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Optimal Production Plan of Food Crop Production in Peri-Urban Areas of Adamawa State, Nigeria

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Abstract
The study analyzed optimal food crop production plan and resource allocation among peri-urban farmers in Adamawa State, Nigeria. Primary data were collected from 198 peri-urban farmers using structured questionnaire. Linear programming model were used as analytical tools. The result revealed that the optimal production plan gave a programme value of ₦49, 423.718 as the gross margin of production and recommended the production of only two out of the ten enterprises included in the model. These enterprises are the sole cowpea (0.247 ha) and maize/sorghum (0.951 ha) enterprises. The resources' allocation pattern revealed only two of the constraints was fully utilized in arriving at the optimal solution. These land size (ha) and agrochemicals (litres), their corresponding shadow prices are ₦17,511.95, ₦5,810.02 respectively. The optimal farm plan recommends that peri-urban farmers should allocate their resources in such a way that the two crops enterprises are produced according to these hectares allocation to maximize total Gross Margin of ₦49, 423.718 per hectares. It also recommended the problem of inefficient allocation, farmers should be given proper orientation and basic training in major farm management techniques; this will help them to be more efficient in allocation of productive inputs.
Keywords: Optimal production Plan, Peri- urban, food, crops, Agriculture and Adamawa State.

INTRODUCTION

Peri-urban agriculture is an industry located within (intra urban) or on the fringe of a town, an urban center, a city or metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, using mainly human and material resources, inputs and services found in and around that urban area, and in turn supplying human and material resources, outputs and services largely to that urban area" (Mougeot, 1999). With increasing numbers of rural poor migrating to cities, more urban dwellers are being born into impoverished families, and in some cases not-so-poor families are slipping below the poverty line (Mougeot, 1999, Mougeot (ed.), 2005). Numerous studies have shown that Peri-urban agriculture (PUA) can play a key role in providing valuable food security and income generation among urban households (Egziabher *et al*., 1994; Lynch *et al.*, 2001). The world's population is rapidly becoming urbanized as the world's urban population increased from 30 percent in 1950 to 47 percent in 2002 (Kennedy, 2003). Thus the number of people living in and round cities is on the increase. About 50 percent of the world's population now lives in cities; 77 percent of Latin Americans live in cities, while in Asia and Africa the proportion is currently 39 per cent, climbing at a rate of 3 and 4 per cent per year respectively. The numbers of urban poor are rapidly increasing. Urbanization in sub-Saharan Africa is growing at alarming trends such that as population grows at an annual rate of 2.8 percent, urban population grows at a rate of 6.8 percent. In Nigeria, population grew at an average of 2.83 percent between 1999 and 2004 while urban population grew at the rate of 4.7 percent within the same period. This rapid increase in urbanization poses new and different challenges for food security. It is hard for most cities in developing countries to provide sufficient employment for their rapidly increasing population. As a consequence, the urbanization process goes hand in hand with increase in urban poverty, dubbed the 'urbanization of poverty' (Haddad *et al.,* 1999). According to UN-HABITAT, slum populations in urban areas of developing countries were estimated at 870 million in 2001 and are expected to increase by an average of 29 million per year up to 2020. The costs of supplying and distributing food from rural areas to urban areas or importing food for the cities are also rising.

Optimization is commonly used approach to solve problems of production planning in the sense of optimal resource allocation given the changing conditions that farms face. The linear programming is a mathematical procedure utilising the simplex algorithm which aims to find the optimal combination of farm enterprises under maximisation or minimisation of the linear objective function (Kay *et al*., 2008). The LP has been introduced by Dantzig in 1947 (Lee and Olson, 2006) and since then it has been successfully used in finding an optimal production plan in different areas, most often with an objective function for maximizing the total gross margin or net income. LP has been already proven as useful method in farm production planning (Scarpari and Beauclair, 2010; Alabdulkader *et al.*, 2012; Kebede and Gan, 1999; Majewski and Was., 2005), whereas Boehlje and Eidman (1984) stressed that this method can be applied to all resource allocation problem the farmer is faced with. It also proved to be more applicable for solving complex problems than other more simple methods as budgeting and marginal analysis. LP models require clear definition of farm activities, resource requirements and specific constraints such as capital and labour constraints (Hazell and Norton, 1986). It gives solution that is combination of activities which maximize the value of the objective function (gross margin or net revenue) within a predetermined list of opportunities and constraints (land, labour and capital) (Turner and Taylor, 2003).

Optimum farm production eliminates inefficiency in resource use, and guarantees food availability (Etim *et al.*, 2007). Previous studies by (Aromolaran, 1992, Adewumi, 2002, Adejobi, 2004, Adeoti, *et al.*, 2008 and Ibrahim and Omotesho, 2011) have integrated diverse goals within Linear Programming models for optimal farm planning. Based on the foregoing, this study aims to use the linear goal programming technique to develop an optimal production plan which can serve as a guide for resource allocation by peri-urban farmers in order to sustain or maintain the self-reliance in food crop production in peri-urban areas of Adamawa State.

Methodology

The study was conducted in Adamawa State in the North-eastern geopolitical zone of Nigeria. The State lies between latitudes 7^0 and 11^0 North of the equator and longitudes 11^0 and 14^0 East of the Greenwich. Its shares boundaries with Taraba state in the South west, Gombe in its North-west and Borno to the North. The state has an international boundary with the Cameroon Republic along its eastern border (Adebayo, 1999). The population of the state according to 2006 census figure stood at 3.17 million people with the total land area of 38,741 square kilometres, this is about 4.4 percent of the land area of Nigeria. (NPC, 2006). It has 21 Local Government Areas.

Adamawa state climate is characterized by distinct dry and rainy seasons, which is typically of tropical climate. The rainy season starts in April and ends in October. The average rainfall ranges from 700mm in the northwest to 1600 mm in the southern part (Adebayo, 1999). The dry season is from November to March, which is also part of the harmattan period when the dust laden easterly trade winds from the Sahara desert have a marked effect on the climate of the state.

Majority of the people in Adamawa State are farmers. Crops produced include groundnut, cotton, maize, yam, cassava, guinea corn, millet, beans, sweet potato and rice. A cattle rearing is a major occupation, while village communities living on the banks of River Gongola and Benue in the State engage in fishing and dry season production of vegetable crops like tomato, onion, pepper, amaranthus, okra, garden egg and melon using wash bore and tube well irrigation with water pumps.

Method of data collection

Primary data were collected through the use of structured questionnaires and interview schedule which was administered to the peri-urban food crops farmers by the researcher and trained enumerators.

Sampling Procedure and Sample Size

The target population for this study was all the peri-urban farmers in Adamawa state. Purposive sampling technique was used for the study. These are Yola, Mubi and Numan. In the second stage, two (2) peri-urban areas were identified from each of the three urban centres – Yola (Ngurore and Gerio), Mubi (Vimtim and Muchalla) and Numan (Ngballang and Vulpi), using a simple random sampling technique to form the peri-urban centers. The third stage involved the random selection of peri-urban food crop farmers from each of the six (6) peri-urban centers earlier selected- Ngurore, Gerio, Muchalla, Vimtim, Vulpi and Ngballang (Table 1). Therefore, a total sample size of two hundred (200) peri-urban food crop farmers was used for the study, however 198 was correctly filled questionnaire and used for analysis.

Table 1 List of Main Urban Centers, Peri urban areas

Main Urban centers	Peri-urban areas sampled	Number questionnaires administered
Yola	Ngurore	35
	Gerio	47
Numan	Vulpi	26
	Ngballang	30
Mubi	Vimtim	23
	Muchalla	37
Total Number		198

Sources: Recognizance farm survey, 2013

Methods of data analysis

Inferential statistics was employed in the analysis of data. The inferential statistics include Linear Programming technique was employed in determining the optimal production plan and resources allocation in peri-urban food crop production.

Linear Programming

Linear programming is a mathematical programming model used in the optimization of a linear function of one or more variables subject to one or more linear constraints. The model is useful in situations where the objective is to efficiently allocate scarce resources among competing activities. It is also used in determining farmers' optimal crop enterprise combination and resource allocation. This involves determining enterprise combination that maximizes the enterprise Total Gross Margin (TGM) subject to production constraints associated with the available resources.

The farmer is assumed to maximize his Gross margin by selecting appropriate enterprise combinations to meets his objective. Mathematically, the model, which was modified by Tauer (1983) after Hazell (1971), is stated below:

The empirical model:

Objective function: Maximize $Z=\sum a_i X_i$……………………….1

Linear Constraints: Subject to: $\sum b_{ij} X_i \leq G_j$…….…………………..2

Non-negativity condition: $X_i \geq 0$………....………………....3

Where

Z= Total Gross Margin to be maximized which is the objective function

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

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

G_j= Available resources for the j^{th} activity

X_i= Decision variable to be maximized which are the different activities or enterprises

And $X_i \geq 0$: Non-negativity condition

Activities in the model and the price coefficient

Food crop production enterprises were grouped into sole cropping and mixed cropping. For each crop production activity, the unit of activity is one hectare.

Input coefficients

The input coefficient refers to the requirement of a crop activity in respect of the inputs of the different resources measured in terms of hectare basis (unit of land). The input coefficient for all the crops activities were calculated on the basis of the actual quantities of different resources used for this food crop activities. For instance, the input –output coefficients for hired labour are refers to the amount of hired labour in man days used in producing a hectare of that particular crop enterprise.

Resources constraints/restriction in the model:

Six constraints were incorporated in the model. These are land size (in hectares), inorganic fertilizer (in 50 kg bags), seeds (grain equivalent), hired labour (in man days), family labour (in man days), and agrochemicals (in litres).

The Linear Programming input Matrix used for the Optimization Iteration is presented thus;

Maximize Z: $54245.30X_1 + 44454.91X_2 + 41261.17X_3 + 40405.95X_4 + 60380.00X_5 + 38419.27X_6 + 60773.86X_7 + 42215.10X_8 + 55543.79X_9 + 54740.71X_{10}$……………1

Subject to:

Farm Size (ha): $0.98X_1 + 0.81X_2 + 1.22X_3 + 1.03X_4 + 0.90X_5 + 1.10X_6 + 1.47X_7 + 1.75X_8 + 1.33X_9 + 1.83X_{10} \leq 1.18$ 2

Inorganic Fertilizer (kg): $97.24X_1 + 69.01X_2 + 40.81X_3 + 50.60X_4 + 88.39X_5 + 70.42X_6 + 72.66X_7 + 90.04X_8 + 96.95X_9 + 83.33X_{10} \leq 168.18$ 3

Seed (kg): $20.61X_1 + 15.76X_2 + 14.53X_3 + 15.06X_4 + 18.82X_5 + 29.91X_6 + 9.57X_7 + 11.46X_8 + 16.34X_9 + 13.551X_{10} \leq 37.38$ ..……...4

Agro-chemicals (litres) : $6.52X_1 + 5.21X_2 + 10.44X_3 + 3.85X_4 + 7.69X_5 + 6.53X_6 + 7.42X_7 + 6.91X_8 + 9.22X_9 + 5.021X_{10} \leq 4.95$…….5

Family Labour (man days): $20.08X_1 + 22.95x2 + 15.98X_3 + 12.94X_4 + 18.33X_5 + 21.65X_6 + 19.15X_7 + 18.01X_8 + 19.01X_9 + 116.821X_{10} \leq 40.44$……6

Hired Labour (man days): $12.87X_1 + 15.87X_2 + 8.41X_3 + 9.11X_4 + 11.08X_5 + 712.23X_6 + 13.30X_7 + 9.41X_8 + 13.82X_9 + 8.19X_{10} \leq 28.62$……………………………………………………………..7

$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \geq 0$………………………….....8

RESULTS AND DISCUSSION

Optimal Production Level of Food Crops Resource Allocation

The optimal farm plan was generated for maximizing total gross margin (TGM) using the linear programming model is based on the assumption that profit maximization is the underlying behavioral principles guiding the farmer in their resource use and allocation decision. Although ten enterprises were included in the model, only two of the enterprises ten enterprises enter the optimal plan. The enterprises are the sole cowpea and maize/sorghum.

The feature of the optimal farm plan in Table 2 shows only two out of the enterprises entered the optimal plan. The recommended enterprises are sole cowpea and maize/sorghum enterprises. For sole cowpea the existing plan allocated 0.81 hectares while the optimal plan obtained from the programming output recommends 0.25 hectares, consequently, for maize/sorghum enterprises, the existing plan allocated 1.03 hectares while the optimal plan recommends 0.951 hectares. This finding agrees with that of Maurice, (2012),

The optimal farm plan recommends that peri-urban farmers should allocate their resources in such a way that the two crops enterprises are produced according to these hectares allocation to maximize total Gross Margin of ₦49, 423.718 per hectares. Therefore the resources allocation patterns shows that the sole cowpea and maize/sorghum enterprises are the dominants enterprises. The excluded food crops enterprises or the non-basic activities are Sole Groundnut, Cassava/Maize, Sole Rice, Sole Sorghum, Millet/Sorghum, Sole Maize, Maize/Cowpea/Sorghum and Sorghum/Groundnut/Millet. The marginal opportunity cost or income penalties for including any of the non-basic activities in the optimal plan are presented in Table 2.

MPC are marginal returns to investments of available resources. In a maximization problem, they are income penalties; indicating the amount by which farm income would be reduced if any of the excluded activities is forced into the programme. Olayemi *et* al., (1999), had earlier reported that any resource that is abundant, that is not used up by a programme, is not a limiting resource and has a zero MPC as it does not constrain the attainment of a programme's objective and vice versa. Usually however, only the excluded activities have positive shadow prices. For the included activities, MPC was zero. The higher the MPC of an excluded activity, the lower is its chance of being included in the final plan. The MPC of excluded activities obtained as by-products of the linear programme solution for peri-urban for the sampled farmers are presented in Table 2. Results in the table indicate the amount by which farm gross income would be reduced if any of the activities appearing in the table is forced into the programme.

Table 2 Basic Cropping Activities and their hectares Allocation in the optimal plan.

Basic activity	Basic solution (ha)	MPC
Sole Cowpea	0.247	0.000
Maize/Sorghum	0.95	0.000
Excluded Activities		
Sole Groundnut	0.00	49, 636.27
Cassava/Maize	0.00	40, 760.12
Sole Rice	0.00	59.83
Sole Sorghum	0.00	18,783
Millet/Sorghum	0.00	8,079.14
Sole Maize	0.00	28,578
Maize/Cowpea/Sorghum	0.00	21, 315.61
Sorghum/Groundnut/Millet	0.00	5,947.13
Maximized objective	(Programme value)	₦49,423.718

Source: Linear Programming output MPC= Marginal opportunity cost (reduce cost)

Resources Allocation and Use pattern

The resources included in the model include land size, inorganic fertilizer, seeds, agrochemicals, family labour and hired labour. The pattern of the usage is presented in the Table 3. The pattern of resource utilization that led to optimal plan shows that only two resources constraint were fully utilized in arriving at the optimal solution. The resources are land size and agrochemicals, and their shadow prices were ₦17, 511.21 and ₦5, 810.02 respectively. The land resource is fully exhausted; an additional hectare for production would increase the farm gross margin by ₦17, 511.21, as shadow price by which the total gross margin would be increased if one more unit of land is brought into the production (Kay *et al.*, 2008). Similarly, one litre increase in agrochemicals would increase farm gross margin by ₦5, 810.0.

The non-fully utilized resources as shown on table 3 include inorganic fertilizer (102.9kg) and seeds (19.2 kg) family labour (14.5 man days) and hired labour (16.03 man days). This implies that given the optimal plan, these resources are not a constraint to food crops production in the study area. Indicating that there resources are inefficiently utilized by peri-urban farmers in the study area. This finding is in consistent with earlier studies conducted by Tanko *et al.,* (2011) and Igwe *et al.,* (2011) who reported resources misallocation among farmers in Nigeria.

Table 3 Resources Allocation and Use pattern

Resource(constraints)	Use status	Slack	Dual (Shadow) Price
Land size(ha)	Fully utilized	0.00	17,511.95
Inorganic fertilizer(kg)	Not fully utilized	102.99	0.000
Seeds(kg)	Not fully utilized	19.16	0.000
Agrochemicals(litres)	Fully utilized	0.00	58,10.02
Family labour(man days)	Not fully utilized	12.45	0.000
Hired labour(man days)	Not fully utilized	16.03	0.000

Source: Linear Programming output.

Conclusion

The optimal farm plan generated by the linear programming output for maximizing total gross margin(TGM) recommends two enterprises namely, sole cowpea (0.25 Ha) and maize sorghum(0.95 Ha). The maximized total gross margin is ₦49, 423.718 from the average farm size of 1.18ha. The non-basic activities include sole maize, Sorghum/cowpea, Sole rice, Sole Sorghum, maize/cowpea, Maize/rice, Maize/cowpea/sorghum and maize/rice/sorghum. When one hectare of the non-basic activities is forced into the plan, the optimal cost of production will increase by the margin equal the marginal productivity cost value. Only two constraints were fully utilized in arriving at the optimal solution. These are farm size (ha) and agrochemicals (litres). There shadow prices are ₦17, 511.96 and ₦5, 810.02 respectively. The non-fully utilized resources include inorganic fertilizer (103 kg), seeds (19.2 kg), family labour (12.5 man days) hired and labour (16.03 man days). Indicating that there resources are inefficiently utilized by peri-urban farmers in the study area. The optimal farm plan recommends that peri-urban farmers should allocate their resources in such a way that the two crops enterprises are produced according to these hectares allocation to maximize total Gross Margin of ₦49, 423.718 per hectares. Land is a limiting factor in the peri-urban areas; therefore government policy should concentrate on addressing this issue by allocating some portion of peri urban lands for permanent farming purposes.

References

Adebayo, A.A (1999). Climate I and II. *Adamawa State in Maps.* (eds) Paraclete publisher, Yola, Nigeria. PP 20-26

Adejobi A.O, P.M Komawa, V.M Manyong, J.K Olayemi. (2004). Optimal crop combinations under limited resource use: Application of Linear Goal Programming model to small holder farmers in the drier savannah zone of Nigeria. *Journal of Technol Inst Inno Sust Rur Developt,* 17(1): 8 -10

Adeoti, A.I. Olayemi, J.K. and Awoyemi, T.T. (2008). Optimal plans for Fadama farming in the derived savavanah zone of Nigeria: Application of dynamic programming. Tropical and Subtropical Agro ecosystems 8(1):37-44,

Adewumi, M.O. A (2002). Multiobjective Approach to Small Scale Farm Planning in Kwara State, Nigeria. Unpublished Ph.D Thesis University of Ilorin, Nigeria,

Aromolaran, A.B.(1992). Multiobjective and Resource Allocation Behavior of Small farmers in Ifedapo Area of Oyo State, Nigeria. Unpublished Ph.D Thesis Department of Agricultural Economics University of Ibadan, Nigeria.

Alabdulkader A.M., Al-Amoud A.I., Awad F.S. (2012) Optimization of the Cropping Pattern in Saudi Arabia Using a Mathematical Programming Sector Model. *Agric. Econ.-Czech,* 58: 56-60

Boehlje M.D., Eidman V.R. (1984). Farm Management. John Wiley and Sons, Pp 806.

Egziabher, A. G., Lee-Smith, D., Maxwell, D. G., Memon, P. A., Mougeot, L. and Sawio, C. (1994). Cities Feeding People: An Examination of Urban Agriculture in East Africa, *International Development Research Centre*, Ottawa.

Etim, N.A and G.E. Edet, (2007). Determinants of Poverty among Peri- Urban Farming Households in Uyo Nigeria. *Nigerian Journal of Agric. Food Environ,* 5: 39–43

Haddad, L., Ruel, M., and Garrett, J. (1999) 'Are urban poverty and under nutrition growing? Some newly assembled evidence', World Development 27 (11)

Hazell, P.B.R, Norton, R.D. (1986) Mathematical Programming for Economic Analysis in Agriculture. New York, Macmillon, p.400

Hazell, P.B.R. (1971). "A Linear Alternative to Quadratic and Semi Variance Programming for Farm Planning Under Uncertainty" *American Journal of Agricultural Economics* Vol. 53, 53-62.

Ibrahim, H. and Omotesho, A.O. (2009). An assessment of the sustainability of vegetable production under *Fadama* in the northern guinea savannah zone of Nigeria. *Electronic Journal of Environment Agriculture and Food Chemistry* 8 (11):1156-1163.

Igwe K.C, Onyenweaku C.E, Nwaru J.C. (2011). Application of Linear Programming to Semi- Commercial Arable and Fishery Enterprises in Abia State, Nigeria. Management

Kay D. R., Edwards M. W., Duffy A. P. (2008) Farm management. McGraw-Hill Companies, New York.

Kebede E., Gan J. (1999): The Economic Potential of Vegetable Production for Limited Resource Farmers in South Central Alabama. *Journal of Agribusiness 17, 1: 63-75*

Kennedy, G (2003): Food security in the context of urban Sub-saharan Africa. Food Africa Internet Forum

Lee S.M., Olson D.L. (2006). Introduction to Management Science. Cengage Learning Custom Publishing.

Lynch, K. Binns, T. and Olofin, E. A. (2001). Urban agriculture under threat: the land security question in Kano, Nigeria. Cities 18:159– 71

Majewski E. Was A. (2005). Optimal Structure of Farm in a Region –A Modeling Approach. 99th *EAAE Seminar*, Copenhagen

Maurice, D.C (2012). Optimal Production Plan and Resource Allocation in food crop production in Adamawa State, Nigeria. Unpublished Ph.D thesis Modibbo Adama University of Technology Yola, Nigeria.

Mougeot, L. (1999). Urban Agriculture: Definition, Presence, Potential and Risks, Main Policy Challenges. Report submitted for presentation at *International Workshop on Growing Cities, Growing Food,* La Habana, Cuba.

Mougeot, L. J. A. (ed.) (2005). AGROPOLIS: The Social, Political and Environmental Dimensions of Urban Agriculture. Earthscan, London.

National Population Commission (NPC), (2006). *Population Census of the Federal Republic of Nigeria*. Analytical Report at the National Level, National Population Commission, Abuja

Olayemi, J. K. and C. E. Onyenweaku (1999). Quantitative Methods for Business Decisions. Bosude Printers Limited, Ibadan, Nigeria. p 346

Scarpari .M. S. Beauclair E.F. (2010). Optimized Agricultural Planning of Sugarcane using Linear Programming. *Revista Investigacion Operacional*, Vol. 31, No. 2: 126-132

Tanko, L. Baba, K.M and Adeniyi, O.B (2011). Analysis of Competiveness of mono-cropping and mixed crop enterprises in farming system of smallholders' farmers in Niger state, Nigeria. *International Journal of Agric Sciences* 1(6). 344-355

Tauer, L.W. (1983): "Target MOTAD", *American Journal of Agricultural Economics* 65:607-610 August 1983.

Turner J., Taylor M. (2003). Applied Farm Management. Blackwell Publishing, BSP Professional Books.

Zgajnar J. (2007) Optimization of Production Activities on Individual Agricultural Holdings in the Frame of Different Direct Payments Options. *Acta agriculturae Slovenica, 90: 45-56*