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APPLICATION OF LINEAR PROGRAMMING TO SEMI-COMMERCIAL ARABLE AND FISHERY ENTERPRISES IN ABIA STATE, NIGERIA

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ABSTRACT

Linear programming technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity. The growing fisheries sub-sector among arable crop farmers in Ohafia Agricultural Zone necessitated the development of a prototype LP model for the semi-commercial farmers in the area. A circle was selected from each of the three blocks within Ohafia Agricultural Zone using a sampling frame from the Zonal Office of the Agricultural Development Programme (ADP). Thirty respondents were randomly selected to develop optimum enterprise combination and to carry out the investigation on maximization of gross returns from semi-commercial agriculture in the Zone. Major arable crops undertaken by farmers who combine their crop farming with fishery enterprise were identified. A list of these farmers derived from the zonal office of Agricultural Development Programme in Ohafia formed the sampling frame. With the assistance of the three extension officers in the chosen zone, a cost route approach was used to generate data from the production season to the marketing of products. A Linear programming technique was applied to determine the optimum enterprise combination using 2009/2010 farm data. Out of the twelve production activities, made up of ten cropping activities and two fish enterprises, only two – one for crop and livestock enterprises respectively is recommended by the model for farmers to achieve a gross income of N342,763.30. This will help in enhancing food security among rural farmers in study area in particular and the country in general.

Keywords: *Linear programming, optimum combination, existing enterprises, optimum plan, Ohafia.*

INTRODUCTION

The protein usually needed for growth and replacement of various cells of the body is often lacking in the diets of most Africans particularly Nigeria that has many problems facing her agricultural production (Olorunfemi, 2006; Obasanjo, 1990). Protein intake can be increased through the consumption of crops such as soya beans, groundnut, pigeon peas and beans. However, with respect to Abia state, a good representation of these classes of food crops does not thrive within her agro ecological zone. Given that there is per acutely low consumption of animal protein generally, arable crop farmers who produce for subsistence and commercial purposes need to be planned for bearing in mind animal enterprise integration or mixed farming.

Generally, allocation problems are concerned with the utilization of limited resources to best advantage (Lucey, 2002). If there were no resource constraints, the farmer perhaps could allocate without optimizing or optimize without considering the allocation implication but not both (Olayemi and Onyenweaku, 1999). Greater emphasis upon efficient utilization of the existing resources and combination of enterprises in an optimal manner in the food crop sub-sector is paramount.

Mixed crop-fishery systems constitute the backbone of much agriculture in the tropics with the demand for livestock products forecasted to skyrocket well into the next century (Delgado *et al*., 1999). An understanding of the pathways that different production systems may follow in Nigerian agriculture cannot therefore be overemphasized. In reality, optimum may encompass many things including utilizing resources in their most

efficient and productive manner; providing favourable cash flows; satisfying attractiveness constraints of buyers and or production; maximizing profits in the short and long run and satisfying current demand trends and preventing oversupply situation. The real challenge is to find a production mix that accomplishes all or most of these things. It is certainly not easy but the procedural step to achieving balance is possible through the use of LP technique (Okolie *et al*, 2010).

METHODOLOGY

Three blocks were selected from the zone. The third stage involved the circle level, whereby three circles were selected in each block. This gave a total of three circles. The fourth stage involved selecting a village (farming community) from each of the three circles. A list of arable crop farmers who may be involved also in fish enterprises were identified with the assistance of the village heads and the extension agents in each of the three villages so chosen across Ohafia Agricultural zone of Abia State, Nigeria. It was this list that constituted the actual sampling frame for the study. Ten potential farmers belonging to this class was chosen and a total of thirty respondents were used for the study. Two enumerators from the zone were hired and trained to assist in data collection using designed questionnaire. Fish enterprise was incorporated in the model as some of the arable crop farmers were involved in one form of livestock or the other. Fish was restricted to 1000 fish.

The general deterministic LP model of the study is a gross margin maximization model designed to find out the optimum solutions.

The model patterned after Osuji (1978) and with adaptation from Tanko (2004) on the minimum restrictions is specified mathematically as:

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

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

Z is to be maximized subject to:

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

$$X_j \geq 0 \quad \ldots 3$$

Where

aij = the amount ‘‘a’’ of the resource ‘‘i’’ used in the production o one unit of ‘’j’’.

b = level of available resources.

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

m = number of activities in the programme.

$\sum f_{ic} X_j \geq F_{ic}(\min)$ (minimum subsistence farm-family tuber/cereal crop requirement) ... 4

$\sum f_{if} X_j \geq F_{ia}(\min)$ (minimum subsistence farm-family protein requirement) ... 5

where

$F_{ic(\min)}$ = Minimum quantity of root/tuber crops required by the farm family per annum in tons (i=1,2,3...n)

$F_{if}(\min)$ = Minimum quantity of protein required by farm family per annum in tons (i = 1)

RESULTS AND DISCUSSION

Farm Resource Allocation under Existing and Optimum Cropping/Enterprise Pattern

Land Allocation under Existing and Optimum Plans

The existing land use in terms of hectarage allocation and for fish capacity and their optimum plans are presented in Table 1. The smallholder farmers usually cultivate several plots altogether less than a hectare per farmer devoted to different crops in scattered locations as indicated in the existing plan. Due to optimization, cassava/maize/cocoyam was the predominant and only cropping pattern among the numerous selected arable crops while fish II, usually between July-December was the only fish enterprise that appeared in the optimum plan.

Thus contrary to the existing plan that 0.64 hectares be dedicated to cassava/maize/cocoyam, the optimum recommends 2.58 hectares while 0.25 100 fish should be combined with it to maximize gross returns from the available arable land and fish capacity available in the area.

Table 1: Existing and Optimum Cropping/Enterprise Pattern for Arable Crop and Fish Farms in Ohafia, Abia State, Nigeria

S/N	Cropping/Enterprise Pattern	Existing Plan	Optimum Plan
1.	Yam	0.18 (5.94%)	-
2.	Cassava	0.41 (13.53%)	-
3.	Yam/Melon	0.18 (5.94%)	-
4.	Yam/Maize	0.34 (11.22%)	-
5.	Cassava/Maize	0.24 (7.92%)	-
6.	Cassava/Melon	0.22 (7.26%)	-
7.	Cassava/Maize/Cocoyam	0.64 (21.12%)	2.58 (100%)
8.	Cassava/Maize/Melon	0.22 (7.26%)	-
9.	Cassava/Maize/Yam	0.41 (13.53%)	-
10.	Yam/Maize/Melon	0.19 (6.27%)	-
11.	Fish II – Jan-June	0.19 (44.19%)	-
11.	Fish II- July-December	0.24 (55.81%)	0.25
Total Cropped Area		3.03	2.58
Total Fish Capacity		0.45	0.25
% Sole Crops		19.47%	0%
% Crop Mixtures		80.52%	100%
% Fish I		44.19%	0%
% Fish II		55.81%	100%

Source: Field Survey Data, 2009/2010

Gross Margin per Hectare in Naira in the Existing and Optimum Plans
The gross margin for the existing and optimum plans is presented in Table 2. It indicates that the optimum plan is in increase in gross margin over the existing plan by 44.6%.

Table 2: Gross Margin per Hectare in Naira in the Existing and Optimum Plans

	Existing Plan	Optimum Plan	Increase/Decrease	Percentage
Value	N188,736.29	N342,763.30	154,027.01	44.6

Source: Field Survey Data, 2009/2010

Human Labour Days Utilization in man hours for Selected Arable Crops and Fish Enterprises
Human labour utilized for different farm operations involving arable crops and fish production for existing and optimum plans is presented in Table 3. Whereas the existing plan indicated that 300 mandays of labour should be used, the plan recommended that it be increased to 374 mandays for crops as against 34.32 man hours for fish enterprise which was very much lower than the 234 mandays of labour usage in the existing plan. There is therefore clear evidence of labour resource misallocation among farmers in the area.

Table 3: Human Labour Days Utilization in man hours for Selected Arable Crops and Fish Enterprises in Ohafia Agricultural Zone, Abia State, Nigeria

Labour Periods	Existing Plan	Optimum Plan
Arable Crops		
Land preparation and planting	60	49.03
1st Weeding	70	74.84
2nd Weeding	80	93
Harvesting	90	157.42
Total	**300**	**374.29**
Fish		
Feeding	210	18.26
Cleaning	15	12.5
Sorting	5	3.19
Harvesting	4	0.37
Total	**234**	**34.32**

Source: Field Survey Data, 2009/2010

Marginal Value Product of Resources
Table 4 and 5 respectively show the marginal value products of land and livestock capacities and labour respectively. The marginal value product of land in the optimum plan for crops and livestock capacity was zero. However, the marginal value product of labour was N450.00 during first weeding and N100.70 for the 2nd weeding operations and n350.00 for harvesting operations for crop enterprises. On the other hand for all labour periods under fish enterprises the marginal value product of labour was zero.

Table 4: Marginal Value Product of Land and of Livestock Capacity

Land I	Land II
0.00	0.00

Source: Field Survey Data, 2009/2010

Table 5: Marginal Value Product of Labour for Arable Crops and Fish Enterprises in Ohafia Agricultural Zone, Abia State, Nigeria

Labour Periods	MVP
Arable Crops	
Land preparation and planting	0.00
1st Weeding	450.00
2nd Weeding	100.70
Harvesting	350.00
Fish	
Feeding	0.00
Cleaning	0.00
Sorting	0.00
Harvesting	0.00

Source: Field Survey Data, 2009/2010

Shadow Prices of Excluded Activities

Shadow prices are marginal returns to increments of available resources. In the context of maximization problem, only the excluded activities have positive shadow prices. They show the amount by which income would be reduced if any of the excluded activities is forced into the programme. The shadow prices of the excluded activities for the arable crop and fish enterprises in Ohafia agricultural zone obtained as by-products of the linear programming solution are presented in Table 6.

From the results in Table 6, yam/melon had the least propensity to depress farm income. If forced into the plan while Fish I usually done between January and June had the highest propensity to reduce gross return from the selected farms.

Table 6: Shadow Prices (in Naira) of Excluded Activities in Linear Programming Solution

S/N	Excluded Activity	N
1.	Yam	85,960.95
2.	Cassava	64,315.50
3.	Yam/Melon	56,527.94
4.	Yam/Maize	78,348.18
5.	Cassava/Maize	81,979.97
6.	Cassava/Melon	84,086.30
7.	Cassava/Maize/Melon	94,918.77
8.	Cassava/Maize/Yam	132,710.40
9.	Yam/Maize/Melon	94,189.63
10.	Fish 1- Jan-June	154,200.00

Source: Field Survey Data, 2009/2010

Sensitivity Analysis

A unit increase of land for the crops, labour across all peaks for crops and livestock as well as mean wage rate and least of the peaks were observed under sensitivity analysis. Table 7 shows their various effects on the obtained optimum gross margin. Result show that gross margin remained unchanged following a unit increase on land while when labour was parametized by 1 manday across the various peak, optimum plan increased by N900.70, representing a 0.26% of the obtained gross margin.

The means of the wage rate for crops and fish enterprises were respectively N475.00 and N963.40. When each was parametized, the gross margin decreased by 0.53% from what it was while it increased by 0.14% following for the mean wage rate for crops and for fish respectively. However, the least wage rates of N350.00 for crops and N426.80 for fish when used for the sensitivity analysis remained as it was observed in the effect of the mean for that of fish while the gross margin remained unchanged as the least wage rate for crops was parametized. A reduction of land devoted to selected arable crops by 1 hectare on the other hand reduced gross margin by N7,212.70K.

Table 7: Effect of Sensitivity Analysis on Gross Margin on Optimum Plan

Effect	Previous Plan	New Optimum Plan	Increase/Decrease	Percentage
1 hectare	N342,763.30	N342,763.30	0.00	0.00
1 manday	N342,763.30	N343,664.00	900.70	0.26
Mean Wage Crop	N342,763.30	N340,956.90	-1806.40	0.53
Least Wage crop	N342,763.30	N343,247.20	483.90	0.14
Mean Wage Fish	N342,763.30	N343,247.20	483.90	0.14
Least Wage Fish	N342,763.30	N342,763.30	0.00	0.00
Reduce by 1 ha	N342,763.30	N335,550.60	-7212.70	2.10

Source: Field Survey Data, 2009/2010

CONCLUSION

A liner programming analysis for maximization of the gross margin of farmers involved in a combination of selected arable crops and fisheries enterprises reveal that in planning for an average farmer, 2.58 hectares of land be devoted to cassava/maize/cocoyam while 0.25 100 fish be incorporated to achieve a gross margin of N342,763.30. When parametized by increase of a unit of land, gross margin did not increase, implying that land is not really a limiting resource as such while for a unit increase in manday, gross margin increased from its obtained optimum plan by 0.26%. Policies of government that would help farmers secure a steady labour supply in the rural areas would help improve relatively on their gross margin for the selected arable and fish enterprise combination.

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