

**OPTIMAL PLANS FOR FADAMA FARMING IN THE DERIVED
SAVANNAH ZONE OF NIGERIA: APPLICATION OF DYNAMIC
PROGRAMMING**

**[PLANES OPTIMOS PARA LA AGRICULTURA EN LA ZONA DE SABANA
DE NIGERIA: APLICACION DE MODELOS DE PROGRAMACION
DINAMICA]**

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SUMMARY

The study generated optimal farm plans in the dynamic decision environment of the farmers using a dynamic programming model for farms under Government irrigated agricultural program, Fadama farming. The model integrates technical and economic constraints with farmer's objectives. The optimal farm plan obtained gives a farm income of ₦57, 402.76 from 0.45hectares in the first year. This is expected to increase over time by 31.06 percent in five years. The plan supports mixed cropping but with sole okro as the predominant enterprise. The cultivation of non-leafy vegetables like pepper and tomatoes will also increase farm income. As more capital is made available by reinvesting income, the hectarage cultivated to okro will increase, thereby increasing income. Land and family labour are constraining but the effect of the latter is ameliorated by hiring labour. The study concludes that fadama farming is profitable with potentials for growth if land is increased and capital is reinvested. This requires institutional support to assist farmers access groundwater on lands located away from perennial streams.

Keywords: Fadama farming, dynamic programming, optimal farm plan, Nigeria

INTRODUCTION

Nigeria has abundant natural resources and favourable climate. The country is expected to be self – sufficient in food production but it is yet to achieve this goal as food demand outstrips the domestic supply (Adeoti, 2001; Rahji, 1999). Hence, beginning from the late 1980's the Federal Government, through the Agricultural Development Projects (ADPs) started to develop small-scale private irrigation systems in Fadama lands for wheat and vegetable cultivation,

RESUMEN

El presente estudio generó planes para sistemas Fadama incluidos en el programa de irrigación, empleando modelos de programación dinámica. El modelo integra limitantes técnicas y económicas en conjunto con los objetivos de los productores. Los planes óptimos permitirían obtener un ingreso de ₦57, 402.76 a partir de 0.45 hectáreas durante el primer año. Se proyecta un crecimiento de 31.06% en un periodo de 5 años. El plan permite cultivos mixtos, pero okro es el cultivo predominante. El cultivo de otros vegetales como pimientos y tomates también incrementaría el ingreso de los productores. Si más capital es disponible al reinvertir el ingreso, la extensión de cultivo dedicada al okro aumenta con el consecuente mayor ingreso. La disponibilidad de tierra y el trabajo familiar son limitantes del sistema, sin embargo este último puede ser subsanado mediante la contratación de trabajadores. Se concluye que la producción en Fadama es rentable y con potencial de crecimiento si más tierra es disponible y el capital reinvertido. Estas opciones requieren de apoyo institucional para proporcionar a los productores acceso a agua en tierras alejadas de los ríos.

Palabras clave: Fadama, programación dinámica, Nigeria.

especially during the dry season. Fadama is an Hausa word for low lying seasonally flooded areas in the river plains. Fadama farming is dry season farming carried out usually between the months of November and April every year. In 1993, the fadama irrigation system received a boost with the launching of a new project known as the National Fadama Development Project. The project was designed to accelerate the pace of fadama development, increase food production and farm incomes.

The first phase of the project, which started in 1993, was rounded off in 1999 while the second stage was also concluded recently. The successes recorded thus far have brought about the need to expand the scope of the project to a third phase. The project has attracted the attention of many agricultural planners and researchers lately. While few studies have examined the resource – use efficiencies of farms under fadama production (Adeoti,2003; Okoruwa *et al.*, 2002; Dittoh, 1991), studies on optimal mix of enterprises which will assist in achieving project objectives are rare. This study is to bridge this gap and provide optimal farm plans over time. Farm households' decisions on land use are dictated by their resource endowments, relative prices of inputs and outputs, exogenous factors such as access to credit and their objectives. Olayemi (1980) argued that small farmers actually maximize a composite of objectives, with profit maximization being only one of these. Other objectives considered important by the farmer are the production of minimum food required by the farm family, risk minimization and the balancing of income and leisure. This view has been supported by Upton (1996) who believes that small farmers want to maximize utility rather than profit. The main thrust of this study is to generate optimal farm plans that maximize farm incomes while meeting the objective of the farmer within their resource endowments and economic environment over a period of time. Specifically, it will determine the optimum enterprise mix for a representative whole – farm business; and, examine the growth pattern in the whole-farm business over a period of five years.

METHODOLOGY

The study from which this paper was drawn was carried out in the Derived Savannah Zone of Kwara State, Nigeria. The state is one of the 36 states in the country. A multistage sampling technique was used to get the required sample. The state currently has sixteen local government areas and has been stratified into four zones by the Kwara State Agricultural Development Project (KWADP). Two of the zones are in the Derived savannah belt and they cover five local government areas. Farmers in these five local government areas form the sample frame for the study. The choice of the derived savannah zone was informed by a good representation of both migrant and native farmers involved in irrigation in the zone.

The second stage of sampling involved the purposive selection of villages within these local government areas in which KWADP had contact farmers participating in its irrigation project. The last stage was the random sampling of farmers that were interviewed. A sample of 135 farmers was taken but only 130 farmers gave complete and consistent responses which were used for analysis. Data were collected on

quantities and prices of farm inputs namely land, labour, capital, water and. outputs. The quantities and market prices of the outputs from the various enterprises on the farm and the quantities consumed by the households were also obtained.

Analytical Technique

Farming systems analysis necessarily implies analysis on a whole-farm basis. Mathematical programming provides one method by which this may be done to varying degrees of complexity while allowing for alternative specifications of the farmer's objectives. Its analysis is concerned with the performance and viability of alternative farming system possibilities in the context of the farmer's constraints and objective (Charry *et al.*, 1992).

Linear programming has been a popular choice for modeling farmer decision making in response to technical and institutional innovations (Louhichia K *et al.*,2004; Elvio G *et al.*,2002, Thangata P *et al.*,2002 ,Abdulkadir A and Ajibefun I,1998; Calkins 1981). The linear programming model is used to determine the net farm incomes and the best enterprise mix. Linear programming involves the optimization of a linear objective function, given a set of linear constraints. An extension of it is the dynamic programming which is an optimization approach that transforms a complex problem into a sequence of simpler problems, its essential characteristic is the multistage nature of the optimization procedure. The dynamic programming has been adopted for the following reasons:

- a. The main thrust of the study is irrigated farming which involves investment in irrigation facilities and, in particular, fadama irrigation system, investments in motorized pumps and other low-cost water lifting devices. Since the costs and benefits of this investment extend beyond a year, a dynamic programming analysis is considered appropriate to investigate the situation.
- b. The resource allocation in one period can, through carry-over effects, affect allocations in succeeding periods.
- c. Farmers' decision-making process is a dynamic process, as they revise their decisions periodically, based on the outcomes of previous periods' decisions.

A dynamic model consists of a series of single period (linear or non-linear) models linked together by the investment decisions made in each period and their impact in later periods (Hazell and Norton, 1986). The model's objective is to find an optimal policy of allocating resources at each stage of a multi-stage decision process, with a view to obtaining an optimum

overall program and in the context of the interdependence of stages.

The problems that can be solved with dynamic programming must have the following two basic features. It must be possible to break the decision problem into a series of single-stage decisions, where at each stage; the decision involves the selection of one or more control variables. Also, the problem can be defined for any number of stages but must have the same structure for all stages.

The structure of a dynamic programming problem must consist of a series of decisions $U_1, U_2 \dots U_n$. A point in time at which a decision is made is a decision stage. Any decision U_i made at the i^{th} decision stage has two consequences. Firstly, it results in a change in the state of the decision system from X_i at stage i to X_{i+1} at stage $i+1$. A change is shown by the transformation function written as $X_{i+1} = t_i (X_i, U_i)$. Secondly, the decision results in a return at each decision stage, given the return function $a_i (X_i, U_i)$. The overall objective of the analysis must be to select the decision sequence $U_1, U_2 \dots U_n$, so that a separable objective function of the n^{th} stage is optimized. The common objective function is the sum of stage returns or the present value of stage returns.

$$\sum_{i=1}^n a_i \{X_i, U_i\}$$

The final decision to be taken (U_n) determines the terminal state of the system X_{n+1} . If there is a final value $F(X_{n+1})$ associated with the terminal state, it is included in the objective function.

Generally, a dynamic programming problem with an additive objective function has the form:

$$\text{Max } U_1, \dots, U_n = \sum_{i=1}^n a_i \{X_i, U_i\} + F \{X_{n+1}\}$$

Subject to:

$$X_1 = \bar{X}_1$$

$$X_{i+1} = t_i \{X_i, U_i\} \quad i = 1, \dots, n.$$

Where:

- U_i = Decision on activity level
- \bar{X}_1 = Level of resource stock available at stage 1
- $F \{X_{n+1}\}$ = Final value of the resource stock remaining at stage $n+1$
- n = Number of stages
- $a_i \{X_i, U_i\}$ = Stage return

One way of solving a dynamic programming problem is to transform it into a series of linear programming

problems. The solution of one such linear programming problem becomes part of the side constraints of the next one. The solution can start from the top down to the bottom or vice versa. Markov chain process is another technique used to solve dynamic programming problems (Olayemi and Onyenwaku, 1999).

Model Specification

The dynamic linear programming model was developed based on the representative farm. A representative farm is an average farm, which incorporates the essential characteristics of the group it represents (Plaxico et al., 1963). This study is based on the safety first objective of the farmer which incorporates the minimum food requirement of the farm household into the model along with its objective of maximizing income. In the model, all resources are restricted to their average values.

The Empirical Model

The mathematical representation of the models is expressed in the following set of equations.

$$\text{Max } Z = \sum_{t=1}^T \sum_{j=1}^n P_{jt} X_{jt} - \sum_{t=1}^T W_t H_t - \sum_{t=1}^T r_t k_t -$$

$$\sum_{t=1}^T r_b k_b t - \sum_{t=1}^T NP_t NF_t$$

$$j = 1, 2 \dots n;$$

$$t = 1, 2, \dots T$$

Subject to the following constraints

Resource Constraints:

$$\sum_{t=1}^T \sum_{j=1}^n a_{ijt} X_{jt} \leq b_{it}$$

Consumption Constraints:

$$\sum_{t=1}^T \sum_{j=1}^n X_{jt} \geq d_{jt}$$

Non-negativity Constraints

$$X_{jt} \geq 0$$

Where:

- Z = The sum of gross margins for crop enterprises over a period of five years.
- P_{jt} = The net price of the j^{th} activity in year t .
- W_t = Wages paid per standard-day for labour hiring activity in year t .

H_t = Total number of standard-days of hired labour in year t .

r_t = Interest rate or opportunity cost on own capital in year t .

k_t = Amount of own capital utilized in year t .

rb_t = Interest rate charged on borrowed capital in year t .

kb_t = Amount of borrowed capital in year t .

NP_t = The net price of non-farm activities in year t taken as the average value of non-farm income per standard-day in year t .

NF_t = Number of standard-days of labour spent on non-farm activities in year t .

j = Number of real activities 1, 2, ... n .

t = Number of years considered 1, 2, ... T .

a_{ijt} = The quantity of the i^{th} resource required per unit output of activity j in year t .

b_{it} = The level of the i^{th} resource available in year t .

X_{jt} = The level of the j^{th} real activity in tons in year t .

d_{jt} = The minimum level of the j^{th} real activity in tons, required by the farm household in year t .

The model consists of six real activities which are the crop production enterprises. They are sole okro, sole amaranthus (ama), sole maize (maz), okro/amaranthus mixture (okro/Ama), tomatoes/pepper mixture (Tom/Pep) and amaranthus/cochorus mixture (Ama/cho). It also has other activities which are labour hiring activities, the opportunity cost of own-capital, interest rate charged on borrowed capital from both formal and informal sources and the income from non-farming activities. There are also additional six minimum food production constraints, which are the minimum quantities of okro, amaranthus, maize, tomato, pepper and cochorus required by the farm family. The eleven resources are mainly irrigable farmland, family and hired labour grouped bimonthly for the six-month period of a production period which are November/December family labour (ND Fam Lb), January/February family labour (JF Fam Lb), March/April family labour (MA Fam Lb), November/December hired labour (ND Hir Lb), January/February hired labour (JF Hir Lb) and March/April hired labour (MA Hir Lb); available own-capital, maximum level of capital that can be borrowed from both formal (Borrowed capital I) and informal (Borrowed capital II) sources and the available labour time for non farming activities

The first-year optimal linear programming solution obtained for the representative farm is dynamized over a five-year period. The linear static model is dynamized by:

- (i) incorporating the level of outputs of the previous years as inputs in the current year;
- (ii) adjusting the physical resource levels based on resource usage in the previous year;

- (iii) revising farmer's own equity contribution, that is, own-capital, by incorporating the profit generated within the previous year's programme into the current year's LP matrix; Steps (i) – (iii) are achieved by revising the right hand side of the current year's LP matrix as advised by the LP result of the previous year;
- (iv) adjusting the prices of outputs to reflect inflation in the economy.

The results are discussed by highlighting the value of the programme, the enterprise combination, the marginal opportunity costs of excluded real activities from the optimal programme, resource use patterns and the marginal value product of limiting resources.

RESULTS AND DISCUSSION

The programming result of a representative fadama farm is contained in Table 1. The value of the programme is ₦ 57, 402.76 which represents the farms maximized total gross margin. This implies that, given the representative farm's resource constraint set and its safety first objective, the optimal allocation of resources will yield a maximum total gross margin of about ₦ 57,402.76 from the enterprise included in the optimal plan. Out of the six enterprises considered in the model, five enterprises enter the optimal solution at different levels. They are sole okro (0.33ha), sole amaranthus (0.01ha), sole maize (0.08ha), tomato/pepper mixture (0.01ha) and amaranthus/cochorus mixture (0.02ha). Only okro/amaranthus mixture is excluded from the programme. The hectareage allotted to sole okro cultivation in this model is about 73.33 percent of the available land thereby emphasizing the dominant position of this enterprise in fadama irrigation production system. The marginal opportunity costs (MOCs) of enterprises that are excluded from the optimal plan represent income penalties. They are the amounts by which the programme value will be reduced if one hectare of each of the excluded enterprises is forced into the programme. They show the weak competitive positions of the excluded enterprises. Generally, the higher the marginal opportunity cost of an enterprise, the less competitive it is. The marginal opportunity cost of the excluded enterprise, okro/amaranthus mixture, is ₦ 28,240.39. With this high marginal opportunity cost, it is not profitable to introduce it into the plan as it will wipe off 49.20 percent of the farm's total gross margin; if an hectare of the enterprise is forced into the plan.

The resource –use pattern shows that five resources are constraining in the model. These are land, November/December family labour, January/February family labour, March/April family labour and farmer's own capital. Throughout the production period, the available family labour is fully utilized, hence the need

for the hiring of labour to supplement family labour. Similarly, the inadequacy of the farmer's own capital necessitated the borrowing of capital from formal sources. The shadow prices of limiting resources represent their net marginal value products (MVP). The more limiting a resource is, the higher is its MVP. It is indicative of the productivity of resources on the farm, or the amount of increase in the farm's total gross margin that can be obtained by using an additional unit of the scarce resource. According to Ogunfowora et al (1973), it is the maximum price that should be paid for an extra unit of a limiting resource. The net marginal value product of land is ₦ 19,651.00. Land has a high net MVP, and increase in this vital resource will increase the total gross margin of farms significantly. Family labour for all the months has an MVP of N200, which means an extra unit of family labour will increase farm's total gross margin by N200. Own-capital has a net MVP of ₦ 0.08 which implies that every increase of 100 naira in the farmer's own capital will increase the value of the programme by N8.

The result over a five year period based on farm investment decision is explained in terms of the changes in the programme value, enterprise combinations, marginal opportunity costs of excluded enterprises (See Table 1) and the resource use pattern. The resource use pattern is discussed with respect to the marginal value products of limiting resources and the non-fully used up resources in the plan.

As shown in Table 1, the programme value increased over the five years, though unevenly. In year one, the programme value is ₦ 57,402.76. This increases consistently to ₦ 75,230.39, in year five which represents a 31.06 percent increase in programme value over the five-year period. The mean total gross margin over the five-year period is ₦ 66,371.89. Five out of the six enterprises in the representative farm model are included in the plan. The enterprise combination consists of three sole enterprises and two mixed enterprises. Hectarages allocated for different enterprises changed over the years.

Table 1. Dynamic linear programming result for the representative farm.

	Years				
	1	2	3	4	5
Programme Value in ₦	57402.76	62714.68	65952.13	70559.52	75230.39
Included Activities in Ha	Okro (0.33)	Okro (0.43)	Okro (0.46)	Okro (0.47)	Okro (0.48)
	Ama (0.01)	Ama (0.01)	Ama (0.01)	Ama (0.01)	Ama (0.02)
	Maz (0.08)	Maz (0.08)	Maz (0.08)	Maz (0.05)	Maz (0.03)
	Tom/Pep (0.01)	Tom/Pep (0.01)	Tom/Pep (0.01)	Tom/Pep (0.02)	Tom/Pep (0.02)
	Ama/Cho (0.02)	Ama/Cho (0.02)	Ama/Cho (0.02)	Ama/Cho (0.02)	Ama/Cho (0.02)
MOC of Excluded Activities in ₦	Okro/Ama (28,240.39)	Okro/Ama (29297.72)	Okro/Ama (48714.69)	Okro/Ama (52907.37)	Okro/Ama (49894.16)
MVP of Fully Used Resources	Land (19651)	Land (23399.08)	-	-	-
	ND Fam Lb (200)	ND Fam Lb (200)	ND Fam Lb (941.81)	ND Fam Lb (1059.96)	ND Fam Lb (1187.57)
	JF Fam Lb (200)	JF Fam Lb (200)	JF Fam Lb (200)	JF Fam Lb (200)	JF Fam Lb (200)
	MA Fam Lb (200)	MA Fam Lb (200)	MA Fam Lb (200)	MA Fam Lb (200)	MA Fam Lb (200)
	-	-	ND Hir Lb (741.81)	ND Hir Lb (859.96)	ND Hir Lb (987.57)
	Own Capital (0.08)	Own Capital (0.08)	Own Capital (0.08)	Own Capital (0.08)	Own Capital (0.08)
MVP = Marginal Value Product or shadow price	MOC = Marginal Opportunity Cost				

For the whole period, sole okro has the largest hectareage. Its allocation increased from 73.33 percent of the total area cultivated in year one to 84.21 percent in year five. The hectareage planned for sole maize remains constant in years one to three but declined in year four by 37.50 percent and in year five by 62.50 percent. This shows that, as, more capital and farmland are made available; there is an increase in the hectareage allocated for sole okro while that of sole maize decreases. Sole amaranthus, tomato/pepper mixture and amaranthus/Cochorus mixture are admitted into the plan at very low hectareages. The total area allocated to these enterprises increased from year one to three by 28.89 percent. There was however, a marginal decrease of 1.72 percent in total area allocated for their cultivation in years four and five. In the five year period, the total area for cultivation increased by 26.67 percent. The only excluded activity in the five-year period is the okro/amaranthus mixture. The MOCs increased over the first four years by 87.35 percent and declined marginally by 5.69 percent in year five. The mean MOC is ₦ 41,810.87, which implies that, on the average, forcing an hectare of okro/amaranthus mixture into the plan will reduce the average total gross margin by ₦ 41,810.87 or 62.99 percent.

The resource use pattern for this production system is shown in Tables 2 and 3. Table 2 shows the marginal value product of resources that were fully used up

while Table 3 gives a summary of the resources that are surplus in the plan. With the reinvestment of capital and the revision of the operating capital used on the farm, the land available for cultivation becomes inadequate. This leads to an increase in the net marginal value product of land from ₦ 19,651 in year one to ₦ 23,399.08 in year two, an increase of 19.07 percent. But with an increase in land made available for cultivation in succeeding years, land becomes non-limiting in years three to five. Throughout the period, family labour is constraining. With an increase of 28.89 percent in total hectareage planned for cultivation in year three and 27.17 percent in years four and five, November/December hired labour becomes limiting. For the same reason, farmer's own capital remains constraining throughout the period.

As shown in Table 3 with an increase in total hectareage planned for cultivation in years three to five, November/December hired labour becomes limiting. For the same reason, farmer's own capital remains constraining throughout the period which necessitated the use of credit. This was sourced from formal sources only. The non-fully used up borrowed capital from formal sources increased from ₦ 4,439.21 in year four to ₦ 7,257.39 in year five, an increase of 63.48 percent. This shows that in the fifth year, the farmer's need of credit has reduced and farm activities are better financed by the income from the farm.

Table 2. Comparison of marginal value product of fully used resources for the representative farm in the 5-year period.

Resources	Unit	Years				
		1	2	3	4	5
Land	₦	19651	23399.08	0	0	0
ND Fam Lb	₦	200	200	941.81	1059.96	1187.57
JF Fam Lb	₦	200	200	200	200	200
MA Fam Lb	₦	200	200	200	200	200
ND Hir Lb	₦	0	0	741.81	859.96	987.57
Own Capital	₦	0.08	0.08	0.08	0.08	0.08

Source: Extracted from Table 1

Table 3. Comparison of non-fully used resources for representative farm in the five-year period.

Resources	Unit	Years				
		1	2	3	4	5
Land	Ha	0	0	0.02	0.03	0.03
ND Hir Lb	Std	4.18	1.10	0	0	0
JF Hir Lb	Std	29.71	22.91	21.87	21.25	21.35
MA Hir Lb	Std	6.24	3.14	2.21	2.08	2.02
Borrowed Capital I	₦	9038.38	5371.99	5690.61	4439.21	7257.39
Borrowed Capital II	₦	8929	8929	8929	8929	8929

Source: LP Output.

Model summary

The study was designed to provide the optimal farm plan that will meet the safety-first objective of the representative fadama farm within its resource endowments and economic environment. The growth in farm income over a five-year period was also examined. The result of the analysis gives a total gross margin of ₦57, 402.76 in year one. The plan allows for the cultivation of five enterprises out of the six enterprises in the model in year one. These enterprises are sole okro (0.33 ha), sole amaranthus (0.01ha), sole maize (0.08ha), tomato/pepper mixture (0.01ha) and amaranthus/Cochorus mixture (0.02 ha). About 73.33 percent of the available land is for the cultivation of sole okro. Only okro/amaranthus is excluded from the plan. The resources that are constraining include land, November/December family labour, January/February family labour, March/ April family labour and own capital.

The dynamic programming result shows a 31.06 percent growth in total gross margins over the five-year period and a mean value of ₦66, 371.89. The five enterprises that entered the plan in year one remained in the plan for the whole planning period. They are sole okro, sole amaranthus, sole maize, tomato/pepper mixture and amaranthus/Cochorus mixture. Growth in total hectareage cultivated is by 26.67 percent over the period. The land area allocated to sole okro increased from 73.33 percent of the total area cultivated in year one to 84.21 percent in year five. Okro/amaranthus mixture remains the only excluded enterprise. Resources that are constraining for the whole period are November/December family labour, January/February family labour, March/ April family labour and own capital. Land is constraining in the first two years while November/December hired labour is constraining in the last three years only.

CONCLUSION

It is concluded that under the existing resource constraints, farms under fadama irrigation production system is very profitable and there exists room for growth if land is increased and capital is re-invested. The policy implication is that more land be made available for fadama farming because it will increase farm incomes. Due to limited availability of land in areas close to perennial streams, the use of groundwater as a viable option should be exploited. This requires institutional support of the authorities. While okro is a highly profitable enterprise in irrigation production systems, the cultivation of non-leafy vegetables like tomatoes and pepper should be undertaken along with leafy vegetables on farms under irrigation, as it will increase farm incomes over time.

The cultivation of okro/amaranthus mixture should not be encouraged as it will reduce farm incomes.

REFERENCES

- Abdulkadri, A.O., and Ajibefun, I.A. 1998. Developing alternative farm plans for cropping system decision making. *Agricultural Systems*, 56: 431 - 442.
- Adeoti A.I. 2001. Economic analysis of irrigated and rainfed production systems in Kwara State, Nigeria. PhD Thesis in the Department of Agricultural Economics, University of Ibadan, Ibadan
- Adeoti A.I and Olayemi J.K. 2003. Measuring the technical efficiencies of fadama farmers in the derived savannah zone of Nigeria. *Nigerian Journal of Economic and Social Studies*, 44:1-16
- Calkins, P.H. 1981.: Adaptations of linear programming for planning rural development. *American Journal of Agricultural Economics*, 63: 247-254.
- Dittoh, J.S. 1991. Efficiency of agricultural production in small and medium scale irrigation in Nigeria. In: *Issues in Africa Rural Development*, C.R. Doss and C. Olson (eds). Arlington, Virginia, Winrock International. Pp: 152-174.
- Charry A, Daramola A.G and Dillon J.L. (1992): Application of mathematical programming in farming systems research and extension. *Agricultural Systems in Africa*, 2: 31-37.
- Elvio Giasson,, Ray B. Bryantb and Nelson L. Billsc 2002. Environmental and economic optimization of dairy manure management: a mathematical programming approach. *Agronomy Journal* 94:757-766.
- Hazell P.B.R and Norton R.D. 1986. *Mathematical programming for economic analysis in agriculture*. New York, USA: Macmillan.
- Louhichia Kamel, Véronique Alaryb and Patrice Grimaudb 2004. A dynamic model to analyse the bio-technical and socio-economic interactions in dairy farming systems on the Réunion Island. *Animal. Research*. 53: 363-382
- Ogunfowora, O. and Norman, D. 1973. An optimization model for evaluating the stability of sole cropping and mixed cropping

- systems under changing resources and technology levels. *Nigerian Journal of Rural Economics and Sociology*, 8: 61-76.
- Okoruwa, V.O, Akinleye S.O and Mafimisebi,T.E 2001. Relative efficiency of fadama farmers in Southwest Nigeria: An application of profit function techniques. *Journal of Agricultural Extension*, 5: 45-53.
- Olayemi, J.K. and Onyenweaku, C.E. 1999. *Quantitative methods for business decisions*. Ibadan: Bosude Press Ltd.
- Olayemi J.K. 1995. Food security in Nigeria. DPC Research Report No. 2
- Olayemi, J.K. 1980. Food crop production by small farmers in Nigeria. In: *Nigerian small farmers*. S.O. Olayide, J.A. Emeka, A.E. Bello (eds). Pp. 18-33.
- Plaxico J.S. and Tweeten L.G. 1963. Representative farms for policy and project research. *Journal of Farm Economics*, 45: 1458-1468.
- Rahji M.A.Y. 1999. Dimensions of rural poverty and the food self-sufficiency gap in Nigeria. In: *Food security in Nigeria*. Fabiyi Y.L and Idowu E.O (eds). Obafemi Awolowo University, Ile-Ife. Nigeria.
- Thangata P, Hildebrand P, and Gladwin C. 2002. Modeling agroforestry adoption and household decision making in Malawi. *African Studies Quarterly* 6 (1-2): <http://web.africa.ufl.edu/asq/v6/v6i1a11.htm>
- Upton, M. 1996. The Farmer's production choices. In: *The economics of tropical farming systems* Allan Buckwell, Ian Caruthers, Hassan Hakimian, Jonathan Kydd and John Prescott (eds). pp: 49-68.

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