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# OPTIMUM PRODUCTION PLAN FOR YAM BASED CROPPING SYSTEMS IN GANYE LOCAL GOVERNMENT AREA OF ADAMAWA STATE, NIGERIA

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***ABSTRACT***

Population pressure is linked in one way or the other to the shrinking size of most-small holder farms over time. The study addressed optimum production plan for yam-based farmers in Adamawa State, Nigeria. Primary data used were collected from 298 farmers, using structured questionnaire. Data were analysed using descriptive statistics and linear programming model. The results revealed that yam-based crop production in the study area was predominantly a male activity (72.15%), with a mean age of 48 years. The mean household size was 10 persons with minimum of 2 persons and maximum of 23 persons. Majority (83.22%) of the farmers had formal education. Also 71.48% of the farmers engaged in farming on full time basis. On average, the farmers had 15 years of farming experience and cultivated 2.02ha of land. The optimal farm plan generated by the linear programming output for maximizing Total Gross Margin (TGM) recommended Yam/Maize/Groundnut on 1.58ha and Yam/Sorghum/ Cowpea on 3.42ha. The result also revealed that gross margin could be increased from ₦402, 496.93 in the existing plan to ₦635, 057.72 in the optimized plan. It was concluded that production inputs were not optimally utilized. The optimal farm plan recommends that yam-based farmers should produce crop mixtures Yam/Maize/Groundnut and Yam/Sorghum/Cowpea based on their hectarage allocations to maximize Total Gross Margin of ₦1, 723,046.49.

**Keywords:** Linear programming, yam-based, optimal plan, crop mixture, gross margin.

## INTRODUCTION

Agriculture, a major resource based activity in terms of capital and labour utilization, has the potential of increasing Nigeria's food self-sufficiency (FAO, 2020). However, domestic food crop production has not kept pace with population growth, resulting in rising food import and declining levels of national self-sufficiency (FAO, 2021). Actual yield of major food crops are lower than their potential yield (FAO, 2022). Yam is one of the principal food crops in Nigeria, both in terms of land under cultivation and in volume and value of production. It is one of the carbohydrate foods that is nutritionally superior to most roots and tubers in terms of digestible proteins and minerals (calcium, magnesium and potassium) *(*Ebewore *et al.,* 2020*).*

Yam is an important food crop especially in the Yam zones of West Africa, comprising, Nigeria, Cameroon, Benin, Togo, Ghana and Cote d'Ivoire. Nigeria is the main producer of yam in the world with 70% of the world output, followed by Ghana, Cote d'ivoire, Benin and Togo (IITA, 2021). It has a world production value of USD $50.1M (ITS, 2021).

Yam based intercropping system is currently receiving global attention because of its prime importance in world agriculture. The crops in yam-based crop mixture are arable crops which are food crops planted and harvested at maturity within one production cycle or season. Yam based cropping system is a system in which yam production is the predominant rural activity among several other crops, livestock or off-farm production activities (FAO, 2020). The practice of intercropping is popular because of its advantages over sole cropping which include yield stability, security against crop failure and higher combined returns per unit area of land (Maikasuwa and Ala, 2020).

Linear Programming (LP) models are useful in decision making where numerous resources are available and efficient allocation becomes difficult. Developing optimum farm plan for smallholder farmers could lead to the resolution of the food crises in Nigeria (Adewumi *et al.,* 2020). The objective of a typical farm or farmer whether it be maximization of net profit or cost minimization of production is achieved through optimal plan derived from the simplex algorithm of the final plan (Igwe *et al.,* 2019). Some studies that adopted Linear Programming Model to resource allocation or optimum enterprise combination are hereby reviewed. Giroh (2020) in his study on optimal resource allocation in yam-based cropping systems in Yorro Local Government Area of Taraba State revealed that the Linear Programming model recommended Yam/Cowpea/Sorghum and Yam/Maize/Groundnut/Cowpea out of the five enterprises. For Yam/Cowpea/Sorghum, the existing plan allocated 2.08ha, while the optimal plan obtained from the programming recommended 4.37ha. For Yam/Maize/Groundnut/Cowpea, the existing plan allocated 2.08ha, while the optimal plan recommended 1.11ha. The optimal farm plan recommends that yam-based farmers should allocate resources in such a way that the two crop enterprises are produced according to that hectarage allocation to maximize Total Gross Margin of ₦2, 031,084.081ha.

In the same vein, Umaru (2021) reported that out of the fourteen enterprises included in the model, only four activities entered the programme. These enterprises were: Sole Tomato, Tomato/Pepper, Tomato/Rice and Tomato/Pepper/Rice and the maximized gross margin per hectare was ₦199, 958.08. Despite wider application of Linear Programming in many studies,

its application in yam-based cropping system is scanty. The broad objective of the study was to analyze the optimum production plan in yam-based cropping systems in Ganye Local Government Area of Adamawa State, Nigeria. The specific objectives were to, describe the socio-economic characteristics of yam farmers; examine resource allocation pattern and estimate the cost and returns of yam-based cropping systems.

## METHODOLOGY

### Study Area:

The study was conducted in Ganye LGA of Adamawa State, Nigeria. The Local Government Area lies between latitude $8^{o}45'$ and $8^{o}$ 26'N and longitude $12^{o}$ 09' and $12^{o}$ 03'E of the Greenwich meridian. It covers an area of about 14,561.120km$^2$. The area shares international boundary with Cameroun Republic to its south east border, also Toungo and Jada LGAs in the southern part and Taraba State to the west. The climate of the area is the tropical south-humid type with marked dry and rainy seasons. The area is well noted for its agricultural potentiality which earned it the name, food basket of Adamawa State, due to the varieties of food and cash crops cultivated and marketed in the area. Yam is one of the major cash crops that are produced. The major economic activities in the area is agriculture, and the food crops grown in the area are Maize, Sorghum, Cowpea, Cassava and Potatoes, while cash crops such as Groundnuts, Rice, Yam and Sugarcane are produced in large quantities. Major livestock reared in the zone are cattle, sheep and goats (NARLS, 2020). Data for the study were collected with the use of questionnaire and covered 2022 cropping season.

### Sampling Procedure:

Multi-stage sampling procedure was used in selecting the respondents. In the first stage, four out of the ten wards in Ganye LGA were purposively selected because of the predominance of yam cultivation. In the second stage, three villages in each of the selected wards were purposively sampled from the lists of yam producing villages, making a total of twelve villages. The sampling frame for this study consisted of 2,916 Yam-Based Farmers. Finally a total of three hundred and thirty (330) farmers were selected using simple random sampling technique through the proportional allocation sampling technique (Cochran, 1977) out of which 298 questionnaire were retrieved and used for the study.

### Analytical technique

Descriptive and inferential statistics were used to analyse the data collected. The descriptive statistics was employed in describing the socio-economic characteristics of the respondents. While Linear Programming model was used to determine the resource allocation pattern in the study area. Linear Programming was used in the optimization of resources and achieving efficiency in yam-based production planning. It is based on the assumption that maximization of the gross margin is the underlining principles guiding the farmers in their productions.

The gross margin and net profit analysis were used to estimate costs and returns associated with yam-based cropping systems. The Linear Programming model used is expressed as;

Max Z = $\sum aiXi$ .....(3)

Subject to

$\sum bijXi \leq Gi$ ……..… (4)

Where;

Z = Total Gross Margin maximized which is the objective function

$a_i$ = Gross Margin of the $i^{th}$ enterprise/hectare

$b_{ij}$ = Input-output coefficients or the quantity of resources i required to produce a unit of an activity j

$G_i$ = Available resources for the $i^{th}$ activity

$X_i$ = Maximized decision variables which are the different activities or enterprises.

Also the Gross Margin model is specified as follows:

GM = GI – TVC..... (5)

Where;

GM = Gross Margin from yam-based production (₦/ha)

GI = Gross Farm Income (₦/ha)

TVC = Total Variable Cost (₦/ha)

## RESULTS AND DISCUSSIONS

### Socio-Economic Characteristics of the Respondents

The Socio-economic characteristics of the respondents is presented in Table 1. The results revealed that majority (72.15%) of the respondents were male, married with mean age of 48 years. This however indicates that the farmers are in their productive years capable of carrying out farming activities. The result is in line with the findings of Ani *et al*. (2021) who reported that age has a positive relationship to the productivity of yam farmers. Similarly, the table also revealed that majority of the respondents 83.22% had one form of formal education or the other, indicating that most of the farmers are literate and could be receptive to agricultural innovation. This agreed with the assertion of Umaru (2021) that the level of farmers' education has positive effects on their productivity and efficiency. Yam based cropping system is dominated by small scale farmers as evidence by a mean farm size of 2.02 hectares. This agreed with the assertion of Ibitoye and Onimise (2021) that majority of yam farmers in Nigeria are small-scale farmers operating at subsistence level. Respondents have large household sizes with mean household size of 10 people. This implies that farmers have a ready source of family labour and there would be less dependent on hired labour. This also conformed to the work of Taphee (2020) who reported that household size is an important source of family labour, especially in traditional agriculture where farming is highly labour intensive.

Furthermore, the yam-based farmers were experienced in farming with mean farming experience of 15 years. Farming experience influence the managerial capability of the farmer. This is in line with the findings of Taphee (2020), who stated that older farmers were observed to have higher productivity than younger farmers. Majority of the respondents (51.68%) had no contact with the Extension agent. This however, might negatively affect the efficiency of the farmers.

**Table 1: Socio-Economic Characteristics of the Respondents**

| Variable | Frequency | Percentage (%) | Mean |
|---|---|---|---|
| **Age** | | | |
| 20-29 | 18 | 6.04 | |
| 30-39 | 47 | 15.77 | |
| 40-49 | 114 | 38.26 | 48 |
| 50-59 | 82 | 27.51 | |
| 60 and above | 37 | 12.42 | |
| **Total** | **298** | **100** | |
| **Gender** | | | |
| Male | 215 | 72.15 | |
| Female | 83 | 27.85 | |
| **Total** | **298** | **100** | |
| **Marital Status** | | | |
| Married | 245 | 82.21 | |
| Single | 35 | 11.74 | |
| Divorced | 02 | 0.67 | |
| Widowed | 16 | 5.38 | |
| **Total** | **298** | **100** | |
| **Educational Level** | | | |
| No Formal Education | 50 | 16.78 | |
| Primary Education | 80 | 26.85 | |
| Secondary Education | 118 | 39.59 | |
| Tertiary Education | 50 | 16.78 | |
| **Total** | **298** | **100** | |
| **Farm Size (ha)** | | | |
| ≤ 1 -2 | 234 | 78.52 | |
| 3 -4 | 52 | 17.45 | 2.02 |
| > 4 | 12 | 4.03 | |
| **Total** | **298** | **100** | |
| **Household Size** | | | |
| 1-5 | 45 | 15.10 | |
| 6-10 | 148 | 49.66 | 10 |
| 11-15 | 70 | 23.49 | |
| 16-20 | 25 | 8.39 | |
| >20 | 10 | 3.36 | |
| **Total** | **298** | **100** | |
| **Farming Experience (Years)** | | | |
| 1-5 | 27 | 9.06 | |
| 6-10 | 65 | 21.81 | |
| 11-15 | 62 | 20.81 | 15 |
| 16-20 | 104 | 34.90 | |
| >20 | 40 | 13.42 | |
| **Total** | **298** | **100** | |
| **Extension Visit** | | | |
| Visited | 144 | 48.32 | |
| Not-Visited | 154 | 51.68 | |
| **Total** | **298** | **100** | |

Source: Field Survey, 2022

**Resource Allocation Pattern of Respondents**

The result in Table 2, revealed that out of the six activities or enterprises included in the model, two activities entered the programme. The recommended enterprises were,

Yam/Maize/Groundnut and Yam/Sorghum/Cowpea. For Yam/Maize/Groundnut enterprise, the existing plan allocated 0.13ha, while the optimal plan obtained from the programming recommended 1.58ha. Similarly, for Yam/Sorghum/Cowpea enterprise, the existing plan allocated 0.12ha, while the optimal farm plan recommended 3.42ha. The optimal farm plan recommended that farmers should allocate resources in such a way that the two crop enterprises are produced according to this hectarage allocation to maximize total gross margin of ₦1, 723,046.49.

The excluded activities are the non-basic activities, which include, Sole Yam, Yam/Cowpea, Yam/Maize and Yam/Maize/Cowpea. The marginal opportunity cost (MOC) are income penalties indicating the amount by which farm income will decrease if any of the non-basic activities was forced into the programme. If one hectare of the non-basic activities is forced into the plan, the optimal cost of production will increase by a margin equal to the MOC, indicating either gain or loss. Yam/Maize/Cowpea enterprise had the highest penalty, if forced into the plan with MOC of ₦177, 540.71.

**Table 2: Result of Linear Programming for Yam-Based Farmers**

| Enterprise | Solution (ha) | MOC |
|---|---|---|
| Sole Yam | 0.00 | 136,298.19 |
| Yam/Cowpea | 0.00 | 166,399.19 |
| Yam/Maize | 0.00 | 18,143.36 |
| Yam/Maize/Cowpea | 0.00 | 177,540.71 |
| Yam/Maize/Groundnut | 1.58 | 0.00 |
| Yam/Sorghum/Cowpea | 3.42 | 0.00 |
| Maximized Objective | | 1,723,046.49 |

Source: Field Survey, 2022

**Gross Margin (₦/ha) in the Existing and Optimized Farm Plan**

The existing gross margin of the farmers was compared with the optimized gross margin obtained from the programme. The result in Table 3, revealed that the gross margin per hectare obtained from the existing farm in Yam/Maize/Groundnut enterprise was ₦402,496.93, while the maximized gross margin per hectare obtained from the programme was ₦635,057.72, indicating 57.78% increase. Similarly, the gross margin per hectare obtained from the existing farm in Yam/Sorghum/Cowpea enterprise was ₦317, 783.94, while the maximized gross margin per hectare obtained from the programme was ₦1, 087,968.77, indicating an increase of 242.36%. The optimized gross margin per hectare from the two enterprises exceeded their actual values. This implied that in the short run, production of Yam/Sorghum/Cowpea enterprises brings in more profit per hectare than Yam/Maize/Groundnut enterprises. The farmers could shift their cultivation to Yam/Sorghum/Cowpea enterprise as its cultivation brought in more profit than the other enterprise.

**Table 3: Gross Margin (₦/ha) in the Existing and Optimized Farm Plan**

| Enterprise | Existing Plan | Optimized Plan | Increase/Decrease | Percentage |
|---|---|---|---|---|
| Yam/Maize/Groundnut | 402,496.93 | 635,057.72 | 232,560.79 | 57.78 |
| Yam/Sorghum/Cowpea | 317,783.94 | 1,087,968.77 | 770,184.83 | 242.36 |

Source: Field Survey, 2022

**Resource Allocation and Use Pattern in Yam-Based Cropping System**

The result of resource allocation and use pattern in Table 4, revealed that two out of the six resource constraints (inputs) were fully utilized in arriving at the optimal solution. These were seed and family labour. The dual (shadows) prices of limiting resources represent their net Marginal Value Product (MVP). The more limiting a resource is the higher is its MVP. It is an indication of the amount of increase in the objective function or total gross margin that can be obtained by using an additional unit of the scarce resources. Total Gross Margin (TGM) will increase by ₦1, 553.03 and ₦11, 673.90 for one kilogramme increase in the quantity of seed and one manday increase in family labour. The non-fully utilized resources are land, fertilizers, agro-chemicals and hired labour. This however indicates that these resources are inefficiently utilized by yam based farmers in Ganye Local Government Area of Adamawa State.

**Table 4: Resource Allocation and use pattern in yam-based cropping system**

| Resource Constraint | Use Status | Slack | Dual (Shadows Price) |
|---|---|---|---|
| Land (ha) | Not-Fully Utilized | 592.09 | 0.00 |
| Seed (kg) | Fully Utilized | 0.00 | 1,553.03 |
| Fertilizer (kg) | Not-Fully Utilized | 73.45 | 0.00 |
| Agro-Chemicals (lt) | Not-Fully Utilized | 12.00 | 0.00 |
| Hired Labour (Manday) | Not-Fully Utilized | 30.49 | 0.00 |
| Family Labour (Manday) | Fully Utilized | 0.00 | 11,673.90 |

Source: Field Survey, 2022

**Costs and Return Analysis of Yam-Based Cropping Systems**

Analysis in Table 5 showed costs and returns associated with yam-based cropping systems from where the gross margin per hectare (GM/ha) were obtained for the various crop enterprises. Yam/Cowpea had the highest (GM/ha) of ₦409, 735.39, followed by Yam/Maize with (GM/ha) of ₦403, 533.66. Yam/Maize/Cowpea enterprise had the least (GM/ha) of ₦254, 007.44. The GM/ha in all the six enterprises were positive and the operating ratio was less than one (<1), indicating higher returns per naira invested.

## Table 5: Costs and Returns for Yam-Based Cropping Systems

| Cropping Enterprises | Total Variable Cost (TVC) | Total Fixed Cost (TFC) | Total Cost (TC) | Gross Income (GI) | Gross Margin (GM) | Net Farm Income (NFI) | Operating Ratio (OR) |
|---|---|---|---|---|---|---|---|
| Sole Yam | 236,542.65 | 23,206.20 | 259,748.85 | 571,882.35 | 335,339.70 | 312,133.50 | 0.41 |
| Yam/Cowpea | 264,522.19 | 21,655.03 | 286,177.22 | 674,257.58 | 409,735.39 | 388,080.36 | 0.39 |
| Yam/Maize | 247,466.34 | 17,810.54 | 265,276.88 | 651,000.00 | 403,533.66 | 385,723.12 | 0.38 |
| Yam/Maize/Cowpea | 293,257.27 | 23,147.96 | 316,405.23 | 547,264.71 | 254,007.44 | 230,859.48 | 0.54 |
| Yam/Maize/Groundnut | 240,464.61 | 21,174.18 | 261,638.79 | 642,961.54 | 402,496.93 | 381,322.75 | 0.37 |
| Yam/Sorghum/Cowpea | 289,000.91 | 22,602.73 | 311,603.64 | 606,785.85 | 317,784.85 | 295,181.21 | 0.48 |

Source: Field Survey, 2022

## CONCLUSION

Results revealed that 72.15% of the respondents were male in their productive years, with mean age of 48years, married with mean household size of ten (10) persons. Similarly, 83.22% of the farmers had one form of formal education or the other, with average farming experience of 15 years, and were predominantly small holder farmers cultivating an average of two hectares. The optimal farm plan generated by the Linear Programming output to maximized Total Gross Margin (TGM) recommended two enterprises which were; Yam/Maize/Groundnut (1.58ha) and Yam/Sorghum/Cowpea (3.42ha). Furthermore, the optimal farm plan recommended that Yam-Based farmers should allocate resources in such a way that the two crop enterprises are produced according to hectarage allocations to maximized total gross margin of ₦1, 723,046.49. The study recommends that government and financial institution should provide financial support through small credit scheme to help farmers to expand their production. Also, research institutions should develop low cost technologies that will reduce the level of labour inputs for various farm operations.

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