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A GOAL PROGRAMMING APPROACH TO MULTI-OBJECTIVE FARM PLANNING AMONG SMALL-SCALE ARABLE CROP FARMERS IN KOGI STATE, NIGERIA

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SUMMARY

The purpose of this study was to develop prototype farm plans according to the multi-objective production goals of small-scale arable crop producers in Kogi State, Nigeria. A multi-stage sampling technique was used to select a total of 137 farm households in different local government areas (LGAs). A structured questionnaire complemented with interview schedule was used to collect primary data from the respondents. Descriptive statistics and linear goal programming were used for data analysis. The results obtained indicate that the optimal plan of generating an income of ₦242,076.20 requires 0.368 ha of melons, 0.044 ha of yam/maize mixture and 0.259 ha of sorghum/groundnuts. The optimal net profit was 44.05% higher than that achieved by implementing the existing plan. To meet family food requirements, the solution plan prescribed devoting 0.048 ha to cassava, 0.211 ha to sorghum, 0.368 ha to melons, 0.074ha to Bambara nuts, and 1.065 ha to sorghum/groundnuts to generate an income of ₦158,475.00. To minimize paid labour and generate an income of ₦168,325.50, the plan prescribed devoting 0.195 ha to rice, 0.502 ha to melons and 0.246 ha to Bambara nuts. Out of the three basic farm household objectives considered, meeting family food requirements and limiting labour expenditure were overachieved, whereas the objective of maximizing farm income was underachieved. A great deal of the existing staple food plan was found consistent with the prescribed optimal plan, except in the case of existing cassava and Bambara nut production which was falling short of the optimal production prescribed. The maize/groundnut production had the lowest shadow prices. However, land, labour, capital, agrochemicals, fertilizers and seeds constituted the limiting resources in the plan. It was found that these resources were not optimally allocated in the existing plan for arable crop activities. Therefore, the respondents were advised to utilize their resources as prescribed in the optimum plan, supported by farm advisory services in selecting good crop mixtures.

Key words: goal programming, multi-objective, farm planning, arable crops, farmers, Kogi State

INTRODUCTION

Over the past years, there have been concerns about the impending threat of food crises in many countries, including Nigeria (Attah, 2012). The declining farm productivity has become evident by low yields owing to inefficient production processes (due to technical and allocative inefficiencies), inadequate agricultural investments (resulting in a complete reliance on on-farm resources), inappropriate and labour-intensive agricultural technology, poor prioritization of farm objectives, inconsistent and rapidly diminishing soil productivity, inefficient traditional management system, etc. A typical farmer in the world is faced with a myriad of choices for allocating farm

resources between crop and livestock production possibilities to optimize production objectives. Identifying the best farm plan is a difficult task for any farmer, but it is especially difficult for small-scale farmers with little or no formal education. Consequently, small-scale farmers have had to make farm planning decisions based on tradition, intuition or introspection.

Multi-objective programming (MOP) or vector optimization is a branch of multi-criteria decision analysis (MCDA), whereas goal programming is a subset of MOP. It entails the simultaneous optimization of several often-competing goals while adhering to a set of resource restrictions. Goal programming, according to Adejobi et al. (2003), is an enhanced extension of linear programming that has been demonstrated to be useful in solving multi-objective problems. In small-scale agriculture, a farming system is integrated in the household economy, which integrates both production and consumption, and it is influenced by the system's multiple goals (Igwe et al., 2012). Most of the time, the goals or objectives are inconsistent. Therefore, it is presumed that the farmers' primary goals are to provide food for their families throughout the year, accumulate monetary revenue, and ensure the minimal use of hired labour (Adejobi et al., 2003). However, little attention had been devoted to the utilization of mathematical programming models aimed at achieving multiple production objectives of small-scale farmers in developing economies such as Nigeria. This is evidenced by the near absence of empirical studies on farm planning in Nigeria, Kogi State in particular. Accordingly, such research gap requires attention in the quest for agricultural transformation.

By and large, the focus of resource allocation in farm planning is achieving the optimal utilization of limited resources. The managerial strategy employed in the implementation of optimal farm plans can significantly affect the cost of production and objective prioritization. Therefore, the most efficient use of available resources in arable crop production is of paramount empirical and economic importance. Optimal farm plans are of great significance to the sustainability of arable crop enterprises and achieving the overall enhancement of farm production. The findings obtained in this study will advise practicing farmers on how to combine resources in a bid to achieve their multi-objective production goals.

This study therefore sought to develop prototype farm plans according to the multi-objective production goals of small-scale arable crop farmers in different local government areas (LGAs) of Kogi State, Nigeria. The plans were aimed at identifying the highest ranking activities on the basis of the overachievement/underachievement of objectives considered and available resources utilized. Upon analysing the existing farm plans, the optimal plans were developed relative to the multi-objective production goals of arable crop farmers considered. Moreover, the resources limiting production were identified, as well as their poor allocation, in order to maximise the farmer's profit in the study area.

MATERIAL AND METHODS

This study was carried out in Kogi State, Nigeria (located between 6°42' and 7°30' latitudes north of the Equator and 5°20' and 7°53' longitudes east of the Greenwich meridian). According to the 2006 national population census, the state has a population of 3,314,043 and a projected population of 4,541,038 for 2016 at an annual growth rate of 3.2% (NPC, 2006). The state consists of 21 local government areas grouped into four agricultural zones (namely Zones A, B, C and D), each zone having six, four, six and five LGAs, respectively. It covers a total land area of 29,833 km². The vegetation comprises diverse leguminous wood land, forest Savannah and a wide expansion of *Fadama* land. Agriculture is the major economic activity in the state, which boasts a lot of solid mineral deposits, arable land, water and favourable weather conditions. Igala, Ebira and Okun are three major ethnic groups in the state, with other minor discernible ethnic groups.

A multistage sampling procedure was adopted in this study. In the first stage, one LGA from each of the four agricultural zones (namely Zones A, B, C and D) was purposively selected because of high crop production activities in these LGAs. One community was randomly selected from each of the LGAs in the second stage, giving a total of four communities. In the third stage, the Yamane formula (1967), specified in Equation 1, was used to proportionately sample farmers in each community, totalling 137 farmers enrolled in the study.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where:

N - population/frame,

e - limit of tolerable error (0.05 or 95% confidence interval)

n - sample size

1 - constant.

Primary data were collected by means of a structured questionnaire which was complemented with interview schedule to each farm household head. The questionnaire was administered by the authors and well-trained local enumerators. In addition to the information obtained from the household heads, data were also obtained by measurements, i.e. the farm and plot sizes were measured using a measuring tape, a Gunther's chain and a compass. The farms outputs were also measured. For mixed crop enterprises, the average number of each mixture and the prevailing market prices were used to estimate potential net returns. Descriptive statistics and linear goal programming were used for data analysis.

The development of optimal farm plans and identification of limiting resource factors in the study area were achieved using the linear goal programming model (LGP). The LGP model is a tool used for handling multiple and normally conflicting production objectives. As argued by Adejobi et al. (2003), the empirical model used was specified in Equations 2 to 6 as follows:

$$\text{Minimize } Z = \sum_{i=1}^n (W_i^+ + d_i^+ + W_i^- d_i^-) \quad (2)$$

Subject to:

$$AX - d_i^+ + d_i^- \quad (3)$$

$$BX (\leq \geq) C \quad (4)$$

$$X_{ij} \geq 0 (j = 1, 2, \dots, m) \quad (5)$$

$$d_i^+, d_i^- \leq 0 (i = 1, 2, \dots, n) \quad (6)$$

where:

Z - objective functions

W_i^+, W_i^- - the numerical differential weights assignment to the deviational variables d_i^+, d_i^- of goal i

d_i^+, d_i^- - the vectors ($n \times 1$) of the negative and positive deviations of goal i

A - the (n, m) matrix which represents the relationship between the decision variable vector, $X(m, 1)$ and the goal vector, $G(n, 1)$. The decision variable vector represents inputs which are transformed by matrix 'A' to produce desired output

I - the identity matrix

B - the (c, m) matrix of coefficients which relate the decision variables to the constraints vector C ($c, 1$)

n - number of goals

m - number of decision variables

c - number of constraints

$\sum$ - summation sign.

The deviational variables (d_i^+, d_i^-) were derived from the household characteristics. The main objectives assumed to be pursued by any farm household in the study area were defined as follows:

1. provision of adequate food to ensure at least minimum farm-family food requirements of the household throughout the year,
2. earning improved monetary farm income to meet the financial requirements of the farm household, and
3. maximizing the use of family labour by minimizing the use of paid labour.

The optimality of the system was assessed on the basis of these objectives. For the three assumed objectives of farm households, the indicators were measured according to Adejobi et al. (2003) as follows:

1. The indicator for adequate caloric intake was obtained by using the food security index computed as shown in Equation 7:

$$FSI = \frac{\text{per capita food expenditure of the } i^{th} \text{ household}}{2/3 \text{ mean per capita food expenditure of all households}} \quad (7)$$

where:

FSI - food security index

Whereby if $FSI \geq 1$ = food secure i^{th} household and if $FSI \leq 1$ = food insecure i^{th} household, the monetary income proxied by a minimum of 70% of the average expenditure of the households and the labour saving proxied by the desired level of cash expenditure on labour.

The objectives of arable crop producing farm households were prioritized by the households considered. Ensuring food security, i.e., adequate food intake all year round was ranked first, followed by adequate income and minimum expenditure on paid labour. Pre-emptive weights were also attached to these objectives according to the ranking, with the first objective carrying the highest weight. Table 1. shows the programming matrix.

Table 1. Programming matrix of the objective function structure of the basic LPG model for typical arable crop farm household (Source: Constructed by ranking goals and attaching weights after the field survey, 2016)

Objective	Goal statement	Objective function statement to minimize	Deviation variable in objective function	Priority level	Pre-emptive weights
1. Provision of food year round	Min. maize intake	Underachievement	d-	1	3
	Min. sorghum intake	Underachievement	d-	1	3
	Min. rice intake	Underachievement	d-	1	3
	Min. cowpea intake	Underachievement	d-	1	3
	Min. millet intake	Underachievement	d-	1	3
	Min. cassava intake	Underachievement	d-	1	3
	Min. melon intake	Underachievement	d-	1	3
	Min groundnut intake	Underachievement	d-	1	3
	Min. Bambara nut intake	Underachievement	d-	1	3
2. Gross Farm Income	Desired level of farm income	Underachievement	d-	2	2
3. Paid Labour	Specified level of expenditure	Overachievement	d+	3	1

The three main objectives of farm households considered were formulated. Objective 1, i.e., the provision of adequate food to meet the minimum farm-family food requirements, was incorporated in the formulation of resource restrictions.

Objective 2, i.e., maximizing the net farm income was achieved using a model including the gross income deducted by the costs of land, labour, depreciated capital items, agrochemicals, fertilizers, seeds, transportation, processing and storage costs.

The model is specified in Equations 8 to 15:

$$\text{Maximize } Z = \sum_{j=1}^n P_j X_j - \sum_{t=1}^n P_t Y_t - MC - DC - R \quad (8)$$

Subject to:

$$\sum_{j=1}^n L_j \times j \leq L_s \text{ (Land size)} \quad (9)$$

This implies that the total land size (in hectares) requirements of n crop is equal to/less than the total variable land size devoted to all crop varieties.

$$\sum_{j=1}^n a_j X_j - X_t - L_t \leq H_t \text{ (Human Labour)} \quad (10)$$

This implies that the total man-days of human labour required to produce n crop activities are equal to/less than the total available human labour.

$$\sum_{j=1}^n C_j X_j - M_t \leq C_t \text{ (Total capital)} \quad (11)$$

This implies that the capital required (in ₦) to produce n crop is equal to/less than the total amount of capital available.

$$\sum_{j=1}^n S_j X_j - O_t \leq S_t \text{ (Seed)} \quad (12)$$

This implies that the total seed (in kg) requirements of n crop is equal to/less than the total available seed.

$$\sum_{j=1}^n A_j X_j - G_t \leq A_t \text{ (Agrochemical)} \quad (13)$$

This implies that the total agrochemical (in litres) requirements of n crop is equal to/less than the total available agrochemicals.

$$\sum_{j=1}^n F_j X_j - J \leq F_t \text{ (Fertilizer)} \quad (14)$$

This implies that the total fertilizer (in kg) requirements of n crop is equal to/less than the total available fertilizers.

$$X_j, L_t, M_t, O_t, G_t, J \geq 0 \quad (15)$$

where:

Z - net farm income,

X_j - unit of activity of the j^{th} crop farmers in Naira

P_j - price of the output unit of the j^{th} crop farmer

M - cost of transportation per activity

D - cost of processing

R - cost of storage

l_j - input coefficient of land

a_j - input coefficient of labour man-days for j^{th} cropping activities

C_j - input coefficient of the capital used in producing one hectare of j^{th} crop

S_j - input coefficient of seeds in kilograms for j^{th} cropping activities

A_j - input coefficient of agrochemicals in litres for j^{th} cropping activities

F_j - input coefficient of fertilizers in kilograms for j^{th} activity

$\sum_{j=1}^n$ = summation of j^{th} cropping activities where $j=1,2,3,\dots,n$.

Objective 3 entailed minimizing the hired labour employment. Labour hiring constituted part of the total variable cost of production. Labour hiring was needed to complement household labour during critical periods of labour requirement. The minimization of hired labour was incorporated as another objective function and formulated as shown in Equation 16:

$$\text{MinHL}_i = \sum \text{HL}_i = \sum (\text{TL}_i - \text{FL}_i) X_i \quad (16)$$

where:

HL_i - hired labour requirement of crop i

TL_i - total labour requirement of crop i

FL_i - family labour available for the production of the crop i .

The basic programming matrix includes the activities considered in the models, their resource requirements, net prices, and resource restrictions for different arable crop farmers. The input-output coefficient, also known as the technical coefficient, denotes the unit of resource required for an activity. In this study, they refer to the requirements of small-scale farms with respect to different resources measured per unit of activity, i.e. one hectare of land. The input-output coefficient for labour refers to the quantity of human labour in man-days required to produce a unit of activity. The input-output coefficient for capital represents the amount of capital used to produce “ n ” crop activities on one hectare. For agrochemicals, it was the quantity required (in litres) to produce a unit of an activity. The input-output coefficient for fertilizer was the quantity of fertilizer (in kg) required to produce an activity. For seed, it was

the quantity of seeds (in kg) required to produce a unit of an activity in the enterprise. The input-output coefficient for transportation was the amount (in Naira) required to produce a unit of activity. The input-output coefficients (a_{ij} s) are the averages of all the farmers for each of the cropping activities investigated.

The net price coefficient " P_j " in the model refers to the gross value of output per hectare for each crop activity whether sole or in mixture. The price coefficient of a human labour hiring activity was the ruling wage rate per man-day, the prevailing market rate of interest for capital borrowing and the marketing cost per unit output for a selling activity.

Resource constraints refer to those resources which are in scarce supply in the study area at levels which are likely to limit or restrict output maximization. The most limiting resources in the study area were land, labour, capital, agrochemicals, fertilizer and seeds. These resources could be restrictive during the critical periods of production activities.

The model production activities included the following crops: cassava, millet, rice, maize, sorghum, cowpea, groundnut, melon, Bambara nut, maize/groundnut, cassava/maize, yam/maize, maize/cowpea, sorghum/groundnut, maize/melon, and maize/Bambara nut. The model also included the following activities: labour hiring, capital borrowing, cassava selling, millet selling, rice selling, maize selling, sorghum selling, cowpea selling, groundnut selling, melon selling and Bambara nut selling activities. For each of the arable crop activities, the unit of an activity was one hectare.

The selling activities facilitated the sale of crop outputs realized from the various arable crop enterprises. The net price of a selling activity was derived in Naira per kg of respective crop activities. They provided the avenue via which the services or output of one activity may be transferred to another activity in the model to safeguard redundancy and fuller utilization of the resources. Capital and labour transfer activities were incorporated in the models to ensure their transfer and optimum utilization from one period to another within the production process provided it was deemed profitable. The coefficient of labour and capital transfer activities appeared in the programming matrix with coefficients of +1 for the capital and labour to be transferred and -1 for the capital or labour receiving the transfer. The capital was considered as the working capital required in meeting day to day expenses incurred on the farm. It included depreciated costs of cutlasses, hoes, sickles, files and baskets.

RESULTS AND DISCUSSION

The existing and optimal farm plans based on multi-objective production goals

The optimization of each of the three production goals considered was performed and compromise solutions were obtained using multi-objective goal programming within a linear programming framework. The optimization results obtained are presented in Table 2.

Maximizing net farm income

Table 2. shows differences between the existing and optimum farm plans according to the objective of maximizing farm income. The existing plan for all the enterprises considered identified a total of 16 cropping patterns. However, the optimal plan prescribed only three cropping patterns: 0.368 ha of melon, 0.044 ha of yam/maize mixture and 0.259 ha of sorghum/groundnut mixture, including tubers, legumes, cereals and vegetables. A striking feature of this plan is the predominance of crop mixtures over individual crops, indicating that crop mixtures possess competitive advantage over sole crops. This is consistent with the results of Amos et al. (2004), Adewumi (2017) and Jirgi et al. (2018), who argue that mix cropping enterprises are more productive than sole cropping, generating higher returns. However, Igwe et al. (2011), who conducted a similar study, reported that sole crops were in a better competitive position. It is noteworthy that the sampled farm households in Kogi State are actively involved in the production of commercial crops, which makes maximizing farm income one of the primary objectives.

Net profit reveals how much a farmer earns considering the production costs incurred. In other words, net profit is the difference between the cost of production (variable costs) and sales revenue. The net profit realized per hectare by the respondents according to the existing and optimal plans are presented in Table 2. The results obtained indicated that the net profit per hectare in the existing plan was ₦168, 055.40/ha, whereas the net profit per hectare in the optimal plan was ₦242, 076.20/ha. A difference of ₦72,020.80 indicates a 44.05% increase in the optimal plan as compared to the existing plan. This is congruent with the findings of Tanko & Baba (2010) and Adewumi et al. (2018), who conducted a similar study among rural farmers in Niger and Kwara States and found that the marginal return was much lower in the existing plan than in the optimal plan. The implication of this finding is that average farmers have the potential to maximize their net returns in the study area. The assiduous and judicious use of resources by households will increase their net returns as prescribed in the plan.

Table 2. The optimization of the objectives (Source: Field survey, 2016)

Objective indicator	Function	Existing plan	Optimum plan		
			Maximized income	Meeting food requirements	Minimized hired labour
Income (₦/ha)		168,055.40	242,076.20	158,475.00	168,325.50
Hired labour (man-days)			172.048	42.832	2.149
Food requirement (ton)				0.628	
Activities					
Cassava		2.600	-	0.048	-
Millet		2.800	-	-	-
Rice		2.000	-	-	0.195
Maize		1.900	-	-	-
Sorghum		1.200		0.211	-
Cowpea		2.600	-	-	-
Groundnut		1.750	-	-	-
Melon		1.500	0.368	0.368	0.502
Bambara nut		1.800	-	0.074	0.246
Maiz/Groundnut		2.400	-	-	-
Cassava/Maize		2.600	-	-	-
Yam/Maize		2.000	0.043	-	-
Maize/Cowpea		1.600	-	-	-
Sorghum/Groundnut		2.500	0.259	1.065	-
Maize/Melon		1.500	-	-	-
Maize/Bambara nut		1.300	-	-	-

Meeting family food requirements

To achieve the objective of meeting the family food requirements on the farms considered, the optimal plan prescribes the following crops and their respective hectarages (Table 2): cassava (0.048 ha), sorghum (0.211 ha), melons (0.368 ha), Bambara nuts (0.074 ha) and a sorghum/groundnut mixture (1.065 ha). However, the solution plan further specifies that these crops will yield a net income of ₦158,475.00, which is slightly lower than what was obtained in the existing plan. This implies that the objective of meeting the family food requirements on the farms in the study area could limit their overall income.

Table 3. shows that the staple food of the households considered include cereals, legumes, tubers and vegetables. A majority of the food requirements in the existing plan were consistent with the prescribed optimal plan, except for crops such as sorghum which had a positive increase of 0.479 tons according to the optimal plan. A further examination of other two crops with shortfalls (namely cassava (-0.533 tons) and Bambara nuts (-0.032tons)) according to the existing plan, indicates that the households need to increase the quantity of these crops. This lends credence to the argument of Omotesho & Mohammed (2010), who report that rural households require these food crops to maintain human health needed for laborious agricultural production activities. The optimal staple food plan ensures that resource-poor rural households get their basic food needs met at the lowest feasible cost.

Table 3. Minimum staple food requirements by the households considered (in tons) (Source: Field survey, 2016)

Commodity	Existing plan	Optimum plan	Increase over the existing plan
Rice	0.839	0.839	0
Groundnut	0.565	0.565	0
Maize	0.813	0.813	0
Sorghum	0.661	1.140	0.479
Cowpea	0.701	0.701	0
Millet	0.256	0.256	0
Cassava	1.631	1.098	-0.533
Melon	0.193	0.193	0
Bambara nut	0.051	0.019	-0.032

Minimization of hired labour

To minimize hired labour, the solution production mix in Table 2. is composed of crops like rice (0.195 ha), melons (0.502 ha) and Bambara nuts (0.246 ha), generating a net income of ₦168,325.50. Of sixteen crops considered, three crops were prescribed to be less labour demanding with their respective optimum hectarages. Furthermore, the optimal plan showed that sole crops were less hired-labour demanding. This implies that, from an agronomic perspective, it is easier to produce sole crops than crop mixtures.

Shadow prices of excluded activities

Shadow prices are the marginal returns on resource investments. They are income penalties in a maximization problem, indicating how much farm income would be decreased if any of the exempted activities were enforced into the program. According to Olayemi & Onyenweaku (1999), any surplus resource that is not completely utilized by the programme is not a constraining resource and has a zero shadow price because it does not limit the achievement of the programme's goal, and vice versa. Only excluded activities usually have positive shadow prices. Shadow prices for the included activities are zero. Higher shadow prices of any excluded activity imply a lower chance of such activity to be included in the final plan, and vice versa. The shadow prices of excluded activities are presented in Table 4. The results obtained indicate the amount by which net profit would be decreased if any of these excluded activities are forcefully undertaken by the farmers. For instance, if a maize/groundnut mixture activity (which has the least shadow price) is undertaken, the value of the objective function will be reduced by ₦20,096.78. The same applies to other excluded activities. Bambara nuts had a shadow price of ₦342,539.50, which is higher than that of the maize/groundnut enterprise. Therefore, the maize/groundnut mixture activity was in a better competitive position than other activities in the programme, which is consistent with the findings of Adejobi et al. (2003). However, Bambara nuts had the highest propensity to depress income as prescribed by the programme.

Table 4. Shadow prices (in Naira) of excluded activities considered (Source: Field Survey, 2016)

Excluded activities	Shadow prices (₦)
Cassava	163,273.20
Millet	68,491.19
Rice	163,395.70
Maize	176,537.50
Sorghum	118,536.20
Cowpea	216,331.70
Groundnut	183,751.80
Bambara nut	342,539.50
Maize/Groundnut	20,096.78
Cassava/Maize	112,822.50
Maize/Cowpea	114,784.40
Maize/Melon	88,570.66
Maize/Bambara nut	106,005.60

Factors limiting the objective of profit maximization

The factors limiting the objective of profit maximization on the farms considered were obtained from the LP output, especially the marginal value products. The optimal resource use and allocation patterns, depicting the surplus and shadow prices, are summarized in Table 5. The following resources were in surplus: transportation, processing and storage. These resources were in excess of the actual requirements by the crop farmers in the study area and were therefore non-limiting.

Marginal value products of resources indicate how much the value of the programme will increase if the resource is increased by a unit. Only limiting resources have positive shadow prices. The shadow prices of limiting resources in the optimized plans are indicated for resources that were abundant, i.e., were not used up by the programme. Therefore, any resource that was not used up is a non-limiting resource and has a zero shadow price, as it does not impede the programme's objective, and vice versa (Hassan et al., 2005; Adewumi et al., 2018; Ibrahim et al., 2019). The available resources that impeded the programme's objective in the optimized plans are shown in Table 5. The following shadow prices were determined: land (₦63,248.288), labour (₦6.6566), capital (₦1,932.794), agrochemicals (₦0.7191), fertilizers (₦12.9692), and seeds (₦1.4798). Accordingly, if any of these resources is increased by 1% or one unit, the optimal profit will increase by the same amount. The factors of land, labour, capital, agrochemicals, fertilizers and seeds were found limiting, whereas all the other resources were non-limiting. This is congruent with the findings of Omotesho & Muhammed (2010) and Igwe et al. (2013), who argue that the efficient and full utilization of resources leads to output maximization.

Table 5. Marginal value products of resources (Source: Field Survey, 2016)

Resource	Use Status	Slack/Surplus	Shadow price (₦)
Land	Fully utilized	-	63,248.288
Labour	Fully utilized	-	6.6566
Capital	Fully utilized	-	1,932.794
Agrochemical	Fully utilized	-	0.7191

Fertilizer	Fully utilized	-	12.9692
Seeds	Fully utilized	-	1.4798
Transportation	Not fully utilized	37.8328	-
Processing	Not fully utilized	8.4862	-
Storage	Not fully utilized	92.3088	-

Farm plan objective structure and goal attainment

The results of the Linear Programming Goal Solver (LIPs), which shows the extent to which farm plan objectives were achieved, is presented in Table 6. Of the three basic farm household objectives considered, the following two were overachieved: meeting family food requirements and limiting cash expenditure on labour. The family food requirements of the households are further underpinned by their staple food requirements all year round. This is consistent with the findings of Omotesho & Muhammed (2010), who affirmed that securing food is of paramount importance despite the fact that it constitutes a larger proportion in the expenditure pattern of rural households. Furthermore, the respondents ensured the minimum use of paid labour, which was reflected in the household resource utilization patterns.

The household target of meeting adequate income was underachieved in the objective plan. This could be accounted for by poor management and failing to maximize the output for commercial purposes. It is also the reason why a number of households take to different off-farm activities that are income generating. The difference between the existing and optimal farm plans is shown in Table 6. The maximization of farm income requires the efficient utilization of existing resources. During off-farm periods, farmers are usually idle so labour could be channelled into other income-yielding enterprises, the proceeds of which could be ploughed back into the farming business to optimize the goal of obtaining output and increasing farm income.

Table 6. Farm plan objective structure and goal attainment (Source: Field survey, 2016)

Objective of production	Goal statement	Objective function statement to minimize	Deviation variable in objective function	Priority level	Pre-emptive weights
Meeting Minimal Farm Family Food Requirements	Adequate Food intake	Overachievement	d ⁺	1	3
Income to Meet Household Financial Needs	Adequate Income	Underachievement	d ⁻	2	2
Limit Cash Expenditure on Labour	Specified level of Expenditure	Overachievement	d ⁺	3	1

CONCLUSION

The results obtained indicate that resources were not optimally allocated in the existing plan for arable crop activities in the study area. However, the area has the great potential for arable crop production provided resources are maximized. If optimally planned, a typical farmer in the study area could realize up to ₦242,076.20/ha. On balance, with the current structure of the available farm production resources, an average farm household in the study area was unable to fully achieve its production goals. Therefore, the following recommendations were made:

1. Farmers should organize their resources as prescribed in the optimal plans and produce basic crops such as melons, yam/maize and sorghum/groundnuts according to the recommended hectare allocation.
2. Extension services should advise farmers on the optimal resource allocation and cropping patterns and should be included in governmental programs and policies aimed at empowering farmers to boost agricultural production.
3. Farmers should intensify the use of family labour rather than paid labour.
4. To boost their resource base, farmers are enjoined to register with cooperative societies or organized farmer groups to enhance their access to capital and productive resources.

Conflict of interest: The authors declare that they have no conflict of interest.

REFERENCES

- Adejobi A.O, Kormawa P.M, Manyong V.M., Olayemi J.K. (2003): Optimal crop combinations under limited resource conditions: Application of linear goal programming model to smallholder farmers in the drier savannah zone of Nigeria. *Journal of Technological and Institutional Innovations for Sustainable Rural Development*, 17(1): 8-10.

- Adewumi A. (2017): Optimum production plans for cassava-based crop farmers in Kwara State, Nigeria. Unpublished MTech Thesis, Department of Agricultural Economics and Extension Technology, Federal University of Technology, Minna Nigeria.
- Adewumi A., Jirgi A.J., Yisa E.S., Tanko L. (2018): Optimum production patterns for cassava-based crop farmers in Irepodun and Moro Local Government Areas of Kwara State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 11(1): 111-122.
- Amos T.T., Chikwendu D.O., Nmadu J.N. (2004): Productivity, technical efficiency and cropping patterns in the savannah zone of Nigeria. *Journal of Food, Agriculture and Environment*, 2:173-176.
- Attah A.W. (2012): Food Security in Nigeria: The Role of Peasant Farmers in Nigeria. *African Research Review Journal*, 6(4): 173-190.
- Hassan I., Ahmad B., Akhter M., Aslam M. (2005): Use of linear crop model to determine the optimum cropping pattern: A case study of Punjab. *Electronic Journal of Environmental Agricultural and Food Chemistry*, 4(1): 841-850.
- Ibrahim F.D., Oformata A.O., Jirgi A.J., Adewumi A. (2019): Optimum production plan for maize-based crop farmers in Niger State, Nigeria. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*, 18(3): 35-41.
- Igwe K.C., Onyenweaku C.E., Nwaru S. (2011): Application of linear programming to semi-commercial arable and fishery enterprises in Abia State, Nigeria. *International Journal of Economics and Management Sciences*, 1(1): 75-81.
- Igwe K.C., Onyenweaku C.E., Nwaru J.C. (2012): Optimum combination of arable crops and selected livestock enterprises among farmers in Abia State, Nigeria. *International Journal of Applied Research and Technology*, 1(6): 72-82.
- Igwe K.C., Onyenweaku C.E., Tanko L. (2013): A linear programming approach to combination of crop, monogastric farm animal and fish enterprises in Ohafia agricultural zone, Abia State, Nigeria. *Global Journal of Science Frontier Research Agriculture and Veterinary Sciences*, 13(3): 22-32.
- Jirgi A.J., Adewumi A., Yisa E.S., Okpanachi F.O. (2018): Raising the income of smallholder farmers in Kwara State, Nigeria: A case study of cassava-based crop farmers. *Ethiopian Journal of Environmental Studies and Management*, 11(6): 697-706.
- NPC (2006): National Population Commission. Population data in Nigeria; 2006. Available: <http://www.population.gov.ng/population-data-in-Nigeria> (Accessed 13 September 2015)
- Olayemi J.K. & Onyenweaku C.E. (1999): *Quantitative Methods for Business Decisions*. Bosude Printers Limited, Ibadan, Nigeria.
- Omotesho O.A. & Muhammed L. (2010): Optimal food plan for rural households' food security in Kwara State Nigeria: The goal programming approach. *Journal of Agricultural Biotechnology and Sustainable Development*, 2(4): 007-014.
- Tanko L. & Baba K.M. (2010): Raising income level of farmers in Niger State, Nigeria: A linear programming approach. Research Finding of University Board of Research (UBR) Funded Study, Federal University of Technology, Minna, Nigeria.
- Yamane T. (1967): *An Introductory Statistics*. 2nd ed. New York: Harper and Row.

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