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OPTIMAL RESOURCE ALLOCATION IN YAM-BASED CROPPING SYSTEMS IN YORRO LOCAL GOVERNMENT AREA OF TARABA STATE NIGERIA

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Abstract

Rising rural population densities in Nigeria are profoundly affecting farming systems with localized land pressures being experienced by many rural farmers. This study was conducted to examine optimal resource allocation in Yam-based cropping systems among farmers in Yorro Local Government Area of Taraba State, Nigeria. Primary data used for the study were collected from 142 farmers using structured interview schedule. Data were analysed using descriptive statistics and linear programming model. Results revealed that respondents were small-scale farmers characterized by large family size and were well experienced in farming with a mean farming experience of 23 years. Respondents adopted mixed cropping as a result of scarcity of land and to avoid crop failure. Profitability analysis revealed that yam based cropping systems were profitable where Yam/Cowpea/Sorghum had the highest gross margin of ₦372,500.00 followed by Yam/Maize/Groundnut/Cowpea (₦362,990.00) respectively. 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 2.36 ha 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 this hectarage allocation to maximize Total Gross Margin of ₦2,031,084.08/ha.

Key words**:** *optimal plan, profitability, linear programming, yam- based, Yorro, Nigeria*

INTRODUCTION

Root and tuber crops are important in food security and income for 2.2 billion people in developing countries and crops comprise crop covering several genera. They are staple food crops, being the source of daily carbohydrate intake for the large populace of the world. Root and tuber crops refer to any growing plant storing edible materials in subterranean root, corm or tuber and yam is a member of this important class of food [1].Yam is an important food crop especially in the yam zones of West Africa, comprising, Nigeria, Cameroon, Benin, Togo, Ghana and Cote d'Ivoire. This zone produces more than 90% of the total world production which is estimated at about 20 – 25 million tonnes per year [13]. The biggest yam harvest, globally was in 2008 when world produced 54 million metric tonnes of yam, with Nigeria producing an annual average of 35.017 metric tonnes [4]. 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 [8]. The crop yield depends on how and where the setts are planted, sizes of mounds, interplant spacing, provision of stakes for the resultant plants, yam species, and tuber sizes desired at harvest. Small-scale farmers in West and Central Africa often intercrop yams with cereals and vegetables. Yam based crop mixture (YBCM) is a common crop mixture system practised in farming communities of Nigeria. Yam, the based crop of YBCM, is an important food crop in Nigeria [4]. The crops in YBCM are arable crops which are food crops planted and harvested at maturity within one production cycle or season. However, crop mixture is a viable strategy for spreading the risks of crop failure and labour demands for critical operations of sowing, weeding and harvesting [3]. 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. The practice of intercropping is popular because of its advantages over sole cropping which include yield stability, security and higher profitability due to higher combined returns per unit area of land. The practice of inter cropping controls erosion and weeds and allows a more even distribution of farm labour than sole cropping and serves as enterprise combination which is a security against crop failure. The cropping combination is also agriculturally compatible. In 2010, the world harvested 48.7 million tonnes of yam, 95 percent of which was produced in Africa. Rising rural population densities in Nigeria are profoundly affecting farming systems and indeed the overall trajectory of economic systems in ways that are underappreciated in current discourse. Population pressure is linked in one way or another to the shrinking size of most smallholder farms over time; more continuous cultivation of fields, contributing to land degradation and unsustainable forms of agricultural intensification; the rise of land rental and purchase markets and changes in land allocation institutions, all of which are rapidly altering farm structure; and the challenges that Nigeria is currently experiencing in achieving broad-based and inclusive forms of farm income growth. The extent, distribution and exploitation of land are factors that have long been identified as fundamental influences on agricultural development paths and poverty reduction [9]. Nigeria is typically characterized as land abundant, with the implication that land endowments pose no serious constraint for agricultural development, but our starting point for studying the impacts of population density is the recognition of Nigeria's spatially heterogeneous distributions of rural populations, giving rise to acute localized land pressures being experienced by many rural farmers.

Linear Programming (LP)is a mathematical model which seeks to maximize profit or minimize cost as an objective function and with objective function constraints which are expressed as linear mathematical statement and decision variables having continuous or discrete values. The word "Programming" is concerned with the optimal allocation of limited resources to various competing demands. It is a mathematical method of optimizing problems towards achieving the best outcome as solutions. It was developed by Charnes and Coopers in 1961 and has been widely used in Agriculture and Management Sciences.

Ibrahim [5] examined optimal maize-based enterprise in Soba Local Government Area of Kaduna State, Nigeria using linear Progamming analysis. The result indicated that a gross margin of ₦56,920.30 was obtained in the planned farm as against ₦26,282.00 per hectare of maize/cowpea in unplanned farm. Ibrahim and Omotesho [6] examined an optimal enterprise combination for vegetable production under Fadama in North central Nigeria. The result of optimal plan obtained achieved 88 percent of the goals considered. Igwe *et al.* [7] applied a linear programming model (LP) model and determined the optimum enterprise combination in Abia State in Nigeria. The result showed that out of the twelve production activities made up of ten cropping activities and two fish enterprise, only two were recommended by the model for farmers to achieve a gross income of ₦342,763.30. Maurice [10] examined optimal production plan and Resource Allocation in food crop production in Adamawa State, Nigeria using linear programming. The result showed that out of the eleven basic activities included in the LP model, only three activities entered the programme namely sole groundnut (0.28ha), maize/sorghum (0.26ha) and maize/sorghum/cowpea (1.88ha). He further reported that food crop farmers should allocate their resources in such a way that three crop enterprises could be produced according to the hectares allocated.

Despite wider application of linear programming in many studies, its application in yam based cropping system in particular is scanty. The broad objective of the study is to analyze enterprise combination in a Yam-based cropping systems in Yorro Local Government Area of Taraba State, Nigeria. The specific objectives were to describe the socio-economic characteristics of yam

farmers; identify the various crops in the yam-based cropping systems; examine resource allocation pattern and estimate cost and returns among respondents in the study area.

MATERIALS AND METHODS

The Study Area. The study was conducted in Yorro Local Government Area of Taraba State, Nigeria. The Local Government Area lies between latitude 8.17˚N and 9.7˚N and longitude 11˚ 66˚E and 11˚ 46˚E of Greenwich meridian. The Local Government Area lies to the North-Eastern part of Taraba State, bordered by Zing Local Government Area to east, Lau Local Government Area to the North, Jalingo and Ardo-Kola Local Government Areas to the West and Bali Local Government Area to the South. The Local Government Area has a land area of 21,200 km^2 with a projected population of 60,894 people. The Local Government Area has tropical climate marked by dry and rainy seasons. The rainy season starts in April and ends in October. The wettest months are August and September. The mean annual rainfall ranges from 800 mm to 1,000 mm and the mean daily temperature ranges between 18.8˚ C and 34.4˚C. The dominant soil types in the Local Government Area are ferruginous sandy loamy soil. The main vegetation cover of the Local Government Area is made up of scattered trees, while the topography is essentially marked with mountainous land traversed by small streams between them [14].

Source of Data. Primary data were used for the study and were collected using structured interview schedule administered to the respondents to collect the desired information from the 2017/2018 production season.

Sampling Size/Sampling Technique: The population for this study comprised of yam farmers in Yorro Local Government Area of Taraba State. A sample size of two hundred and fifty (250) yam farmers was considered from the eight (8) farming villages, where one hundred and fifty (150) farmers were selected using proportionate and random sampling technique. Out of this number, 142 interview schedules were retrieved and used for the study.

Method of Data Analysis

Descriptive statistics and inferential statistics were used to analyse the data collected. The descriptive statistics was used to achieve objectives i and ii while linear programming was used to achieve objective iii (resource allocation pattern) among respondents. The gross margin analysis was used to estimate costs and returns associated with yam based cropping systems among respondents(objective iv).

The model is specified as follows:

$$GM = TR - TVC \quad \text{..... (1)}$$

where: GM = Gross Margin TR = Total Revenue and TVC = Total variable Cost .

The linear programming model used is expressed as:

$$MaxGM=128{,}132.50X_1+372{,}500X_2+54976X_3+201990X_4+362990X_5+106{,}313X_6 \leq 330{,}450.70 \quad \text{.....(2)}$$

Subject to:

$$\text{Land} = 690.80X_1+ 154.12X_2+ 565.98X_3+ 295.16X_4+ 227.94X_5+386.2X_6 \leq 2320.2\text{.....(3)}$$

$$\text{Fertilizer} = 487.50X_1+167.63X_2+150.37X_3+314.25X_4+ 226.62\ X_5+268.8X_6 \leq 1615.17\text{.....(4)}$$

$$\text{Herbicide} = 225X_1+52.50X_2+99.25X_3+61.90X_4+99.75X_5+ 107.2X_6 \leq 646.35\text{.....(5)}$$

$$\text{Seeds} = 33X_1+46.50X_2+20.25\ X_3+65.25X_4+61.87X_5 +45X_6 \leq 271.87\text{.....(6)}$$

$$\text{Family labour} = 115.5X_1+74.25X_2+58.25X_3+189.38X_4+ 46.50X_5 +96X_6 \leq 580.28\text{.....(7)}$$

$$\text{Hired labour} = 42X_1+210.65X_2+273X_3+232.31X_4+130.80\ X_5+177.40X_6 \leq 1066.16\text{.....(8)}$$

The parameters were estimated using Tora Optimization system (TOS), version 2.00, 2006.

RESULTS AND DISCUSSIONS

Respondents' Socio-economic Characteristics

Summary statistics of respondent's socio-economic variables as contained in Table 1 revealed that the minimum age of respondents was 18 years with a maximum of 78 while the mean age was 46 years with variations in the ages of respondents as revealed by standard deviation. Farmers were relatively older and may portend danger to food production in the study area. The finding is in line with the works of Migap and Audu [11] and Donye *et al.* [2] that yam production was carried out by the elderly farmers. Government should intensify efforts in the provision of infrastructure in rural areas to attract young people and encourage food production. Furthermore, yam- based cropping systems was small scale enterprise as evidenced by a mean farm size of 2.7 hectares. Respondents have large family sizes with a mean family size of 9 people which could be used a source of labour for production activities. Also, respondents were experienced with minimum, maximum and mean experience of 12, 47 and 23 years respectively. With years of experience, it is expected that respondents will be efficient in managerial decision and the choice of enterprise and adoption of improved farm practices. Studies have shown that experienced farmers are better off than inexperienced ones.

Table 1. Summary statistics of selected socio-economic variables of Respondents

Variable	Minimum	Maximum	Mean	Standard deviation
Age	18	78	46	13.928
Farm experience	12	47	23	13.771
Farm size	0.5	6	2.7	1.301
Family size	1	22	9	4.801

Source: Field survey 2019.

Respondents' Cropping pattern and Reasons for Intercropping

Yam- based cropping systems have been found to be agriculturally compatible and economically feasible in many farming communities in Nigeria. Analysis in Table 2 showed the various cropping combinations. The purpose of mixed cropping is to generate beneficial biological interaction between the crops, which can also increase yield and stability, more efficient use of the available resources and reduces weeds pressure. Reddy *et al.* [12] stated that mixing species in cropping system may lead to a range of benefits that are expressed on various space and time scales, from short-term increase, in crop yield and quality, to longer term agro-ecosystem sustainability, up to societal and ecological benefits.

From this result, where maize or sorghum is used, the farmers may use fewer stakes while legumes in the cropping combination improves soil fertility through nitrogen fixation ability inherent in the legumes.

Table 2. Cropping Combination and Reasons for Mixed Cropping (N= 142)

Cropping combination	Total hectarage	Frequency	Percentage
Yam / Maize /Groundnut	53.15	80	63.49
Yam/Cowpea / Sorghum	73.08	110	87.30
Yam / Millet /Groundnut	69.76	105	83.33
Yam / Maize /Cowpea	79.72	120	95.24
Yam / Maize / Groundnut / Cowpea	64.45	97	76.98
Sole Yam	43.24	16	

Source: Field Survey 2016.

Reasons for yam- based cropping system may not be farfetched; diversification and scarcity of land due to rising population as well as conversion of arable land for construction.

Table 3 showed that 50.79% of respondents mixed up their crops because of land scarcity, 42.06% of the respondents mixed up their crops because of fear of failure while 7.14% of multiple yield advantages. The study area falls in quite a mountainous area which is a hindrance to the acquisition of more agricultural land. This cropping system is used to maximize production and diversify crops from a parcel of land either in time or space than would be obtained by one crop. Studies have established that many intercropping systems may give higher and more stable yields than their component crops grown as sole crop, this may give rise to the efficient use of the available resources.

Table 3. Reasons for Mixed Cropping (N= 126)

Reason For cropping combination	Frequency	Percentage
Crop Failure	53	42.06
Scarcity of land	64	50.79
Multiple crop yield advantage	9	7.14

Source: Field Survey 2019.

Resource Allocation Pattern of Respondents

Linear programming was used in the optimization of resources and achieving efficiency in yam-based production planning. The optimal farm generated for maximizing total gross margin (TGM) was predicated on the premise /assumption that profit maximization is the basis guiding the farmers in their resource use and allocation decisions. Out of the six activities included in the model, two entered the model (Table 4).

The recommended enterprises were Yam/Cowpea/Sorghum and Yam/ Maize/Groundnut/Cowpea. For Yam/Cowpea/Sorghum, the existing plan allocated 2.36 ha while the optimal plan obtained from the programming recommended 4.37 ha.

Table 4. Linear Programming Result

Enterprise	Solution	MOC
1. Yam / Maize /Groundnut	0.00	40840.68
2. Yam / Cowpea / Sorghum	4.37	0.00
3. Yam / Millet /Groundnut	0.00	268082.90
4. Yam / Maize /Compea	0.00	264562.15
5.Yam / Maize /Groundnut /Cowpea	1.11	0.00
6. Sole Yam	0.00	230696.85
Max. objective		2,031084.08

Source: Field Survey 2019.

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 farmers should allocate resources in such a way that the two crop enterprises are produced according to this hectarage allocation to maximize TGM of ₦2,031084.08/ha.

The non basic activities (Table 5) includes Yam/maize/groundnut,Yam/millet/Groundnut and Yam/Maize/Cowpea. The marginal opportunity cost (MOC) shows by how much the programme value will decrease if any of the non-basic activities is forced into the programme. For instance, 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 MOC, indicating either gain or loss. Enterprise 3 (Yam/Millet /Groundnut) has the highest penalty if forced into the plan with MOC of ₦268,082.90.

Table 5 is the resource utilization pattern and shows that only fertilizer and hired labour out of the resource constraints were fully utilized i n arriving at the optimal solution. Their dual p rices indicate amount by which the objective f unction will increase if these inputs are increa sed by one unit. TGM will increase by 1,074.7 5 and 913.08 for one kilogramme of fertilizer and one man day of hired labour. The non-full y utilized resources are land, herbicides, seeds and family labour indicating that these resour ces are inefficiently utilized by yam farmers i

n Yorro. This result is consistent with that of Maurice [10] who found out that land, agroch emicals; seeds were not fully utilized by farm ers in Adamawa State.

Table 5. Resources allocation and use pattern

Resource Constraint	User Status	Slack	Dual price
Land	Not fully utilized	18.88	0.00
Fertilizer	Fully utilized	0.00	1074.75
Herbicides	Not fully utilized	424.84	0.00
Seeds	Not fully utilized	21.56	0.00
Family labour	Not fully utilized	33.53	0.00
Hired labour	Fully utilized	0.00	913.08

Source: Field Survey 2019.

Costs and Return Analysis of Yam- based Cropping Systems

Analysis in Tables 6A and 6B showed that land preparation, planting and weeding in a yam based cropping systems were the dominant cost of production in the study area. All the enterprise combinations were profitable. Yam/cowpea/sorghum had the highest gross margin of ₦372,500.00 followed by Yam/maize/Groundnut/Cowpea (₦362,990.00), Yam/Maize/Cowpea (₦201,990.00) while the least was Yam/Millet/Groundnut with a gross margin ₦54,976.00 respectively.

Table 6A. Profitability analysis /hectare of enterprise combination of Respondents

Enterprise	Cost Item	Value	Percentage of Total Cost
Yam /Maize /Groundnut	Land preparation	₦ 27737.22	28.44
	Planting	₦ 16070.46	16.47
	Weeding	₦ 16197.59	16.61
	Agrochemicals	₦ 8081.49	8.28
	Application of agrochemicals	₦ 9413.14	9.65
	Harvesting operation	₦ 4389.23	4.5
	Transportation	₦ 10437.69	10.7
	Other farm operation	₦ 5218.68	5.35
	TVC	₦ 97545.5	
	TR	₦ 225,678	
	GM Yam	₦53,338.54	
	GM Maize	₦29,307.35	
	GM Groundnut	₦45,436.61	
	GM(TR-TVC)	₦128,132.50	
Yam / Cowpea / Sorghum	Land preparation	₦ 35358.85	28.21
	Planting	₦ 20936.51	16.71
	Weeding	₦ 19529.76	15.58
	Agrochemicals	₦ 11670.22	9.31
	Application of agrochemicals	₦ 12096.42	9.65
	Harvesting operation	₦ 7210.523	5.75
	Transportation	₦ 11842.90	8.65
	Other farm operation	₦ 5706.31	6.14
	TVC	₦ 125351.50	
	TR	₦497,851.50	
	GM Yam	₦186,129.19	
	GM Cowpea	₦81,130.51	
	GM Sorghum	₦45,436.61	
	GM(TR-TVC)	₦372,500.00	
Yam / Millet /Groundnut	Land preparation	₦ 13868.07	35.06
	Planting	₦ 3938.75	9.95
	Weeding	₦ 8177.45	20.67
	Agrochemicals	₦ 1691.42	4.28
	Application of agrochemicals	₦ 3826.23	9.67
	Harvesting operation	₦ 1507.08	3.81
	Transportation	₦ 4429.73	11.20
	Other farm operation	₦ 2121.27	5.36
	TVC	₦ 39560	
	TR	₦ 95,536.00	
	GM Yam	₦28,325.33	
	GM Millet	₦6450.30	
	GM Groundnut	₦20,2 00.37	
	GM(TR-TVC)	₦ 54,976.00	

Source: Field survey 2019.

Table 6B. Profitability analysis /hectare of enterprise combination of Respondents

Enterprise	Cost item	Value	Percentage of Total Cost
Yam / Maize /Cowpea	Land preparation	₦ 31874.16	29.24
	Planting	₦ 18073.25	16.58
	Weeding	₦ 14980.64	13.75
	Agrochemicals	₦ 12146.97	11.15
	Application of agrochemicals	₦ 10517.54	9.65
	Harvesting operation	₦ 6138.85	5.63
	Transportation	₦ 7427.64	6.81
	Other farm operation	₦ 7830.97	7.19
	TVC	₦ 108990	
	TR	₦ 309,990.00	
	GM Yam	₦84,309.25	
	GM Maize	₦60,315.10	
	GM Cowpea	₦57,365.65	
	GM(TR-TVC)	₦ 201,990.00	
Yam / Maize / Groundnut / Cowpea	Land preparation	₦ 21017.17	27.41
	Planting	₦ 14418.48	18.8
	Weeding	₦ 12946.28	16.88
	Agrochemicals	₦ 6138.69	8.01
	Application of agrochemicals	₦ 8399.33	10.96
	Harvesting operation	₦ 3022.34	3.94
	Transportation	₦ 7632.50	9.95
	Other farm operation	₦ 3102.21	4.05
	TVC	₦ 76677	
	TR	₦ 439,667.00	
	GM Yam	₦136,121.25	
	GM Maize	₦45,373.75	
	GM Groundnut	₦110,747.50	
	GM Cowpea	₦70,450.19	
	GM(TR-TVC)	₦ 362,990.00	
Sole Yam	Land preparation	₦ 28,653.02	30.62
	Planting	₦ 13378.25	14.29
	Weeding	₦ 15581.32	16.65
	Agrochemicals	₦ 7713.23	8.24
	Application of agrochemicals	₦ 8031.44	8.58
	Harvesting operation	₦ 7130.15	7.62
	Transportation	₦ 9095.54	9.72
	Other farm operation	₦ 4007.07	4.28
	TVC	₦ 93590.00	
	TR	₦ 199,903.00	
	GM(TR-TVC)	₦ 106,313.00	

Source: Field survey 2019.

CONCLUSIONS

The study revealed that yam – based cropping systems was predominantly by relatively older farmers with large family sizes and is a small -scale business which was profitable. Yam/co wpea/sorghum and Yam/ Maize/Groundnut/C owpea out of the six enterprises were recomm ended. For Yam/Cowpea/Sorghum, the existin g plan allocated 2.36 ha while the optimal pla n obtained from the programming recommend ed4.37ha. ForYam/Maize/Groundnut/Cowpea , the existing plan allocated 2.08ha while the o ptimal plan recommended 1.11ha. The optima l farm plan recommends that yam farmers sho uld allocate resources in such a way that the t wo crop enterprises are produced according to maximize Total Gross Margin of ₦2,031,084. 08/ha. Government should intensify efforts in the provision of infrastructure in rural areas to attract young people and to encourage food pr oduction.

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