*American Journal of Experimental Agriculture*
*3(2): 412-431, 2013*

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# A Linear Programming Approach to Food Crops and Livestock Enterprises Planning in Aba Agricultural Zone of Abia State, Nigeria

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***Authors' contributions***

*This work was carried out by the first author KCI in collaboration between all authors. Guided by the expertise advice of the second author CEO, the corresponding author KCI designed the study, performed the analysis, wrote the protocol, and wrote the first draft of the manuscript. Both authors managed the analyses of the study. The corresponding author KCI managed the literature searches. However, all authors read and approved the final manuscript.*

***Research Article***

***Received 4th June 2012***
***Accepted 3rd March 2013***
***Published 26th March 2013***

## ABSTRACT

Linear programming technique was applied to farm data obtained from thirty arable crop farmers during 2010 farming season to maximize gross margin from various combination of arable crop and selected livestock enterprises. Optimization and reallocation of available resources were 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/*Mucuna Floanei* while 0.14 of 500 birds of broiler 1 raised usually between January – May and 0.11 of 1000 fish of fish 2 done between July – December and 0.07 of 15 pigs be produced. Given the mean farm size of 0.45 hectares, the farming orientation is still subsistence. It is recommended that crop mixtures be undertaken by farmers in combination with poultry and fish enterprises for improved gross margin. Policies of Government should be geared

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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 among farm labour.

*Keywords: Linear programming; arable crops; livestock; existing; optimum; plan.*

## 1. INTRODUCTION

According to [1], 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 [2].

The external sector is dominated by petroleum, which generates 95% of Nigerian foreign exchange earnings while agriculture contributes less than 5%. The domestic economy where agriculture thrives must therefore be improved upon and sustained and if possible its external sector impact enhanced. This is because indication of high potential for increased food production in Nigeria is glaring given that Nigeria has a land area estimated at about 98.3 million hectares out of which about 71.2 million hectares accounting for about 70% are cultivable while only about 34 million hectares accounting for one third of total land area are under cultivation [3]. Although the large population and the demand for food are obvious, taking advantage of the abundant arable land requires optimal allocation of the meagre resources at the disposal of the poor resource farmers who provide for the majority of the nation's food need and in this way restrain a repetition of the past experiences where the nation had to resort to massive food importation leading to rising food import bills [4].

With particular reference to the southern states of Nigeria, where an inheritance tenural arrangement is practised and farmland is seriously fragmented leading to individual farmland shrinking in the years past, the phenomena has been prominent [5,6]. This situation has culminated in persistent food crises in Nigeria as the gap between population and food production continues to widen [7,8] and crop productivity seem to have been declining [9]. This problem is compounded by the fact that the farming systems in the developing countries are made up of smallholder farms whose farm enterprises also include livestock. The goals of these small-scale crop farmers spanning through efficient allocation of resources through optimum enterprise combination, year round provision for the household, monetary income accumulation and minimizing expenditure on labour have not been fully achieved in sub-Saharan Africa [10,11].

Modelling of crop and livestock enterprises has remained under-developed and its applicability impaired by problems of calibration and lack of data. However, there is need for a paradigm shift considering their importance in smallholder farming systems. This research is part of the attempt to address optimization of farm enterprises under mixed farming conditions. This is because modelling for crop and selected livestock enterprises among the farm households represent a modest impression of the prevailing agrarian condition of the study area. Although farming is small scaled, farmers generally, rarely specialize along crop and livestock without a relative combination of both enterprises.

Linear programming (LP), as applied to farm planning represents a systematic method of determining mathematically the optimum plan for the choice and combination of farm enterprises, so as to maximize income or minimize costs within the limits of available farm resources [12]. Optimum decision making which is based on a quantitative analysis for achieving “desired goal” has been applied to Punjab farmers in India in spite of their complex situation compounded by the difficulty of comprehending the techniques at the initial stage of their learning process [13]. On technical stand, the Nigerian farmers like these Punjab farmers are small-scale farmers who operate with crude implements, cultivate small pieces of land and have a poor resource base. They are faced with the problem of optimal utilization of their meagre resources to raise their incomes and consequently their living standards [14].

The challenge to improve on the contribution of agriculture to the Nigeria economy makes a study of this nature a worthy venture. Besides, most farm management studies in Abia State attempted production function analysis revealing the marginality conditions of resource use with respect to production of individual or selected enterprises. Such type of analysis in addition to being very partial in nature addressed only the existing aspect in the organization and operation of the farm business, and fails to answer as to what would be the optimum combination of enterprises under given restraining conditions. With particular focus on the arable crop farms and selected livestock enterprises, this study has contributed to knowledge in this way. Developing a prototype enterprise plan in arable crop based production would be useful in the extension education package for use by extension workers. This is because how the farmers are to use any developed technologies and incentives would depend on their effective and efficient utilization of their productive resources [15].

## 2. LITERATURE REVIEW

Mathematical programming models belonging to the general class of the allocation models are used for determining optimal decisions and patterns of resource allocation [16]. They offer the best prospects for success in optimizing work. Although they necessarily involve the linearization of many relationships, practitioners find that this feature usually does not restrict the realism of these models too much [17,18]. Agricultural production planning therefore apart from shedding light on efficient utilization of resources in the farm, makes possible the charting of those courses of action that help in the attainment of maximum net returns and/or increased farm incomes, and in this way bring a structural transformation of the present agricultural economy, which is inevitable, if Nigeria is to meet her food requirements [19,20].

Generally, mathematical programming tools have been employed variously covering wide range of activities like crop farming, mixed farming, horticultural crops, livestock alone, various breeds and varieties, all sorts of combinations of different activities [13]. In a regional/inter-regional framework, linear programming approach has been used for studies in optimum resource allocation and resource requirements in many countries [21,22,23,24,25]. Within Nigeria, application of linear programming models to farm enterprises in various states has also been reported [26,20]. However, arable crop based farms or the livestock component particularly animals whose production cycles last within a year are yet to be fully targeted. [27] reported that the use of LP makes it possible to devise equilibrium solution, which include the specification of products levels, factor and product prices. The prototype enterprise combination expected from this study shall thus assist in answering many resource allocation problems that would enhance farm productivity.

While farmers have different reasons for the cropping systems adopted and the enterprises combined, two major reasons that are most outstanding are that of net income stabilization and maximization. Income maximization entails comparison of costs and returns from the different enterprises; and as a decision guide to farmers towards the realization of their production goals, it is necessary that they know the most reliable number and types of enterprises to combine [28]. Various approaches have been scientifically used in studies that involved analysis of cropping patterns in many countries over time.

Although not much has been done in direct agricultural production planning using LP in the study area, related studies have been carried out within agro-allied industries in the present millennium in Nigeria. [7] applied Linear Goal Programming (LGP) technique to model the farm-family crop enterprise with the view to develop an optimal crop enterprise combination that would enable the small holder farmer meet their most important goals of providing food for the family throughout the year, accumulating monetary income and ensuring minimum use of paid labour. The results reveal that only 4 out of 18 basic cropping activities identified in the study area entered the program. A striking feature of this plan is that there is no sole cropping included in the model. This plan will utilize the minimum cost of N6485.16/ha to produce the minimum food required, minimum income and would ensure minimum f paid labour. The result further showed that some household resources such as land were in excess of actual household requirements.

The LP was applied to optimum combination of farm enterprises in Kebbi State, Nigeria and found that farm enterprises were not optimally allocated in the existing plan and that significant increase in net farm income in the optimum over the existing plans prevailed. Under the existing technology and resource availability, crop mixtures were in a better position than sole crops. Results of the sensitivity analysis showed that increasing the area under cultivation resulted in increase in the optimum farm income, which suggested that more arable land should be employed in crop production [20].

Resource allocation pattern was analyzed by [29] for 120 food crops farms in Imo State, Nigeria using the LP technique for optimizing resources. Results showed a divergence between the existing and optimum farm plans under limited and borrowed capital situations. The formulated optimum plans were subjected to sensitivity analysis to enable choice of a particular optimum solution which conforms to the farms production characteristics and resource constraints. Farm resources were not optimally allocated and after optimization, farm income and employment of labour could be increased. Results showed that increasing the area under cultivation by 2 hectares would result in optimum farm income increasing by N80, 994.00K and N67, 521.60K representing 87.94% and 54.18% under the limited and borrowed capital situations. The increase in revenue was as a result of utilizing those resources that were idle when land posed a constraint to production.

LP was applied to determine optimal farm plan in evaluating food security status of farming households and recommended that the production of Cassava, Maize/Cowpea, and Benniseed and Groundnut/Yam enterprises at 0.64, 0.34, 0.35 and 0.22 ha respectively to yield a net return of 141, 692.89 naira. The study further established that maize, cassava and yam were the food security crops, which effective allocation of resources for increased production was recommended as well as introduction of participatory family planning techniques among the food insecure households [30]. Optimal farm plan was examined in sweet potato cropping systems in Kwara State during the 2004 farming season and found the average farm size as 0.91 ha. The optimal crop combination was sweet potato/cassava cropping system and the optimal gross margin was N14766 per hectare. While capital was a

limiting resource, land and labour were non-limiting and there were 0.06 ha of unused land and 3.13 man-days of unused labour. Increased capital investment was recommended for increased production of the crop [31]. In another work by [32], optimal crop combination in small-scale vegetable irrigation farming scheme: Case study from Niger Republic was investigated in the 2002 farming season. The study showed that the optimal crop combination was the tomato-based crop mixtures consisting of tomato/cucumber/onion/okra/watermelon. The optimal value of the programme was CFA 329, 681 which is N95, 014.25K at N145.00K per dollar where 1 US dollar is equivalent to 495 CFA as at the time of the study. This optimal was obtained by cultivating 0.165 hectare of the enterprise at a gross margin of CFA 1, 998,069 per hectare. Pepper / tomato / cucumber / watermelon, carrot / potato/ pepper / onion / garden egg, onion / watermelon / tomato / okra and cabbage / lettuce / pepper/ onion enterprises did not enter the final plan, since they have a non-zero opportunity cost indicating that they were not in the best competitive positions as compared to tomato / cucumber / onion / okra / watermelon enterprise. Land was the only limiting resource indicated by its opportunity cost of resources used. Whereas there were 1,589.7 man-days of unused labour, 405.7 ha $cm^3$ of unused water and CFA1, 07,444.8 of unused capital, the shadow price of land was CFA1, 998, 069, indicating that by increasing land cultivation by one hectare, the gross margin would increase by CFA1, 998, 069.

## 3. METHODOLOGY

### 3.1 Study Area and Sampling Technique

Multistage stratified random sampling method was used to sample thirty arable farmers some of whom are involved in raising livestock particularly monogastrics. Aba agricultural zone was chosen from the state. This was the first stage. The second stage involved listing all the blocks in the zone which at time of this study were twelve. A block, precisely Umunne ise block was selected in Aba zone. The third stage involved the circle level, whereby three circles were selected from the block. With the aid of the extension officers in the area and village heads, ten farmers selected from the sampling frame derived from the zonal office were identified and interviewed using pretested structured questionnaire. This constituted the third stage.

### 3.2 Data Collection

Data were solicited for using the cost route approach in the 2010 farming season. This involved particularly for the food crops fourth nightly visit to the farmer. The farm household made up of the farmer, his wife or wives and children constitute the unit of analysis. However because farms are owned by farm household head the discussion on the socioeconomic characteristics centred on them.

The output from the farms was also measured. The yields of various crops were obtained mainly by the use of Yield Plot Method applied by [26,20]. In the case of crop mixtures, the average number of each crop was determined per hectare yields and applied to the total hectares of each mixture. The prevailing market price was used to estimate potential gross returns. Where vegetables were involved; a different approach was adopted bearing in mind the local units of the harvest made. Harvested and consumed crops as well as the selected livestock enterprises were also estimated.

## 3.3 Analytical Technique for the Study

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

## 3.4 Assumptions Underlying LP Model Specification

In building the basic matrix used for the study and the various activities considered in the programme, the activity coefficients otherwise resource requirements, the output prices etc, certain assumptions were made. The activities in the models were grouped into crop production activities which are either sole crops or crop mixtures, livestock production activities, human labour, and product selling activities. For each of the crop production activities the unit of activity is one hectare. The price coefficient ''$P_j$'' of a production activity in the model is the gross value per hectare. For a human labour activity, the ruling wage rate (naira per manday) is the price coefficient. For a selling activity; the price coefficient is the price per ton of the product sold. To ensure fuller utilization of capital and labour, labour activities were incorporated in the model even though capital was not considered separately in the model.

Transfer activities otherwise called the transfer rows provide a vehicle whereby the services or output of one activity may be transferred in the model to another activity. The coefficient for labour transfer activities appear in the programming matrix as -1 labour receiving the transferred capital. The objective function coefficient for these activities was put at zero since the labour transfer will not affect the gross farm income in any way.

Land, labour input, minimum tuber / cereal crop requirement and minimum protein requirement in terms of livestock products were incorporated in the model. The minimum requirement accounts for the crops or livestock needed to fulfil home consumption required by subsistence farmers who are less market oriented. This is guided by the fact that farm income maximization is not the only objective of these farmers. Ensuring family survival and some bit of self-sufficiency are some other objectives of the farmer as he rations his resources and aim to maximize income.

Only one type of land restriction was classified for crops. For the livestock enterprises, livestock capacities were used as proxy to define size of farm. The other restrictions in the model included particularly for the selected livestock enterprises were:

i) Each poultry enterprise be it broiler or layers was fixed at a capacity of 500 birds;
ii) Egg production was fixed at a capacity of 1000 crates;
iii) Pig enterprise was limited to a capacity of 15 pigs;
iv) and the fish enterprise was limited to a capacity of 1000 fish.

Each of these livestock capacities represented a unit of activity in each case.

### 3.5 Specification of Linear Programming Technique

The linear programming technique was used in order to actualize the objectives of the study. Based on the assumptions already made, a model developed by [26] with adaptive features of [20] was modified and applied to determine the optimum enterprise combination. It is a gross margin maximization problem stated as:

$$\text{Maximize } Z = \sum_{j=1}^{n} P_j X_j - \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} X_{ij} \quad \ldots 1$$

Z is to be maximized subject to:

$$\sum_{j=1}^{m} a_{ij} X_j \leq b_i \quad \ldots 2$$

where i = 1, 2, … m; j = 1, 2, … n

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

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

And non-negativity restrictions:

$X_j \geq 0$ ... 5

where
Z = Gross margin of total output
$X_j$ = Decision variable, for instance the number of hectares the farmer devoted to the production of a crop or a combination of crops or a combination of crops or livestock capacities produced by farm
$P_j$ = The gross value per hectare of the jth activity be it crop or per livestock capacity for livestock enterprises
$C_{ij}$ = Cost per unit of ith input used in the production of the jth activity
$X_{ij}$ = Quantity of ith input in jth activity
$a_{ij}$ = the amount ‘‘a’’ of the resource ‘‘i’’ used in the production o one unit of ‘‘j’’
b = level of available resources
$b_i$ = the level ‘‘b’’ at which resources ‘‘i’’ is available
m = number of activities in the programme
$F_{ic(min)}$ = Minimum quantity of root/tuber crops required by the farm family per annum in tons (i=1,2,3...n)
$F_{ia}(\min)$ = Minimum quantity of protein required by farm family per annum in tons (i = 1,2,3,...n)

## 4. RESULTS AND DISCUSSION

### 4.1 Socioeconomic Characteristics of Farmers

A summary of the statistics of farmers in Aba agricultural zone of Abia State examined included those of age, sex, marital status, educational status, farming experience, household size and off-farm income. This summary is presented in Table 1

**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 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 a 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.

### 4.2 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 |
| ٤ | | | |
| 0.88 – 1.02 | | 1 | 3.33 |
| 1.03 – 1.17 | | 2 | 6.67 |
| ٤ | | | |
| 1.93 – 2.07 | | 1 | 3.33 |
| ٤ | | | |
| 3.88 – 4.02 | | 1 | 3.33 |
| **Total** | | 30 | 100 |
| **Mean** | 0.45 | | |
| **Standard Deviation** | 0.81 | | |

*Source: Field Survey Data, 2010*

## 4.3 Existing and Optimum Cropping / Enterprise Patterns

The existing and optimum enterprise patterns for the sampled farmers are presented in Table 3.

The study prescribed that 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/*mucuna floanei* 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.

There is therefore a departure in the types of crops included in the existing plan. While some of the farmers cropped yam as sole, in line with their consumption pattern, the linear programming method did not include sole crop given that it has a very weak competitive position. [26] had observed a similar trend among crop combinations. This seems to have persisted over time perhaps due to the small scale nature of these farmers; a situation that would obviously may not favour commercialization on the grounds of sole cropping. Except there is a structural change in the farm crop size of the farmers it may be difficult to achieve sole cropping contributing in resolving the maximization problem of an average farmer in the area.

## 4.4 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 3. Existing and optimum cropping/enterprise Patterns for Aba Agricultural Zone Abia State, Nigeria**

| Cropping pattern | Existing plan (ha) | | Optimum plan (ha) | |
|---|---|---|---|---|
| | Size of farm | Percentage | Size of farm | Percentage |
| 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 leaf | 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/Melon | 0.24 | 6.37 | - | - |
| 9. Cassava/Maize/Cocoyam | 0.31 | 8.22 | 0.33 | 17.01 |
| 10. Cassava/Maize/Yam/*mucuna floanei* | 0.13 | 3.45 | - | - |
| 11. Cassava/Maize/Yam/Cowpea | 0.13 | 3.45 | - | - |
| 12. Cassava/Maize/Melon/*mucuna floanei* | 0.33 | 8.75 | 1.30 | 67.09 |
| 13. Cassava/Maize/Melon/Cowpea | 0.13 | 3.45 | - | - |
| 14. Cassava/Maize/Yam/Melon | 0.28 | 7.43 | - | - |
| 15. Cassava/Maize/Yam/Melon/Telferia leaf | 0.85 | 22.55 | - | - |
| 16. Broilers 1 Jan-May | 0.48 | 57.14 | 0.14 | 100 |
| 17. Broilers 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 | |
| % Broilers | | 100 | | 100 |
| Fish | 1.65 | | 0.11 | |
| % Fish | | 100 | | 100 |

*Source: Field Survey, 2010*

**Table 4. Gross margin (in Naira) for existing and optimum plans for the selected farmers in Aba zone**

| Zone | Existing Plan | Optimum Plan | Increase/Decrease over Existing Plan | % |
|---|---|---|---|---|
| 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 [33]. 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.

## 4.5 Labour Utilization

Labour utilization by an average farmer 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 in Aba Agricultural Zone**

| | Existing | Optimum |
|---|---|---|
| **Crop** | | |
| LPP | 110 | 102.07 |
| 1st Weeding | 90 | 21.79 |
| 2nd Weeding | 90 | 58.98 |
| Harvesting | 120 | 98.73 |
| **Total** | **410** | **281.50** |
| **Livestock** | | |
| Feeding | 140 | 30.64 |
| Cleaning | 70 | 11.26 |
| Sorting | 10 | 1.58 |
| Harvesting | 15 | 0.28 |
| **Total** | **235** | **43.76** |

*Source: Field Survey, 2010*

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

## 4.6 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. [16] 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 price was 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 leaf | 10, 625.42 |
| 6. | Cassava/Maize/Yam | 39, 387.92 |
| 7. | Cassava/Maize/Melon | 28, 290.35 |
| 8. | Cassava/Maize/Yam/*Mucuna floanei* | 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 leaf | 8, 729.18 |
| 12. | Broiler II – August – December | 165, 200.80 |
| 13. | Fish I – January – June | 34, 200.00 |

*Source: Field Survey Data, 2010*

In the study area, a total of about 13 activities were excluded from the programme as indicated in Table 6. The situation in Aba agricultural zone showed 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 [33], in which yam/okra, a mixed cropping enterprise had the least shadow price of N254.71.

The disparity in location and resource endowment could give explain on the sharp contrast. For instance, in the study area where [33] did their research, the farmers had access to tractor hiring and a mean farm size very much greater than was obtained in Aba zone. Besides, incorporation of livestock enterprises was not considered in modelling these farmers in the former, and so, its inclusion in this later study could have introduced variations as their combination with crops will obviously affect farmers' decision on allocation of their resources. Among the livestock enterprises, broiler II usually done between August and December had the highest shadow price of N165,200.80.

## 4.7 Shadow Prices of Available Resources in the Optimized Plans

Of all the resources in Aba zone, only the human labour I (1$^{st}$ Weeding) for the crop category was limiting. It implies that none of the other basic resources constrained the attainment of the objective function. This is indicated in Table 7.

**Table 7. Shadow prices (in Naira) of limiting resources in Aba**

| Category | Resource | Status | Shadow price |
|---|---|---|---|
| Crop | Human Labour I (1st Weeding) | Tight | 310.18 |

*Source: Computed from Field Survey Data, 2010*

## 4.8 Minimum Staple Food/Livestock Requirements

Farmers in the study area as they push to maximize gross margin also ensure family survival and self-sufficiency. 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 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*

## 4.9 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 [26,20]. 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.

## 4.10 Effect of Increasing Area under Cultivation

Table 9 shows the effect of increasing area under cultivation. 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 remained constant. On the activities remaining unchanged, a similar response had been observed in previous research in another area [20]. However, relative to study area, 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 programme necessary for an average farmer to 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*

## 4.11 Effect of Varying Labour Use on the Optimum Gross Margin

Labour use was increased by 25 percent of what was available in the zone for crops and decreased by the same for livestock to see their respective effect on the optimum gross margin. This is presented in Table 10. Increasing labour by 25% of that available in Aba zone increased the value of the objective function by about N6, 979.10, which represents 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*

## 4.12 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 on optimum gross margin was also examined. This is shown in Table 11. Reduction in labour wage increased the gross margin as expected, implying that farmers would increase their gross margin if there is a decrease in the cost of labour. Alternatively, any technology that will reduce cost of labour is bound to increase gross returns in the area.

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

| Previous Optimum (N) | Present Optimum (N) | Increase (N) | % Change |
|---|---|---|---|
| 374, 850.80 | 376, 586.30 | 1, 735.50 | 0.46 |

*Source: Computed from Field Survey Data, 2010*

### 4.13 Effect of Varying the Quantity of Feed used for Livestock Production

Table 12 shows the effect of increasing the quantity of feed given to livestock by an average farmer in the area. Increase in 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) | Increase (N) | % Change |
|---|---|---|---|
| 374, 850.80 | 374, 850.80 | 0.00 | 0.00 |

*Source: Computed from Field Survey Data, 2010*

## 5. 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 showed that among about twenty enterprises that cut across arable crop and selected livestock enterprises in the existing plan, that only six enterprises none of which should include sole cropping were prescribed by the model to achieve a gross margin of N374,850.80. 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 labour as well as decrease in wage rate calling for additional labour in crop farming in particular as well as wage policies among farmers. The analysis favoured the strategy of mixed cropping at the level of the existing technology practised by the farmers. Massive introduction of high-yielding crop varieties in addition to the use of improved cultural practices is essential given the small scale nature of the farmers. It is therefore recommended that the optimal combination of enterprises be integrated in developing a prototype for the zone.

## ACKNOWLEDGEMENTS

Dr Tanko Likita who provided the software used for the analysis of the data and the contribution of Dr Jude Nwaru who was a member of the supervisory committee during the first author's Doctor of Philosophy degree (Ph.D.) Dissertation were very fundamental to the success of the research. Mr. Gideon Nmamerenwa and Mr Bismark assisted in the collation of data for the socioeconomic characteristics of the respondents.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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## APPENDIX

### Aba Zone - Programme

### Activity

| Code | Name |
|---|---|
| P01 | Yam production in hectare |
| P02 | Cassava/maize production in hectare |
| P03 | Yam/melon production in hectare |
| P04 | Cassava/melon in hectare |
| P05 | Maize/yam/telferia production in hectare |
| P06 | Cassava/maize/melon production in hectare |
| P07 | Maize/yam/melon production in hectare |
| P08 | Cassava/maize/yam production in hectare |
| P09 | Cassava/maize/cocoyam production in hectare |
| P10 | Cassava/maize/yam/ *mucuna floanei* production in hectare |
| P11 | Cassava/maize/yam/cowpea production in hectare |
| P12 | Cassava/maize/melon/ *mucuna floanei* production in hectare |
| P13 | Cassava/maize/melon/cowpea production in hectare |
| P14 | Cassava/maize/yam/melon production in hectare |
| P15 | Cassava/maize/yam/melon production in hectare |
| P16 | Broiler production per 500 birds for season 1 (Jan – May) |
| P17 | Broiler production per 500 birds for season 2 (Aug – Dec) |
| P18 | Fish production per 1000 fish for season 1 (Jan – June) |
| P19 | Fish production per 1000 fish for season 2 (July – Dec) |
| P20 | Pig production per 15 pigs |
| P21 | Human labour I requirement land preparation and planting |
| P22 | Human labour I requirement in mandays 1$^{st}$ weeding |
| P23 | Human labour I requirement in mandays 2$^{nd}$ weeding |
| P24 | Human labour I requirement in mandays Harvesting |
| P25 | Human labour II requirement in mandays feeding |
| P26 | Human labour II requirement in mandays Cleaning |
| P27 | Human labour II requirement in mandays Sorting |
| P28 | Human labour II requirement in mandays Harvesting |

| | |
|---|---|
| | Yam selling in naira per ton |
| P29 | |
| P30 | Cassava selling in naira per ton |
| P31 | Maize selling in naira per ton |
| P32 | Melon selling in naira per ton |
| P33 | Telferia selling in naira per ton |
| P34 | Cocoyam selling in naira per ton |
| P35 | *Mucuna floanei* selling in naira per ton |
| P36 | Cowpea selling in naira per ton |
| P37 | Broiler I selling in naira per ton for season 1 |
| P38 | Broiler II selling in naira per ton for season 2 |
| P39 | Fish I selling in naira per ton for season 1 |
| P40 | Fish II selling in naira per ton for season 2 |

## Resource Restrictions

| Code | Name |
|---|---|
| R0 1 | Land I for crop production |
| R02 | Land II rep by stock capacity in 500 birds |
| R03 | Land III rep by stock capacity in 1000 fish |
| R04 | Land IV rep by stock capacity in 15 pigs |
| R05 | Human labour I requirement in mandays land preparation and planting |
| R06 | Human labour I requirement in mandays 1$^{st}$ Weeding |
| R07 | Human labour I requirement in mandays 2$^{nd}$ Weeding |
| R08 | Human labour I requirement in mandays Harvesting |
| R09 | Human labour II requirement in mandays Feeding |
| R10 | Human labour II requirement in mandays Cleaning |
| R11 | Human labour II Hiring requirement in mandays Sorting |
| R12 | Human labour II Hiring requirement in mandays Harvesting |
| R13 | Feed in tons |
| R14 | Transfer row (yam in tons) |
| R15 | Transfer row (cassava in tons) |
| R16 | Transfer row (maize in tons) |
| R17 | Transfer row (melon in tons) |
| R18 | Transfer row (telferia in tons) |
| R19 | Transfer row (cocoyam in tons) |
| R20 | Transfer row (*mucuna floanei* in tons) |
| R21 | Transfer row (cowpea in tons) |
| R22 | Transfer row (broiler I in tons) |
| R23 | Transfer row (broiler II in tons) |
| R24 | Transfer row (fish I in tons) |
| R25 | Transfer row (fish II in tons) |

| | |
|---|---|
| R26 | Transfer row (pig in tons) |
| R27 | Minimum tuber requirement yam in tons |
| R28 | Minimum tuber requirement cassava in tons |
| R29 | Minimum tuber requirement maize in tons |
| R30 | Minimum tuber requirement cocoyam in tons |
| R31 | Minimum protein requirement broiler in tons |
| R32 | Minimum protein requirement fish in tons |
| R33 | Minimum protein requirement pig in tons |

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