



Original Contribution

OPTIMAL FARM PLAN FOR VEGETABLE PRODUCTION UNDER FADAMA IN NORTH CENTRAL NIGERIA

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ABSTRACT

This study determined an optimal enterprise combination for vegetable production under Fadama in north central Nigeria. The model considered both economic and environmental goals simultaneously in a composite objective function. The optimal farm plan gave a programme value of ₦ 41802.8 as the total variable cost of production and recommended the production of only four out of the nine cropping enterprises included in the model. These enterprises are the Sole Onion, Sole Tomato, Sweet pepper/Tomato and Hot pepper/Tomato enterprises. However, an additional 0.22 hectares of land was used by the optimal plan in addition to the 0.74 hectares available. The optimal plan achieved 88 percent of the goals considered. The study concludes that an expansion of the land area for crop production under *Fadama* is critical to an improvement in the sustainability of vegetable production in north central Nigeria. Furthermore, the inclusion of environmental goals or considerations in farm decision making by *Fadama* farmers is not necessarily antagonistic to their profit maximization objective. The formulation of policies that would encourage land consolidation in the *Fadama* communities will be vital in enhancing the sustainability of crop production under *Fadama*.

Key words: Sustainability, economic goal, environmental goals, programming, soil, Indicators, Nigeria

INTRODUCTION

The production of vegetables is an important component of the farming systems of the northern states of Nigeria where irrigation is practiced. This is because; it is a very lucrative economic activity due to the availability of markets in the vicinity of the production areas and in the southern states where there is high demand for them (1). In Nigeria, the bulk of the Vegetables are produced under *Fadama* by small holders who cultivate small plots and use low input technology. A *Fadama* is a wetland or the seasonally flooded or floodable plains along major savanna rivers and / or depressions on the adjacent low terraces.

A sustainable production of vegetables to meet the demands of an ever increasing population in the country is of great concern (2). This is

because, the domestic demand for them is met essentially from local production, and the importation of fresh vegetables into Nigeria is uncommon. In addition, a study by (3) observed that the current system of vegetable production under *Fadama* in north central Nigeria was not sustainable. Based on the foregoing, this study aims to use the linear goal programming technique to develop an optimal farm plan which can serve as a guide for resource allocation by *Fadama* farmers in order to sustain or maintain the self reliance in vegetable production that Nigeria currently enjoys. Optimum farm production eliminates inefficiency in resource use, and guarantees food availability (4).

Previous studies by (5, 6, 7 and 8) have integrated diverse goals within Linear Programming models for farm planning, but applications involving environmental variables within the multi criteria decision making frame work in Nigeria are not common. The importance of including environmental variables in farm planning is very important in public and private decision making and cannot

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be overemphasised. This study is therefore an obvious departure from the previous applications of the mathematical programming technique in Nigeria.

MATERIALS AND METHODS

The study was conducted in Kaduna state located in north central Nigeria. The state is located on the southern end of the High Plain of Nigeria, bounded by parallel $9^{\circ}03'N$ and $11^{\circ}32'N$, and extends from the upper River Mariga on $6^{\circ}05'E$ to $8^{\circ}48'E$. From the 1,939 registered *Fadama* farmers producing tomato, onion and pepper in four Local Government Areas noted for intensive production of vegetables, a proportionality factor was used to select 200 *Fadama* farmers for the study using simple random sampling. However, information from only 192 *Fadama* farmers was found useful. The proportionality factor is specified as follows,

$$n = nL/NL * 200 \dots\dots\dots 1.$$

where,

n = sample size per local government

nL = number of *Fadama* Users Groups members per local government

NL = Total number of *Fadama* Users Groups members

Data on inputs and outputs as well as their market prices were also collected. Surface soil samples (0-15cm) were collected with an auger. Eight composite samples were collected from each cropping system and bulked to produce one sample per cropping system. The samples were air-dried and sieved with a 2 mm sieve for analysis. The soil samples were analyzed for the following, soil pH, Nitrogen, Phosphorus and Organic Matter content of the soil. These were chosen based on the recommended environmental and economic variables for monitoring and schedules under the *Fadama* II project (9). Data analysis was done using a linear goal programming model, Net farm income and descriptive statistics.

The Goal Programming (GP) model was chosen because it is an efficient tool for integrating agro ecological (environmental) and socio economic information and to explore possibilities for a sustainable agriculture (10). GP dates back to the seminal work of (11). Its application has since become popular for tackling multi objective problems. This study utilized Weighted Goal Programming because

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it requires less time and data and considers all goals simultaneously in a composite objective function. In mathematical terms, the model may be represented as follows as adapted from (12) and modified.

$$\text{Minimize } Z_1 = \sum_{i=1}^g (\alpha_i \cdot n_i + \alpha_i \cdot p_i) \dots\dots\dots 2$$

$$\text{Subject to} \\ \sum_{j=1}^g A_{ij} X_j + n_i - p_i = a_i \dots\dots\dots 3$$

$$\sum_{k=1}^m A_{kj} X_j \leq b_k \dots\dots\dots 4$$

$j=1$
 $X_j, n_i, p_i \geq 0$ for all j and i
 Where,

Z_1 = Function of objectives that includes the total cost of production per hectare of each crop enterprise as well as the positive and negative deviations for the goals respectively (12 and 7).

n_i = negative deviation if a_i under achieved,

p_i = positive deviation if a_i is over achieved

α_i = weight or relative importance attached to deviation n_i and p_i

A_{ij} = matrix of a_{ij}

a_{ij} = marginal contribution of x_j for achieving goal a_i

a_i = aspiration or threshold level for the i th goal

X_j = j th crop production activity

A_{kj} = coefficient of the use of b_k for the j th crop production activity

b_k = level of the k th resource available

m = number of resources

g = number of goals

$$n_i * p_i = 0$$

The condition ($n_i * p_i = 0$) implies that the product of the deviations must equal zero for any goal. Thus, there cannot be both over and under achievement of a goal simultaneously. Two sets of goal were considered. These were the economic and environmental goals. A total

of nine goals (five economic and four environmental) were identified (**Table 1**). The threshold level determined for each goal

(**Table 2 and 3**) was the target or aspiration level (a_i) respectively in the goal programming Model.

Table 1. Structure of the objective function of the weighted goal programming model

Goal	Goal statement Achievement of	Objective function to minimise	Deviation variable in objective function	Priority Level	Weight
Maximise the yield of tomato	Achievement of the potential crop yield per hectare	Under achievement	n^-	1	5
Maximised the yield of onion	Achievement of the potential crop yield per hectare	Under achievement	n^-	1	5
Maximised the yield of Hot and sweet pepper	Achievement of the potential crop yield per hectare	Under achievement	n^-	1	5
Stabilise farm income	Achievement of desired income level	Under achievement	n^-	1	5
Maintain soil health and Reduce environmental impacts	Maintain acceptable levels of; Organic Matter,	Under achievement	n_i	1	5
	Nitrogen and	Over achievement	p_i	1	5
	Phosphorous in the soil	Over achievement	p_i	1	5
Improve soil PH	Maintain acceptable soil PH level	Neither under nor over achievement	$p_i * n^-$	1	0

Table 2. Thresholds for the environmental goals

Indicators	Unit	Threshold level
PH	nil	6.5 - most crops do well within a range of 6-7.
Nitrogen	gkg^{-1}	3- a value above 3 is very high and can lead to an extension of the vegetative growth of crops .
Phosphorus	$mgkg^{-1}$	20 - any value above 20 is high and can lead to a reduction in crop yield.
Organic Carbon	gkg^{-1}	68.8 - any value above this limit is considered very high and Nitrogen mineralization is reduced.

Table 3. Thresholds for the economic goals

Indicator	Unit	Threshold level
Yield	Kg	Potential yield in kg per hectare (CAYS, 1999)
Farm Income	₦	5 % better than the average Net Farm Income among the sampled Fadama farmers.

The objective function was to minimize the positive (p_i) and negative (n_i) deviations attached to the goals. A weight of equal

importance was attached to all the goals because each one of them is considered very important for the sustainability of vegetable

production system. A weight of zero was attached to the pH goal due to the condition ($n_i * p_i = 0$) earlier specified.

RESULTS AND DISCUSSION

Cropping enterprises among the *Fadama* farmers

The vegetable production systems obtainable in the study area were identified and the result is presented in **Table 4**. The result shows that both sole and mix vegetable cropping systems are practiced by the *Fadama* farmers in the study area. In terms of land area cultivated, about 51 % of the total *Fadama* land cultivated was devoted to sole vegetable enterprises. The mix cropping enterprises occupy the remaining 49%. The commonest mixtures include; Tomato/Onion, Sweet Pepper/Tomato, Hot Pepper/Tomato, Sweet Pepper/Onion and the Hot Pepper/Onion enterprises. The

Onion/Tomato/Pepper enterprises is the least in terms of both the percentage of total *Fadama* land area cultivated (2 %) and the numbers of *Fadama* plots cultivated. In addition, majority of the *Fadama* plots (30 %) were planted with Tomato as a sole crop. The largest percentage area of the total *Fadama* land cultivated (25.5 %) was devoted to the cultivation of Tomato/Onion enterprise. In terms of both land area cultivated and the number of *Fadama* plots cultivated, the sole Tomato, Tomato/Onion and the sole Onion enterprises are the important enterprises for vegetable production in the study area. This implies that Tomato and Onion are very important vegetable in the study area. The pattern of land allocation observed may not be unconnected to the returns /earnings from the respective vegetable enterprises.

Table 4. Enterprise combinations for vegetable production

Crop combination	No. of plots	Total Area cultivated (ha)	% of Total area cultivated
Tomato/Onion	30	46.4	25.5
sole Tomato	53	43.2	23.8
Sole Onion	44	27.95	15.40
Sole Sweet pepper	24	13.15	7.2
Sweet Pepper/Onion	10	11.7	6.4
Sweet Pepper/Tomato	25	9.31	5.0
Sole Hot Pepper	19	9.07	5.0
Hot Pepper/Onion	17	8.9	5.0
Hot Pepper/tomato	13	8.58	4.7
Onion/Tomato/Pepper*	7	3.2	2.0
Total	242**	181.46	100

* Both sweet and hot pepper

** Some *Fadama* farmers have more than one plot

Fertility status of *Fadama* soils in the study area

The result of the soil analysis conducted is presented in **Table 5**. The organic matter content of the soil was medium, while the phosphorous content was high. The total N status of the soil however was very low. This

result corroborates earlier reports (13) that tropical soils are intrinsically low in N. The PH of the soil on the other hand was within an acceptable limit suitable for crop growth. Using these soil properties as fertility indices, it is evident that the *Fadama* soils in the state were generally low in fertility.

Table 5. Some properties of *Fadama* soils

	Indices			
	Organic Matter (g kg ⁻¹)	Nitrogen (g kg ⁻¹)	Phosphorus (mg kg ⁻¹)	PH
Range	8.56-12.57	0.35-0.70	18-37	6-6.7
Mean	11.77	0.48	27	6.25

Optimal farm plan for vegetable production

The optimal farm plan was generated using the goal programming model. Although ten cropping systems were identified in the study area, only nine of the enterprises were included

in the model. The Onion/Tomato/Pepper enterprise was not included because less than 5% of the respondents practice it. The vegetable production activities that entered the optimal plan are presented in **Table 6**.

Table 6. Basic cropping activities and their hectare allocations in the optimal plan

Basic Activity	Hectareage (ha)
Sole Onion	0.06
Sole Tomato	0.37
Sweet Pepper/Tomato	0.16
Hot pepper/Tomato	0.37
Value of Programme ₦ 41802.8	

The feature of the optimal farm plan in **Table 6** shows that only four out of the nine cropping enterprises entered the optimal plan. The enterprises are the Sole Onion, Sole Tomato, Tomato/Onion, Sweet pepper/Tomato and Hot pepper/Tomato enterprises. A programme value of ₦41802.80 was obtained. This implies that a representative *Fadama* farmer will incur a total variable cost of ₦41802.80 if they allocate their resources according to the hectareage allocations suggested by the optimal goal programming model. The recommended allocation pattern shows that the Sole Tomato and the Hot pepper/Tomato enterprises are the

dominant enterprises and both accounted for about 76% of the land area in the optimal plan. This was followed by the Sweet pepper /Tomato enterprise which accounts for only 17% of the land area. A striking feature of the optimal plan is the emergence of some of the dominant enterprises (Sole Tomato and Sole Onion enterprises) in the unplanned farm.

The excluded vegetable enterprises or the non basic activities are, Sole Hot Pepper, Sole Sweet Pepper, Tomato/Onion, Sweet pepper/Onion, and the Hot Pepper/Onion. The opportunity costs or penalties for including any of the non basic activities in the optimal plan are presented in **Table 7**.

Table 7. Opportunity cost of non basic activities

Excluded activities	Opportunity cost- ₦
Sole Hot Pepper	17606
Sole Sweet Pepper	90405
Tomato/Onion	14089
Sweet pepper/Onion	70973
Hot Pepper/Onion	14082

The opportunity costs for of the non basic activity implies that the optimal cost of production will increase by an amount equal to the opportunity costs for each non basic activity if it is forced into the plan. The activity with the highest penalty was the Sole Sweet Pepper enterprise, while that with the

least penalty was the Hot Pepper/Onion enterprise.

Resource allocation and use pattern

The resources included in the model include, Land, Labour, Urea and N.P.K fertilizer, Agro-chemicals and Seeds. The pattern of their usage is presented in **Table 8**.

Table 8. Resource utilization patterns

Resources	Status	Slack/surplus	Shadow price
Land	tight	0.22	0
Labour	loose	0	491.60
Urea fertilizer	loose	53.1	0
N.P.K fertilizer	loose	67	0
Insecticides	tight	0	1022
Onion seeds	tight	0	586
Tomato seeds	loose	.0001	0
Pepper seeds (Hot)	loose	.0003	0
Pepper seeds (Sweet)	loose	0.498	0

The pattern of resource utilization that led to the optimal plant shows that only three resources were fully utilized. These resources are, Insecticides, Onion seeds and land. Their shadow prices are essentially their real cost. Thus, the real cost of insecticides in the study area was ₦1022 while that of Onion seed was ₦586. In addition the programme value will decrease by ₦1022 and ₦586 if additional units of insecticides and onion seeds are used respectively. The non-fully utilized resources on the other hand include Labour, Urea fertilizer, N.P.K fertilizer, Tomato and Sweet/Hot Pepper seeds. This implies that given the optimal plan, these resources are not a constraint to vegetable production in the study area. An additional 0.22 hectares of land was used by the optimal plan in addition to the 0.74 hectares available. A similar finding was also made by (8). However, due to mounting demographic pressures, and the complicated

tenural arrangements in *Fadama* communities, the increase in the size of *Fadama* lands may not be feasible. Therefore, alternative farming systems/practices that can help improve the productivity of *Fadama* lands have to be introduced in the *Fadama* communities.

Extent of goal attainment by *Fadama* farmers

The G.P model utilized for this sought to identify feasible levels of attainments and probably compromises among goals. This is because according to (14), the G.P technique operationalises the simonian “satisficing” approach to the achievement of decision makers’ objectives (15). For example, if a decision maker sets targets for achievement, an acceptable solution is found by minimizing the deviations from the sets of targets. From **Table 9**, about eighty eight percent of the goals specified were fully achieved.

Table 9. Goal achievement by *Fadama* farmers

Goals	Target	Underachievement	Overachievement
Income Goal	₦ 61492.09	₦ 20876	0
Yield Goal (Onion)	12500 kg	0	12293
Yield Goal (Tomato)	12000 kg	0	9851
Yield Goal (Hot Pepper) Yield	2250 kg 2500	0	1930
Goal (Sweet pepper) Organic	kg 68.8 g kg ⁻¹	0	2430
Matter Goal	3.0	0	58.72
Nitrogen Goal	20 mg kg ⁻¹	0	2.54
Phosphorous Goal	6.5	0	3.13
PH Goal		0	0

The economic goals for the yields of Onion, Tomato, Hot and Sweet pepper were overachieved while the income goal was underachieved. The level of it’s under achievement however was by about 34 percent from the target. This deviation may not affect the *Fadama* farmer adversely because the income goal complimented the attainment of

other goals in the model. In GP, especially when the WGP formulation of the GP technique is utilized short run profit could be traded for the attainment of other goals (16). In this respect, the result of the WGP model is realistic considering the fact that conflicting goal that are and in different dimensions are incorporated in the model. In addition, this

finding imply that the inclusion of environmental goals or considerations in farm decision making by *Fadama* farmers is not necessarily antagonistic to the profit maximization objective of an average *Fadama* farmer in the study area. For the environmental goals, the PH goal was fully achieved, while the Nitrogen, Phosphorous and Organic matter goals were overachieved.

It therefore implies that if *Fadama* farmers adopt the recommendations of the optimal solution, the production goals of *Fadama* farmers in the study area could be achieved. Most importantly, the optimal plan will enhance the performance of the current system of vegetable production through improvement in the productive potentials of the system.

CONCLUSION

An expansion of the land area for crop production under *Fadama* is critical to an improvement in the sustainability of vegetable production in north central Nigeria. Furthermore, the inclusion of environmental goals or considerations in farm decision making by *Fadama* farmers is not necessarily antagonistic to their profit maximization objective. The introduction of participatory soil improvement strategies such as integrated soil fertility management and the formulation of policies that would encourage land consolidation in the *Fadama* communities are hereby recommended.

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