ANALYSIS OF LAND USE OPTIMIZATION OF MAIZE-BASED CROPPING SYSTEM IN BENUE STATE, NIGERIA

BY

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ABSTRACT

The study examined land use optimization of maize-based cropping system of farmers in Benue State, Nigeria. Specifically, determined the optimal farm plan of maize farmers and examined the sensitivity of the optimum farm plan to changes in inputs in the study area. Multistage sampling technique was used to select 100 respondents for the study. Data for the study were obtained from primary source with the aid of well-structured questionnaires and analyzed using descriptive and inferential statistics. The optimum farm plan showed that the best enterprise is the mixture of maize/cowpea and it is recommended in the area at 1.56 ha. Land as a constraint is limited and is a tight resource while inputs such as labour, seed and agro-chemical were slack. The opportunity cost of using additional unit of labour, seeds and other inputs were zero (0). It was concluded that proper farm plan is a vital tool for profit making, educating farmers on the need for proper crop combination is to help to address the issue of land shortage since land is a vital input for agricultural productivity. The shadow price for land indicated that land is a tight resource while labour, seeds and other inputs were slacked resources. It was recommended that crop farmers in the study area should be educated on land use optimization strategy and farmers should be encouraged to cultivate a mixture of short term duration crops with long term duration crops.

Keywords: Cropping System, Land Use, Optimal Farm Plan, Optimization, and Sensitivity

INTRODUCTION

Maize is one of the main staple crops in Nigeria and featured among the five food crops (cassava, maize, wheat, rice and sugar) whose production is to be promoted for attainment of food self-sufficiency as revealed by the Minister of Agriculture and Water Resources (Sayyadi, 2008). Apart from being a food crop, maize has equally become a commercial crop on which many agro-based industries depend on for raw materials (Oluwatayo *et al.* 2008. Maize contributes about 80 percent of poultry feeds and this has great implication for protein intake in Nigeria (Food and Agriculture Organization, FAO, 2008). Thus, maize can be considered very vital to the economic growth of the nation through its contribution to food security and poverty alleviation.

According to the International Institute for Tropical Agriculture, IITA (2009), Nigeria's low maize productivity was attributed to poor seed supply system, little or no use of improved seeds, herbicides and fertilizers, increased levels of biotic and abiotic constraints, low investment in research for development, inefficient marketing systems, the fact that prices of inputs have tripled in the last ten years and also global warming and its associated effects which have contributed to this by changing the rainfall pattern leading to erratic and unreliable rainfall, in some cases resulting in drought.

Optimization is the act of achieving or getting the best possible result under given or certain circumstance. In the design, construction, and maintenance of engineering systems, engineers must take many technological and managerial decisions at several stages. The ultimate goal of all decision is to minimize the effort required or to maximize the desired benefits. In everyday life, whether consciously or unconsciously, people always do the optimization to meet their needs. The optimization done by ordinary people is more based on intuition than optimization theory. Linear programming is a way to solve the problem of allocation of limited resources such as land, labor, raw materials, and the like in the best way possible to obtain optimal results (FAO 2008).

Cropping Systems refers to the type and sequence of crops grown and practices used for growing them. It encompasses all cropping sequences practiced over space and time based on the available technologies of crop production. Cropping systems have been traditionally structured to maximize crop yields. Now, there is a strong need to design cropping systems which take into consideration the emerging social, economic and ecological or environmental concerns. Conserving soil and water and maintaining long-term soil productivity depend largely on the management of cropping systems, which influence the magnitude of soil erosion and soil organic matter dynamics. While highly degraded lands may require the land conversion to non-agricultural systems (e.g., forest, perennial grass) for their restoration, prudently chosen and properly managed cropping systems can maintain or even improve soil productivity and restore moderately degraded lands by improving soil resilience. Crop diversification is an important option in sustainable agricultural systems. Management of cropping systems implies management of tillage, crop residue, nutrients, pests, and practices for soil conservation. For example, excessive use of chemicals (e.g., fertilizers) for growing crops, particularly in developed countries, has raised concerns over increasing risks of non-point source pollution (Blanco-Canqui and Lal, 2010).

Optimization of maize based cropping system for optimum production has not been ascertain especially in Benue State, hence this study seeks to identify the best cropping system for maize for optimum production in the study area.

The utilization of land involves a complexity of interacting variables such as population, the land tenure system, urbanization, migration, communal crisis, the level of technology, the stage of a region's development and even the various propensities in the taste of the community in question. It is evident therefore that, land use is not static but it changes in accordance with the changes in all the above variables. This is to say that there is heterogeneity in the land use of any given area due primarily to the influence of certain factors operating naturally or caused by man. A good knowledge of land use of any given geographical region has to do with the human activities on land, the facilities placed on the land, the effects of such human activities on the environment and the actual people making use of the land under consideration.

Although, various studies have been carried out on maize production in Nigeria such as Aye and Mungatana (2011) on sustainability of maize based cropping system. However, empirical research has shown that little or no work has been done on the optimization of maize based cropping system to enhance productivity and efficient land use. Therefore necessitating need for this present study to bridge the gap in research. The specific objectives of this study were to determine the optimum farm plan and also examine the sensitivity of the optimum farm plan to change in input.

METHODOLOGY

The study was carried out in Benue State, Nigeria. Benue State is situated between Latitudes $6^0$30'N and $8^0$15'N and Longitudes $7^0$30'E and $10^0$00'E with land area of about 34,059 km^2 and a population of 2,780,398 by 1991 Census and 4,253,541 by 2006 estimate. The study area has three agricultural zones; zone A, B and C. Benue State experiences two distinct seasons, the wet season and the dry season. The rainy season lasts from April to October with annual rainfall in the range of 1120 to 1500 mm. The dry season begins in November and ends in March. The climate is characterized by high temperature regime, ranging from 27-380C as mean annual. Relative humidity is between 60-80%.

It has a vegetation cover of the guinea savannah type. The main river systems include the River Benue and the River Katsina Ala which together with their tributaries, traverse the area. The drainage system of the Cross-River basin bordering the lower Benue basin to the south rises from the area, through the River Konshisha and its tributary rivulets and streams, flowing southwards into the main basin of the Cross River to the south. The region is well drained and presents good potential for water resources development The State is underlain by both basement and sedimentary rocks which vary in character across the State. Basement complex rocks comprising ancient igneous and metamorphic rocks, occur mainly in Kwande, Ushongo, Guma, Vandeikya and the eastern part of Oju LGAs.

The state is located in the North Central geo-political Zone of Nigeria, and bordered by Nassarawa State in the North, Taraba State in the East, Enugu, Ebonyi, and Cross Rivers States in the South and Kogi State in the west (Babatimehin *et al.*, 2015).

The population of this study consists of all maize crop farmers in Benue State, Nigeria. Multi–stage sampling was used in the collection of data from the respondents. Firstly, (2) two out of the three agricultural zones of the study area were selected. Secondly, 2 (two) Local Government Areas each were selected purposefully based on the level of maize crop farming practiced in the areas from the two (2) agricultural zones selected earlier. Thirdly, two (2) villages from each of the Local Government Area were visited for data collection. In summary a total of four (4) Local Government Areas, eight (8) villages, twelve respondents from four villages and thirteen respondents from another four villages based on their involvement in maize based cropping. (100 respondents) were considered in the sample collection process.

Data for the study were collected from primary sources. The data were generated through the use of a well-structured questionnaire designed to capture the objectives of this study. The questionnaire was administered to one hundred (100) randomly sampled respondents across the study area.

Data for this study was analyzed using linear programming. A linear programming model is used to determine optimum farm plan across the various maize based cropping systems in the study area. To achieve the second objective, the linear programming was repeated with changes in the resource mix or unit revenues of the activities known parametric linear programming or sensitivity analysis was utilized. According to Beneke and Winterboer (1973), parametric programming was used to estimate the effect of changes in the net price for each activity unit or the level or amount of each resource at the outset.
Parametric analysis was used to generate a series of optimal solutions associated with continuous variation in the planning parameters. The complexity in ascertaining the objectives of traditional farmers makes the definition of meaningful and operational objective function a difficult problem in the application of linear programming (Sanni, 2000). However, the two most commonly used goal programming methods to minimize deviations with respect to the expected objective are the Lexicographic Goal programming (L.G.P) and Weighted Goal Programing (W.G.P).

In this study, the Lexicographic Goal Programming method (L.G.P) was used. L.G.P assume that a decision maker attaches a priority (profit) to the set goals in preemptive fashion, that is, the fulfillment of any set goal situated in a higher priority (food security) X_0 is preferable to the fulfillment of any other set goals situated in a lower priority(profit) X_j.

In L.G.P, higher priorities goals are satisfied first, then the lower priority are considered, hence the hexiographic order (Romera and Rehman 1993). This method has been used for similar optimization studies by Etuk (1979), and Sanni (2000).

The empirical model is of the form

Maximize $Z_f=\sum_{j=1}^{n} P_jX_j-\sum_{i=1}^{n} WL_t-\sum_{i=1}^{n} Fq-\sum_{j=1}^{n} Mu_t-\sum_{i=1}^{n} PY_t-\sum_{i=1}^{n} M_t-\sum_{i=1}^{n} Q_t-D-R$

Subject to: $\sum_{j=1,s=1}^{n} b_jX_j \leq L_s$(land)

$\sum_{i}^{n} dX_j-L_t \leq L_b$(labour)

$\sum_{(i=1,2,3)}^{n} CX_j-M_t \leq C_j$(capital)

$\sum fX_j \geq f_{mm}$(minimum household food availability)

X, L, K, P, R, M0 › 0

Where:

Zf = Total farm income

X_j = Unit of crop activity in ha

P_j = Gross value of output per hectare of the j^{th} crop activity in ₦

W = Wage rate per unit hire of labour in ₦

W_{Lb} = Wage rate per unit of labour in ₦

F = Fertilizer price per 50kg bag in ₦

q = Quantity of 50kg bags of fertilizer used

M = Quantity of planting material used in kg

U = Unit price per kg of planting materials in ₦

P = Marketing expenses per unit of the product sold in t^{th} period

Y = Units of crop products sold in t^{th} period

Int = Interest paid on borrowed capital in ₦

Qt = Other variable cost items in ₦, e.g family labour, agro chemical, etc.

D = Depreciation in fixed cost items such as equipment, implements, tools etc in ₦

R = Rent on land in ₦

Fmm = Minimum quantity of food crops available to the farming household per annun

Ijt = Input coefficient of land which is 1ha with restrictions

Ajk = Input coefficient of labour (in mandays) for j^{th} crop activities in the period in ₦

Cjk = Level of management used in producing of 1ha of j^{th} crop activity in t^{th} period in ₦

$\sum_{j=1}^{n}$ = summation of j^{th} crop activities (j=1 ton).

RESULTS AND DISCUSSION

Activities in the Optimum Farm Plan of the Basic Model

The features of the optimum farm plan of the representative farms were shown in Table 1. Out of the many crop enterprises specified in the model, only seven were selected because these were the enterprise carried out by 2.5 percent of the total respondents as a mark of popularity of the enterprises and not those carried out by less people. These were maize, maize-groundnut, maize-cassava, maize-soybean, maize-yam maize-cowpea.

The optimum plan showed that the best way to cultivate crops is the mixture of maize and cowpea as opposed to the prevailing way of growing crops as sole crops or as other mixtures and is recommended in the area at 1.56ha and this is in agreement the findings of Abah *et al* (2016) who find out that the mixture of maize-cowpea is the best optimal farm plan. This implies that an average farmer who has an average of 1.56ha of farm land should cultivate only 2.07ha of maize-cowpea enterprise. This would enable him maximize his return estimated at ₦718140.13.

Table 1: Optimum Farm plan of the Basic Model

Enterprise	Variable	Value	Obj. Coeff.	Obj. Value Contribution
Maize	X_1	0.00	27500.00	0.00
Maize-Sorghum	X_2	0.00	346851.53	0.00
Maize-Yam	X_3	0.00	281761.51	0.00
Maize-G/nut	X_4	0.00	147062.19	0.00
Maize-Cowpea	X_5	1.07	76567.69	718140.13
Maize-Cassava	X_6	0.00	422653.88	0.00
Maize-Soybean	X_7	0.00	387812.12	0.00

Objective Value (Max.) = 718140.13

Constraints in the Model

The result in Table 2 shows that land as a resource is a tight resource. This implies that land is not surplus in supply and the available land was completely used up. The other resources namely labour; seeds and other inputs are slack. This implies that farmers do not need to incur any additional cost to use an additional unit of each of them since they are abundantly available, that is slack of 42.60 man-day of labour, ₦72631.17 for seed and ₦15753.94 for other inputs respectively.

Table 2: Summary of the Constraints in the Model

Constraints	Status	RHS	Slacks or Surplus
Land	Tight	1.56	0.00
Labour	Loose	125.16	42.60
Seed	Loose	387658.34	72631.17
Agro Chemical	Loose	47341.63	15753.94

Source: Field survey, 2021

RHS- Right Hand Side

Sensitivity Analysis of Resource Use

The results of the sensitivity analysis of the various enterprises determined are presented in Table 3. The result showed that if you reduced current objective coefficient of maize-cowpea enterprise from 675568.89 to minimum objective coefficient of 608123.55 or increased infinitely the optimal solution will remain the same. The result also shows that for other enterprises if you reduced the current objective coefficient to the minimum objective coefficient of negative infinity (-infinity) the result will remain the same. This implies that only maize-cowpea enterprise attains optimum cost reduction.

The result also shows that for enterprise such as maize, maize-sorghum, maize-yam, and maize-groundnut if the costs of inputs are reduced to the following price level for each enterprise ₦457292.34, ₦37890.64, ₦579260.61, and ₦354651.54 respectively the optimal farm level will be obtained. It also indicated that for enterprises such as maize-cassava, maize-soybean if the costs of inputs will be reduced to ₦539272.54 and ₦37890.64 respectively, optimal farm plan will be obtained.

Table 3: Sensitivity Analysis of Resource Use

Enterprise	Variable	Current Obj. Coefficient	Min. Obj. Coefficient	Max. Obj. Coefficient	Reduced Cost
Maize	X_1	323562.87	-infinity	762825.12	457292.34
Maize-Sorghum	X_2	377621.12	-infinity	435712.86	37890.64
Maize-Yam	X_3	306522.00	-infinity	675762.38	579260.61
Maize-G/nut	X_4	523652.88	-infinity	962925.42	354651.54
Maize-Cowpea	X_5	675568.89	608123.55	Infinity	0.00
Maize-Cassava	X_6	424652.88	-infinity	962925.42	539272.54
Maize-Soybean	X_7	367822.22	-infinity	435712.86	37890.64

Source: Field survey, 2021

Shadow Price Analysis of Resource Use

The shadow price for land in Table 4 was ₦442813.75. This very high value of land is an indication that land is a vital input in production. Shadow prices indicate the amount by which the gross margin would be increased or decreased by using an additional unit of the resources. The shadow prices are positive for limiting resources and zero for slack resources. The more limiting a resource is, the higher is its shadow price. Thus, for an additional use of 1 hectare of land is made, the farm income would increase by ₦442813.75. This finding suggests that an increase in farm size will obviously be of immense benefit to the production system in the study area.

The opportunity cost of using additional unit of labour, seeds and other input is 0 as shown in Table 6, this is because the status of labour, seed and other inputs are 0. This means that you do not need to incur any additional cost to use an additional unit of labour, seeds and other inputs since they are abundantly available.

Table 4: Shadow Price Analysis of Resource Use

Constraints	Current RHS	Min. RHS	Max. RHS	Shadow Price
Land	1.56	0.00	2.32	442813.75
Labour	125.16	114.56	Infinity	0.00
Seeds	387658.34	20380.27	Infinity	0.00
Other Inputs	47341.63	10267.70	Infinity	0.00

Source: Field survey, 2021

CONCLUSION AND RECOMMENDATIONS

The study showed that the mixture of maize-cowpea was found to be the best optimal farm Enterprise. Increase in farm size will obviously be of immense benefit to the production system in the study area. The opportunity cost of using additional unit of labour, seeds and other input was zero (0). The high value of land was an indication that land was a vital input in production. Based on findings from this study, the following recommendations are made:

1. Proper farm plan is a vital tool for profit making,
2. Educating farmers on the need for proper and right crop combination will help to address the issue of land shortage since land is a vital input for agricultural productivity.
3. All stakeholders in farming enterprises should educate crop farmers on land use optimization strategy.
4. Farmers should be encouraged to cultivate a mixture of short term duration crops with long term duration crops.

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