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OPTIMAL CROP PLAN OF COOPERATIVE FARMERS IN OSUN STATE, NIGERIA: A LINEAR PROGRAMMING APPROACH

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Abstract: *Optimal level of production requires better use of existing resources at the lowest possible cost. Despite the inherent advantage of cooperatives to the agricultural sector, the question of how farmers under cooperative umbrella use farm resource for optimal outcome remains unanswered. This study investigates optimal crop mix for cooperative farmers in rural communities in Southwest Nigeria. Primary data were collected for the study through structured questionnaire. The data were fitted to Linear Programming Model. Three different cropping patterns are identified among the cooperative farmers. Based on the results from linear programming model, only maize, cassava and yam are admitted in the final plan and this combination is to be produced at 2.23 hectares. The gross margin value associated with the plan is ₦156, 235.781 (1$ = N365). Input resources such as land, labour, fertilizer, and chemicals are not fully utilized. The slack values for these inputs are 0.31, 651.20, 1929.6 and 140.76 respectively. The sensitivity analysis shows that seed/seedling is the only binding resource in the final plan with a shadow price which suggests that proper allocation of seed and seedlings would improve returns to cooperative farmers. There is need for appropriate farm management strategies to ensure optimal return for farmers. More education and training is suggested to boost cooperative farmers understanding of optimum strategy that is needed to improve production and earnings.*

Keywords: *cooperatives, rural, crops, linear programming, optimum plan*
JEL Code: Q10, Q13

INTRODUCTION

The significance of cooperative farming lies in the opportunity to pool limited resources together in particular areas of activities to achieve mutual economic related advantage (Milovanovic and Smutka, 2018; Bishop, 2012). Since the historical beginning of cooperative movement, a large number of successes have been recorded across the globe (Argaw, 2012). Some of the recorded advantages of farm related cooperatives include provision of inclusive access to land resources (Birchall, 2003), market access (Barrow et al. 2005), and agricultural related services (Adeyemo, 2004). Despite the inherent advantage of cooperatives to the farming and agricultural sector, the question of how farmers under cooperative umbrella use farm resource for optimal outcome remains unanswered. The level of efficiency of smallholder resources has important implications for the agricultural and rural development. Optimal level of production requires better use of existing resources at the lowest possible cost. The efficient method of producing a product is that which uses the least amount of resources to get a given amount of the product. An increase in efficiency in arable crop production could present a ray of hope and could lead to an improvement in the welfare of the farmer and consequently a reduction in their poverty level and food insecurity. As noted by Likita (2005), low yields could be attributed to inefficient techniques of production and input mix, over utilization of household resources, and over dependence on physical labour use instead of machines.

Agriculture in Nigeria as in most other developing countries is dominated by small farm producers who play a vital role in the overall development of Nigeria. Aside provision of food for the ever increasing population, employment opportunities are also provided for over 65 per cent of the population. Raw materials and foreign exchange earnings for the development of the industrial sector are also expected from Nigeria agricultural sector (Oladeebo, 2004; Olaoye, 2014). Despite the importance of agriculture to the Nigerian system, smallholder farmers still constitute about 80% of the farming population in Nigeria who are also characterized by low level of production (Awoke and Okorji, 2004). These farmers usually produce on small scale at subsistence level, with an average land size of five hectares on annual basis. But, available evidence shows that farmers who produce at relatively low scale may not be able to maximize return without optimal cropping plan. It is expected that optimal level of productive activities ensures efficient resource utilization (Hassan et al., 2005). Possibility of achieving optimum level in production, in addition to a number of factors, could be attributed to appropriate specification of inputs or resource allocation issues. However, allocation problems are generally related to utilization of limited resources to best advantage (Lucey, 2002). In the absence of resource constraints, a producer could allocate resources without being able to optimize (Olayemi and Onyenweaku, 1999). Consequently, it is important to lay greater emphasis on utilization of limited resources and appropriate combination of crop enterprises in an optimal manner in the food supply sector. However, limited studies exist on determination of optimal crop combination for resource poor farmers. This study provides answers to the following research questions: What is the optimum cropping plan for arable crop enterprises? Given the resource constraints and possible alternative combinations, how should the respective farmer allocate available resources to optimize output? What is the minimum size of hectares required for each of the farmers to maximize profit? Is the optimum plan different from the existing crop farm plans for farmers? Answers to these questions are provided through careful analysis of the data using linear programming approach.

Optimum decision making is based on a quantitative analysis for achieving desired goal of arable farmers. The use of linear programming in management and decision making originated in the 1940s during World War II, when a team of British scientists applied it in decisions among the military regarding the best utilization of war material (Taha, 2011). Generally, mathematical programming tools have afterwards been employed in wide range of farm related activities including crops and livestock (Mehta, 1992). In a regional/inter-regional framework, linear programming approach has been used for studies in optimum resource allocation and resource requirements in many countries (Mellaku, et al. 2018; Wankhade and Lunge, 2012; Gadge et al. 2014).

Under cooperative setting, a number of farmers have been found in different clime with tendencies to pool together their resources to improve production and rural farm earnings (Allahdadi, 2011; Verhofstadt and Maertens, 2015; Baruwa et al. 2016). But, the scope of cooperative farming is remains unknown in Nigeria. However, within Nigeria, application of linear programming models to farm enterprises in various states has also been reported (Tanko, 2004; Igwe et al. 2012). The usage include specification of different levels of products, factor and product prices. While farmers have different reasons for the cropping systems adopted and the enterprises combined, two major reasons that are most outstanding are that of net income stabilization and maximization. Although different levels of crop plan have been suggested for farmers, most recommendation to farmers is strictly limited to different geographical boundaries of farmers. For example, Phillip et al., (2019) in Northern Nigeria recommended combinations involving groundnut, sorghum and maize. Earlier, Igwe and Onyenweaku (2013) did a mix up between crop and livestock making it difficult to have a clear policy guide for the farmers. Tanko (2010) was able to conclude that farm enterprises combination is not optimal for most farmers in Northern part of Nigeria, except in a condition where farmers could be given opportunity to have access to more arable land.

Opportunity to maximize return from adequate crop plan is found to be hindered by poor distribution of financial assets to farmers on equitable basis (Ohajianya and Oguoma, 2009). Farm resources were found to be poorly optimized as areas of cultivation were found to be small. Central to resolving food shortage amidst growing population is determination of adequate crop combination plan for farmers. Ibrahim and Bello (2009) found that combination of maize, cassava and yam was found to be central to resolving food insecurity in Nigeria. Optimal farm plan was examined in sweet potato cropping systems and the optimal crop combination was sweet potato/cassava cropping system. While capital was a limiting resource, land and labour were non-limiting and there were 0.06 ha of unused land and 3.13 man-days of unused labour. Increased capital investment was recommended for increased production of the crop.

Babatunde et al., (2007) found the optimal crop combination in vegetable farming to include mix of tomato, cucumber, onion, and watermelon enterprise. But, contrary to similar studies, land was found to be the limiting factor. Tanko et al., (2006) employed linear programming to determine the most profitable enterprise in Nigeria. The results reveal existence of divergence between the existing and optimum farm plans for the different tenure groups. Farm resources were not optimally allocated and there is a considerable scope for increasing farm incomes by reallocating the existing resources in an optimal manner. Also, the findings of Igwe et al., (2011) on optimum enterprise combination through linear Programming application, showed that combination of crops involving cassava, maize and cocoyam is appropriate for farmers. In addition to geographical variation associated with most existing studies, gross margin analysis of the suggested enterprises is usually not included. Policy recommendation involving optimal analysis is better supported with gross margin analysis to provide clear guide to farmers on the appropriate direction to follow with respect to crop combination to achieve desirable optimal outcome.

MATERIALS AND METHODS

The study was carried out in Osun State, located in Southwestern part of Nigeria with approximately 9,026 km^2

in terms of land area. Primary data were collected using questionnaire. A two-stage sampling technique is used. The first stage involves random selection of two villages from three local government areas in the study area. The last stage involves selection of twenty members of cooperative farming group from each of the villages using the snowball sampling technique. Thus, a total of one hundred and twenty respondents were sampled. Data collected covers socio-economics of respondents, quantities and prices of inputs and outputs. Analysis of the data was carried out using descriptive statistics and linear programming model.

The objective function of the linear programming (LP) is total gross income less the total variable costs (TVC). The TVC includes the costs of human labour, tractor/power tiller hiring, and marketing. Other variable costs include depreciation on fixed cost items and rent on land. Following Tanko (2004), Alam, et al. (1995) and Sama (1997), the implicit form of the model is presented as:

$$Max\ Z = X_1 + X_2 + X_3 \ldots Xn \qquad (5)$$

Subject to:

$X_1 + X_2 + X_3 \leq$ Ls (Land) (6)

$X_1 + X_2 + X_3 \leq$ Sd (Seed) (7)

$X_1 + X_2 + X_3 \leq$ Fz (Fertilizer) (8)

$X_1 + X_2 + X_3 \leq$ ch (Chemical (9)

$X_1 + X_2 + X_3 \leq$ mac (Machine) (10)

$X_1 + X_2 + X_3 \leq$ Lab (Labour) (11)

Where,

Z = Total Net farm income of the farm in Naira (N) currency (1$ = 360 N), Ls=Total available land in hectares for the crops, Sd = Amount spend on seeds, Fz = Amount spend on fertilizer, Ch =Amount spend on various chemicals, Mac=Tractor hired over a period, Lab=Number of hired human labour. The constraints were land, labour (human), tractor/power tiller and capital require that the amount of a resource required to produce the n crop activities must not exceed the available. The price coefficient of a production activity in the model is the gross value of output per hectare of all the crops. For a human labour hiring activity, the price coefficient is the ruling wage rate. The price coefficient of a tractor hiring activity is the cost of hiring. For a capital borrowing activity, the price coefficient is the prevailing market rate of interest, while for a selling activity; the price coefficient is the marketing expense per unit of the product sold. The input coefficient is the requirement of a crop activity in respect of the inputs of the different resources measured in terms of per hectare basis (unit of land). The input coefficients for all the crop activities are calculated on the basis of the actual quantities of different resource that are used for those crop activities. Six restrictions/constraints were incorporated in the model. These are: land, human labour, machine, fertilizer, seed, and chemicals requirement constraints.

The crop activities in the model were three; intercrops maize/cassava, maize/cassava/yam, and maize/cassava/pepper/tomatoes. About 50% (60) cultivated maize/cassava, 16.7% (20) cultivated maize /cassava/yam, while 33.3% (40) cultivated maize/cassava/ pepper/ tomatoes.

Linear programming model specifications

The model shows the unit of each resource combined to obtain the optimum farm plan.

$MaxZ = 13323.95X_1 + 701875.8X_2 + 179603.7X_3$

Subject to:

$1.0X_1 + 1.0X_2 + 1.0X_3 \leq 2.54$ *ha (Land)*

$409.41X_1 + 409.41X_2 + 397.9X_3 \leq N1044.25$ *(seed)*

$5123.8X_1 + 4882.35X_2 + 5000X_3 \leq$ N12797.62 *(fertilizer)*

$990.1X_1 + 1041.9X_2 + 771.01X_3 \leq$ ₦2460 *(Chemical)*

$3548.5X_1 + 3176.47X_2 + 3188.9X_3 \leq$ ₦8371.77 *(Machine)*

$3252.14X_1 + 3644.12X_2 + 3337.39 0_3 \leq$ ₦8762.92 *(Labour)*

The objective function (Z) is maximization of the gross margin of the enterprise combined, subject to: X1 = hectare cultivated to maize/cassava intercrop, X2 = hectare cultivated to maize/cassava/yam intercrop and X3 = hectare cultivated to maize/cassava/pepper/Tomatoes intercrop.

RESULTS AND DISCUSSION

Results in Table 1 show the descriptive characteristics of the respondents. Most of the respondents fall in the age bracket below 50 years indicating the level of youth involvement in agriculture. Expectedly, due to gender perception in the study area, more male (80%) are involved in farming activities. Very high percentage (83.3%) of the respondents is married. Level of education of the respondents is relatively impressive with 35.8% having attended primary school education while 36.7% of the respondents attended secondary school. This implies that 72.5% have formal education. The distribution of the respondents by their major occupation shows that 65.8% were farmers. Mode of land acquisition varies: 54.17% of the respondents obtained land by inheritance, 41.7% by rent, while 4.2% purchased their land. The table below shows the distribution of the respondents according to their farm size. Descriptive of land size shows that 78.3% of the respondents have between one and three hectares, 11.8% uses 3.5 to 5.5 hectares, 5% uses 6 to 8 hectares while 4.9% uses 8.5 hectares of land and above.

Table 2 presents the cropping system, production cycles and enterprise combination among the sample respondents. Most of the sample farmers engage in intercropping (54.7%) while 47.5% produce sole crop. These crops are usually produced once a year (54.7%) by some farmers while 45.3% produce twice a year. The enterprise combination of the cooperative farmers varies among different categories of crop including maize, cassava, pepper, tomatoes and yam. However, 49.6% of the farmers combine maize and cassava on the same land area, 33.7% combine maize, cassava, pepper and tomatoes while 16.7% combine maize, cassava and yam.

Table 1: Characteristics of sample respondents

Variables	Description	Frequency (%)
Age (years)	Below 20	8(6.8)
	21-30	19(16.1)
	31-40	29(24.6)
	41-50	24(20.3)
	51-60	23(19.5)
	Above 60	15(12.7)
Gender	Male	96(80.0)
	Female	24(20.0)
Marital	Single	8(6.7)
	Married	100(83.3)
	Divorced	2(1.7)
	Widow/Widowers	10(8.4)
Education	Informal	23(19.2)
	Primary	43(35.8)
	Secondary	44(36.7)
	Tertiary	10(8.3)
Farming experience (years)	1-10	30(25.0)
	11-20	41(34.17)
	21-30	49(40.83)
Occupation	Farming	79(65.8)
	Civil service	7(5.8)
	Trading	34(31.3)
Forms of land acquisition	Inheritance	65(54.17)
	Rent	50(41.66)
	Purchased	5 (4.17)
Land size (ha)	1-3	94 (78.3)
	3.5-5.5	14 (11.8)
	6-8	6 (5)
	8.5 and Above	6(4.9)

Table 2: Production, activity and crop combination of the farmers

	Activity	Frequency (%)
Cropping system	Mono cropping	57 (47.5)
	Intercropping	63(52.5)
Production cycle per year	Once	64 (54.7)
	Twice	53 (45.3)
Enterprise combination	Maize/cassava	60(49.6)
	Maize/cassava/pepper/tomatoes	40(33.7)
	Maize/cassava/yam	20(16.7)

Linear programming analysis of the enterprise combinations

The optimum farm plan of the three identified enterprise combinations of the sampled cooperative farmers is presented in Table 3. The LP outcome supports one (1) out of the 3 basic cropping activities included in the model. The supported activity and its land area allocation (ha) is combination of maize, cassava and yam at 2.23 ha. The optimal solution occurs with most of the resources not fully utilized. The gross margin realized for the optimal farm plan was ₦156, 235.781 (1$ = N356) (programme value). In order to achieve this, the LP results suggest that 2.23 units of maize/cassava/yam should be produced. This implies that the objective of income maximization requires that the farmers should do away with the non-basic activities, and focus more on production of maize/cassava/yam, because forcing in the non-basic activities will reduce the programme value. With respect to resources, the result shows that only one of the specified resources was fully utilized in arriving at the optimum solution. This resource is seed/seedling. The shadow price for the fully utilized resource was N1, 496.15 (1$ = N356). Shadow price is the maximum amount a farmer would be willing to pay for the next unit of input constraints. This implies that if additional value seed/seedling is available, if properly allocated, it would contribute ₦1, 496.15 (1$ = N356) to the farmer's income.

The non-fully utilized resources were land, labour, fertilizer, machinery and chemical. Respectively, the excess values for these non-fully utilized resources (slack value) are 0.31, 651.20, 1929.6, 1301.02 and 140.76 for land, labour, fertilizer, machine and chemical respectively. The LP programme suggests that if the optimum farm plan is to be implemented, the cooperative farmers should spend ₦8, 111.72, ₦10, 868.00, ₦7, 070 and ₦2,319.24 on labour, fertilizer, machine and chemical respectively while 2.23ha of land should be used. The non-basic activities were maize/cassava and maize/cassava/pepper/tomatoes. The non-basic activities have the reduced cost or reduced gradient of ₦599,216.46 (1$ = N356) and ₦415,715.96 (1$ = N356) respectively. Reduced cost is signified by how much the programme value will decrease if any of the non-basic activities was forced into the programme.

Table 3: Linear programming model result

Objective		Original value	Final value	
Enterprise combination		156235.78	156235.78	
Maize/Cassava		0	0	
Maize/Cassava/Yam		2.23	2.23	
Maize/Cassava/Pepper/Tomato		0	0	
Constraints	**Value**	**Status**	**Slack**	**Shadow value**
Land	2.23	Not binding	0.31	0
Seed	1044.25	Binding	0	1496.15
Fertilizer	10867.25	Not binding	1929.62	0
Chemical	2319.24	Not binding	140.76	0
Machine	7070.75	Not binding	1301.02	0
Labour	8111.72	Not binding	651.20	0
Enterprise 1	0	Binding	0	0
Enterprise 2	2.23	Not binding	2.23	2.23
Enterprise 3	0	Binding	0	0

Table 4: Sensitivity analysis of the LP programme

Objective	Final Value	Reduced Cost
Enterprise Combination	156235.78	156235.78
Maize/Cassava	0	-59921.46
Maize/Cassava/Yam	2.23	0
Maize/Cassava/Pepper/Tomatoes	0	-41571.96

DISCUSSION AND CONCLUSION

This study focused on evaluation of crop enterprise combination among cooperative farmers. The analysis of the optimal combination of arable crops through linear programming approach is the core of the study. The optimum cropping plan for crop enterprises is identified under resource constraints while other existing enterprise options for the cooperative farmers are also presented. The study also identified the minimum size of hectares needed for the farmers to achieve the goals. This is consistent with the suggestion of Mellaku et al., (2018). The results from six rural communities in part of south west region of Nigeria suggest that the performance of enterprise allocation through linear programming approach returns higher gross margin for the identified optimum crop enterprise combination.

There is evidence that the optimal combination of crops for cooperative farmers should be a combination of maize, cassava and yam on a minimum land size of 2.23 hectares. While there is existence of geographical difference in studies and lack of focus on cooperative farmers, the findings of this study largely agree with Igwe et al., (2013) on the optimal combination of crops. Also, earlier studies of Ibrahim & Bello (2009) show that farmers would benefit immensely from combination of maize, cassava and yam in savanna region. Yet, most of the resources for this optimal solution are not fully utilized. By implication, cooperative farmers need to do away with activities that are non-basic. Inclusion or forcing of non-basic activities into farming programme could result in 'reduced cost' or 'reduced gradient'. Under different land size and geographical difference, our findings partly align with Phillips et al. (2019) who found inclusion of maize as part of the optimal combination of crops. Reduced cost normally signifies how much the programme value will decrease in the presence of non-basic activities. The only resource input that is fully utilized in the LP solution is seed/seedling of the identified crops. The shadow price for the seed/seedling is measurable suggesting that proper allocation of additional unit of the resource input would lead additional increase in return. Furthermore, the LP solution indicates that a number of resources are not fully utilized by the cooperative farmers. These include land, labour, fertilizer, machinery and chemical with relatively high slack values. Aside, enterprise combinations such as maize and cassava on one hand, and maize, cassava, pepper and tomatoes on the other are found to exist among the cooperative farmers. But, none of these two levels of enterprise combinations are found to be optimal.

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