Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

OPTIMUM ENTERPRISE MIX UNDER RISK AND LIMITED RESOURCE CONDITIONS AMONG SMALLHOLDER LIVESTOCK FARMERS IN KWARA STATE, NIGERIA

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ABSTRACT
The study developed optimum and a set of risk efficient livestock enterprise mix for smallholder farmers in Kwara State, Nigeria. Multi-stage sampling procedure was used to select 127 smallholder livestock farmers. A structured questionnaire complimented with interview schedule was used to obtain cross-sectional data from the farmers. Data were analyzed using descriptive statistics, farm budgeting technique, LP (linear programming) and T-MOTAD (Target minimization of total absolute deviation) models. The LP result prescribed 0.25TLU of cattle/goat/sheep, 0.37TLU of broiler and 0.47TLU of broiler/layer for optimum gross margin in plan I; and 0.29TLU of cattle/goat/sheep, 0.37TLU of broiler and 0.47TLU of broiler/layer were prescribed in plan II under the limited resource condition. A set of feasible risk efficient farm plans I, II and III were obtained with the T-MOTAD model. The plan I prescribed 0.25TLU of cattle/goat/sheep, 0.37TLU of broiler and 0.47TLU of broiler/layer. Plan II prescribed 0.07TLU of cattle/goat/sheep, 0.28TLU of broiler and 0.79TLU of broiler/layer; and plan III prescribed 0.36TLU of cattle/goat/sheep, 0.05TLU of broiler, 0.48TLU of cockerel and 0.23TLU of broiler/layer. Gross margin increased from ₦218,170.75/TLU in the existing plan to ₦242,662.30/TLU and ₦247,676.00/TLU in optimum plans I and II, respectively, and to ₦242,670.60/TLU, ₦235,065.60/TLU and ₦222,897.90/TLU in risk efficient plans I, II and III, respectively. Gross margin was more sensitive to variation in the prices of output than other variables. Labour and capital were the major limiting resource across all the plans for the livestock enterprises. It was concluded that the livestock farmers had the potential to maximize gross margins per unit enterprise in the optimum and risk efficient farm plans as resources were not optimally allocated in the existing plan for livestock activities. Farmers should therefore adopt the prescribed optimum and risk efficient farm plans.

Keywords: Farm Plans, Livestock Enterprises, Limited Resources, Kwara, Smallholder Farmers, Risk.

INTRODUCTION
Agriculture has continued to contribute immensely to the wellbeing of Nigerians as well as the economy of the country as it provides food, raw materials for agro-based industries as well as income to the farmers (Sani *et al.*, 2013). The livestock industry as an important component of the general agriculture is a key contributor to the economic growth and development of any nation as it has the capacity for providing food, employment, farm energy, manure and revenue for the farmers and even the government as argued by Ojiako and Olayode (2008). Livestock production in Nigeria constitutes 6% of the total Gross Domestic Product (GDP) and 25% to the agriculture sector over the last two decades (Ogunniyi and Ganiyu, 2014). 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.

Smallholder farmers who are key actors in economy of many countries of the world are characterised with limited level of resources and are faced with the challenge of competing choices for allocating farm resources between different farm enterprises. The farmers' ultimate aim is to attain production objectives by making efficient utilisation of the limited available resources at their disposal and combining farm enterprises optimally as affirmed by Ohajianya and Oguoma (2009) and Igwe *et al.* (2015). Foster and Rauser (1991) 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 according to Adubi (1992) is a pervasive phenomenon in any economic activity which is particularly important in traditional agriculture where it affects production decisions and adoption of technology among others. Many factors including weather, diseases, insect infestations, general economic conditions, the development and adoption of technological innovations, public and private institutional policies interact to create a unique decision making environment for the agricultural producer. Smallholder farmer's production decisions are generally made under this environment of risks and uncertainties.

Mathematical programming as an optimization tool 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). These mathematical programming tools such as the quadratic programming (QP) along with linear programming/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 popular methods in the agricultural economics literature on risk-return analysis particularly in Nigeria. However, most of these research efforts aimed to inquire into the possibilities of maximising farm production and income 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 in the risk programming models. There is need for farmers to also consider the livestock enterprises as suitable strategies for augmenting the farm income and in all intent, enterprise diversification.

In this study, the focus was on incorporating risk into farm planning model to derive integrated optimum livestock enterprise combinations that will offer more realistic solutions and increase farm income for the smallholder livestock farmers in Kwara State, Nigeria. 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 incomes and food security. Risk efficient farm enterprise plans will provide a valuable guide to existing and intending livestock farmers and will be a huge step towards efficient resource allocation, increased production and income generation which will in the long run enhance food security and improve the farmers' standard of living.

MATERIALS AND METHODS

The Study Area

The study was conducted in Kwara State, Nigeria. 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. The mean annual rainfall ranges between 1000mm and 1500mm. The State has a total population

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

of 2,371,089 persons (Kwara State Planning Commission (KWSPC), 2007) and a projected population of 3,490,209 as at 2020. The State has a total land area of 32,500 square kilometres (Kwara State Ministry of Agriculture and Natural Resources (KWSMANR), 2010). 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 and rearing animals. The major tribes in the State are Yoruba, Nupe and Baruba. Other tribes present include Fulani, Igbo and Hausa.

Sampling Procedure

A multi-stage sampling procedure was employed for this study. All smallholder livestock farmers in Kwara State constituted the population of study. The farmers were identified and selected with the assistance of the village heads and the resident extension agents. A total of 127 livestock farmers were sampled for the study.

Method of Data Collection

Primary data were used for this study. The cross-sectional data were collected from the farmers through a limited cost-route approach in the study area with the aid of a structured questionnaire. The structured questionnaire was complimented with interview schedules. Resident extension agents and enumerators were trained to assist during the data collection process. This was to facilitate access given this category of extension agents and enumerators are conversant with the study locations and are familiar with the target farmer populations.

Analytical Techniques

Data analysis involved the use of descriptive statistics, farm budgeting model, linear programming and target-minimization of total absolute deviation (T-MOTAD) models. Descriptive statistics involved the use of tables, percentages and means.

A farm budgeting model was used to estimate the costs and returns associated with the various livestock enterprises undertaken by the smallholder farmers. The gross margins (GM) as well as the corresponding net farm incomes (NFI) were computed. The farm budgeting model following Ibeun *et al.* (2018) and Adewumi *et al.* (2018) was used and is specified in equation 1 and 2:

$$GM = \sum_{i=1}^{n} P_{yi}Y_i - \sum_{j=1}^{m} P_{xj}X_j \quad \ldots(1)$$

$$NFI = \sum_{i=1}^{n} P_{yi}Y_i - \sum_{j=1}^{m} P_{xj}X_j - \sum_{k=1}^{o} F_k \quad \ldots(2)$$

where;

GM = Gross Margin,

NFI = Net farm income,

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

P_{yi} = Unit price of the product,

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

Linear programming (LP) model was used to derive optimum livestock combination plan for the smallholder farmers in the study area. The LP model adopted from Igwe *et al.* (2013), Bamiro *et al.* (2015) and Jirgi *et al.* (2018) and modified for this study is specified in equation 3. The objective function of the model was to maximize the gross margin of the smallholder farmers for each livestock enterprise undertaken which is total farm revenue less the total variable costs of production, that is gross income minus costs of breed stock, feed, veterinary services, vaccination and medications, labour, commission fees and transportation. For this study, the unit of activity for each livestock enterprise was one tropical livestock unit

Journal of Agripreneurship and Sustainable Development (JASD)
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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

(TLU).
The objective function was stated as:

$$\text{Maximize } Z_l = \sum P_j X_j \quad \ldots (3)$$

Subject to:

$$A_{ij}X_j \leq \beta_i t \quad \ldots (4)$$

$$\sum L_{ij}X_j \geq f_l \text{ (Min)(Minimum farm family livestock product requirement)} \quad \ldots (5)$$

and

$$X_j \geq 0 \quad (\text{non} - \text{negativity assumption}) \quad \ldots (6)$$

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} = 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 in t^{th} period,
L_{ij} = Minimum farm family i^{th} livestock product requirement for j^{th} farm enterprise.
F_l = Level of food (livestock protein) consumed in kilograms/annum in t^{th} period.

Target minimization of total absolute deviation (T-MOTAD) model was also used to analyse the data. To incorporate risk into the LP model, the modified T-MOTAD model adopted following 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 condition was used as the target return (T_r) in this model. The objective function was specified as:

$$Max\ E(Z) = \sum P_j X_j \quad \ldots (7)$$

Subject to:

$$\sum A_{ij}X_j \leq \beta_i \text{ (Technical resources requirement for livestock activities)}, \quad \ldots (8)$$

$$\sum L_{ij}X_j \geq \delta_i \text{ (Farm family livestock product requirement)}, \quad \ldots (9)$$

$$\sum C_{rj}X_j \geq T_r \text{ (Absolute deviations from } T_r\text{)}, \quad \ldots (10)$$

$$\sum P_r Y_r = \lambda \text{ (Risk: – ve deviations (₦))} \quad \ldots (11)$$

and

$$X_j \geq 0 \quad \ldots (12)$$

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

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

λ = A constant parameterised from M to 0.

RESULTS AND DISCUSSION

Costs and Return Analysis of Smallholder Livestock Enterprises

The result of the costs and returns analysis for each livestock enterprises undertaken by the smallholder farmers in Kwara State is presented in Table 1. The variable and fixed costs of production, revenue, gross margin and net farm income per unit enterprise were computed. 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 constitute the variable cost of the livestock enterprise. The fixed cost items were depreciation on tools, rent, tax and interest on credit. Based on the estimated gross margins, net farm incomes and the gross ratios, it is that all the livestock enterprises in the area were profitable. Layer enterprise is the most profitable with a net farm income of ₦278,631.08 which is closely followed by broiler/layer enterprise with net farm income of ₦268,824.96. On the hand, cockerel and goat enterprises were the least profitable livestock enterprises with net farm income of ₦122,520.29 and ₦172,045.18, respectively. However, the computed gross ratios revealed that sheep and cattle/sheep were the most profitable livestock enterprises while broiler and broiler/cockerel were the least profitable. The profitability of livestock enterprises in the study are is in consensus with the reports of Bamiro *et al.* (2015) and Jacob (2019) that livestock enterprise is a profitable farm enterprise in Southwest and Niger State Nigeria, respectively.

Table 1: Cost and Return Analysis of Livestock Enterprises Undertaken by the Farmers

Livestock Enterprises	Average amount (Naira per tropical livestock unit (TLU))						
	TVC	TFC	TC	TR	GM	NFI	GR
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

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

Source: Field survey data (2019)

Livestock Enterprise Combinations under Risk and Limited Resource Conditions

This section presents results of analysis of optimum livestock enterprise mix that will maximize the gross margins of the farmers under risk and limited resource conditions in the study area. With LP model, optimum plan I aimed at gross margin maximization alone under owned and borrowed capital was obtained, while optimum plan II was obtained under the limited resource condition. Given the risky nature of livestock enterprises and since farmers

Journal of Agripreneurship and Sustainable Development (JASD)
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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

differ in the degree to which they accept risk, the risk attitudes are generally classified as risk-averse, risk-takers and risk-neutrals. Among the sampled farmers, those who are risk neutrals and risk takers are most likely to adopt optimum plans I and II. Furthermore, a set of feasible risk efficient farm plans (I, II and III) were also obtained with the T-MOTAD model by parameterizing 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.

The result of existing, optimum and risk efficient livestock enterprise plans using the LP model and T-MOTAD model for livestock enterprises is presented in Table 2. It shows that the farmers' existing livestock plan, 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 plan 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 result prescribed 0.25TLU for cattle/goat/sheep, 0.37TLU for broiler and 0.47TLU for broiler/layer for the smallholder famers 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) that recommended broiler and layer 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 2: 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	1.20	-	-	-	-	-
Goat	1.50	-	-	-	-	-
Sheep	1.30	-	-	-	-	-
Cattle/goat	1.40	-	-	-	-	-
Cattle/sheep	1.30	-	-	-	-	-
Goat/sheep	1.10	-	-	-	-	-
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
Layer	1.10	-	-	-	-	-
Cockerel	1.25	-	-	-	-	0.48
Layer/cockerel	1.05	-	-	-	-	-
Broiler/cockerel	1.08	-	-	-	-	-
Broiler/layer	0.99	0.47	0.47	0.47	0.79	0.23
Broiler/layer/cockerel	1.05	-	-	-	-	-

Source: Field survey data (2019)

Looking further at Table 2 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 risk

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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

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 position to yield more returns for the smallholder farmers. They are also the optimal means to meet the farm family protein requirement 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.

Marginal Opportunity Cost of Excluded Livestock Enterprises

The marginal opportunity costs also known as shadow prices of the excluded livestock enterprises in the various obtained plans are presented in Table 3. 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 guide the farmers towards the attainment of profit maximization and 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 a better competitive position to fit into the various derived plans respectively compared to the other excluded enterprises. Amazingly, in all the derived plans, sole goat enterprise had the highest MOC value. The implication of this is that sole goat enterprise has the worst competitive position to fit into the various derived plans, respectively, among all the other excluded enterprises. This is a strong indication that the smallholder farmers should stare clear from sole goat enterprise if they aim to maximize profit and minimize the associated risk in livestock enterprise in Kwara State. Specifically, 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.

Table 3: 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: Field survey data (2019)

Journal of Agripreneurship and Sustainable Development (JASD)
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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

Marginal value product (MVP) of resources under livestock enterprises

The result obtained from the LP and T-MOTAD solutions for livestock enterprises showing the marginal value product of resources also known as shadow prices is presented in Table 4. 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. However, on the contrary, human 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.

Table 4: 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)

*Figures in parenthesis are slack/surplus values; HL = Human labour
Source: Field survey data (2019)

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

Gross margin in Existing, Optimum and Risk Efficient Livestock Plans

The average 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 in the area is presented in Figure 1. The estimated gross margin in the existing farm plan was ₦218,170.75/TLU. Whereas, average 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 is an average 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. This result is similar to those obtained from the study carried out by Bamiro *et al.* (2015) and Jacob (2019) on optimum livestock production plans among farmers in the Southwest and Niger State Nigeria, respectively. It also corroborates the findings of Jirgi *et al.* (2018) that gross margins obtained in optimized farm plans offers a higher and better value than the gross margins obtainable in the farmers' existing farm plans.

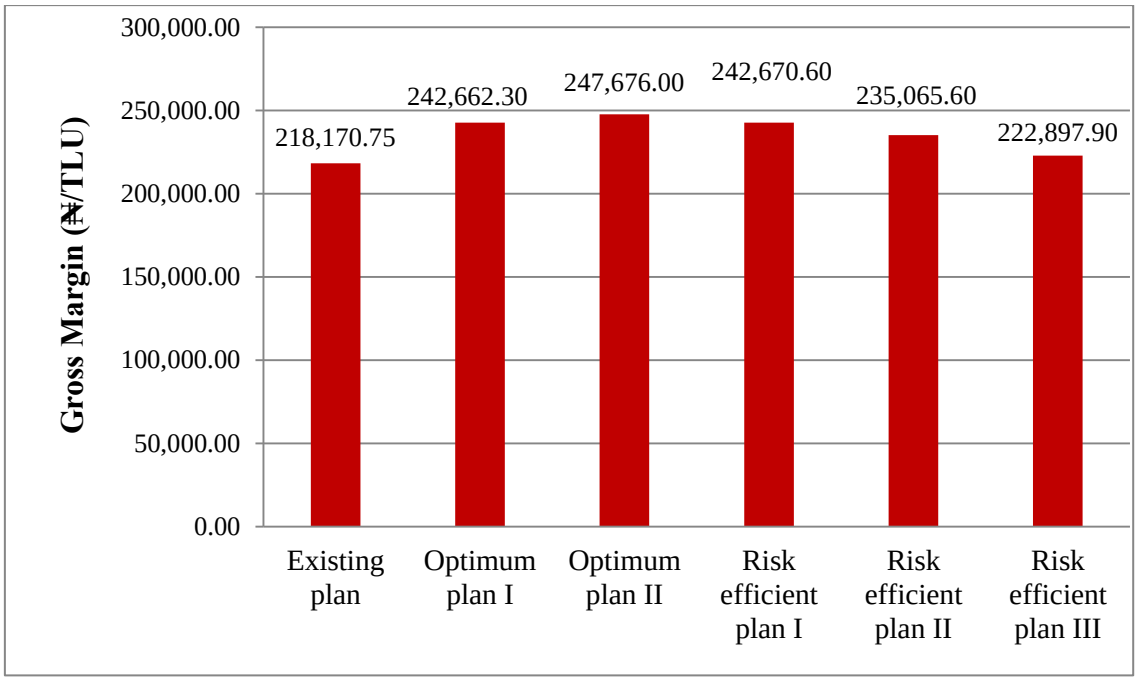


Figure 1: *Gross margin in the existing, optimum and risk efficient livestock plans*

More so, as presented in Figure 1, 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 average 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. The average gross margins obtained in the risk efficient plans are slightly lower than those obtained in optimum plans I and II, especially for risk efficient plan II and III. The differences in these gross margins could be regarded as the risk premium payable by the smallholder farmers for foregoing more risky optimum farm plans and adopting farm plans with minimized risk.

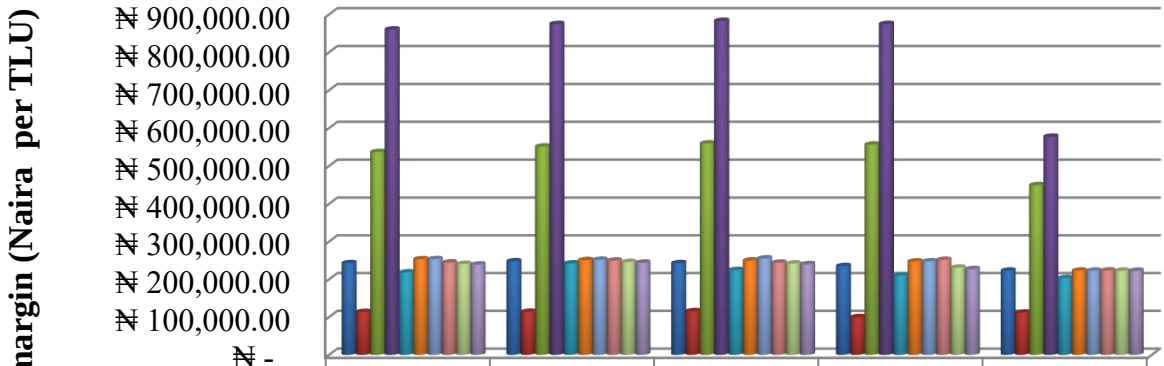
It is worthy to note that the average gross margin of the farmers increased across the optimum and risk efficient plans. It however increased proportionately highest in optimum plan II and least in risk efficient plan III. The implication of these increments in the optimum and

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

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.

Sensitivity Analysis of Gross Margin for Livestock Enterprises

Sensitivity analysis was carried out to examine the effect of varying selected variables on the gross margins of the livestock farmers in the derived plans. The results are presented in Figure 2. The 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 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 livestock production.



	Optimum plan I	Optimum plan II	Risk efficient plan I	Risk efficient plan II	Risk efficient plan III
Previous value	₦ 242,662.3	₦ 247,676.0	₦ 242,670.6	₦ 235,065.6	₦ 222,897.9
Output price (-50%)	₦ 113,494.9	₦ 113,939.4	₦ 115,646.9	₦ 99,709.34	₦ 111,678.4
Output price (+50%)	₦ 536,649.4	₦ 551,085.3	₦ 559,348.1	₦ 556,388.2	₦ 449,288.4
Output price (+100%)	₦ 859,922.8	₦ 874,400.4	₦ 882,740.4	₦ 874,409.7	₦ 576,937.4
Capital (-50%)	₦ 218,344.3	₦ 241,981.3	₦ 224,429.6	₦ 210,724.2	₦ 203,095.6
Capital (+50%)	₦ 253,014.5	₦ 250,835.3	₦ 249,658.3	₦ 247,234.3	₦ 222,897.9
Capital (+100%)	₦ 253,372.0	₦ 251,543.6	₦ 255,200.4	₦ 247,435.2	₦ 222,897.9
Labour (-50%)	₦ 244,527.0	₦ 249,534.8	₦ 243,958.8	₦ 251,503.5	₦ 223,260.7
Labour (+50%)	₦ 240,814.2	₦ 245,857.4	₦ 241,742.4	₦ 230,997.3	₦ 222,735.1
Labour (+100%)	₦ 238,957.8	₦ 243,996.0	₦ 239,886.0	₦ 226,929.1	₦ 222,572.3

Figure 2: *Sensitivity analysis of gross margin to variation in output price, capital and labour wage rate for smallholder livestock enterprises*

When prices of out was varied at -50.00%, it was observed that gross margin 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 margin marginally increased by more than 100.00%

across all the plans. Also, gross margin increased marginally by more than 200.00% across all the plans except in risk efficient plan III wherein it only increased by 158.83% when prices of output was varied by +100.00%. This is clear indication that gross margin in livestock enterprises is very sensitive to changes in prices of output.

The sensitivity analysis of gross margin to variation in amount of capital revealed that when capital was reduced by 50.00%, 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 varied by +50%, gross margin increased slightly by 4.27%, 1.28%, 2.88%, and 5.18% in all the plans, respectively, except in risk efficient plan III. Similar result was recorded when capital was varied by +100%, the obtainable gross margin for the farmers increased slightly except in risk efficient plan III.

For variation in human labour wage rate, 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 were recorded at -50.00% variations. When varying the wage rate of labour by +50.00%, it was observed that gross margin 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. Whereas, variation by +100.00% in labour wage rate resulted to marginal decrease in the gross margin across all plans by an average of 1.55% only. 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.

CONCLUSION AND RECOMMENDATIONS

It was concluded based on the findings of this study that resources were not allocated optimally by the smallholder livestock farmers in Kwara State. Nonetheless, all the enterprises considered were profitable in the study area. The mixed farm enterprises were in better competitive positions than sole farm enterprises in the optimum and risk minimized plans. 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 farmers have the potential to maximize their gross margin by adopting the optimum and risk efficient farm plans prescribed in the LP and T-MOTAD solutions, that is, they should undertake the various enterprise mixtures that fit into the plans. This would help them to achieve increased farm incomes, reduced cost of production, risk minimization and food security. In essence, the optimum plans should be incorporated in to extension education content of the Kwara State ADP.

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