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Optimal Farm Plan in Sweet Potato Cropping Systems: The Case of Offa and Oyun Local Government Areas of Kwara State, North-Central Nigeria

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Abstract: This study examines optimal farm plan in sweet potato cropping systems. Primary data were collected, during the 2004-farming season, from ninety-eight sweet potato farmers who were selected from Offa and Oyun local government areas of Kwara State in the north-central zone of Nigeria. Descriptive statistics were used to describe the socio-economics characteristics of the sweet potato farmers. Linear programming model was used to determine the optimal farm plan. Descriptive analysis shows that 92.8% of the farmers were male while 7.2% were female. 67.3% were within the age range 31-50 years, 14.3% were above 60 years and the average age of the farmers was 43 years. 28.6% of the respondents were illiterates, while 71.4% had one forms of education or the other. 99% of the farmers have households with more than five members. Over 60% of the farmers cultivate maximum of 1.0 ha of sweet potato and only 2% cultivate more than 3.0 ha. The average farm size was 0.91 ha. The optimal crop combination was sweet potato/cassava cropping system and the optimal gross margin was N14766 ha^{-1}. 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 is recommended for increased production of the crop.

Key words: Sweet potato, optimal farm plan, linear programming, cropping system, labour

INTRODUCTION

Sweet potato (*Ipomea batatas* L.), belongs to the family *Solanaecae* and it originated from South America from where it was introduced to Europe between 1565 and 1573 (Adam, 2005). By the middle of the eighteen-century, sweet potato had become widely cultivated in Europe and thereafter it spread to Africa and other parts of the world. Globally, sweet potato is a very important food crop. It ranked fourth in terms of world most important food crop-after rice, wheat and corn (Horton and Sawyer, 1985). Also, of the world's root and tuber crops, sweet potato ranked third after Irish potato and cassava (Ikeorgu, 2003). Tewe *et al*. (2003) reported that sweet potato is only a minor root crop in tropical Africa despite its potentials as indicated by its growth in terms of production. According to Tewe *et al*. (2003) it is the only crop, among the root and tuber crops that had a positive per capita annual rate of increase in production in Sub-Saharan Africa. Sweet potato has a high yield potential that may be realized within a relatively short growing season and it can adapt to a wide range of ecological conditions ranging from 0-2000 meters above sea level and can grow in areas between 30°N and 30°S of the equator. Presently, it does not find much use as food in most parts of Africa except in Burundi, Rwanda and Zaire, which accounted for over 46% of African sweet potato production in 1984 (Tewe *et al*., 2003).

In Nigeria, sweet potato cultivation is still restricted to few states and its production is mainly for home consumption. The 1955-1960 agricultural sample survey censuses reported that 37,000 tonnes of sweet potato and Irish potato were produced on 14,985 hectares of land in northern Nigeria. However, after taking into consideration small amount of production in other parts of the country, it was estimated that land area planted to sweet potato increased from 12,590 to 15,795 hectares from 1959 to 1970. Onwueme (1978), reported that the areas of potato (Irish and sweet potato) cultivation in Nigeria as at 1971 were the middle-belt and riverine states.

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Estimates of sweet potato production in Nigeria vary widely among different sources. The report of the Presidential Task Force on alternate formulation of livestock feeds in 1992, sets the national output at 530,000 tonnes for 1990, while FAO estimated that 143,000 tonnes of sweet potato were produced in 1990. FAO statistic, though lower, did show a major increase in the production of sweet potato in the 1990s, with output growing by nearly ten times over the decade (Tewe *et al*., 2003). In addition FAO (2002) reported that the output of sweet potato increased from 143,000 tonnes in 1990 to 2,468,000 tonnes in 2000. Area under cultivation increased from 13,000 ha to 381,000 ha while yield decreased from 11 to 6.8 t ha^{-1} over the same period of time.

Tewe *et al*. (2003) reported that Kwara state is the main area of sweet potato production in the north-central zone of Nigeria. In Offa and Oyun local government areas in particular, it is a staple root crop that is consumed by most households. It is usually cultivated on marginal land and on farms less than one hectare in size. FAO (2002), found that 80% of sweet potato produced in Nigeria is used for households consumption. This is because, the root is a rich source of energy and vitamin A, the leaves are eaten as vegetable and the vine provides forage for ruminants.

In Nigeria, meeting the food and nutrients need of the ever-increasing population has been a huge task for every successful government. How well this objective is achieved is often used to judge the performance of any government. In its effort to meet this objective, government in 2002 commissioned the national Special Programme on Food Security (SPFS) in partnership with the Food and Agricultural Organization (FAO). As a complement of this programme, a presidential initiative on cassava, rice and oil palm was set up and three commodity development and marketing companies were established. Among them, the Arable Crops Development and Marketing Company (ACDMC), has the mandate to ensure increased cultivation and marketing of root and tuber crops including sweet potato (Idachaba, 2004). The inclusion of sweet potato on the mandate of the ACDMC in addition to other food crops was considered appropriate, because it has been reported that sweet potato has a long history as a food security crop in Nigeria. For example Tewe *et al*. (2003) reported that sweet potato is capable of meeting the consumption need of the households as well as generating income for them to enable them buy other food crops.

In the humid zone of Nigeria, sweet potato is usually planted in crop mixtures. It is mostly intercropped with cassava, maize, cocoyam or sorghum. When it is intercropped with cassava for example, it is planted on the ridges while cassava is planted in furrows. Soil from the sweet potato is heaped around the cassava stands when the sweet potato is harvested. Planting in this zone is usually done twice a year. The first planting between March and April at the onset of the rainy season, while the second planting is done between October and December usually in waterlogged areas. The tuber matures five to six months after planting and the first harvest could be done three months after planting. Harvesting of matured tuber is usually done staggered. In the sub-humid zone (which include Kwara state), sweet potato is usually intercropped with maize, cassava, yam, sorghum or millet. Like in the humid zone planting could also be done twice in a year in the sub-humid zone.

Tewe *et al*. (2003) submitted that the International Institute for Tropical Agriculture (IITA), Ibadan and the National Root Crops Research Institute (NRCRI), Umudike have reported high agronomic yield potential of sweet potato as a food security crop in Nigeria, however, this high potential is yet to be converted into increased output under the present cropping system. One of the reasons identified for the failure to achieve increased sweet potato production in Nigeria is the bad agronomic system of cultivation. According to Tewe *et al*. (2003), sweet potato is usually grown in crop mixtures that have negative effect on its output. In order to make suggestions on how to achieve increased production of the crop, there is a need to examine the best (optimal) crop combination in sweet potato cropping systems. This is what this study hopes to achieve. The study also describes the socio-economic characteristics of sweet potato farmers and concludes by recommending steps to achieve increased output of the crop.

MATERIALS AND METHODS

This study is carried out in Kwara state in the north-central zone of Nigeria. Nigeria, presently made up of 36 states is divided into six geo-political zones for political, agricultural, industrial and educational planning. These zones are; north-central, north-west, north-east, south-west, south-east and south-south. In the north-central zone, there are six states namely Kwara, Kogi, Niger, Nassarawa, Plateau and Benue. The north-cenral zone is under the moist savannah agro-ecological zone. The state lies between latitude 7° 15′ and 6° 18′ N of the equator. Two local government areas namely, Offa and Oyun local government areas were selected purposively for the study. These local government areas were selected based on the fact that they are the major producer and together they account for over 80% of the output of sweet potato in the state (KWADP, 1996). Kwara state, one of

the north-central state was created in 1967 and the total population of the state was about 1.55 million in 1991 out of which farmers account for about 80% (KWADP, 1996). The state shares boundaries with Oyo, Osun, Ondo, Kogi, Ekiti and Niger states. It shares an international boundary with the Republic of Benin. The state presently comprises of sixteen local government areas. A humid tropical climate prevails over the state and it has two distinct seasons; the rainy and dry seasons. The rain season lasts between April and October and the dry season between November and March. The rainfall ranges between 50.8 mm during the driest months to 2413.3 mm in the wettest period. The mean annual rainfall is about 1500 mm. The minimum average temperature throughout the state is about 21°C while; the maximum averages temperature is about 35°C. The mean annual temperature is about 32°C.

The state is primarily agrarian with great expanse of arable land and rich fertile soils. The state has a total land area of about 32,500 km^2, which is 3.5% of the total land area of the country, which is put at 923,770 km^2 (FAO, 1995a). 75.9% (24,668 km^2) of the land is arable, 14.1% (4,583 km^2) is forest and 10% (3,250 km^2) is not available for use. Agricultural production is largely peasant and small-scaled relying heavily on the use of manual labour equipped with crude implements, while fertilizers, mechanical implement, improved seeds and agrochemicals are also used to some extent. The typical cropping systems in the state are maize-based system, yam-based system, cassava-based system and rice system in areas located along river Niger, the major river in the state. Mixed cropping, shifting cultivation and crop rotation are the predominant methods of cropping in the state. The major crops cultivated in the state include yam, maize, rice, cassava, sweet potato, groundnut, cowpeas, sorghum, melon, okra, pepper and some leafy vegetables (KWADP, 1996). Majority of the food cultivated are eaten, while small amount of the food are sold in the market to earn cash income for household upkeep.

Sampling procedure: Combinations of purposive and two-stage random sampling techniques were used to select the respondents for this study. Offa and Oyun local government areas were purposively selected because they are the major sweet potato producing areas in Kwara state and they account for over 80% of the output of sweet potato in the state (KWADP, 1996). After selecting the two local government areas, the second stage of the sampling was the random selection of five villages from each of the two local government areas. The final stage of sampling was the random selection of 10 sweet potato farmers from each of the 10 selected villages using the Kwara state Agricultural Development Project sweet potato producing farm households' listing as the sampling frame (KWADP, 1996).

Data collection and analysis: The primary data were collected from ninety-eight sweet potato farmers selected from Offa and Oyun local government areas of Kwara state. The data were collected from the respondents by means of a structured questionnaire. The researchers administered the questionnaire with the assistance of trained research assistants from the Kwara State Agricultural Development Project (KWADP). The data collected include among others, the socio-economic characteristic of the respondents, types of crop grown, farm size, crop combinations, agronomic practices, crop yield, the various input used, their quantities and the prices of inputs and outputs in the area during the 2004 farming season. Descriptive statistics were used to describe the socio-economic characteristics of sweet potato farmers in the selected local government areas. To determine the optimal crop combination in sweet potato cropping systems, the linear programming technique was used.

The linear programming model: Linear programming tool find easy application in optimization problem, where the aim is to maximize or minimize a linear objective function subject to a set of linear constraints. For optimal crop combination problem, the linear programming is considered appropriate because the farmer is interested in a crop combination that maximizes his or her gross margin. Thus, the solution of the linear program matrix represents the profit maximizing crop combination under the present cropping system and this solution can be tested for changes in resource availability under alternative crop combination (Okuneye, 1985b).

The general linear programming model can be expressed as:

$$\text{Maz } Z = C_1X_1 + C_2X_2 + \ldots\ldots\ldots + C_nX_n$$

Subject to:

$A_{11}X_1 + A_{12}X_2 + \ldots\ldots + A_1nXn = B_1$

$A_{21}X_1 + A_{22}X_2 + \ldots\ldots + A_2nXn = B_2$

$Am_1X_1 + Am_2X_2 + \ldots\ldots + AmnXn = Bn$

$X_1, X_2, \ldots\ldots Xn = 0$

Where:

- Z = The objective function (gross margin)
- m = Number of resources
- n = Number of activities
- X_j = Nmber of units of activity j, for j = 1, 2, …… n
- B_i = Amount of resource I available for I = 1, 2, ……m
- C_j = Contribution of Z for each unit of activity j for j = 1, 2, …. n
- A_{ij} = Amount of ith resource consumed by each unit of activity j.

RESULTS AND DISCUSSION

The summary of the descriptive statistic is presented in Table 1. It shows that majority of the sweet potato farmers were men. This indicates a clear case of gender bias in favour of men in sweet potato farming in the study area. About two-third or 67.3% of the respondents fell within the age group of 31-50 years, while fourteen farmers representing 14.3% were above 60 years of age. The implication of this is that majority of the sweet potato farmers were middle-aged and young people indicating a great potential for increased production other things being equal. Fourty nine percent of the respondents have primary education and above. Twenty two percent received adult education while 28.6% are illiterates. The implication of close to half the population of farmers having formal education is that adoption of innovation in sweet potato production could be high, since education plays a vital role in adoption of innovation. Abiola and Omoabugan (2001), has shown that farmer's literacy level, which is largely determined by education level, have positive relationship with farm productivity and efficiency.

The farm size distribution shows that more than half (60.2%) of the farmers cultivate between 0 and 1 hectare of sweet potato. 37.5% cultivate between 1.1 ha and 3.0 ha while only 2% cultivate more than 3.0 ha. This probably shows that sweet potato cultivation in the study area is still small-scaled and at subsistence level. Household size distribution revealed that majority of the farm households (63.3%) has between 6-10 persons. Ninty nine percent of the households have more than five members. Following directly from this result, it would be expected that farmers should be able to cultivate more land since more labour is available. However, this was not the case in sweet potato production probably because some members of the households might not be working on the sweet potato farms.

The linear programming results: For the linear programming model, three enterprises were identified as the prominent in sweet potato cropping system. These are X_1 (sweet potato/cassava/maize), X_2 (sweet potato/cassava) and X_3 (sweet potato/yam). The linear programming matrix, showing the gross margin, the available capacity and the used capacity for each enterprise combination is shown in Table 2.

The linear programming model was analyzed using ''Solver'' software programme. The model was run based on the inputs shown in the linear programming matrix above. The solution of the linear programming analysis is presented in Table 3.

Table 1: Summary of descriptive statistics of sweet potato farmers, Kwara state

Characteristics	Frequency	Percentage
Gender		
Male	91	92.8
Female	7	7.2
Age (years)		
1-20	0	0
21-30	6	6.1
31-40	31	31.6
41-50	35	35.7
51-60	12	12.3
Above 60	14	14.3
Education level		
Illiterates	28	28.6
Adult education	22	22.4
Primary education	26	26.5
Secondary education	18	18.4
Tertiary education	4	4.1
Farm size (ha)		
0.01-1.00	59	60.2
1.10-2.00	32	32.7
2.10-3.00	5	5.1
Above 3.00	2	2.0
Household size		
1-5	1	1.0
6-10	62	63.3
11-15	35	35.7

Source: Field survey, 2004

Table 2: Linear programme matrix of sweet potato production, Kwara state

Gross margin (N)	11325	15963	7446	Used capacity	Available capacity
Enterprises	X_1	X_2	X_3		
Objective function	11325	15963	7446		
Land (ha)	1.0	1.0	1.0	3.0	0.99
Labour (man-days)	49.38	50.45	49.35	149.18	49.82
Capital (N)	5159.9	5420.5	5241.9	15822.3	5016.3

Source: Author's survey data, 2004

Table 3: Linear programming solution for sweet potato cropping systems in Kwara state

Basics	X_1	X_2	X_3	S_1	S_2	S_3	B (i)
	11325	15963	7446	0	0	0	
S_1	0.048	-0.17	0.03	1	0	-0	0.06
S_2	1.355	0	0.562	0	1	-0	3.13
X_2	0.952	1	0.967	0	0	-0	0.925

Source: Author's survey data, 2004

Table 4: Opportunity cost of enterprises and resources in sweet potato cropping systems

Enterprises	Final value	Opportunity cost	Resources	Final value	Opportunity cost
X_1	0	3869.9	Land (ha)	0.06	0
X_2	0.925	0	Labour (days)	3.13	0
X_3	0	7991.1	Capital (N)	0	2.94

Source: Author's survey data, 2004

Table 3 shows that only enterprise X_2 (sweet potato intercropped with cassava) entered the final solution. The optimal value of the programme is N14766 ha^{-1}. This is the value of the entered programme, which is obtained by cultivating 0.925 ha of the enterprise at a gross margin of

N15963 ha^{-1}. Enterprises X_2 (sweet potato intercropped with cassava and maize) and X_3 (sweet potato intercropped with yam) did not enter the programme. This result indicates that the best crop combination in sweet potato cropping systems in the area is sweet potato and cassava. The opportunity cost of the enterprises and the resources are shown in Table 4.

Table 4 shows that the opportunity cost of the excluded enterprises were N3869.9 ha^{-1} for the sweet potato/cassava/yam enterprise and N7991.1 ha^{-1} for the sweet potato/yam enterprise. The included enterprise (sweet potato/cassava) had zero opportunity cost. This result indicates that by forcing X_1 (Sweet potato/ cassava/maize), which is an excluded enterprise into the programme, the value of the programme would be reduced by N3869.9. Similarly, by producing a unit of X_3 (sweet potato/yam), the value of the programme would be reduced by N7991.1. The result in table 4 also shows that capital (N) is the only limiting resource. Land (ha) and labour (man-days) are non-limiting resources in sweet potato cropping system. There were 0.06 ha of unused land and 3.13 man-days of unused labour in the programme. The shadow price of capital was N2.94, which indicates that by increasing capital investment by N1, the gross margin would increase by N2.94. The result implies probably that for optimal production under the sweet potato cropping system, capital resource investment should be increased since land and labour are not limited. Increased naira investment therefore, would lead to increased sweet potato output in the study area.

CONCLUSION

This study examines the optimal crop combination in sweet potato cropping system. Primary data were collected through a cross-sectional survey of ninety-eight sweet potato fermers selected from Offa and Oyun local government areas of Kwara state, north-central zone of Nigeria. The data were analyzed using descriptive statistics and linear programming techniques. Descriptive analysis shows that 92.8% of the farmers were male while 7.2% were female. 67.3% were within the age range 31-50 years, 14.3% were above 60 years and the average age of the farmers was 43 years. 28.6% of the respondents were illiterates, while 71.4% had one forms of education or the other. 99% of the farmers have households with more than five members. More than 60% of the farmers cultivate maximum of 1.0 ha of sweet potato and only 2% cultivate more than 3.0 ha. The average farm size was 0.91 ha.

The linear programming result shows that of the three identified enterprises combination in sweet potato cropping system; sweet potato/cassava enterprise entered the programme. The value of the programme was N14766 ha^{-1}. This implies that the optimal crop combination was sweet potato/cassava with the final value of N14766 ha^{-1}. While land and labour were non-limiting resources in sweet potato system, capital was a limiting resource. Based on this result it is suggested that sweet potato farmers in the area should concentrate and intensify the cultivation of sweet potato/cassava combination that gave the optimal farm plan. In addition, increased capital in naira should be invested in sweet potato cultivation. Farmers are advised also to take advantage of unlimited land and labour for increased production of the crop.

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