-	-	-
Soybean	1.160	-	-	-	-	-
Cassava/Groundnut	1.300	-	-	-	-	-
Cassava/Maize	1.210	-	-	-	-	-
Cassava/Melon	1.100	-	-	-	-	-
Cassava/Sorghum	0.910	-	-	-	-	-
Cassava/Soybean	1.290	-	-	-	-	-
Maize/Cowpea	1.370	0.090	0.330	0.240	0.820	0.830
Maize/Groundnut	1.020	-	-	-	-	0.610
Maize/Melon	1.290	-	-	-	-	-
Maize/Sorghum	1.500	-	-	-	-	-
Maize/Soybean	1.080	-	-	0.080	0.130	-
Maize/Yam	0.910	0.670	0.280	0.410	-	-
Sorghum/Groundnut	1.420	-	-	-	-	-
Sorghum/Okra	1.120	-	-	-	-	-
Sorghum/Soybean	1.340	-	-	-	-	-
Sorghum/Yam	1.090	-	-	-	-	-
Cassava/Sorghum/Groundnut	0.930	0.530	0.510	0.540	0.520	0.100
Cassava/Maize/Cowpea	0.700	-	-	-	-	-
Cassava/Maize/Groundnut	1.390	-	-	-	-	-
Cassava/Maize/Melon	1.000	-	-	-	-	-
Cassava/Maize/Okra	1.290	-	-	-	-	-
Cassava/Maize/Soybean	1.370	-	-	-	-	-
Maize/Sorghum/Soybean	1.130	0.760	0.780	0.740	0.490	0.090
Catfish	1.020	0.150	-	-	-	-
Fingerlings	1.380	-	-	-	0.290	-
Broiler	1.372	-	-	-	-	-
Layer	1.622	-	-	-	-	-
Cockerel	1.304	0.410	-	-	-	0.030
Layer/Cockerel	1.066	-	-	-	-	-
Broiler/Cockerel	0.737	-	-	-	-	-
Broiler/Layer	1.179	-	1.500	-	-	-
Broiler/Layer/Cockerel	1.009	-	-	-	-	-
Goat	0.760	-	-	-	-	-
Sheep	1.497	-	-	-	-	-
Goat/Sheep	1.077	0.630	-	0.790	0.790	0.780

Table 53: Gross margin in the existing, optimum and risk efficient farm plans

Variable	Existing plan	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Gross Margin (₦)	230,786.39	480,069.80	457,160.90	396,329.10	385,718.60	405,977.60

Table 54: Marginal opportunity cost of excluded farm enterprises

Excluded farm enterprises	Marginal opportunity cost (₦/ha)				
	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Cassava	132,437.20	134,035.40	131,968.40	145,849.40	111,496.10
Maize	106,493.50	119,608.50	102,665.10	107,893.90	103,985.50
Melon	125,754.60	120,534.80	127,277.20	121,783.00	110,886.80
Sorghum	76,187.16	92,912.02	71,304.67	61,360.57	60,276.50
Soybean	79,452.34	92,373.63	75,678.95	92,871.04	61,708.50
Cassava/Groundnut	23,342.65	21,973.56	23,743.13	27,051.65	13,395.75
Cassava/Maize	295,074.80	335,845.40	283,174.80	291,893.10	304,320.10
Cassava/Melon	98,423.01	89,875.44	100,915.90	104,828.40	72,223.71
Cassava/Sorghum	249,132.00	243,608.00	250,741.10	78,476.41	52,829.39
Cassava/Soybean	120,392.90	83,076.13	131,282.90	125,872.80	102,664.70
Maize/Groundnut	32,098.03	45,185.06	28,281.56	18,325.67	-
Maize/Melon	201,965.60	201,861.80	201,995.90	191,669.80	190,820.00
Maize/Sorghum	169,005.00	187,718.80	163,542.70	90,059.36	95,124.98
Maize/Soybean	7,570.62	33,510.96	-	-	8,148.66
Maize/Yam	-	-	-	130,960.00	72,172.91
Sorghum/Groundnut	205,888.70	224,208.30	200,540.30	61,854.05	24,296.83
Sorghum/Okra	12,959.72	4,970.90	267,514.60	93,710.39	64,790.99
Sorghum/Soybean	187,369.40	186,781.90	187,537.30	32,577.87	7,014.90
Sorghum/Yam	231,235.50	244,056.30	227,489.70	131,078.30	206,151.60
Cassava/Maize/Cowpea	92,577.59	102,516.40	89,675.22	242,982.90	209,752.70
Cassava/Maize/Groundnut	16,566.23	10,537.07	18,329.63	167,105.40	187,925.90
Cassava/Maize/Melon	221,410.50	223,023.30	220,939.60	359,464.10	365,336.20
Cassava/Maize/Okra	12,487.00	4,789.60	240,232.00	365,658.50	392,472.30
Cassava/Maize/Soybean	87,534.80	107,836.70	81,608.89	242,190.30	245,420.00
Catfish	-	3,939.82	3,028.68	3,095.92	3,068.50
Fingerlings	11,237.27	1,221.53	448.48	-	495.49
Broiler	38,285.60	38,035.95	49,811.43	35,809.49	87,707.40
Layer	18,962.09	71,223.03	25,877.93	146,202.80	34,194.15
Cockerel	-	49,947.54	206,569.60	302,773.90	-
Layer/Cockerel	34,577.67	73,881.09	61,794.34	117,576.00	46,426.14
Broiler/Cockerel	59,010.32	77,535.00	109,239.70	77,634.34	57,052.36
Broiler/Layer	12,750.40	-	17,400.70	93,470.52	22,992.60
Broiler/Layer/Cockerel	132,274.60	133,701.20	159,476.10	195,590.20	155,125.90
Goat	70,914.96	115,447.10	64,255.38	84,271.59	75,880.69
Sheep	28,764.57	49,780.18	34,777.91	40,072.11	36,820.62
Goat/Sheep	-	115,447.40	-	-	-

Table 55: Marginal value product of resources under combined farm enterprises

Resource	Optimum plan I		Optimum plan II		Risk efficient plan I		Risk efficient plan II		Risk efficient plan III	
	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus	MVP	Slack/Surplus
Farm size	0	0.58	0	0.72	0	0.61	0	0.66	0	1
Pond size	0	2.63	0	2.77	0	2.77	0	2.48	0	2.77
Livestock capacity size	0	205.39	0	204.92	0	205.63	0	205.63	0	205.62
Owned capital	9.96	0	0.5	0	12.72	0	6.2	0	7.36	0
Borrowed capital	0	2538.67	-	-	0	3672.23	0	3490.26	0	3591.81
HL for land preparation	1396.2	0	1277.01	0	1430.91	0	2000	0	0	0.34
HL for planting	0	1.55	0	2.3	0	1.71	0	1.93	0	5.04
HL for weeding	0	77.83	0	53.06	0	61.95	180.29	0	559.02	0
HL for fertilizer application	1000	0	1000	0	1000	0	1000	0	0	4.27
HL for harvesting (crops)	1000	0	1000	0	1000	0	1000	0	1000	0
HL for pen/pond preparation	1000	0	1000	0	0	0.19	0	0.05	0	0.18
HL for cleaning	500	0	500	0	500	0	500	0	500	0
HL for feeding	500	0	500	0	500	0	500	0	500	0
HL for sorting	0	0.51	500	0	0	0.79	0	0.73	0	0.78
HL for harvesting (fish)	0	15.68	0	27.94	0	13.8	0	11.09	0	5.06
HL for harvesting (livestck)	0	22.07	0	19.09	0	20.83	0	18.15	0	12.05
Seed	0	261.64	0	851.71	0	636.6	0	1258.7	0	1428.84
Fertilizer	0	73.24	0	151.18	0	119.64	0	181.57	0	167
Agrochemical	0	6.23	0	7.78	0	6.72	0	8.06	0	9.68
tractor/power tiller	0	3.34	0	3.8	0	3.41	0	3.02	0	1.4
Feed	350	0	350	0	74.01	0	350	0	290.6	0
fingerlings stock	0	9.83	0	12	0	12	0	12	0	12
Breed stock (fish)	0	2	0	2	0	2	0	1.42	0	2
Breed stock (goat)	0	3.25	0	8.25	0	1.9	0	1.9	0	2.02
Breed stock (sheep)	0	4.62	0	6.5	0	4.12	0	4.12	0	4.16
Breed stock (broiler)	0	64.5	300	0	0	64.5	0	64.5	0	64.5
Breed stock (layer)	0	64.75	400	0	0	64.75	0	64.75	0	64.75
Breed stock (cockerel)	0	9.83	0	60.5	0	60.5	0	60.5	0	57.37
Lime	31.71	0	0	0.29	0	0.29	32.52	0	0	0.29

HL = Human labour

APPENDIX H

Sub-Saharan Africa Livestock Conversion Units

Table 56: Tropical livestock unit (TLU) conversion table

Livestock	Weight of animal (kg)	TLU equivalent
Cattle		
Bull > 3years	320	1.20
Castrated adult male (oxen > 3years)	400	1.42
Immature males (< 3years)	200	0.85
Mature cow (calved >once)	250	1.00
Heifers	180	0.78
Pre-weaning males	70	0.38
Pre-weaning females	80	0.43
Goat	25	0.20
Sheep	25	0.20
Poultry	3	0.04
Rabbit	3	0.04
Pigs	50	0.30

Source: Njuki *et al.* (2011)

APPENDIX I

Probability values of Calculated Z-Scores

Table 57: Probability of Achieving Selected Negative Z-Scores

Z-Score	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-4.00	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
-3.90	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
-3.80	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
-3.70	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
-3.60	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
-3.50	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
-3.40	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
-3.30	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.20	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007	0.0007	0.0007
-3.10	0.0012	0.0012	0.0011	0.0011	0.0011	0.001	0.001	0.001	0.0009	0.0009
-3.00	0.0016	0.0015	0.0015	0.0014	0.0014	0.0014	0.0013	0.0013	0.0013	0.0012
-2.90	0.0021	0.002	0.002	0.0019	0.0019	0.0018	0.0018	0.0017	0.0017	0.0016
-2.80	0.0028	0.0027	0.0026	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0022
-2.70	0.0037	0.0036	0.0035	0.0034	0.0033	0.0032	0.0031	0.003	0.0029	0.0029
-2.60	0.0048	0.0047	0.0046	0.0045	0.0043	0.0042	0.0041	0.004	0.0039	0.0038
-2.50	0.0063	0.0062	0.006	0.0058	0.0057	0.0055	0.0054	0.0052	0.0051	0.005
-2.40	0.0083	0.0081	0.0078	0.0076	0.0074	0.0072	0.0071	0.0069	0.0067	0.0065
-2.30	0.0107	0.0105	0.0102	0.0099	0.0097	0.0094	0.0092	0.0089	0.0087	0.0085
-2.20	0.0138	0.0135	0.0132	0.0128	0.0125	0.0122	0.0119	0.0116	0.0113	0.011
-2.10	0.0177	0.0173	0.0169	0.0165	0.0161	0.0157	0.0153	0.0149	0.0146	0.0142
-2.00	0.0226	0.022	0.0215	0.021	0.0205	0.02	0.0195	0.0191	0.0186	0.0182
-1.90	0.0285	0.0278	0.0272	0.0266	0.026	0.0254	0.0248	0.0242	0.0237	0.0231
-1.80	0.0357	0.0349	0.0341	0.0334	0.0327	0.0319	0.0312	0.0305	0.0298	0.0292
-1.70	0.0444	0.0434	0.0425	0.0416	0.0407	0.0398	0.039	0.0381	0.0373	0.0365
-1.60	0.0546	0.0535	0.0524	0.0514	0.0503	0.0493	0.0483	0.0473	0.0463	0.0453
-1.50	0.0667	0.0654	0.0642	0.0629	0.0617	0.0605	0.0593	0.0581	0.0569	0.0558
-1.40	0.0808	0.0793	0.0778	0.0763	0.0749	0.0735	0.0721	0.0707	0.0694	0.068
-1.30	0.0969	0.0952	0.0935	0.0918	0.0902	0.0886	0.087	0.0854	0.0838	0.0823
-1.20	0.1153	0.1133	0.1114	0.1095	0.1077	0.1058	0.104	0.1022	0.1004	0.0986
-1.10	0.1359	0.1337	0.1316	0.1295	0.1274	0.1253	0.1232	0.1212	0.1192	0.1172
-1.00	0.1589	0.1565	0.1541	0.1517	0.1494	0.1471	0.1448	0.1425	0.1403	0.1381
-0.90	0.1842	0.1816	0.179	0.1764	0.1738	0.1713	0.1687	0.1662	0.1638	0.1613
-0.80	0.2119	0.209	0.2062	0.2034	0.2006	0.1978	0.195	0.1923	0.1896	0.1869
-0.70	0.2419	0.2388	0.2357	0.2327	0.2296	0.2266	0.2236	0.2207	0.2177	0.2148
-0.60	0.2741	0.2708	0.2675	0.2642	0.2609	0.2577	0.2545	0.2513	0.2482	0.245
-0.50	0.3083	0.3048	0.3013	0.2978	0.2944	0.2909	0.2875	0.2841	0.2808	0.2774
-0.40	0.3444	0.3407	0.337	0.3334	0.3297	0.3261	0.3225	0.3189	0.3154	0.3118
-0.30	0.382	0.3782	0.3744	0.3706	0.3668	0.363	0.3593	0.3555	0.3518	0.3481
-0.20	0.4209	0.4169	0.413	0.4091	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.10	0.4604	0.4564	0.4525	0.4485	0.4445	0.4406	0.4366	0.4327	0.4287	0.4248
0.00	0.5	0.4961	0.4921	0.4882	0.4842	0.4802	0.4763	0.4723	0.4683	0.4644

Table 58: Probability of Achieving Selected Positive Z-Scores

Z-Score	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.00	0.5	0.5039	0.5079	0.5118	0.5158	0.5198	0.5237	0.5277	0.5317	0.5356
0.10	0.5396	0.5436	0.5475	0.5515	0.5555	0.5594	0.5634	0.5673	0.5713	0.5752
0.20	0.5791	0.5831	0.587	0.5909	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.30	0.618	0.6218	0.6256	0.6294	0.6332	0.637	0.6407	0.6445	0.6482	0.6519
0.40	0.6556	0.6593	0.663	0.6666	0.6703	0.6739	0.6775	0.6811	0.6846	0.6882
0.50	0.6917	0.6952	0.6987	0.7022	0.7056	0.7091	0.7125	0.7159	0.7192	0.7226
0.60	0.7259	0.7292	0.7325	0.7358	0.7391	0.7423	0.7455	0.7487	0.7518	0.755
0.70	0.7581	0.7612	0.7643	0.7673	0.7704	0.7734	0.7764	0.7793	0.7823	0.7852
0.80	0.7881	0.791	0.7938	0.7966	0.7994	0.8022	0.805	0.8077	0.8104	0.8131
0.90	0.8158	0.8184	0.821	0.8236	0.8262	0.8287	0.8313	0.8338	0.8362	0.8387
1.00	0.8411	0.8435	0.8459	0.8483	0.8506	0.8529	0.8552	0.8575	0.8597	0.8619
1.10	0.8641	0.8663	0.8684	0.8705	0.8726	0.8747	0.8768	0.8788	0.8808	0.8828
1.20	0.8847	0.8867	0.8886	0.8905	0.8923	0.8942	0.896	0.8978	0.8996	0.9014
1.30	0.9031	0.9048	0.9065	0.9082	0.9098	0.9114	0.913	0.9146	0.9162	0.9177
1.40	0.9192	0.9207	0.9222	0.9237	0.9251	0.9265	0.9279	0.9293	0.9306	0.932
1.50	0.9333	0.9346	0.9358	0.9371	0.9383	0.9395	0.9407	0.9419	0.9431	0.9442
1.60	0.9454	0.9465	0.9476	0.9486	0.9497	0.9507	0.9517	0.9527	0.9537	0.9547
1.70	0.9556	0.9566	0.9575	0.9584	0.9593	0.9602	0.961	0.9619	0.9627	0.9635
1.80	0.9643	0.9651	0.9659	0.9666	0.9673	0.9681	0.9688	0.9695	0.9702	0.9708
1.90	0.9715	0.9722	0.9728	0.9734	0.974	0.9746	0.9752	0.9758	0.9763	0.9769
2.00	0.9774	0.978	0.9785	0.979	0.9795	0.98	0.9805	0.9809	0.9814	0.9818
2.10	0.9823	0.9827	0.9831	0.9835	0.9839	0.9843	0.9847	0.9851	0.9854	0.9858
2.20	0.9862	0.9865	0.9868	0.9872	0.9875	0.9878	0.9881	0.9884	0.9887	0.989
2.30	0.9893	0.9895	0.9898	0.9901	0.9903	0.9906	0.9908	0.9911	0.9913	0.9915
2.40	0.9917	0.9919	0.9922	0.9924	0.9926	0.9928	0.9929	0.9931	0.9933	0.9935
2.50	0.9937	0.9938	0.994	0.9942	0.9943	0.9945	0.9946	0.9948	0.9949	0.995
2.60	0.9952	0.9953	0.9954	0.9955	0.9957	0.9958	0.9959	0.996	0.9961	0.9962
2.70	0.9963	0.9964	0.9965	0.9966	0.9967	0.9968	0.9969	0.997	0.9971	0.9971
2.80	0.9972	0.9973	0.9974	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9978
2.90	0.9979	0.998	0.998	0.9981	0.9981	0.9982	0.9982	0.9983	0.9983	0.9984
3.00	0.9984	0.9985	0.9985	0.9986	0.9986	0.9986	0.9987	0.9987	0.9987	0.9988
3.10	0.9988	0.9988	0.9989	0.9989	0.9989	0.999	0.999	0.999	0.9991	0.9991
3.20	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993	0.9993	0.9993
3.30	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.40	0.9995	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996
3.50	0.9996	0.9996	0.9996	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997
3.60	0.9997	0.9997	0.9997	0.9997	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998
3.70	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998
3.80	0.9998	0.9998	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.90	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
4.00	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999