



**EFFICIENT RESOURCE ALLOCATION PATTERNS FOR CASSAVA BASED FOOD
CROP FARMERS IN ABIA STATE, NIGERIA: AN APPLICATION OF LP AND
T- MOTAD MODELS**

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ABSTRACT

The study developed efficient cassava-based enterprise patterns for smallholder farmers in Abia State. Multi-stage sampling procedure was used to select 120 smallholder cassava-based farmers. A structured questionnaire was used to obtain cross-sectional data from the farmers. Data were analyzed using descriptive statistics, farm budgeting technique, Linear Programming and Target Minimization of Total Absolute Deviation (T-MOTAD) models. The LP result prescribed 0.69ha, 0.63ha, 0.62ha, 0.54ha, 0.58ha and 0.56ha for CY, CP, COk, CMzMe, CYOkP and CMzYP respectively for the smallholder famers. A set of feasible risk efficient farm plans I, II and III were obtained with the T-MOTAD model. Plan I also prescribed 0.69ha, 0.63ha, 0.62ha, 0.54ha, 0.58ha and 0.56ha for CY, CP, COk, CMzMe, CYOkP and MzYP enterprises respectively. 0.59ha for CY, 0.6ha for CP, 0.63ha for COk, 0.58ha for CMzMe, 0.52ha for CYOkP and 0.65ha for MzYP were prescribed in risk efficient plan II; and in risk efficient plan III, 0.40ha, 0.47ha, 0.45ha, 0.43ha, 0.60ha, 0.51ha 0.54ha and 0.35ha for CMz, CY, CP, COk, CMzMe, CMzY , CYOkP and MzYP respectively were prescribed for the farmers.. Gross margin increased from ₦170,717.61/ha in the existing plan to ₦215,667.56/ha in optimum plan, and to ₦209,009.57/ha, ₦197,281.27/ha and ₦188,881.96/ha in risk efficient plans I, II and III, respectively. Labour and capital were the major limiting resource across the plans for the enterprises. It was concluded that the cassava farmers had the potential to maximize gross margins per unit enterprise in the optimum and risk efficient farm plans as resources were not optimally allocated in the existing plan. Farmers should therefore adopt the prescribed optimum and risk efficient farm plans.

Keywords: Allocation, Cassava, Efficient, Enterprise and Resource

INTRODUCTION

Smallholder farmers are central to this renewed emphasis on world food demand. Smallholder farmers are the main producers of the global food demand and they account for between 60 to 80 percent of the food produced in the developing nations (IFAD, 2018). There are more than 570 million smallholder farmers globally cultivating about 75% of the world agricultural land (FAO, 2016). Of the two-thirds of sub-Saharan Africa's population that resides in the rural areas, majority can be regarded as smallholder farmers (FAO, 2016). Nigeria is predominantly an agrarian economy, engaging about two-thirds of the country's workforce Simonyan and Onu, (2018). Food security as well as ensuring there is food for all is one pressing issue that is posing a challenge to Nigeria in particular and to the world community in general (Global Food Security, 2011). Two major ways of curbing this food security issue is increasing agricultural productivity and also addressing resource allocation problems.

Generally, smallholder farmers have finite resources and time and always want to make the most of them optimally. In this manner, Smallholder farmers are usually confronted with these challenges of how to allocate scarce production resources for optimal cropping activities that maximize their objectives such as food security for the family, steady flow of income and efficient



resource usage among others (Majeke *et al.*, 2013). Smallholder farmers also do not only produce different crops but also have to choose among the varieties of ways of producing them as resources are limited and traditionally, such decisions are usually influenced by farmers' experiences, instincts and neighborhood comparison (Hazell and Norton, 1986). However, instincts and experience do not always guarantee optimal results (Mohamad and Said, 2011). In Abia State, Nigeria, as it is in most of the southern agro ecological zones of Nigeria, farmers grow cassava in mixtures with maize, melon, cocoyam, yam and vegetables while some grow it sole (Udealor *et al.*, 2019). Traditionally, an average of three to five crops is combined in a mixture. The best combination to give farmers the results desired is a decision they often take by trial and error method, the outcome of which is usually uncertain.

In farm planning, the farmers have two alternative decision criteria. One is to allocate resources so as to maximize cash returns to fixed farm resources; while the other is to allocate resources so as to maximize utility by striking some balance between increasing expected income and minimizing income variability to reflect risk behavior (Umoh and Adeyeye, 2008). In the first case, deterministic linear programming model can be used to derive the profit maximizing solution. However, the principal criticism leveled against using deterministic model such as linear programming model as planning tool relates to the embodied assumption that all coefficients are determined with perfect knowledge (Olayemi and Onyenweaku, 1999).

The conventional deterministic model ignores risk and uncertainty, however, and may lead to a farm plan that is unacceptable to a farm operator on the basis of previous experience (Hazell, 1971). This thus informs suggestion of allocation plan for farmers while element of risks and uncertainties are adequately taken care of. Alternative risk efficient resource allocation pattern is therefore predictable through the use of Target MOTAD (Minimization of Total Absolute Deviation) model. The model formulation becomes useful because decision makers often wish to maximize expected return but are concerned about net returns falling below a critical target. This approach is in accordance with safety- first principle. Risk efficient farm enterprise plans will provide a valuable guide to existing and intending cassava-based food crop farmers and will be a huge step towards efficient resource allocation, increased production and income generation which will in the long run enhance food security and improve the farmers' standard of living.

It is against this backdrop that this study sought to determine the optimum production plan for cassava-based crop farmers under risk conditions using risk programming models in Abia State, Nigeria.

MATERIALS AND METHODS

The Study Area.

The study was conducted in Abia State, located within the South East agro ecological zone of Nigeria. Abia State lies within latitude 4° 45' N and 6° 17' N of the equator and longitude 7° 00' E and 8° 00' E of the Greenwich Meridian. It has a tropical climate that is humid all year round, with the rainy season that starts from March-October and dry season that occurs from November-February. Annual rainfall ranges from 2000mm-2500mm and temperature ranges between 22° C and 31° C (NBS, 2019). The topography of the State which is mainly plain to slightly gentle rolling lands and the climatic condition favours the cultivation of various arable crops. The major tribe in the State is Igbo.

Sampling Procedure

A multi-stage sampling procedure was employed for this study. All smallholder cassava-based food crop farmers in Abia State constituted the population of study. The farmers were

identified and selected with the assistance of the village heads and the resident extension agents. A total of 120 cassava-based farmers were sampled for the study.

Analytical Techniques

Data analysis involved the use of farm budgeting model, linear programming and target-minimization of total absolute deviation (T-MOTAD) models. A farm budgeting model was used to estimate the costs and returns associated with the various cassava-based 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 Ibeun *et al.* (2018); Adewumi *et al.* (2021) was used and is specified in equation 1 and 2

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

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

Where;

GM = Gross Margin,

NFI = Net farm income,

Y_i = Output per unit enterprise (where $i = 1, 2, 3 \dots n$ products),

P_{yi} = Unit price of the product,

X_j = Quantity of the variable inputs per unit enterprise (where $j = 1, 2, 3 \dots m$ variable inputs),

P_{xj} = Price per unit of variable inputs, and

F_k = Cost of fixed inputs per unit enterprise (where $k = 1, 2, 3 \dots, o$ fixed inputs).

Linear programming (LP) model was used to derive optimum cassava-based enterprise combination plan for the smallholder farmers in the study area. The LP model adopted from Igwe *et al.* (2011); Jirgi *et al.* (2018); Adewunmi *et al.* (2021) and modified for this study is specified in equation 3.

The objective function of the Linear programming model was to maximize the gross margin of the smallholder cassava-based food crop farmers for each enterprise undertaken which is total farm revenue less the total variable costs of production, that is gross income minus costs of planting materials, agrochemicals, labour, and transportation. Generally, the linear programming model is given as follows:

$$\text{Maximize } Z_i = \sum_{j=1}^n P_i X_j \quad (j = 1, 2, \dots, n) \quad \dots (3)$$

Subject to:

$$\sum_{j=1}^m A_{ij} X_j \leq b_i \quad (i = 1, 2, \dots, m) \quad \dots(4)$$

and

$$X_j \geq 0 \text{ for all } j_s$$

Where:

Z_i = Net Farm Income

X_j = Activity or enterprise undertaken (decision variable),

P_j = Output coefficient or net price (gross margin/unit) of each enterprise activity maximized,

A_{ij} = Input-output coefficients, that is, quantity of i th resource required to produce a unit output of j th activity.

β_{it} = Level of available resources for enterprises in t th period,

The model for determining the optimum farm plans can also be expressed explicitly by the equation:

$$\text{Maximize } Z = P_1X_1 + P_2X_2 + P_3X_3 + \dots + P_8X_8 \quad \dots(5)$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + A_{13}X_3 + \dots + A_{18}X_8 \leq L_s \text{ (Land)}$$

$$A_{21}X_1 + A_{22}X_2 + A_{23}X_3 + \dots + A_{28}X_8 \leq H_t \text{ (Labour)}$$

$$A_{31}X_1 + A_{32}X_2 + A_{33}X_3 + \dots + A_{38}X_8 \leq C_t \text{ (Capital)}$$

$$A_{41}X_1 + A_{42}X_2 + A_{43}X_3 + \dots + A_{48}X_8 \leq S_t \text{ (planting materials)}$$

$$A_{51}X_1 + A_{52}X_2 + A_{53}X_3 + \dots + A_{58}X_8 \leq F_t \text{ (Fertilizer)}$$

$$A_{61}X_1 + A_{62}X_2 + A_{63}X_3 + \dots + A_{68}X_8 \leq A_t \text{ (Agrochemical)}$$

$$\text{and } X_1 \geq 0, X_2 \geq 0, X_3 \geq 0, \dots, X_8 \geq 0$$

Z - Gross Margin (₦/ha),

$X_1, X_2, X_3, \dots, X_8$ - different crop activities or enterprises undertaken (decision variables),

$P_1, P_2, P_3, \dots, P_8$ - Output coefficients per hectare of the different crop activities maximized, A_{ij} -

Input- Output coefficient (quantity of i^{th} resource (land, labour, capital, planting materials, fertilizer, and agrochemical) required to produce a unit output of j^{th} crop activity,

L_s - Level of available land in hectare for crop activities with s restriction,

H_t - Level of available labour in man-day for crop activities in t^{th} period,

C_t - Level of available working capital in Naira for crop activities in t^{th} period,

S_t - Level of available seed in kilograms for crop activities in t^{th} period,

F_t - Level of available fertilizer in kilograms for crop activities in t^{th} period,

A_t - Level of available agrochemical in litres for crop activities in t^{th} period.

Target minimization of total absolute deviation (T-MOTAD) model was also used to analyse the data. To incorporate risk into the LP model, the modified T-MOTAD model adopted following Tauer (1983), Udo et al. (2015b) and Adewunmi *et al.*, (2021) was used. The optimum gross margins obtained from LP models for limited resources condition was used as the target return (Tr) in this model. The objective function was specified as

$$\text{Max } E(Z) = \sum P_j X_j \quad \dots(6)$$

Subject to:

$$\sum A_{ij}X_j \leq \beta_i \text{ (Technical resources requirement for cassava-based activities),} \quad \dots(7)$$

$$\sum L_{ij}X_j \geq \delta_i \text{ (Farm family cassava-based food requirement),} \quad \dots(8)$$

$$\sum Cr_jX_j \geq Tr \text{ (Absolute deviations from } Tr \text{),} \quad \dots(9)$$

$$\sum P_r Y_r = \lambda \text{ (Risk: -ve deviations (₦))} \quad \dots(10)$$

$$\text{and } X_j \geq 0 \quad \dots(11)$$

Where;

(Z) = Expected return per hectare of the plan (₦),

P_j = Output coefficients (gross margin) per hectare of cassava-based enterprise (₦),

X_j = cassava-based enterprise j undertaken (decision variables),

A_{ij} = Technical resource i requirement of cassava-based enterprise j ,

β_i = Level of available technical resource i ,

L_{ij} = Minimum farm family cassava-based food product i requirement of cassava-based enterprise j ,

δ_i = Level of cassava-based food product i consumed,

C_{rj} = Level of total absolute deviations from target returns of cassava enterprise j for state of nature r in Naira,

T_r = Target level of return in Naira,

Y_r = Level of negative deviation below T_r for state of nature r in Naira,

P_r = Probability that state of nature r will occur, and

λ = A constant parameterised from M to 0 .

RESULTS AND DISCUSSION

Costs and Return Analysis of Smallholder Cassava-based Enterprises

The variable and fixed costs of production, revenue, gross margin and net farm income per unit enterprise were computed. The values estimated were on a per-hectare basis and the gross values of each crop output per hectare were calculated based on prevailing market prices in the study area. The variable and fixed costs of production, revenue, gross margin, net farm income, and gross ratio per unit enterprise were computed. The variable cost items included the cost expended on planting materials, labour, fertilizer, agrochemicals, marketing expenses, processing, and storage, while the fixed cost items were those of land rent, depreciation on farm tools and machinery, and interest on borrowed capital. The result of the costs and returns analysis of each cassava-based enterprise undertaken by farmers in Abia State is presented in Table 1. The result in Table 1 showed that the total production costs for cassava-based combinations (CMz, CY, CMe, Cp, CG, CCo, COk, CMzMe, CMzY, CMzCo, CMzOk, CMzP, CMzG, CYOkP, CMzMeCo, CMzYP, and CMzYOk) are ₦ 85,674.50, ₦ 89,142.75, ₦ 93,205.94, ₦ 89,170.36, ₦ 88,608.41, ₦ 72,301.38, ₦ 78,836.85, ₦ 87,450.95, ₦ 82,858.89, ₦ 79,432.59, ₦ 88,221.53, ₦ 77,770.93, ₦ 89,113.04, ₦ 82,947.69, ₦ 90,278.83, ₦ 88,197.80 and ₦ 104,100.08 respectively. A further look at the costs of production shows that cassava-based mixed crop enterprises involving cassava, maize, yam, and okra (CMzYOk) are slightly more cost-intensive than any other cassava-based mixed crop enterprises in Abia State.

Based on the estimated gross margins, net farm incomes, and gross ratios, the result in Table 1 shows that all the crop enterprises undertaken by the smallholder farmers were profitable, given that the computed gross ratios were less than one. CMzMeCo enterprise is the most profitable with a net farm income of ₦214,863.62, which is closely followed by CY enterprise with a net farm income of ₦189,874.05 and by CP with a net farm income of ₦176,557.31. On the other hand, COk enterprise was the least profitable cassava-based enterprise with a net farm income of ₦111,159.96, closely followed by CY enterprise with a net farm income of ₦130,655.16. However, the computed gross ratios revealed that Cassava/Maize/Melon/Cocoyam (CMzMeCo) was the most profitable cassava-based enterprise, while Cassava/Okra (COk) was the least profitable cassava-based enterprise in Abia State. This is consistent with the assertions of Adewumi *et al.* (2021) who noted that a less than one gross ratio is desirable for any farm enterprise; the lower the ratio, the higher the return per Naira invested. A further look at the gross margins, net farm incomes, and gross ratios shows that cassava-based mixed crop enterprises involving yam were slightly more profitable than most other cassava-based crop enterprises in the study area. Thus, this shows that cassava in combination with yam or with other crops has the potential for judicious exploitation of land.

Table 1: Costs and returns analysis of cropping patterns of cassava-based farming farmers in Abia State

S/N	Enterprises	Average value (₦/hectare)						
		Total Fixed Cost	Total Variable Cost	Total Cost	Total Revenue	Gross Margin	Net-Farm Income	Gross Ratio
1	Cassava/Maize (CMz)	37,124.29	48,550.21	85,674.50	255310	206759.8	169,635.51	0.34
2	Cassava/yam (CY)	36,329.06	52,813.69	89,142.75	279016.8	226203.1	189,874.05	0.32
3	Cassava/Melon (CMe)	42,562.66	50,643.28	93,205.94	231150.7	180507.4	137,944.79	0.40
4	Cassava/Pumpkin (CP)	37,841.43	51,328.93	89,170.36	265727.7	214398.7	176,557.31	0.34
5	Cassava/Groundnut (CG)	42,396.53	46,211.88	88,608.41	244559.2	198347.3	155,950.79	0.36
6	Cassava/Cocoyam (CCo)	32,328.90	39,972.48	72,301.38	216181.1	176208.7	143,879.75	0.33
7	Cassava/Okra (COk)	33,757.53	45,079.32	78,836.85	189996.8	144917.5	111,159.96	0.41
8	Cassava/Maize/Melon (CMzMe)	38,823.57	48,627.38	87,450.95	260603.8	211976.5	173,152.89	0.34
9	Cassava/Maize/Yam (CMzY)	33,047.46	49,811.43	82,858.89	257691.2	207879.7	174,832.27	0.32
10	Cassava/ Maize/Cocoyam (CMzCo)	30,906.87	48,525.72	79,432.59	252595.6	204069.9	173,163.05	0.31
11	Cassava/Maize/Okra (CMzOk)	39,073.77	49,147.76	88,221.53	262017.9	212870.2	173,796.41	0.34
12	Cassava/Maize/Pumpkin (CMzP)	33,386.62	44,384.31	77,770.93	208426.1	164041.8	130,655.16	0.37
13	Cassava/Maize/Groundnut (CMzG)	38,357.52	50,755.52	89,113.04	221891.5	171135.9	132,778.43	0.40
14	Cassava/yam/Okra/Pumpkin (CYOkP)	34,994.91	47,952.78	82,947.69	257967.3	210014.5	175,019.63	0.32
15	Cassava/Maize/Melon/Cocoyam (CMzMeCo)	38,210.74	52,068.09	90,278.83	305142.4	253074.4	214,863.62	0.30
16	Cassava/Maize/Yam/Pumpkin (CMzYP)	35,213.06	52,984.74	88,197.80	244307.9	191323.2	156,110.11	0.36
17	Cassava/Maize/Yam/okra (CMzYOk)	41,736.70	62,363.38	104,100.08	268578.2	206214.8	164,478.13	0.39

Source: Field survey data, 2023

Cassava-Based Cropping Pattern in Existing, Optimum and Risk Efficient Plans in Abia State, Nigeria

The results of existing, optimum and risk efficient cassava-based enterprise plans using the LP model and T-MOTAD models for cassava-based crop enterprises in Abia State are presented in Tables 2. The results show that, the smallholder cassava-based farmers' existing, optimum and risk efficient farm plans in Abia State. First, the basic Linear Programming model was used to formulate optimal farm plan aimed at maximizing the net farm return resulting from seventeen different cassava-based food crop combinations identified in the study. The production activities included only crop mixtures as no sole crop farmer was sampled. There are many reasons why the local farmers undertake these crops production patterns. This is crop diversification, a form of risk management strategy adopted by the smallholder farmers to avoid total crop failure and to mitigate risk. Some of the crops can tolerate poor soils and still do well whereas others cannot. Sometime a risk averse farmer is willing to accept a lower average return for lower uncertainty depending on the person's level of risk aversion. This means that improved strategies or technologies developed for farmers should not be evaluated solely in terms of average or expected returns, but risk should also be considered. Also, these crops are the common staple crops that are consumed in the area. The farmers try to cultivate most of these crops in their small portions of farmlands at least for their families' consumption.

Given the risky nature of farm enterprises and since farmers differ in the degree to which they accept risk, the risk attitudes are generally classified as risk-averse, risk-takers and risk-neutrals. Among the sampled farmers, those who are risk neutrals and risk takers are most likely to adopt the optimum plan. Furthermore, a set of feasible risk efficient farm plans (I, II and III) were also obtained with the T-MOTAD model by parameterizing and varying the total absolute deviation (TAD) at 100%, 50% and 0%, respectively. The risk averse farmers would most likely adopt these plans over the risk prone gross margin maximizing optimum plans.

The characteristics of the farmers' existing farm plan, profit maximizing plan and risk efficient plans (I, II & III) using the LP model and T-MOTAD model for cassava-based enterprises in Abia State are presented in Table 2. From the table, only six of the seventeen enterprises were included in the optimum plan. The LP solution recommended cassava/yam (CY), cassava/pumpkin (CP), cassava/okro, (COk), cassava/maize/melon (CMzMe), Cassava/yam/Okra/Pumpkin (CYOkP) and Cassava/Maize/Yam/Pumpkin (CMzYP). These represent the enterprises that are in better competitive position to yield more returns for the farmers. The LP result therefore prescribed 0.69ha, 0.63ha, 0.62ha, 0.54ha, 0.58ha and 0.56ha for cassava/yam (CY), cassava/pumpkin (CP), cassava/okro, (COk), cassava/maize/melon (CMzMe), Cassava/yam/Okra/Pumpkin (CYOkP) and Cassava/Maize/Yam/Pumpkin (CMzYP) enterprises respectively for the smallholder cassava-based food crop farmers in Abia State to maximize their net returns in optimum plan. This finding is similar to that of Adewunmi *et al.* (2018) that recommended cassava/yam/maize and cassava/maize/groundnut enterprises in Kwara State, Nigeria. It also corroborates the finding of Igwe and Onyenweaku (2015); Udo *et al.* (2015b) that cassava/melon/pumpkin and cassava/maize/melon in enterprise combination is optimum for farmers in Eket agricultural zone of Akwa-Ibom State, Nigeria and Aba agricultural zone of Abia State, Nigeria respectively

Result in Table 2 further showed that the T-MOTAD model for risk efficient farm plans for the smallholder farmers prescribed six, six and eight enterprises in plans I, II and III, respectively for the farmers. Again, just as in optimum plan, CY, CP, COk, CMzMe, CYOkP and MzYP enterprises were also prescribed in efficient plans I and II. These same enterprises were also recommended in risk efficient plan III with the addition of cassava/maize (CMz) and

cassava/maize/yam (CMzY). This is a strong indication that these enterprises are in better competitive position to yield more returns for the smallholder farmers in the study area. The striking revelation in the optimum plan and the generated alternative farm plan (Risk efficient plan I) is that both plans prescribed same hectareage for the six enterprises recommended. Specifically, 0.69ha, 0.63ha, 0.62ha, 0.54ha, 0.58ha and 0.56ha were prescribed for CY, CP, COk, CMzMe, CYOkP and MzYP enterprises respectively in risk efficient plan I. Also, 0.59ha for CY, 0.6ha for CP, 0.63ha for COk, 0.58ha for CMzMe, 0.52ha for CYOkP and 0.65ha for MzYP were prescribed in risk efficient plan II; and in risk efficient plan III, 0.40ha, 0.47ha, 0.45ha, 0.43ha, 0.60ha, 0.51ha 0.54ha and 0.35ha for CMz, CY, CP, COk, CMzMe, CMzY, CYOkP and MzYP respectively were prescribed for the farmers. The same hectareage (3.62ha) was recommended for the optimum plan and the risk efficient plans I and II for farmers in Abia State. Probably because the programme recommended the same enterprises (CY, CP, COk, CMzMe, CYOkP and MzYP) in their respective plan. It is also seen in Table 2 that more enterprises entered the most risk efficient plan III. This is diversification which is a form of risk management strategy adopted by the farmers to avoid total crop failure and to mitigate risk.

The results obtained in Table 2 also indicated that the crop mixtures that are not in the parametric programming (T-MOTAD) solutions are not efficient farm plans and with the prevailing farm environment, they are also not risk minimizing strategies with optimum income. The deductions that we can be made from these results are that enterprises in risk efficient plan III are better risk minimized combinations. These generate ideal and quite optimum income with their risk levels. Other combinations that are found in the T-MOTAD solution in I and II are also risk minimized combinations, but can be riskier than those which are found in all the plans.

Table 2: Results of basic linear programming and T-MOTAD models of existing, optimum and risk efficient cassava-based enterprise plans for Abia State

S/N	Cassava-based Enterprises	Farmers existing Plan	LP Solution	T-MOTAD Solution		
			Optimum Plan	Risk efficient Plan I	Risk efficient Plan II	Risk efficient Plan III
1	CMz	0.84(8.62)	-	-	-	0.40(10.7)
2	CY	0.78(8.00)	0.69(19.1)	0.69(19.1)	0.59(16.3)	0.47(12.5)
3	CMe	0.69(7.08)	-	-	-	-
4	CP	0.47(4.82)	0.63(17.4)	0.63(17.4)	0.67(18.5)	0.45(12.0)
5	CG	0.81(8.31)	-	-	-	-
6	CCo	0.49(5.03)	-	-	-	-
7	COk	0.53(5.44)	0.62(17.1)	0.62(17.1)	0.63(17.4)	0.43(11.5)
8	CMzMe	0.86(8.82)	0.54(14.9)	0.54(14.9)	0.58(16.0)	0.60(16.0)
9	CMzY	0.72(7.38)	-	-	-	0.51(13.6)
10	CMzCo	0.42(4.31)	-	-	-	-
11	CMzOk	0.64(6.56)	-	-	-	-
12	CMzP	0.34(3.49)	-	-	-	-
13	CMzG	0.29(2.97)	-	-	-	-
14	CYOkP	0.34(3.49)	0.58(16)	0.58(16.0)	0.52(14.4)	0.54(14.4)
15	CMzMeCo	0.51(5.23)	-	-	-	-
16	CMzYP	0.57(5.85)	0.56(15.5)	0.56(15.5)	0.63(17.4)	0.35(9.3)
17	CMzYOk	0.45(4.62)	-	-	-	-
	Total cropped area (ha)	9.75	3.62	3.62	3.62	3.75

Source: Field survey data, 2023

Figures in parenthesis are the percentage cropped area

Marginal Opportunity Cost (MOC) or shadow prices of excluded activities of optimum and risk efficient farm enterprise plans

In LP and T-MOTAD problems, 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 maximization or optimum/risk efficient 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 included in the optimum plan and vice versa. The marginal opportunity costs also known as shadow prices of the excluded farm enterprises in the various obtained plans are presented in Tables 3. The results show that 11 enterprises apiece were excluded from the optimum plan and risk efficient plans I and II, while nine enterprises were excluded from risk efficient plan III to guide the farmers towards the attainment of profit maximization and risk minimization in Abia State. It further showed that CMz with MOCs of ₦23,593.26 and ₦23,993.71 in the optimum plan and in risk efficient plan I respectively, CMzOk and CMzYOk with MOCs of ₦20,934.08 and ₦14,563.18 in risk efficient plans II and III respectively, had the least MOC values in their respective derived plans. This implies that these enterprises are in a better competitive position to fit into the various derived plans respectively compared to the other excluded enterprises. Interestingly, in all the derived plans, CMzP for the optimum plan, risk efficient plans I and II and, CMzCo for risk efficient plan III had the highest MOC values. The implication of this is that these two enterprises have the worst competitive position to fit into the various derived plans, respectively, among all the other excluded enterprises. This is a strong indication that the smallholder cassava-based food crop farmers should steer clear from CMzP and CMzCo enterprises if they aim to maximize profit and minimize the associated risk in cassava-based food crop enterprise in Abia State. Specifically, CMzCo had MOC or income penalty values of ₦58,105.00, ₦58,542.97, and ₦67,374.67 in the optimum plan and risk efficient plans I and II respectively. On the other hand, CMzCo had MOC value of ₦71,035.41 in risk efficient plan III

Table 3: Marginal Opportunity Cost of excluded cassava-based enterprises for farmers in Abia State

S/N	Cassava-based Enterprises	LP Solution	T-MOTAD Solution		
		Optimum Plan	Risk efficient Plan I	Risk efficient Plan II	Risk efficient Plan III
1	CMz	23,593.26	23,993.71	35,194.09	-
3	CMe	45,424.41	45,767.01	36,304.79	53,075.51
4	CG	53,675.02	53,304.00	27,644.25	40,691.68
5	CCo	49,043.70	49,734.86	56,770.84	39,647.74
6	CMzY	45,072.48	45,691.85	31,761.87	-
7	CMzCo	57,095.14	57,249.90	30,100.37	71,035.41
8	CMzOk	40,421.80	40,266.14	20,934.08	49,624.98
9	CMzP	58,105.00	58,542.97	67,374.67	36,854.40
10	CMzG	31,388.20	31,079.32	32,925.10	24,635.08
11	CMzMeCo	31,032.80	31,714.84	30,977.29	57,914.06
12	CMzYOk	41,380.10	41,597.16	32,125.03	14,563.18

Source: Field survey data, 2023

Net Farm Income in Existing, Optimum and Risk Efficient Cassava-Based Plans

The mean net farm income obtained in Naira per hectare in the existing plan, optimum plans I and II and the risk efficient plans I, II and II for cassava-based food crop enterprises in the study area are presented in in Table 4. The estimated net farm income in the existing farm plan was ₦170,717.61/ha. However, the mean net farm income of ₦215,667.56/ha obtained in the optimum plan was higher. This depicts that there is an average increase of ₦44,949.95/ha, representing 26.33% proportionate change in the optimum plan over the existing plan. This increment satisfies the increased income objective of the farmers. The implication of this increment in the optimum plan is that, an average cassava farmer in the study area has the potential to increase and maximize net returns. This result is similar to those obtained from the study carried out by Jirgi *et al.* (2018); Adewunmi *et al.* (2018) and Udoh *et al.* (2015) who noted that gross margins obtained in optimized farm plans offers a higher and better value than the gross margins obtainable in the farmers' existing farm plans.

More so, as presented in Table 4, the average net farm income obtained from the T-MOTAD solution for risk efficient plans were ₦209,009.57/ha in plan I, ₦197,281.27/ha in plan II and ₦188,881.96/ha in plan III representing 22.43%, 15.56% and 10.64% increase over the existing plan. The average net farm income obtained in the risk efficient plans especially in risk efficient plan III are slightly lower than those obtained in the optimum plan across all the derived plans. The difference in these net returns (net farm income) could be regarded as the risk premium payable by the smallholder farmers for foregoing riskier optimum farm plan and adopting farm plans with minimized risk. It is worthy to note that the average net returns (net farm income) of the farmers increased across the optimum and risk efficient plans. It however increased proportionately highest in optimum plan and least in risk efficient plan III. The implication of these increments in the optimum and risk efficient plans is that, an average smallholder cassava farmer in the study area has the potential to increase and maximize net profit under risk.

The result shows that the returns in the risk minimized plans I, II and III were higher than the returns in the farmer's existing plan thus satisfying the increased income or limited out of pocket cash expenses objective (Salimonu *et al.*, 2008). It also implies that farmers can increase their level of profit with less level of risk.

The result also showed that the optimum plan recorded the highest returns among all the plans. The average farmer would be operating at a high-risk level if he adopts the profit maximization plan (optimum plan) since no consideration for yield variability inherent in crop farming was included in the linear programming model used to formulate the plan. However, these high risks levels can be averted if the average farmer shifts to enterprise mixes with less variability in returns to farm resources. These are risk efficient plans I, II and III with minimized risk.

Table 4 Gross margin in existing, optimum and risk efficient plans for cassava-based food crop

Farmers existing Plan (₦)	LP Solution		T-MOTAD Solution	
	Optimum Plan (₦)	Risk efficient Plan I (₦)	Risk efficient Plan II (₦)	Risk efficient Plan III (₦)
170,717.61	215,667.56	209,009.57	197,281.27	188,881.96
Average Increase in Net Return in the Optimum and Risk Efficient Plans over the Existing Plan (₦)				
-	44,949.95	38,291.96	26,563.66	18,164.35
Percentage Increment in Net Return in the Optimum and Risk Efficient Plans over the Existing Plan (%)				
-	26.33	22.43	15.56	10.64

Source: Filed survey data, 2023



MARGINAL VALUE PRODUCT (MVP) OF RESOURCES UNDER CASSAVA-BASED ENTERPRISES

Any resource that is abundant, that is not used up by the programme, is not a limiting resource and therefore, has a zero shadow price as it does not constrain the attainment of a programme's objective and vice versa (Olayemi and Onyenweaku, 1999). The status therefore of the available resources in the optimized plans that constrained the attainment of the objective programme for is presented in Table 5. For all the derived plans, the results in Table 5 showed that capital had positive MVPs. In the same vein human labour except that for wedding and for pesticide applications in risk efficient plans I and III respectively also recorded positive MVPs. This implies that labour and capital were therefore the limiting resources in cassava-based cropping system in Abia State as they constrained the attainment of the profit maximization and risk minimization objectives of the farmers. The implication is that a unit increase in their usage will lead to increase in the gross margins or net returns of the farmers by their corresponding MVPs. For example, labour for weeding had MVP of ₦1,211.33 in risk efficient plan III. This implies that if labour for weeding is increased by 1 man-day, the value of the objective function will increase by ₦1, 211.33. This agreed with the findings of Ibrahim *et al.*, (2019), , who discovered that labour and capital were the most limiting factors to the attainment of profit maximization of maize based crop farmers in Niger State.

This finding also corroborates those of Igwe *et al.* (2015) and Udo *et al.* (2015) who in their respective work identified labour and capital as factors limiting gross margins of arable crop farmers in Abia and Akwa Ibom States respectively. Ibrahim *et al.* (2020) also identified labour and capital as limited factors to the maximization of maize based farmers' gross margin in Niger State, Nigeria. This finding is also similar to those of Sathyanarayan *et al.* (2010), Baruwa (2013) and Bamiro *et al.* (2015) who reported that human labour and feed were factors limiting the profit maximization objective of livestock farmers. It also corroborates the report of Jacob (2019) and Adewunmi *et al.* (2021) that labour and capital were limiting the gross margin maximization objective of livestock farmers in Niger State.

However, on the contrary land, fertilizer, agrochemicals and planting materials except okro seeds in risk efficient plan II had zero MVPs (shadow prices). This implies that these resources were in excess of the actual requirements to maximize gross margins of the smallholder cassava-based farmers. Consequently, because they are not limiting, they should not be used in production of the activities beyond their current levels. This is also consistent with the assertion of Olayemi and Onyenweaku (1999) who asserted that resources not used up were not limiting in fulfilling the attainment of the programme's. This result lends credence to findings of Igwe *et al.* (2011); Udo *et al.* (2015) Adewunmi *et al.* (2018) who opined that land was not a limiting factor in net return maximizing objective of smallholder arable crop farmers in Kwara State, Nigeria.

Table 5: Marginal value product (MVP) of resources under cassava-based enterprises in Abia State, Nigeria

Resources	LP Solution						T-MOTAD Solution					
	Optimum Plan			Risk efficient Plan I			Risk efficient Plan II			Risk efficient Plan III		
	US	S/S	SP(₦)	US	S/S	SP(₦)	US	S/S	SP(₦)	US	S/S	SP(₦)
A. Land	NFU	5.06	0	NFU	5.06	0	NFU	5.37	0	NFU	4.82	0
B. Human Labour												
1. Land preparation	FU	0	1025.43	FU	0	1025.43	FU	0	999.37	FU	0	1202.16
2. Planting	FU	0	1025.41	FU	0	1025.41	FU	0	996.88	FU	0	1089.28
3. Weeding	FU	0	1025.22	FU	0	1025.22	NFU	341.49	0	FU	0	1211.33
4. Fertilizer application	FU	0	638.31	FU	0	638.31	FU	0	702.54	FU	0	960.15
5. Pesticides application	FU	0	756.32	FU	0	756.32	FU	0	800.11	NFU	230.11	0
6. Harvesting	FU	0	1050.09	FU	0	1050.09	FU	0	1022.93	FU	0	845.49
C. Capital												
1. Owned capital	FU	0	6.58	FU	0	6.58	FU	0	8.92	FU	0	9.26
2. Borrowed capital	FU	0	10.35	FU	0	10.35	FU	0	9.66	FU	0	7.94
D. Planting Material												
1. Cassava	NFU	367.43	0	NFU	367.43	0	NFU	428.52	0	NFU	687.19	0
2. Maize	NFU	277.21	0	NFU	277.21	0	NFU	381.40	0	NFU	456.39	0
3. Melon	NFU	189.46	0	NFU	189.46	0	NFU	200.56	0	NFU	477.32	0
4. Groundnut	NFU	234.64	0	NFU	234.64	0	NFU	209.17	0	NFU	383.41	0
5. Yam	NFU	441.82	0	NFU	441.82	0	NFU	503.74	0	NFU	169.45	0
6. Pumpkin	NFU	231.16	0	NFU	231.16	0	NFU	246.38	0	NFU	183.57	0
7. Cocoyam	NFU	115.75	0	NFU	115.75	0	NFU	316.09	0	NFU	248.73	0
8. Okra	NFU	289.60	0	NFU	289.60	0	FU	0	421.14	NFU	275.09	0
E. Fertilizer (Kg)	NFU	9.22	0	NFU	9.22	0	NFU	7.93	0	NFU	8.86	0
F. Agrochemicals (L)	NFU	0.89	0	NFU	0.89	0	NFU	0.74	0	NFU	1.06	0

Source: Field survey data, 2023

US = Use status; S/S = Slack/Surplus resource; SP = Shadow price; FU = Fully utilized; NFU = Not fully utilized

CONCLUSION AND RECOMMENDATIONS

It was concluded based on the findings of this study that resources were not allocated optimally by the smallholder cassava-based farmers in Abia State. Nonetheless, all the enterprises considered were profitable in the study area. The farm enterprise plans prescribed are optimum and efficient and suggested optimal combinations of enterprises, optimal gross margins, minimized risk and optimal utilization of farm resources under risky environment. The farmer's existing plans, the profit maximizing and risk efficient farm plans have important implications for strategies to improve food crop production in the study area

All the normative farm plans that were undertaken provided alternative farm plans for the smallholders' cassava-based farmers in Abia State, Nigeria. The farm plans that were generated are efficient and they indicated optimum enterprise combinations, optimum farm income and optimum resource use. The study had demonstrated the importance of incorporating risk when modeling farm plans for crop farmers in tropical agriculture. It revealed that farm income will be overestimated if risk is not included in subsistence farm models.

It can also be concluded that appropriate combination of enterprises in crop farming not only helps to increase net farm income but also utilize all available resources efficiently. The farmers have the potential to maximize their gross margin by adopting the optimum and risk efficient farm plans prescribed in the LP and TMOTAD solutions, that is, they should undertake the various enterprise mixtures that fit into the plans. This would help them to achieve increased farm incomes, reduced cost of production, risk minimization and food security. In essence, the optimum plans should be incorporated in to extension education content of the Abia State ADP.

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