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Net Returns Maximizing Combination of Arable Crops among Smallholder Farmers in Kaiama Agricultural Zone of Kwara State, Nigeria

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Authors' contributions

This work was conducted in collaboration among all the authors. All authors read and approved the final manuscript.

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ABSTRACT

The study developed an optimal arable crop combination plans that would maximize the net returns of the smallholder farmers in Kaiama agricultural zone of Kwara State, Nigeria. Multi-stage sampling procedure was used to select 40 smallholder farmers. Interview schedule was used to obtain cross-sectional data from the farmers. Descriptive statistics, farm budgeting technique and linear programming model were used to analyse the data obtained. The results of the analysis showed that mixed crop enterprises were more profitable than sole crop enterprises. The LP result revealed that 1.75 ha of maize/cowpea, 1.64 ha of maize/soybean, 1.40 ha of maize/yam and 0.70 ha of sorghum/soybean were prescribed as solutions to maximize net returns in the optimal plan. The optimal net return was $937.98 which is 52.23% higher than the existing plan. Maize enterprise had the highest marginal opportunity cost while yam had the least. However, Capital and labour constituted the limiting resources in the optimal plan. It was concluded that the smallholder farmers have the potential to maximize net returns as resources were not optimally allocated in the existing plan for arable crop activities. Farmers should therefore adopt the optimum farm plans as prescribed in the LP solution.

Keywords: Net returns; maximization; arable crops; smallholder farmers; Kaiama; Kwara State.

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1. INTRODUCTION

Smallholder farmers are key actors who play significant roles in driving many economies in the world through livelihoods creation and food crops production amongst the rural poor. Nonetheless, these farmers are resource constrained and are technically unable to determine what is optimal in farm resources allocation between competing choices for crop enterprises to undertake. The farmers' ultimate aim is to attain certain production goals by making efficient utilization of the limited available resources at their disposal and combining farm enterprises optimally as suggested by [1,2].

A typical farm anywhere in the world is often encountered with the challenge as to what enterprise to undertake, the level should it be taken up and the optimal combination of enterprises to adopt. According to Egbodion and Ada-Okungbowa [3], combination of farm enterprises in agricultural production economics is a needful relationship which involves allocating limited resources among two or more enterprises. Previously, Adejobi and Kormawa [4] had argued that the level to which one enterprise is combined or substituted with another enterprise partly depends on the inter-relationships between such different enterprises and their corresponding values of products and costs of inputs.

Integration of the farming system often results to a vast change in the farming technique towards maximizing production in the cropping pattern and achieving optimal utilization of resources. Egbodion and Ada-Okungbowa [5] argued that in Nigeria, combination of farm enterprises has become an existent choice for most smallholder farmers due to the rapid human population explosion which has induced increasing demand for non-agricultural land use. Combining farm enterprises has better economic use of land and increased production through diversification at the smallholder farm level without any need to automatically increase the available land. To this end, several researchers such as Igwe et al. [6], Sofi et al. [7], Igwe et al. [8], Bamiro et al. [9] and Adewumi et al. [10] among others have used mathematical programming approaches for studies in optimum combination of farm enterprises and resource requirements in Nigeria. For this study, similar approach was adopted.

Maximizing farm enterprise returns given the limited resources conditions of the farm families by prescribing an efficient enterprise system is germane to improving their growth prospects particularly in terms of increased farm income and food security. Previous studies such as those of Babatunde et al. [11], Ibrahim and Omotesho [12] and Adewumi et al. [13] done to derive optimum cropping plans for smallholder crop farmers especially in Kwara State have failed to inquire into the possibility of maximizing farm returns in Kaiama agricultural zone. This study was therefore conceived to develop a net farm returns maximizing cropping plan for the smallholder arable crop farmers in the area. It is also hoped that the outcome of the study will guide the farmers to undertake profitable and efficient farm enterprises.

2. METHODOLOGY

2.1 Area of Study

The study was conducted in Kaiama agricultural zone of Kwara State, Nigeria. Kaiama is one of the four agricultural zones in the State. It has a total land area of 16,720 square kilometres out of which more than 80% is cultivable [14]. The total population of the area was 333,623 based on the Nigeria 2006 census [15] and was projected to 464,701 as at 2018 going by the State's annual growth rate of 2.8% [16]. Kaiama zone is located between Latitudes 8°35'55"N to 9°54'13"N and Longitudes 2°45'50"E to 4°15'17"E. The agro climatic condition in the zone favours the cultivation of various arable crops including yam, cowpea, soybean, maize, millet, melon, groundnut, sorghum and vegetables. Farming and trading are the major occupations of the people in Kaiama agric zone of the State. The predominant tribes in the area are Bokobaru and Baatonum. Other tribes present include Yoruba, Fulani and Hausa.

2.2 Sampling Procedure

A multi-stage sampling procedure was employed for this study. All smallholder arable crop farmers in Kaiama zone of Kwara State constituted the population of study. At the first stage, one of the districts from the two districts in the zone was randomly selected. The second stage involved the random selection of four farming communities in the district. At the third stage, 10% proportionate sampling of the crop farmers was adopted from [17]. This gave a total of forty smallholder arable crop farmers selected for this study from the four farming communities. The smallholder farmers were identified and selected with the assistance of the village heads and the resident extension agents. The sampling design is presented in Table 1.

2.3 Method of Data Collection

Primary data were used for this study. Interview schedules were conducted to obtain cross-sectional data for 2019 production season from the farmers in the study area through a limited cost-route approach. Resident extension agents and enumerators were trained to assist during the data collection process. The choice of this category of extension agents and enumerators was to facilitate access given they are conversant with the study locations and are familiar with the target farmer populations.

2.4 Analytical Techniques

Data analysis involved the use of descriptive statistics, farm budgeting model and linear programming model.

2.4.1 Descriptive statistics

Descriptive statistics involved the use of tables, percentages and means.

2.4.2 Farm budgeting model

A farm budgeting model was used to estimate the costs and returns associated with the various crop enterprises undertaken by the smallholder farmers. The gross margins (GM) as well as the corresponding net farm incomes (NFI) were computed. The farm budgeting model following Adewumi et al. [18] and Jirgi et al. [19] was used and is specified in equations (1) and (2).

$$GM = \sum_{i=1}^{n} P_{yi}Y_i - \sum_{j=1}^{m} P_{xj}X_j \quad (1)$$

$$NFI = \sum_{i=1}^{n} P_{yi}Y_i - \sum_{j=1}^{m} P_{xj}X_j - \sum_{k=1}^{o} F_k \quad (2)$$

Where;

GM= Gross Margin,
NFI = Net farm income,
Y_i = Output per unit enterprise (where *i* = 1, 2, 3, …, *n* products),
P_{yi} = Unit price of the product,
X_j = Quantity of the variable inputs per unit enterprise (where *j* =, 1, 2, 3, …, *m* variable inputs),
P_{xj} = Price per unit of variable inputs, and
F_k = Cost of fixed inputs per unit enterprise (where *k* =, 1, 2, 3, …, *o* fixed inputs).

For this study, the fixed inputs were depreciated using the straight line method of depreciation. The formula is shown in equation (3).

$$\text{Depreciation} = \frac{\text{Initial Cost} - \text{Salvage Value}}{\text{Number of useful life}} \quad (3)$$

2.4.3 Linear programming (LP) model

Linear programming (LP) model was used to derive optimum crop combination plan for the smallholder farmers in the study area. The LP model used was adopted from Adewumi et al. [20] and Jirgi et al. [21] and specified in equation (4). The objective function of the model is to maximize the gross margin of the smallholder farmers for each crop enterprise undertaken which is total farm revenue less the total variable costs of production. For this study, the unit of activity for each crop enterprise was one hectare.

The objective function is stated as:

$$\text{Maximize } GM_c = P_1X_1 + P_2X_2 + P_3X_3 + \ \ldots . + P_{17}X_{17} \quad (4)$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + \ \ldots + \ A_{117}X_{17} \leq L_S(\text{Land in hectare}) \quad (5)$$

$$A_{21}X_1 + A_{22}X_2 + \ \ldots + \ A_{217}X_{17} - L_t \leq HLL_t(\text{Human labour for land preparation in mandays}) \quad (6)$$

$$A_{31}X_1 + A_{32}X_2 + \ \ldots + \ A_{317}X_{17} - L_t \leq HLP_t(\text{Human labour for planting in mandays}) \quad (7)$$

$$A_{41}X_1 + A_{42}X_2 + \ \ldots + \ A_{417}X_{17} - L_t \leq HLW_t(\text{Human labour for weeding in mandays}) \quad (8)$$

$$A_{51}X_1 + A_{52}X_2 + \ \ldots + \ A_{517}X_{17} - L_t \leq HLF_t(\text{Human labour for agrochemical application in mandays}) \quad (9)$$

$$A_{61}X_1 + A_{62}X_2 + \ \ldots + \ A_{617}X_{17} - L_t \leq HLH_t(\text{Human labour for harvesting in mandays}) \quad (10)$$

$$A_{71}X_1 + A_{72}X_2 + \ \ldots + \ A_{717}X_{17} - M_t \leq OC_t(\text{Owned capital inputs in dollars}) \quad (11)$$

$$A_{81}X_1 + A_{82}X_2 + \ \ldots + \ A_{817}X_{17} - M_t \leq BC_t(\text{Borrowed capital inputs in dollars}) \quad (12)$$

$$A_{91}X_1 + A_{92}X_2 + \cdots + \ A_{917}X_{17} - E_t \leq S_t(\text{Seed in kilograms}) \quad (13)$$

$$A_{101}X_1 + A_{102}X_2 + \cdots + \ A_{1017}X_{17} - B_t \leq F_t(\text{Fertilizer in kilograms}) \quad (14)$$

Table 1. Sampling design for the study

Agricultural zone	District	Farming community	Sample frame	Sample size
Kaiama	Kaiama	Frenaba	71	7
		Mamman Buran	138	14
		Onipako	101	10
		Woro	87	9
Total			397	40

$$A_{111}X_1 + A_{112}X_2 + \ldots + A_{1117}X_{17} - K_t \leq A_t(\text{Agrochemical in litres}) \quad (15)$$

$$A_{121}X_1 + A_{122}X_2 + \ldots + A_{1217}X_{17} - L_t \leq T_t(\text{tractor/power tiller in machine hours}) \quad (16)$$

$$A_{131}X_1 + A_{132}X_2 + \ldots + A_{1317}X_{17} - L_t \leq M_t(\text{Marketing expenses in dollars}) \quad (17)$$

$$FC_{14\,1}X_1 + FC_{14\,2}X_2 + \ldots FC_{14\,17}X_{17} \geq F_c\,(\text{Min})(\text{Minimum farm familyfood crop requirement}) \quad (18)$$

and,

$$X_1 \geq 0, X_2 \geq 0, \ldots, X_{17} \geq 0 \ (\text{non-negativity assumption}) \quad (19)$$

Where;

GM_c = Gross Margin,
$X_1, X_2, X_3, \ldots X_{17}$ = Crop activities or enterprise(s) undertaken (decision variables),
$P_1, P_2, P_3, \ldots P_{17}$ = Output coefficients or net prices (gross margin/ha) of the different crop activities maximized,
A_{ij} (Equations (4) – (17)) = Input-output coefficients, that is, quantity of i^{th} resource (land, human labour for land preparation/ridge making, planting, weeding, fertilizer/agrochemical application and harvesting/processing, owned capital, borrowed capital, seed, fertilizer, agrochemical, tractor/power tiller and marketing expenses) required to produce a unit output of j^{th} crop activity. The unit of crop activity for this study is one hectare,
FC_{14n} = Minimum farm family i^{th} food crop requirement for j^{th} crop enterprise,
L_s= Level of available land in hectare from owned and rented sources for crop activities with s restriction,
HLL_t= Level of available human labour for land preparation/ridge making in man-day in t^{th} period,
HLP_t = Level of available human labour for planting in man-day in t^{th} period,
HLW_t = Level of available human labour for weeding in man-day in t^{th} period,
HLF_t = Level of available human labour for fertilizer/agrochemical application in man-day in t^{th} period,
HLH_t = Level of available human labour for harvesting/processing in man-day in t^{th} period,
OC_t= Level of available owned working capital in dollars in t^{th} period,
BC_t= Level of available borrowed working capital in dollars in t^{th} period,
S_t = Level of available seed in kilograms in t^{th} period,
F_t= Level of available fertilizer in kilograms in t^{th} period,
A_t= Level of available agrochemical in litres in t^{th} period,
T_t = Level of available tractor/power tiller in machine hours in t^{th} period,
M_t = Level of marketing expenses incurred in dollars in t^{th} period, and
F_c= Level of food crops consumed in kilograms in t^{th} period.

3. RESULTS AND DISCUSSION

3.1 Cost and Return Analysis of Crop Enterprises of the Respondents

The result of the costs and returns analysis for each crop enterprises is presented in Table 2. The values estimated were on per hectare basis. The variable cost items include cost expended on labour, seed, fertilizer, agrochemical, tractor hiring, transportation, processing and storage while fixed cost items were depreciation on farm tools and machinery and interest on borrowed capital. The result shows that all the crop enterprises undertaken by the small holder farmers were profitable given that the computed gross ratios were less than one. This is consistent with the assertion of Olukosi and Erhabor [22] that a less than one gross ratio is desirable for any farm enterprise; the lower the ration, the higher the return per naira invested. A further look at the gross margins, net farm incomes and the gross ratios shows that mixed crop enterprises were slightly more profitable than the sole crop enterprises in the study area.

Table 2. Cost and return analysis of crop enterprises in the study area

Crop enterprise(s)	Average value ($/hectare)						
	TVC	TFC	TC	TR	GM	NFI	Gross ratio
Maize	135.97	4.54	140.51	416.76	280.79	276.26	0.34
Melon	127.44	8.35	135.80	458.93	331.48	323.13	0.30
Millet	149.80	3.60	153.40	448.37	298.56	294.96	0.34
Sorghum	138.46	4.90	143.36	464.60	326.14	321.24	0.31
Soybean	130.11	4.76	134.88	494.82	364.71	359.95	0.27
Yam	285.44	7.79	293.23	971.31	685.86	678.07	0.30
Maize/Cowpea	158.84	11.59	170.43	798.14	639.30	627.72	0.21
Maize/Groundnut	200.79	9.09	209.88	837.59	636.80	627.71	0.25
Maize/Melon	192.59	19.56	212.14	827.00	634.41	614.85	0.26
Maize/Sorghum	228.38	4.69	233.07	820.81	592.43	587.74	0.28
Maize/Soybean	186.01	5.27	191.28	851.01	65.00	659.73	0.22
Maize/Yam	346.30	15.65	361.95	1,289.31	943.01	927.36	0.28
Melon/Millet	227.76	20.51	248.27	867.04	639.28	618.77	0.29
Sorghum/Groundnut	205.14	3.76	208.90	872.69	667.55	663.79	0.24
Sorghum/Soybean	169.66	14.07	183.73	837.28	667.62	653.55	0.22
Sorghum/Yam	351.33	19.44	370.77	1,319.76	968.43	948.99	0.28
Maize/Sorghum/Soybean	205.39	3.22	208.61	1,338.99	1,133.60	1,130.38	0.16

TVC = Total Variable Cost; TFC = Total Fixed Cost; TC = Total Cost; TR = Total Revenue;
GM = Gross Margin; NFI = Net Farm Income
Exchange rate: $1 = ₦360.00

Table 3. Cropping pattern in the existing and optimum plans

Cropping enterprise	Existing plan (ha)	Optimum plans (ha)	Difference
Maize	0.85	-	-
Melon	0.70	-	-
Millet	0.80	-	-
Sorghum	1.87	-	-
Soybean	0.82	-	-
Yam	1.03	-	-
Maize/Cowpea	1.61	1.75	0.14 (+8.42)
Maize/Groundnut	0.78	-	-
Maize/Melon	0.60	-	-
Maize/Sorghum	1.37	-	-
Maize/Soybean	2.04	1.64	-0.40 (-19.70)
Maize/Yam	1.44	1.40	-0.04 (-2.81)
Melon/Millet	0.50	-	-
Sorghum/Groundnut	1.05	-	-
Sorghum/Soybean	0.87	0.70	-0.17 (-19.86)
Sorghum/Yam	1.23	-	-
Maize/Sorghum/Soybean	1.30	-	-

** Figures in parenthesis are percentages*

This gives credence to the argument of Jirgi et al. [23] that crop mixture has the potentiality to improved productivity per unit land area and time, and also impartial and judicious exploitation of land resources and farming inputs including labour.

3.2 Cropping Pattern in the Existing and Optimum Plans

The result presented in Table 3 shows that the identified crop enterprises in the existing and optimum farm plans. It identified 6 sole and 11 mixed crop enterprises giving a total of 17 crop enterprises undertaken by the smallholder farmers in the area. Only 4 of the 17 crop enterprises namely maize/cowpea, maize/soybean, maize/yam and sorghum/soybean were included in the optimum plan interestingly, all the crop enterprises in the optimum plan were crop mixtures. This implies that mixed crop enterprises are in better competitive position to yield more returns for the farmers that the sole crop enterprises. The LP result prescribed 1.75 ha for maize/cowpea, 1.64 ha for maize/soybean, 1.40 ha for maize/yam and 0.70 ha for sorghum/soybean as optimal for the smallholder famers to maximize their net returns in Kaiama agricultural zone. This finding is similar to that of Adewumi et al. [24] who similarly reported that mixed crop enterprises were better off in terms of productivity than sole crop enterprises for farmers in Irepodun and Moro Local Government Areas of Kwara State, Nigeria.

3.3 Net Returns in Existing and Optimum Plans

The findings as presented in Table 4 revealed that the average net return in Naira per hectare in the existing plan for crop enterprises in the area was estimated to be $616.18. The average net returns of $937.98 per hectare in the optimum plan was however higher. This implies that there is an average increase of $321.80 per hectare representing 52.23% change in the optimum plan over the existing plan. This further implies that an average smallholder arable crop farmer has the potential to maximize net returns in the area. This result is similar to those obtained from the study carried out by Tanko and Baba [25] in Niger State and Adewumi et al. [26] in Kwara State on raising the income level of farmers.

3.4 Marginal Opportunity Cost of Excluded Cropping Activities

In a maximization LP problem, marginal opportunity costs also known as shadow prices for activities are the income penalties that would be experienced by a farmer who forcefully introduces/undertakes any such activity that has been excluded by the optimum solution. In essence, it indicates the amount by which net returns would be reduced if an excluded activity was undertaken or forced into the production plan by the smallholder farmers. The higher the value of the marginal opportunity cost of an excluded activity the lower its chances of being

Table 4. Estimated net returns in existing and optimum plans

Existing plan (₦/ha)	Optimum plans (₦/ha)	Increase/Decrease over existing plan	Percentage change
616.18	937.98	321.80	52.23

Exchange rate: $1 = ₦360.00

Table 5. Marginal opportunity cost of excluded cropping activities

Excluded cropping enterprises	Marginal opportunity cost ($/ha)
Maize	232.55
Melon	79.77
Millet	76.22
Sorghum	93.57
Soybean	177.17
Yam	58.98
Maize/Groundnut	181.81
Maize/Melon	197.60
Maize/Sorghum	151.08
Melon/Millet	148.89
Sorghum/Groundnut	96.30
Sorghum/Yam	121.53
Maize/Sorghum/Soybean	164.26

Exchange rate: $1 = ₦360.00

Table 6. Marginal vale product (MVP) of resources

Resource	Slack/Surplus	Marginal value product ($/unit)
Farm size (ha)	0.08	0.00
Owned capital (₦)	0.00	0.01
Borrowed capital (₦)	0.00	0.03
Labour for land preparation (man-day)	4.03	0.00
Labour for planting (man-day)	3.29	0.00
Labour for weeding (man-day)	0.00	1.99
Labour for fertilizer/agrochemical application (man-day)	0.00	1.74
Labour for harvesting/processing (man-day)	0.00	2.97
Seed (kg)	144.52	0.00
Fertilizer (kg)	98.40	0.00
Agrochemical (litre)	1.13	0.00
Tractor/power tiller (hour)	0.44	0.00

Exchange rate: $1 = ₦360.00

included in the optimum plan and vice versa. The marginal opportunity costs of the excluded cropping activities for this study as obtained from the LP solution is presented in Table 5 and show that 13 crop enterprises were excluded in the optimum plan for the farmers to maximize their net returns. It revealed that yam, millet, melon crop enterprises respectively had the least shadow prices of $58.98, $76.22 and $79.77. This implies that these enterprises respectively are in a better competitive position to fit into the optimum plan as compared to the other excluded enterprises. Conversely, maize and maize/melon enterprises had the highest shadow prices of $232.55 and $197.60 respectively.

3.5 Marginal Value Product (MVP) of Resources

The result presented in Table 6 shows the marginal value product of resources also known as shadow prices as obtained from the LP solution. It revealed that the owned capital, borrowed capital, labours for weeding, for fertilizer and agrochemical application and for harvesting and processing had MVP of $0.01, $0.03, $1.99, $1.74 and $2.97 respectively. This implies that these resources were completely utilized by the programme and were therefore limiting the net returns maximization goal of the smallholder farmers. More so, an additional unit usage of these resources will lead to increase in the net returns of the farmers by their corresponding MVPs. This is in agreement with the submission Hasan et al. [27] that complete usages of resources in a LP solution induce maximization of returns. On the other hand, result also revealed that farm size, labour for land preparation and for planting; seed, fertilizer and agrochemical tractor/power tiller were identified to be surplus as they were not completely utilized in the programme. These resources equally had zero MVPs and imply that they were in excess of the actual requirements to maximize the net returns of the smallholder farmers, therefore, they should not be in further use for the production of the activities. This is also consistent with Olayemi and Onyenweaku [28] who asserted that resources not used up were not limiting in fulfilling the attainment of programme's goal and vice versa.

4. CONCLUSION

It was concluded based on the findings of this study that resources were not allocated optimally by the smallholder arable crop farmers in Kaiama Agricultural Zone of Kwara State. The linear programming solution indicated that mixed crop enterprises were in a better competitive position than sole crop enterprises to minimize the net returns of the farmers in the optimum plans. The LP solution prescribed four two-crop mixtures for the farmers. The farmers have the potential to maximize their net returns by adopting the optimum farm plans prescribed in the LP solution, that is, they should produce the various crop mixtures that fit into the plan based on their hectarage allocation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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