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(Research Article)

Optimum enterprise combination of selected food crops and broiler production systems in the Federal Capital Territory, Abuja, Nigeria

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Abstract

The purpose of this study was to determine the optimum enterprise combination of selected food crops and broiler production systems in the Federal Capital Territory (FCT), Abuja, Nigeria with a view of recommending to the farmers the optimum combination that maximizes their gross margin. A two-stage sampling technique was used to select 80 respondents for the study using a well-structured questionnaire. The data were analyzed using gross margin analysis and linear programming (LP) model. Findings revealed that farmers in the study area combined broiler production with the combination of maize/cassava and maize/sorghum crops. Analysis of the cost and returns showed that all the enterprise combinations were profitable with a gross margin of ₦1,478,449.64, ₦469,690.3 and ₦143,720.8 for broiler, maize/cassava and maize/sorghum combination respectively. The result of the linear programming revealed that broiler production and maize/cassava combination would maximize a gross margin of ₦2,326,408 from cultivating 1.7 ha of maize/cassava and producing 407 broilers. The dual or shadow price of 609987.5 for land and 30546.48 for feed implies that cultivating additional hectare of maize/cassava and feeding the broilers with additional bag of 25kg feed would improve or increase the objective value to a value of ₦2,936,395.5 and ₦2,356,954.48 respectively. Based on these findings we recommend that the farmers should combine maize/cassava and broiler production as these enterprises will increase their gross margin per hectare.

Keywords: Linear Programming; Boiler; Optimum; Gross margin; Poultry

1. Introduction

According to Food and Agriculture Organization [1] the world's population is estimated to reach 9.1 billion by 2050, which is 34% higher than today. To feed this population, overall food production would need to be raised by 70% between 2005/07 and 2050, with production in developing countries almost doubling. Annual cereal production, for instance, would have to grow by almost one billion tons, meat production by over 200 million tons to a total of 470 million tons in 2050, 72% of which in the developing countries, up from the 58% today. Nigeria is the most populous country in Africa with a population of over 230 million [2] and a domestic economy in which agriculture is a dominant sector such that agriculture alone accounts for about 36% of the gross domestic product (GDP) and about 37.99% of total employment in Nigeria as at 2022 [3].

Poultry production is significant to the Nigerian economy because the industry is worth $4.2 billion and contributes about 6 – 8% annually to real gross domestic product (GDP) and about 30% to agricultural GDP making it the largest producer of poultry eggs and fourth largest poultry meat producer in Africa [4]. The industry contributes about 15

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percent of the total annual protein intake [5] and about 10 percent of the Nigerian population is engaged in poultry production [6]. Within the Nigeria poultry sub–sector, broiler production is also an important enterprise because it has incredible potentials for expanding protein supply due to its fast growth rates and productivity of the animal [7].

The agricultural production system in sub–Saharan Africa and Nigeria in particular is comprised of crops and livestock sub–sectors operated in form of sole cropping or mixed farming systems (crops–livestock integration). According to [8] increasing integration of crops and livestock is going to occur over at least the next 30 years in sub–Saharan Africa.

Several distinguishable benefits are derivable from enterprise combination. For instance, [9] noted that crop-livestock systems provide opportunities for the improvement of the two production components of sub-systems at the same time. Also, it allows improvements in the workforce, the stability of production and reducing production related risks; greater chances of producers reaching their socio-cultural aspirations; and greater food security to meet the needs of consumers regarding the diversity and quality of products they may get at a given point in time. Furthermore, a high level of biodiversity is maintained, which is essential to support the intensive agricultural systems required to achieve food security and reduce environmental degradation while concomitantly adapting agriculture to climate change [10]. Therefore, enterprise combination is crucial to bridging the food supply–demand gap, increasing farm returns, mitigate risk and maximize the use of limited and scarce resources. However, the extent to which these complex objectives are realized depends to a large extent on how farmers allocate scarce resources among these competing enterprises in the face of rising cost of inputs.

The major challenge in crop – livestock combination is that farmers find it difficult to effectively allocate resources to each of the enterprises in order to maximize their objectives. The traditional methods of taking such decisions are through farmers' experiences, instincts and neighborhood comparison. According to [11] instincts and experience do not always guarantee optimal results. In a similar vein, [8] pointed out that modelling of crop and livestock enterprises has remained under - developed and although a wide variety of separate crop and livestock models exists, the nature of crop – livestock and their importance in small – holder farming systems make integration difficult.

According to [12] most of the agricultural researches being conducted to benefit the poor in SSA are hampered by the historical lack of cross - disciplinary linkages and cross - sectorial approaches. Failure to address challenges in an integrated manner continues to limit adoption and use of most agricultural research results by smallholders. Consequently, many continue to poorly understand and address interactions that contribute to poverty alleviation, food security, and sustainable resource use by smallholders in SSA [13].

Previous empirical studies on enterprise combination in Nigeria and elsewhere focused primarily on sole crop or livestock (see [14]; [15]; [16]; [17]; among others) while a few that examined crops and livestock combination ([18]; [19]; just to mention a few) did not examine crops and broiler combination. There is dearth of quantitative empirical evidence on crop –livestock integration, especially crop – broiler integration in Nigeria and FCT in particular in recent time. This study was carried out in an attempt to fill this study gap and to compliment the literature on farm enterprise combination.

The outcome of this study would be beneficial to farmers because they are constantly seeking ways of maximize net returns from their investments. This is of particular significance in the face of rising cost of farm inputs and competitive demand for fixed input such as land for other productive uses. The outcome would serve as a guide to farmers on how to maximize the use of available limited and scarce resources.

2. Material and methods

This study was carried out in FCT located within the North central region of Nigeria. It lies within latitude 7^0 25N and 9^0 20N of the equator and longitude 5^0 25E and 7^0 39E of the meridian. The territory occupies an area of about 1,769km$^{2.}$ .There are six area councils in the FCT, namely; Abaji, Munincipal, Gwagwalada, Kuje, Bwari and Kwali. Predominant food crops grown in the area are yam, maize, millet, cassava, Sorghum, Sesame, among others.

Primary data collected using a well-structured questionnaire was used for this study. A two–stage sampling technique was used in the selection of respondents for this study. In stage one, four (4) area councils, namely: Bwari, Gwagwalada, Kuje and Kwali were purposively selected out of the six (6) area councils based on concentration of poultry farms in these areas. In the second stage, twenty (20) poultry farmers who combined food crops with broiler production were selected each from the four (4) area councils giving a total of eighty (80) respondents. Data for the study were collected on the type of food crops combined with broiler production, costs and prices of inputs and outputs, quantities of inputs used and outputs obtained by the respondents. Data on crops were collected for the 2022/2023 cropping season while that on broilers were on average of three batches of production for 2023 production season. Data collected were analyzed using gross margin analysis and linear programming technique.

Gross margin analysis was used to estimate cost and returns associated with crop–broiler production enterprises. The gross margin for each enterprise is specified as follows:

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

Where:

GM = Gross margin
Yi = Enterprise's output per hectare (where i = 1, 2, 3… n products),
P_{yj} = Unit price of the output,
P_{xj} = Price per unit of variable inputs.
X_j = Quantity of the variable inputs per hectare (where j =, 1, 2, 3, m variable inputs)
A linear programming model was used to derive optimum enterprise combination in food crop–broiler production systems in the study area. The LP model is specified as follows

The objective function:

$$Max\ GM = \sum_{i=1}^{n} P_iX_i \quad \text{......... (2)}$$

Subject to:

AX_{11}+ AX_{12} + AX_{13} ≤ L_s (Land Constraint) …………….. (3)

AX_{21}+ AX_{22} + AX_{23} ≤ M_L (Labour Constraint) ………….. (4)

AX_{31}+ AX_{32} + AX_{33} ≤ N_A (Agrochemical Constraint) ………….. (5)

AX_{41} + AX_{42} + AX_{43} ≤ Q_F (Feed Constraint) ………… (6)

AX_{51}+ AX_{52} + AX_{53} ≤ N_c (Flock Capacity Constraint) ………… (7)

And

X_1 > 0 ; X_2 > 0; X_3 > 0 (Non – negativity constraints)

Where:

GM = Gross Margin
X_i = Different food crop - broiler combination or enterprise undertaken (decision variables),
P_i = Gross margin per hectare of the different crop enterprise maximized,
A_{ij} = Input - Output coefficients, that is, quantity of i^{th} resource (land, labour, feed, flock and agrochemical) required to produce a unit output of j^{th} crop - broiler activity,
L_S = Level of available land in hectare for crop activities with s restriction,
M_L = Level of available labour in man-day for crop activities in t^{th} period,
N_A = Level of available agrochemical in litres for crop activities in t^{th} period.
Q_F = Quantity of broiler feed available t^{th} period
N_c = Flock capacity or size that can be produced at t^{th} period

LP was used for the analysis because of the proportionate characteristics of the allocation problems which helps in defining the technical relationship between inputs and outputs [20]. Therefore LP can be used for farm planning and decision making particularly in farming practices of raising more than one crop on the same land at the same time [21] and in combining different enterprises on the farm

3. Results and discussion

The different enterprises' gross margins, resources used and their availability in food crop–broiler production systems in the study area are presented in Table 1.

Table 1 Summary of enterprises and resources used

Enterprise	Gross Margin	Land	Labour	Feed	Agrochemical	Capacity
Broiler (X_1)	1478450	-	98.7	48.4	-	394.6
Maize/Cassava(X_2)	469690	0.8	51.3	-	2.07	-
Maize/Sorghum(X_3)	143721	0.5	46.4	-	1.9	-
Requirement/ Availability		1.3	196	48.4	3.97	500

Source: Field Survey, 2021

As shown in Table 1, all the enterprises embarked upon by the respondents Broiler and Maize/Cassava returns the highest gross margins of ₦1,478,450 and ₦469,690.3 respectively. The total land size available was 1.31 ha out of which 0.77ha was used for Maize/Cassava while Maize/Sorghum mixture was cropped on the remaining 0.54 ha. The total labour available was 196.28 man - days out of which boiler production took 98.67 man–days. Only 50 bags of 25kg broiler feeds were available. Only 4 litres of agrochemical was available while the average number of birds raised by the respondents was 395 even though the flock capacity was 500 birds.

The results of this study revealed two (2) food crops combined with broiler production by respondents in the study area; these are: Maize/Cassava and Maize /Sorghum. Key benefits derived from these combinations is the use of poultry droppings as organic manure to fertilize Maize/Cassava and Maize/Sorghum farms. Consequently, [22] reported that output from the integrated crop livestock system (ICLS) is greater than the sum of its components because the output of one land unit is used as an input for another part of the system and can raise the overall efficiency of the farm and productivity of both the crop and livestock production components. The available land was efficiently utilized and under the same management. Gross margin represents revenue less total variable costs. As shown in Table 1, all the enterprises were profitable but broiler production gave the highest contribution to the LP objective function. Based on these enterprises' gross margins, LP model was used to determine which combination of enterprises maximizes the farmers' objective.

The information in Table 1 was used to formulate a standard linear programming problem specified as follows:

Objective Function

$$\text{Max Z: } 1478450x_1 + 469690x_2 + 143720x_3$$

Subject to:

$$0x_1 + 0.77x_2 + 0.54x_3 \leq 1.31 \text{ [Land Constraint]}$$

$$98.67x_1 + 51.27x_2 + 46.35x_3 \leq 196.28 \text{ [Labour Constraint]}$$

$$48.4x_1 + 0x_2 \; 0x_3 \leq 50 \text{ [Feed Constraint]}$$

$$0x_1 + 2.07x_2 + 1.9x_3 \leq 4 \text{ [Agrochemical Constraint]}$$

$$395x_1 \leq 500 \text{ [Flock Capacity Constraint]}$$

The software, LINGO 18, was used to solve the standard LP problem. An optimal solution was found and the result is presented in Table 2. As shown in Table 2, it is recommended that the respondents should increase the mean number of broilers to 407 birds and produce 1.7 ha of Maize/ Cassava in order to maximize their objective. This represents an increase of 3.04% and 29.77% for number of broilers and the land size used for Maize/Cassava respectively in order to realize a gross margin of ₦2,326,408. As shown in the optimal solution, broiler and Maize/Cassava enterprises entered the final solution and maximized the farmers' objective value of ₦2,326,408. This follows [23] who revealed that the adoption of multiple farm enterprises like crop, dairy, poultry, and fish increased farm net profit by 660 USD per year compared to a less diversified crop only.

Table 2 Enterprise value and reduced cost

Variable	Value	Reduced Cost
Broilers (X_1)	407	0
Maize/ Cassava(X_2)	1.7	0
Maize/Sorghum (X_3)	0	185672

Source: Field Survey and LINGO 18

The reduced cost as shown in Table 2 revealed that broiler and Maize/Cassava enterprises have a reduced cost of zero (0) respectively. This is because they were the enterprises selected in the optimal solution that maximized the objective or contributed to the highest gross margin. Maize/Sorghum enterprise which did not enter the final solution has a reduced cost of ₦185,672.4.

Reduced cost as shown in Table 2 is the amount that the objective coefficient of the variable would have to improve before it would become profitable to give the variable in question a positive value in the optimal solution. Broiler and Maize/Cassava has a reduced cost of zero (0) because they were the enterprises that entered the final solution. The reduced cost of Maize/Sorghum is ₦185,672.4. Since this is a maximization problem, it implies that the objective coefficient of Maize/Sorghum would have to increase by ₦185,672.4 for it to become an attractive alternative to enter into the optimal solution. This would imply an increase of about 129.19 percent over the existing value.

The slack or Surplus and Dual (shadow) prices of inputs/resources is presented in Table 3. As shown in Table 3, both land and feed had a slack or surplus value of zero (0) while that of labour, agrochemical and flock capacity are 7.154, 0.478 and 92.36 respectively.

The slack or surplus in Table 3 tells how close one is to satisfying a constraint as an equality. For a less – than – or – equal to constraint it is called slack while for a greater – than – or - equal to constraint ,it is called surplus. Land and feed had a slack value of zero (0) because the constraint is exactly satisfied. The slack values of labour, agrochemical and flock capacity are 7.154, 0.478 and 92.355 respectively and these represents how close it is to satisfying the right hand side of the equality.

Table 3 Slack or Surplus values and Dual prices of inputs

Row	Name	Slack or Surplus	Dual Price
1	Objective	2326408	1
2	Land	0	609988
3	Labour	7.15359	0
4	Feed	0	30546.5
5	Agrochemical	0.47831	0
6	Flock capacity	92.3554	0

Source: Field Survey, 2021 and LINGO 18

The Dual (shadow) prices of the objective function, land and feed are 1, 609987.5 and 30546.48 respectively with the highest being that of land. Labour, agrochemical and flock capacity has a dual (shadow) prices of zero (0) respectively.

The Dual or Shadow prices is the amount that the objective would improve as the right – hand side or constant term if the constraint is increased by one unit. As shown in Table 3, land has highest dual or shadow price of 609987.5. This implies that cultivating additional hectare of Maize/Cassava would improve or increase the objective value by 609987.5 to a value of ₦2,936,395.5. The dual price for feed is 30546.48. This means that feeding the broilers with additional bag of feed would improve the objective or gross margin by this value to ₦2,356,954.48. Consequently, farmers should contemplate expanding their land size and give more feeds to the broilers to maximize their objective. For instance, [24] reported that the higher the level of feed intake, indicating the higher the level of feed palatability, it is expected that with higher consumption the weight gain obtained is also greater, and more efficient. Labour, agrochemical and flock capacity had dual prices of zero respectively, implying that using additional unit of these resources does not improve the objective or gross margin.

4. Conclusion

The results of this study has proved that combining enterprises leads to higher returns and helps farmers to achieve their production objectives through efficient utilization and management of productive resources. This estimation was made possible using linear programming model rather than relying on intuition and past experiences. The results revealed that all the enterprises were profitable but only broiler and Maize/Cassava production were the two enterprises that entered the final solution because they made the highest contribution to the gross margin. Based on this we recommend that farmers should raise the number of broilers to 407 and use 1.77 ha of land to produce Maize/Cassava in order to maximize their gross margin. Increasing land size and the quantity of broiler's feed are essential to the realization of this objective.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of Interest.

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