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Optimum Cropping Patterns under Limited Resource Conditions: A Micro-Level Study in Imo State, Nigeria

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Abstract: This study was designed to analyse resource allocation pattern for 120 food crops farmers in Imo State, Nigeria and to develop optimum combination of food crops considering available resources. Linear programming technique was used for optimizing resources. Multi-stage stratified random sampling techniques was used in selecting respondents to obtain the data necessary to formulate farm plans, for a representative farm household in Imo State during the 2006 cropping season. Data were collected using the cost route approach. Results show a divergence between the existing and optimum farm plans under limited and borrowed capital situations. Farm resources were not optimally allocated and after optmisation, farm income and employment of labour could be increased. At the margin, ₦1.00 borrowed capital could yield up to ₦1.88 in additional farm income. Sensitivity analysis revealed that wages for hired labour were high and more land should be brought under cultivation in order to increase farm income. Effective farm advisory services that will educate farmers on the efficient allocation of their resources is needed, together with adequate financing of agricultural production.

Key words: Optimum, resource, programming, cost-route, income, sensitivity

INTRODUCTION

The goals of small scale crops farmers spanning through efficient allocation of resources through optimum enterprise combination, year round provision of food for the household, monetary income accumulation and minimizing expenditure on hired labour have not been fully achieved in sub-Saharan Africa (Adejobi *et al*., 2003; Tanko *et al*., 2006). Recent reports by Ano *et al*. (2003) and Ohajianya (2005) revealed that food supply has not kept pace with demand. The food deficit situation resulting from inefficient production techniques, leading to technical, allocative and economic inefficiencies (Nwosu, 1981; Ohajianya, 2006) is worsened by declining crop productivity (Obasi, 2005). Achieving increased productivity in food crops production is therefore, imperative to achieve the goals of the small scale farmers. Presently, little attention is devoted to the role of farm planning in solving the food deficit problem of the small scale food crops farmers (Tanko *et al*., 2006). To ensure substantial improvement in food crops output there is need for effective combination of measures aimed at increasing the level of farm resources and making efficient use of the resources already committed to the food sub-sector (Tanko *et al*., 2006; Adejobi *et al*., 2003; Alam, 1994). Nwosu (1981) advocated the combination of farm enterprises, while Tanko (2005) and Alam *et al*. (1995) indicated the optimum combination of enterprises by developing optimal farm plans. A typical farmer anywhere in the world has limited level of resources and he is faced with the problems of myriad of choices for allocating farm resources between crop and animal enterprises so as to optimize production objectives by making efficient utilization of the available resources and combining the enterprises in an optimal manner. Identifying the best farm plan is a difficult task for small-scale farmers with low literacy level. Therefore, if the limited resources available to the numerous small-scale farmers that produce buck of the food consumed in Nigeria are to be used efficiently, optimum farm plans must be formulated for them by region or locality. Studies in optimum resource allocation in a regional framework using linear programming approach have largely been attempted in many countries (Alam *et al*., 1995; Sama, 1997; Alam, 1994; Onyenweaku and Fabiyi, 1991; Schipper *et al*., 1995; Dipeolu *et al*., 2000; Tanko, 2003; Adejobi *et al*., 2003; Tanko *et al*., 2006). These plans could help policy-makers predict farmers'responses to policy alternatives, thereby

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sharpening the policy decision making process. This study aims at developing optimum cropping patterns and resource allocation for small-scale food crops farmers in Imo State, Nigeria using the linear programming technique.

MATERIALS AND METHODS

This study was conducted in Imo State; located in the south Eastern zone of Nigeria. It had a population of about 2.485 million people in 1991 (Ohajianya and Mgbada, 2006). The state is divided into 27 administrative units called Local Government Areas (LGAs) which are grouped into 3 agricultural zones of Owerri, Okigwe and Orlu. Agriculture is the major occupation of the people and almost all the families farm either as primary or secondary occupation. The ecological zone of the state favours the growing of tree crops, roots and tubers, cereals, vegetables and nuts. These crops are grown in small holder plots usually in mixtures of at least two simultaneous crops. The main cash crop grown in the state is oil palm, while the major food crops are cassava, yam, cocoyam, plantain; maize, rice and vegetables. Most families keep livestock either as part time or full-time farmers. The major types of livestock kept include; sheep, goat, rabbit, pigs and poultry.

The sampling procedure employed was the multi-stage stratified sampling technique. The state was stratified into the three agricultural zones of Owerri, Orlu and Okigwe. From each zone, 2 LGAs were chosen at random and from each LGA 2 communities were randomly selected. In each community, the list of food crops farmers was compiled by the resident extension agent and from this sampling frame, 10 farmers were randomly selected, giving a sample size of 120 farmers. The limited cost route approach based on frequent interviews on forth nightly basis during the 2005 production season was adopted over a 6 months period for the collection of data which started in September, 2005 and lasted till February, 2006 after all the crops were harvested. The socioeconomic characteristics of the farmers and production activities in terms of inputs, outputs and their prices constitute the bulk of the data collected. The yield plot method which involved calculating the yields of 10,000 square meter portions (i.e., 10×10 m plots) on some of the sampled farms which was used by Tanko *et al.* (2006) was employed to estimate the yield of crops. For crop mixtures, the average number of stands of each crop in a particular mixture, was determined and the crops were later on harvested and weighted to determine the per hectare yield of each crop in the mixture. Computed yield figures were then applied to the total hectarage of each mixture to obtain production estimates. These production estimates were then valued at the prevailing market prices to estimate potential gross returns.

The empirical model: The objective function is to maximize Net Farm Income (NFI), which is total gross farm income (TR) minus the Total Variable cost (TV) and Total Fixed Costs (TFC) (NFI = TR-TC). Where TC = TVC + TFC.

The empirical model is of the form;

$$\text{Maximize } Z_f = \sum_{j=1}^{n} P_j X_j - \sum_{t=1} WL_t \sum_{t=1} Fq_t - \sum_{t=1} Mu_t - \sum_{t=1} PY_t - \sum_{t=1} M_t - \sum_{t=1} Q_t - D - R \quad (1)$$

Subject to:

$$= \sum_{j=1,\ S=1,\ 2\ldots}^{n} bX_j \leq L_s \text{ (Land)} \quad (2)$$

$$\sum_{(t)} dX_j - L_t \leq H \text{ (labour)} \quad (3a)$$

$$\sum_{(t=1,\ 2,\ 3)} CX_j - M_t \leq C_j \text{ (capital)} \quad (3b)$$

$$\sum f X_j \geq F_{mm} \text{ (Minimum farm household food requirement)} \quad (4)$$

$$X, L, K, P, R, M \geq 0 \quad (5)$$

where:

Z_f = Total net farm income in ₦
X_j = Units of the jth crop activity in ha
P_j = Gross value of output per hectare of the jth crop activity in ₦
W = Wage rate per unit hire of labour in ₦
L = Wage rate per unit of labour (manday) in ₦
F = Fertiliser price per 50-kg bag in ₦
q = Quantity of 50kg bags of fertilizer used
M = Quantity of planting materials used in kg
U = Unit price per kg of planting materials in ₦
P = Marketing expense per unit of the product sold in t^{th} period
Y = Units of crop products sold in t^{th} period
M_t = Interest paid on borrowed capital in ₦
Q_t = Other variable cost items in ₦, eg family labour, agro-chemical, etc
D = Depreciation on fixed cost items such as equipment, implements, tools, etc in ₦

R = Rent on land in ₦

F_{mm} = Minimum quantity of food crops required y the farming household per annum in tons.

I_{jt} = Input coefficient of land which is 1 ha with restrictions

ajk = Input coefficient of labour (in mandays) for j^{th} crop activity in t^{th} period

Cjk = Amount of capital used in producing 1 ha of j^{th} crop activity in t^{th} period in ₦

$\sum_{j=i}^{n}$ = Summation of jth crop activities (j = 1 to n)

The constraints for land, labour and capital require that the amount of a resource required must not exceed the available quantity.

Activities in the model and the price coefficient "P_j": The activities in the model can broadly be grouped into crop production activities, labour hiring activities, capital borrowing and product selling activities. The crop production activities are broadly grouped into sole crops and crop mixtures. For each of the crop production activities, the unit of activity is 1 ha.

The price coefficient "P_j" of a production activity in the model is the gross value of output per hectare of all the crops. For a labour hiring activity, the price coefficient is the ruling wage rate. For a capital borrowing activity, the price coefficient is the prevailing market rate of interest, while for a selling activity, the price coefficient is the marketing expense per unit of the product sold.

Input coefficients: The input coefficients refer to the requirement of a crop activity in respect of the inputs of the different resources measured in terms of per hectare basis (unit of land). The input coefficients for all the crop activities were calculated on the basis of the actual quantities of different resources used for this crop activities. For instance, the input-output coefficient for labour are denoted by bjt's and they refer to the amount of labour in mandays used in producing a hectare of the jth crop activity in t^{th} period.

Resource constraints/restrictions in the model: Four constraints were incorporated in the model. These are land, labour (with 6 restriction periods namely, land preparation, planting, first weeding, fertilizing, second weeding and harvesting, capital (with three restriction periods namely; April-June, July-September and October-December and food crops requirement constraints. Minimum food crops requirement refers to household food supply, another possible constraint in farm planning (Alam *et al*., 1995; Tanko *et al*., 2006).

Small scale farmers cultivate land area enough with food crops needed to satisfy their household consumption requirement. Their production is less market oriented. It was estimated that a farming household would require a minimum of 20 t of food crops to meet up annual household requirement.

RESULTS AND DISCUSSION

Socio-economic characteristics of farming household heads: The average farming household surveyed had nine persons and the typical farmer interviewed was married, 45 years old and had at least primary education.

Mixed cropping patterns accounted for a greater proportion of the crop production activities. The average farm size per household was 2.05 ha comprising several plots, most plots being <1.5 ha. Farming operations relied primarily on hired labour and traditional farming practices. The operating capital averaged ₦74165 and the farmers that had access to borrowed capital received an average of ₦58470 as farm credit. The mean years of farming experience was 14.3, while the mean number of extension visits was 0.64.

Land allocation under existing optimum plans: The existing land use pattern together with the emerging optimum allocation of land under the limited and borrowed capital situations for the different crop enterprises are presented in Table 1. Farmers under the existing plan devoted more hectares of land to crop mixtures involving cassava/maize (11.22%) followed closely by cassava/ vegetables (10.73%) and yam/cassava/maize/vegetable (10.24%). The farmers devoted more land (78.04%) to crop mixtures and only 21.96% to sole crops.

The optimized plans show that farmers cultivated more crops when they have access to borrowed capital (1.98 ha) than when they used limited or own capital (1.64 ha). Results also show that farmers planted more sole crops when they used limited capital (23.17%) than when they used borrowed capital (20.70%), while mixed cropping was practiced more than sole cropping when borrowed capital was used, as indicated by 79.30 and 76.83% of total cropped area under borrowed and limited capital, respectively. This result suggests, that farmers diversify their crop production enterprise more when they use borrowed capital, so as to guard against crop failure since the loan would be repaid. The results of the optimization plans also reveal that, in order to optimize returns, a farming household in the study area should allocate available land to five crop enterprises. Larger farm sizes, coupled with efficient utilization of resources and better management practices, should translate into increased outputs and farm income.

Table 1: Existing and optimum cropping patterns

Cropping patters	Existing plan	Optimum plans	
		With limited capital	With borrowed capital
Yam	0.15 (7.32)	0.14 (8.53)	0.16 (0.08)
Yam/maize	0.17 (8.89)	0.13 (7.93)	0.18 (9.09)
Yam/maize/vegetable	0.19 (9.27)	0.15 (9.15)	0.20 (10.10)
Yam/cassava/maize/vegetable	0.21 (10.24)	0.18 (10.98)	0.20 (10.10)
Yam/cassava/maize	0.18 (8.78)	0.13 (7.93)	0.19 (9.60)
Cassava	0.19 (9.27)	0.15 (9.15)	0.17 (8.58)
Cassava/maize	0.23 (11.22)	0.17 (10.56)	0.22 (11.11)
Cassava/vegetable	0.22 (10.73)	0.18 (10.98)	0.23 (11.62)
Maize	0.9 (4.39)	0.07 (4.27)	0.08 (4.04)
Maize/vegetable	0.12 (5.85)	0.09 (5.48)	0.10 (5.05)
Cocoyam	0.02 (0.98)	0.02 (1.22)	- -
Cocoyam/maize	0.05 (2.44)	0.05 (3.05)	0.04 (2.02)
Cocoyam/maize/vegetable	0.13 (6.34)	0.10 (6.10)	0.11 (5.56)
Cocoyam/vegetable	0.10 (4.88)	0.08 (4.87)	0.10 (5'.05)
Total cropped area (%)	2.05 (100)	1.64 (100)	1.98 100
Sole crops (%)	21.96	23.17	20.70
Crop mixture (%)	78.04	76.83	79.30

Figures in parentheses are percentages to total, Source: Survey data, 2006

Table 2: Labour utilization (mandays) under limited and borrowed capital situations

Farm operation	Existing plan	Optimum plans		Increase/decrease over existing plan			
		Limited capital	Borrowed capital	Limited capital	(%)	Borrowed capital	(%)
Land preparation	23.27	18.44	20.31	-4.83	-20.76	-2.96	-12.72
Planting	10.25	6.35	8.22	-3.90	-38.05	-2.03	-19.80
First weeding	28.32	19.43	24.59	-8.89	-31.39	-3.73	-13.17
Fertilizing	9.42	4.21	7.53	-5.21	-55.31	-1.89	-20.06
Second weeding	22.48	15.13	39.56	-7.35	-32.70	+17.08	75.98
Harvesting	17.25	23.42	30.65	+6.17	35.77	+13.40	77.68
Total	110.99	86.98	130.86	-24.01	-21.63	+19.87	17.90

Computed from survey data, 2006

Utilization of labour: The utilization of labour for the existing and optimized plans under limited and borrowed capital situations in selected peak labour periods are presented in Table 2. Results show that the optimized plans reduced labour requirement during land preparation, planting, first weeding and fertilizing operations by 12.72, 19.8, 13.17 and 20.06% respectively, but increased labour requirement during the second weeding and harvesting peak periods of farm operations under the borrowed capital situation by 75.98 and 77.68%, respectively. Under the borrowed capital, labour requirement increased by 17.9%, while tightening the capital constrain reduced labour requirement by 21.63%. Due to capital scarcity, the farmers kept their lands fallow under the limited capital situation in the optimized plans. The farmers had to hire more labour during the second weeding and harvesting operations under the borrowed capital situation. Increased labour utilization is necessary and justifiable during the harvesting operation so as to minimize spoilage and deterioration of food crops in the fields.

Net farm income under existing and optimum plans: The net farm income realized from the existing and optimum plans under limited and borrowed capital situations are presented in Table 3. The results show that the optimized plans increased net farm incomes by 40.7 and 56.2% under the limited and borrowed capital situations, respectively. This implies that there was mal-allocation of existing resources and there is scope for increasing farm income by reallocating the existing resources in an optimal manner. The relaxation of the capital constraint by allowing the borrowing of capital raised income by 46.5%. Access to adequate and timely credit facility by farmers is likely to raise farm income. The non-institutional credit sources of the financial market provides the bulk of the agricultural loan used by small scale farmers. But loans from these sources are usually small and inadequate to meet the credit needs of the farmers. At the margin, ₦1.00 in borrowed capital could yield up to ₦1.88 in additional farm income.

Sensitivity analysis: The formulated optimum plans were subjected to sensitivity analysis to enable us chose a particular optimum solution which conforms to the farmers' production characteristics and resource constraints. The results presented in Table 4 that increasing the area under cultivation by 2 ha resulted in optimum farm income increasing by ₦80994.82 and

Table 3: Net farm income (₦) in the existing and optimum plans

	Optimum plans		Increase over existing plan		Increase in borrowed over limited capital situation	
Existing plan	Limited capital	Borrowed capital	Limited capital (%)	Borrowed capital (%)	Amount	(%)
54609.23	92103.45	124633.54	37494.22 40.7	70024.31.56.2	32530.09	46.46

Table 4: Sensitive analysis of the plans under limited and borrowed capital situations

Optimum income from initial programme (₦)		Optimum income for the present model (₦)		Increase in farm income (₦)		Percentage change (%)	
Limited capital	Borrowed capital	Limited capital	Borrowed capital	Limited capital	Borrowed capital	Limited capital	Borrowed capital
92103.45	124633.54	173098.27	192155.23	80994.82	67521.69	87.94	54.18
92103.45	124633.54	139812.33	147492.36	47708.88	22858.82	51.80	18.34

Computed from survey data, 2006

₦67521.69 representing 87.94 and 54.18% under the limited and borrowed capital situations, respectively. The increase in revenue was as a result of utilizing those resources that were idle when land posed a constraint to production.

On the part of the 2nd constraint (labour), where average real wage rates were equated with those institutionally determined, the optimized plans increased farm incomes by 57.80 and 18.34% under the limited and borrowed capital situations, respectively. Labour supply is a positive function of real wage. Since wage rates offered in government owned farms are lower than what the farmers pay their farm hands, its supply will be high relative to demand, the only constraint being the farmers ability to pay. These findings are similar to those of Tanko *et al.* (2006), Adejobi *et al.* (2003), Dipeolu *et al.* (2000) and Alam (1994).

CONCLUSION

The results of the study reveals a divergence between the existing and optimum farm plans under limited and borrowed capital situations. More land was allocated to mixed cropping under borrowed capital situation so as to guard against crop failure and ensure repayment of loans. Resources were not optimally allocated and thus, there is room for increasing farm incomes by reallocating the existing resources in an optimal manner.

Increasing the area under cultivation resulted in an increase in optimum farm income. More land should be brought under cultivation to optimize farm returns.

Reduction in wages for hired labour led to an increase in optimum farm income indicating that the wages were high. Since, farmers have limited cash to hire labour, agricultural productivity will be low so long as labour hiring is an indispensable component of small scale farming and thus there is need to adequately finance agricultural production.

The number of extension visits was very low, there is need for effective farm advisory services and extension programmes that will educate farmers on efficient allocation of their resources so as to ensure increased outputs and farm income.

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