

Optimum Combination of Selected Food Crops and Livestock Enterprises in Aba Agricultural Zone of Abia State, Nigeria: A Linear Programming Approach

Abstract

Linear programming technique was applied to farm data generated from thirty arable crop farmers during 2010 farming season to maximize gross margin from various combinations of arable crop and selected livestock enterprises. Optimization and reallocation of available resources was found to bring significant changes in the existing plan. Twenty enterprises were observed in the existing plan made up of one sole crop, fourteen crop mixtures and five livestock enterprises across poultry, fish and piggery which an average farmer would make a gross margin of N232,317.12. However the LP maximization model recommended that for optimum gross margin of N374,850.00 which is about 61.35% of the existing gross margin, an average farmer should devote 0.31 hectare to yam/maize/melon, 0.33 hectare to cassava/maize/cocoyam and 1.30 hectares to cassava/maize/yam/ukpo while 0.14 of 500 birds of broiler 1 done usually between January – May and 0.11 of 1000 fish of fish 11 done between January – June and 0.07 of 15 pigs be produced. Given the mean farm size of 0.45 hectares, an average farmer should be given more land to achieve improved gross income. Policies of government should be geared towards encouraging individual extension services to achieve increased farm advisory services to help deal with the problem of misallocation of farm resources among farmers as well as possibility of achieving stable wage in the farm labour market.

Keywords: Linear programming, arable crop farmers, livestock, existing, optimum, plan

Introduction

According to Akande (2005), Nigeria is the most populous country in Africa with a population of over 130 million people and a domestic economy, which is dominated by agriculture such that agriculture alone accounts for about 40% of the Gross Domestic Product (GDP) and two thirds of the labour force. Besides, agriculture supplies food, raw materials and generates household income for the majority of the people. Research has shown that mixed crop-livestock systems constitute the backbone of much agriculture not only in the tropics in general but also in Abia State in particular (Igwe *et al*, 2011).

33 The external sector is dominated by petroleum, which generates 95% of Nigerian foreign
34 exchange earnings while agriculture contributes less than 5%. The domestic economy where
35 agriculture thrives must therefore be improved upon and sustained and if possible its external
36 sector impact enhanced. This is because indication of high potential for increased food
37 production in Nigeria is glaring given that Nigeria has a land area estimated at about 98.3
38 million hectares out of which about 71.2 million hectares accounting for about 70% are
39 cultivable while only about 34 million hectares accounting for one third of total land area are
40 under cultivation (Onyenweaku *et al.*, 2008). Although the large population and the demand
41 for food are obvious, taking advantage of the abundant arable land requires optimal allocation
42 of the meagre resources at the disposal of the poor resource farmers who provide for the
43 majority of the nation's food need and in this way restrain a repetition of the past experiences
44 where the nation had to resort to massive food importation leading to rising food import bills
45 (Adedipe *et al.*, 1999).

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47 With particular reference to the southern states of Nigeria, where an inheritance tenural
48 arrangement is practised and farmland is seriously fragmented leading to individual farmland
49 shrinking in the years past, the phenomena has been prominent (Udoh, 2000 and NEST,
50 1991). This situation has culminated in persistent food crises in Nigeria as the gap between
51 population and food production continues to widen (Igben and Branwo, 1982; World Bank,
52 1992). This problem is compounded by the fact that the farming systems in the developing
53 countries are made up of smallholder farms whose farm enterprises also include livestock.
54 Modelling of crop and livestock enterprises has remained under-developed and its
55 applicability impaired by problems of calibration and lack of data. However, there is need for

56 a paradigm shift considering their importance in smallholder farming systems. This research
57 is part of the attempt to address optimization of farm enterprises under mixed farming
58 conditions. This is because modelling for crop and selected livestock enterprises among the
59 farm households represent a modest impression of the prevailing agrarian condition of the
60 study area. Although farming is small scaled, farmers really specialize along crop and
61 livestock without a relative combination of both enterprises.

62

63 **Methodology**

64 Multistage random sampling method was used to sample thirty arable farmers some of whom
65 are involved in raising livestock particularly mongastrics. Three circles were sampled from a
66 chosen block in Aba agricultural zone. With the aid of the extension officers in the area and
67 village heads, ten farmers selected from the sampling frame derived from the zonal office
68 were identified and interviewed using pretested questionnaire.

69

70 The study examined the various enterprises, crops and selected livestock operated by farmers
71 in Aba Agricultural zone of Abia State and analyzed the farmers resource levels and other
72 constraints in their crop and selected livestock farm production to develop optimum
73 enterprise combination for sole crop/livestock and mixed crop/animal mixtures considering
74 the farmers' resources that would maximize the gross margin of farms in the study area in
75 order to determine which of the resources/factors of production is/are limiting in the study
76 area comparing existing and optimum farm plans for farmers in terms of activities and
77 resource utilization.

78

79 In order to actualize these objectives, a model developed by Osuji (1978) with adaptive
80 features of Tanko (2004) was modified and applied to determine the optimum enterprise
81 combination. It is a gross margin maximization problem stated as:

$$\begin{aligned} & \text{Maximize } Z = \sum_{j=1}^m P_j X_j - \sum_{i=1}^n \sum_{j=1}^m C_{ij} X_{ij} \quad \dots 1 \end{aligned}$$

85 where

86 Z = Gross margin of total output

87 X_j = Decision variable, for instance the number of hectares the farmer devoted to the
88 production of a crop or a combination of crops or a combination of crops or livestock
89 capacities produced by farm.

90 P_j = The gross value per hectare of the j th activity be it crop or per livestock capacity for
91 livestock enterprises

92 C_{ij} = Cost per unit of i th input used in the production of the j th activity

93 X_{ij} = Quantity of i th input in j th activity

94 Z is to be maximized subject to:

$$\begin{aligned} & \sum_{j=1}^m a_{ij} X_j \leq \sum_{j=1}^m b_i \quad \dots 2 \end{aligned}$$

98 Where

99 a_{ij} = the amount “ a ” of the resource “ i ” used in the production of one unit of “ j ”.

100 b = level of available resources.

101 b_i = the level ‘‘b’’ at which resources ‘‘i’’ is available.

102 m = number of activities in the programme.

103 $\sum_k X_j \geq F_{ic}(\text{min})$ (minimum subsistence farm-family tuber/cereal crop requirement) ... 3

104

105 $\sum_{kc} X_j \geq F_{ia}(\text{min})$ (minimum subsistence farm-family protein requirement) ... 4

106 And non-negativity restrictions:

107 $X_j \geq 0$... 5

108 where

109 $F_{ic}(\text{min})$ = Minimum quantity of root/tuber crops required by the farm family per annum in tons

110 ($i=1,2,3,\dots,n$)

111 $F_{ia}(\text{min})$ = Minimum quantity of protein required by farm family per annum in tons ($i =$

112 $1,2,3,\dots,n$)

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117 **Results and Discussion**

118 **Socioeconomic Characteristics of Farmers**

119 A summary of the statistics of farmers in Aba agricultural zone of Abia State examined

120 included those of age, sex, marital status, educational status, farming experience, household

121 size and off-farm income. This summary is presented in Table 1.

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123

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Table 1: Summary of Descriptive Statistics of Some Selected Socioeconomic Characteristics of Respondents in Aba Zone

Variable	Sample Size	Minimum	Maximum	Mean	Std Deviation	Variance
Age	30	26.00	70.00	50.23	8.22	67.63
Sex	30	0.00	1.00	0.83	0.38	0.14
Marital status	30	0.00	1.00	0.90	0.31	0.0093
Education	30	0.00	22.00	9.28	5.44	29.56
Experience	30	4.00	40.00	23.30	9.06	82.01
Household size	30	1.00	9.00	5.77	2.39	5.70
Off-farm Income	30	15,500.00	305,760.00	75,788.67	2.4E+09	5.76E+09

Source: Field Survey 2009/2010

The results showed that a typical farmer in Aba zone was about 50 years old, married, had about six family members and attained at least primary education. The mean age was 50 years while an typical farmer in the study area has about six members in his household. Besides farm activities, about N75,788.67 was realized from other activities outside of his own farm activities such as working for others, petty trading, hunting, skilled or unskilled activities etc.

Selected Food Crops Farm holdings of Farmers

The farm size of the selected farmers in the area is presented in Table 2. The farmers were characteristically small holders with a mean farm size of 0.45 hectares. It was only about 16.66% of the farmers that had over 0.72 hectares of farmland for crop production.

Table 2: Frequency Distribution of Farmers According to the Farm Size in the Agricultural Zone

	Range	Frequency	Percentage
	0.13 - 0.27	9	30.00
	0.28 - 0.42	9	30.00
	0.43 - 0.57	3	10.00
	0.58 – 0.72	4	13.33
	ξ		
	0.88 – 1.02	1	3.33
	1.03 – 1.17	2	6.67
	ξ		
	1.93 – 2.07	1	3.33
	ξ		
	3.88 – 4.02	1	3.33
	Total	30	100
	Mean	0.45	
	Standard Deviation	0.81	

Source: Field Survey Data, 2010

Existing and Optimum Cropping/Enterprise Patterns across Agricultural Zones

The existing and optimum enterprise patterns for the sampled farmers are presented in Table 3. The study prescribed that for Aba zone, no sole crop enterprises should be produced but crop mixtures precisely 0.31 hectare of yam/maize/melon, 0.33 hectare of cassava/maize/cocoyam and 1.30 hectares of cassava/maize/melon/ukpo while 0.14 of 500 birds (70.00 birds) of broiler II, 0.11 of 1000 fish (110.00 fish) of fish II and 0.07 of 15 pigs (1.05 pig) of livestock enterprises are to be produced.

Table 3: Existing and Optimum Cropping/Enterprise Patterns for Aba Agricultural Zone Abia State, Nigeria

Cropping pattern	Existing plan (ha)	Optimum plan (ha)
1. Yam	0.18 (4.77%)	—
2. Cassava/Maize	0.57 (15.12)	—
3. Yam/Melon	0.21 (5.57%)	—
4. Cassava/Melon	0.19 (5.04%)	—
5. Maize/Yam/Telferia	0.11 (2.92%)	—
6. Cassava/Maize/Melon	0.03 (0.80%)	—
7. Yam/Maize/Melon	0.08 (2.12%)	0.31(15.98%)
8. Cassava/Maize/Yam	0.24 (6.37%)	—
9. Cassava/Maize/Cocoyam	0.31 (8.22%)	0.33 (17.01%)
10. Cassava/Maize/Yam/Ukpo	0.13 (3.45%)	—
11. Cassava/Maize/Yam/Cowpea	0.13 (3.45%)	—
12. Cassava/Maize/Melon/Ukpo	0.33 (8.75%)	1.30 (67.01%)
13. Cassava/ Maize/Melon/Cowpea	0.13 (3.45%)	—
14. Cassava/Maize/Yam/Melon	0.28 (7.43%)	—
15. Cassava/Maize/ Yam/Melon/Telferia	0.85 (22.55%)	—
16. Broiler 1-Jan-May	0.48 (57.14%)	0.14 (100%)
17. Broiler 11-Aug-Dec	0.36 (42.86%)	—
18. Fish 1-Jan-June	0.45 (27.27%)	—
19. Fish 11-July-Dec	1.20 (72.73%)	0.11 (100%)
20. Pig	1.40 (100.00%)	0.07 (100%)
Total Crop Area	3.77	1.94
% Sole	4.77	0.00
% Crop Mixture	95.23	100
Total Poultry	0.84	0.14
% Broiler	100	100
Fish	1.65	0.11
% Fish	100.00	100.00

Source: Field Survey, 2010

Gross Margin among various Plans

The gross margins for the existing and optimum plans for selected farmers in the zone are presented in Table 4. The optimum gross margin increased by over 50% from the existing plan.

Table 4: Gross Margin (in Naira) for Existing and Optimum Plans for the Selected Farmers in Aba Zone

	Existing Plan	Optimum Plan	Increase/Decrease Over Existing Plan	
Zone				%
Aba	232,317.12	374,850.80	142,533.68	61.35

Source: Field Survey Data, 2010

Results in Table 4 indicate that optimum plans resulted in an increase in gross margin over the existing plan by 61.35% in Aba. The finding was relatively higher to values obtained among crop farmers in Niger State on raising their income level (Tanko and Baba, 2010). The introduction of livestock enterprises among the crop enterprises may explain for the relatively high optimum values relative to studies where only crop enterprises were evaluated.

Labour Utilization

Labour utilization for the different agricultural zone is presented in Table 5. The prescribed labour utilization by the optimum plan in both crop and livestock categories of enterprises were less than as obtained in the existing plan. The abundant availability of human labour contrary to apriori expectation is relative to the area, given that an average farmer in the area cultivates small farm size per planting season due to their sociocultural set up. Farmers in this zone are still holding on tenaciously on shifting cultivation as their best way of soil nutrient resuscitation and conservation. They also argue that fertilizer application inhibit mushroom production.

Table 5: Labour Utilization among farmers in Aba Agricultural Zone

	Existing	Optimum
Crop		
LPP	110	102.07
1 st Weeding	90	21.79
2 nd Weeding	90	58.98
Harvesting	120	98.73
Total	410	281.5
Livestock		
Feeding	140	30.64
Cleaning	70	11.26
Sorting	10	1.58
Harvesting	15	0.28
Total	235	43.76

Source: Field Survey Data, 2010

LPP = Land preparation and planting EXIT = Existing Plan OPT = Optimum Plan

Shadow Prices of Excluded Activities among Selected Farmers in the Zone

Shadow prices are marginal returns to investments of available resources. In a maximization problem, they are income penalties; indicating the amount by which farm income would be reduced if any of the excluded activities is forced into the programme. Olayemi and Onyenweaku (1999) had earlier reported that any resource that is abundant, that is not used up by a programme, is not a limiting resource and has a zero shadow price as it does not constrain the attainment of a programme's objective and vice versa. Usually however, only the excluded activities have positive shadow prices. For the included activities, shadow prices

are zero. The higher the shadow price of an excluded activity, the lower is its chance of being included in the final plan. The shadow prices of excluded activities obtained as by-products of the linear programme solution for Aba, agricultural zone for the sampled farmers are presented in table 6. Results in the table indicate the amount by which farm gross income would be reduced if any of the activities appearing in the table is forced into the programme.

Table 6: Shadow Prices (in Naira) of Excluded Activities in Aba Agricultural Zone

S/N Excluded Activity	Value (N)
1. Yam	249.12
2. Cassava/Maize	33,901.86
3. Yam/Melon	45,545.61
4. Cassava/Melon	1,991.59
5. Maize/Yam/Telferia	10,625.42
6. Cassava/Maize/Yam	39,387.92
7. Cassava/Maize/Melon	28,290.35
8. Cassava/Maize/Yam/Ukpo	1,916.92
9. Cassava/Maize/Melon/Cowpea	20,596.82
10. Cassava/Maize/Yam/Melon	53,847.48
11. Cassava/Maize/Yam/Melon/Telferia	8,729.18
12. Broiler II – Aug - Dec	165,200.80
13. Fish I - January - June	34,200.00

Source: Field Survey Data, 2010

In Aba agricultural zone, a total of about 13 activities were excluded from the programme as indicated in table 6. The situation in Aba agricultural zone revealed that among the excluded arable crop enterprises, cassava/maize/yam/melon mixture has the highest shadow price of N53,847.48 while the yam has the least shadow price of N249.12. This scenario is slightly in

contrast with work by Tanko and Baba (2010), in which yam/okra, a mixed cropping enterprise had the least shadow price of N254.71.

The disparity in location and resource endowment could help throw light on the sharp contrast. For instance, in their study area the farmers had access to tractor hiring and a mean farm size very much greater than is obtained in this study. Besides, incorporation of livestock enterprises was not considered in their modelling, and so, its inclusion could have introduced variations as their combination with crops will obviously affect farmers' decision on allocation of their resources. In this work, where livestock enterprises were considered, broiler II usually done between August and December had the highest shadow price of N165,200.80.

Shadow Prices of Available Resources in the Optimized Plans

In Aba zone, there was only one limiting resource which was human labour I (1st Weeding) for the crop category that constrained the attainment of the objective function out of the numerous resources.

Table 7: Shadow Prices (in Naira) of Resources in Aba Zone

Constraint	Value (N)
Human Labour I (1 st Weeding)	310.18

Source: Computed from Field Survey Data, 2010

Minimum Staple Food/Livestock Requirements

The staple foods for farmers in the area were tubers and cereals for the crops and to meet their protein needs, certain amounts of their livestock were consumed. Results of the minimum staple and protein requirements by households (in tons) in existing and optimum

plans are presented in table 8. For the tubers that appeared in the optimum plan, farmers in Aba zone of Abia State had 11.72 tons of tubers, 0.88 of cereals and a ton of their protein requirement in excess of value in their existing requirements.

Table 8: Minimum Staple and Animal Protein Requirements by Households (in tons) in the Existing and Optimum Plans

Staple Food/Protein	Quantity Requirement		Increase over Existing Plan	
	Existing Plan	Optimum Plan		
Yam	1.24	2.15		0.91
Cassava	1.03	11.84		10.81
Maize	0.36	1.24		0.88
Fish	0.13	0.62		0.49
Pig	0.02	0.53		0.51

Source: Field Survey Data, 2010

Sensitivity Analysis

The sensitivity analysis of the plans to changes in some production variables was observed. Usually as has been established by many researchers in the past, land and labour are variables of utmost interest in such analysis (Osuji, 1978; Tanko, 2004). However, given that feed was incorporated in the model for the livestock enterprises, the effect of increasing quantity of feed available by 50 percent was also observed. In the first scenario, land resource was increased by 50 percent, to see its effect on the optimum plan. In the second scenario, labour was increased by 25 percent across each period for crops and decreased by same for livestock in each zone to see their effect on the optimum plan; in the third scenario, wage was decreased by 50 percent for both crops and livestock and finally, the effect of 50% increase in the quantity of available feed on the programme was observed.

Effect of Increasing Area under Cultivation

In Aba agricultural zone, increasing the area under cultivation by 50 percent did not increase the value of optimum gross margin. Moreover, all the activities that appeared in programme 1 remained constant. On the activities remaining unchanged, a similar response had been observed in previous research in another area (Tanko, 2004). However, relative to Aba zone, experience in field revealed that lands were left to lie fallow for up to five years even when their owners had only very small scattered plots in a farming season. There was a situation where farmers frowned at use of fertilizer to improve soil fertility; advocating for its discontinuation, arguing that it inhibits mushroom growth, which they seek to preserve. There is therefore some form of enlightenment to be done over time and more to be done before an average farmer could by increasing land available to him achieve increased gross margin in the zone.

Table 9: Comparing the Optimum Gross Margins when Land was increased by 50 percent

Previous Optimum (N)	Present Optimum (N)	Increase (N)	% Change
374,850.80	374,850.80	0.00	0.00

Source: Computed from Field Survey Data, 2010

Effect of Varying Labour Use on the Optimum Gross Margin

Labour use was increased by 25 percent of what was available across the zones for crops and decreased by the same for livestock to see their respective effect on the optimum gross margin and this is presented in table10. Increasing labour by 25% of that available in Aba zone increased the value of the objective function by about N6,979.10, which represent a marginal increase of only about 1.86% of the original value obtained.

Table 10: Comparing the Optimum Gross Margins when Labour was increased by 25 percent

Previous Optimum (N)	Present Optimum (N)	Increase (N)	% Change
374,850.80	381,829.90	6,979.10	1.86

Source: Computed from Field Survey Data, 2010

Effect of Varying Labour Wages on the Optimum Gross Margin

Effect of Varying Labour Wages on the Optimum Gross Margin

Given that high wage rate would depress gross margin, effect of reduction of wage rate by 50 percent was also examined. This is shown in table 11.

Table 11: Comparing the Optimum Gross Margins when Wage rate was reduced by 50% across Crops and Livestock

Previous Optimum (N)	Present Optimum (N)	Inc. /Dec. (N)	% Change
374,850.80	376,586.30	1,735.50	0.46

Source: Computed from Field Survey Data, 2010

Effect of Varying the Quantity of Feed used for Livestock production

Increasing the quantity of feed by 25% in Aba zone did not increase the optimum gross margin for an average farmer. Usually, given the nature of the livestock enterprises generally speaking, a point of saturation is always reached at which time it is advisable to disposed perhaps the broiler or the layer; continued feed intake when what is required of the birds have been achieved will if anything else increase variable cost and as such even depress gross margin.

Table 12: Comparing the Optimum Gross Margins when Feed intake available to farmers was increased by 25%

Previous Optimum (N)	Present Optimum (N)	Inc. /Dec. (N)	% Change
374,850.80	374,850.80	0.00	0.00

Source: Computed from Field Survey Data, 2010

Conclusion

The study on application of linear programming in resolving a maximization problem among thirty farm households in Aba Agricultural Zone of Abia State, Nigeria revealed that among about twenty enterprises that cut across arable crops and selected livestock in the existing plan, only a sole crop, two crop mixtures and two livestock enterprises were prescribed by the model to achieve a gross margin of N635,605.80. Thus the exercise showed that resource allocation patterns in the optimum plan were remarkably different from that in the existing plan. Generally, the optimum gross margin was slightly sensitive to increase in land as well as decrease in wage rate calling for additional land as well as wage policies among farmers.

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