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Linear Programming Approach to Combination of Food Crop Enterprises among Gender Fadama III Beneficiaries in Adamawa State, Nigeria

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Abstract:
Linear programming approach was used to analyse combination of food crop enterprises among gender in Fadama III beneficiaries in Adamawa State, Nigeria. Using multistage random sampling procedure, 278 respondents were selected. Analytical techniques used were simple descriptive statistics and Linear Programming techniques. Mean age for the male and female respondents were 40 and 41 years respectively. Respective mean farm sizes of the male and female respondents were 1.89 and 1.39 hectares. The result also reveals that 52% male respondents acquired their land through family inheritance and 42% through leaseholds while majority (85.3%) of the female respondents acquired their land through leaseholds. The acquisition of farm lands through inheritance favoured more male respondents (52%) than their female counterparts (11.6%). The implication of this is that gender disparity in terms of land acquisition was prevalent in the study area and this will limit the productivity of the female fadama crop farmers. Nine crop combination patterns or enterprises were identified to include sole maize, sole rice, sole sorghum, maize/rice, rice/sorghum, maize/sorghum, maize/rice/sorghum, maize/vegetables and maize/rice/vegetables. Theresult on the resource utilization pattern for male farmers showed that four of the resource constraints were fully utilized in arriving at the optimal solution. These are labour, agro-chemicals, inorganic fertilizer and seeds. The dual (shadow) prices of the fully utilized resources indicate the amount by which the objective function will increase if these inputs are increased by one unit. That is, total gross margin will increase by ₦369.32, ₦3384.95, ₦200.31 and ₦864.91 for one-man day increase in labour, one litre increase in agro-chemicals, one-kilogram increase in inorganic fertilizer and one kilogram increase in seed respectively. Similarly, for the female farmers, resource utilization pattern also showed three of the resource constraints were fully utilized in arriving at the optimal solution. These inputs are labour, agro-chemicals and inorganic fertilizer. This also means that total gross margin will increase by ₦65.57, ₦3671.84 and ₦279.27 for one-man day increase in labour, one litre increase in agro-chemicals and one kilogram increase in inorganic fertilizer respectively. The non fully utilized resources among the male farmers was land (452.72 ha) while the non fully utilized resources among the female farmers were land (183.83 ha) and seeds (1,016.02 kg), indicating that these resources were in-efficiently utilized by the male and female fadama crop farmers in the study area. The study recommended that a prototype combination of crop enterprises that emanated from the linear programming should be integrated into the extension education package of the male and female fadama farmers to enable them improve on their farm income.

Keywords: *Linear programming, Crop Enterprises, Gender, Fadama III.*

1. Introduction

Gender is simply the social and cultural definition of being a male or a female and this influences the society's values, expectations, opportunities, resources and assets available to men and women (Adebayo and Anyanwu 2011). Attention to gender in agriculture is not new, but in the past it has often been limited to a few specialized programs targeting women or "mainstreaming" efforts that gave attention to gender within programs (Meinzen-Dick *et al.,* 2012). A number of key development agencies and donors are drawing on gender analysis in their programming, targeting by gender, and building in accountability. A common assumption is that gender analysis focuses only on the status of women in the society. While it gives us insight into issues affecting women, it is focused mainly on the relationship of both men and women to the social and economic structure of a society. Gender analysis is not necessarily about developing programmes for women, although it makes it possible for more to be learnt about the particular issues affecting women. It

is therefore a tool for understanding and for learning more about the activities being done by men and women in society and the problems and opportunities that each face in doing those activities (Omotosho *et al.,*2000).

The concern about the threat posed by poverty has led the Nigerian government to devote considerable attention to alleviating its scourge through various agricultural aid programmes, some in cooperation with civil society and donor agencies. The Federal Government of Nigeria in its deliberate efforts to reduce poverty among rural farmers established the National Fadama Development Project which were implemented in phases called Fadama I, Fadama II and Fadama III projects. 'Fadama' is a *Hausa* name for irrigable land or low lying areas and flood plains underlain by shallow aquifers found along Nigeria's major river systems. Food crops are grown in both rainy and dry seasons within the *fadama* lands by both men and women. While the First National Fadama Development Project (NFDP I) was implemented from 1992-1999 with emphasis on providing tube wells and water pumps to crop farmers through simple credit arrangements aimed at boosting cumulative crop output and used the top-down approach (Nkonya *et al.*, 2008), Fadama II was prepared from 2004 -2009 using Community Driven Approach (CDD) to correct the design shortcomings of *Fadama I* such as paying attention to downstream activities like marketing, processing and infrastructure development, ensuring the participation of all stakeholders at the Federal, State and Local Governments as well as of the ultimate participating *fadama* users. The successful implementation of *Fadama II* project in twelve States of the federation encouraged the Federal Government to expand the scope of the project to cover all the States including the FCT and this metamorphosed into the third phase of the project called *Fadama III.*

Fadama III project came from 2009 -2013, with the objective of increasing the income of users of rural land and water resources on a sustainable basis. The approach is the same with *Fadama II* except for the significant introduction of the support to Agricultural Development Project (ADP) components to carry out specific functions, and the introduction of Fadama user equity fund (FUEF) where the FUGs set aside funds that will constitute capitalization/revolving fund under the project. The recovered amount will remain as financial capital circulating in the community, or may take the form of physical capital depending on the investment decision made by the FUGs which will constitute the basis for the development of sustainable savings and loan schemes (Project Implementation Manual, 2009). Based on the CDD approach, project activities were centered on Fadama User Groups (FUGs) and Fadama Community Associations (FCAs). Each FCA designs and oversees the implementation of a Local Development Plan, which is the blueprint of the development project in that FCA. Because the project uses the CDD approach, beneficiaries were given the chance to choose the kind of activities they want to pursue. This strategy has gained acceptance because of its capacity to develop programs and projects that are capable of empowering the local communities to manage their development agenda, to conform to local demand, and focus on poor and vulnerable groups (Dongier *et al.*, 2001; Gillespie, 2004).

According to Hassan *et al.* (2005) in Igwe *et al.* (2013) farmers' profit cannot be maximized without optimum cropping patterns, which ensure efficient utilization of available resources; and so the use of Linear Programming makes it possible to devise equilibrium solution, which include the specification of products levels, factor and product prices. Studies in optimum resource allocation using LP approaches have largely been attempted in many countries (Tanko *et al.,* 2006). It is the simplest and the most common mathematical programming model and it involves 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. Linear programming technique bridges the gap between abstract economic theories and managerial decision-making, and any linear programming equation should have three specifications, namely: objective function, constraint equation, and non-negativity requirement.

The challenge to improve on the contribution of fadama food crop farmers to Nigeria economy makes this study a necessary one. Therefore, the male and female farmers who are making great effort to optimize their objective function subject to their resource constraints has led to the following research questions:

i. What are the socio-economic characteristics of the male and female fadama farmers?
ii. What is the level of resource allocation for optimal production of the male and female fadama farmers?
iii. What are the constraints faced by the male and female fadama crop farmers?

The broad objective of the study was to use linear programming approach to combination of food crop enterprises among gender fadama III beneficiaries in Adamawa State of Nigeria. The specific objectives are to:

i. describe the socio economic characteristics of fadama food crop farmers in the study area
ii. determine the optimal production level of resource allocation by male and female fadama food crop farmers and;
iii. identify production constraints associated with male and female fadama food crop farmers in the study area.

2. Methodology

2.1. The Study Area

The study was carried out in Adamawa State of Nigeria. The State was created out of the former Gongola State in 1991. It has a land area of about 38,741 square kilometres with a current projected population of about 2.8 million people from 1991 census using annual estimated population growth rate of 2.8 percent (Adebayo, 1999a). It lies between latitudes 7^0 and 11^0 N of the equator and between longitudes 11^0 and 14^0 E of the Greenwich meridian. The State is bounded to the north by Borno State, to the south by Taraba State, and to the north west by Gombe State. It also has an international boundary with the Republic of Cameroon along its eastern border. The State has four agricultural zones base on soil, climate and vegetation. The climate is tropical and is characterized by distinct wet and dry seasons. Mean monthly temperatures ranges from 26.7 ^{0}C in the south to 27.8 ^{0}C in the north eastern part of the state. The mean annual rainfall ranges from 700mm in the north western part of the state. On the other hand, the north eastern strip and the

southern part have over 1,000 mm (Adebayo, 1999b). The major food crops grown in the State are cereals, legumes and root crops, while cash crops are mainly groundnuts, cotton and sugarcane.

2.2. Study Population and Sampling Technique

Multi-stage sampling procedure was employed in the selection of respondents. First stage sampling involved the random selection of 10 out of 20 Local Government Areas. In the second stage, a random selection of 49 and 26 out of a population of 192 and 84 male and female Fadama User Groups respectively was done based on proportionality factor. Finally, four farmers were randomly selected from each of the male and female FUGs to give 196 male farmers and 104 female farmers. This gave a total sample size of 300 farmers. The total number of questionnaires returned from the field was 278 out of 300 administered.

2.3. Data Collection

Data was obtained from both primary and secondary sources. The primary data was collected through administration of questionnaires to sampled food crop farmers of Fadama III beneficiaries in the study area. The services of trained facilitators and extension agents of the Agricultural Development projects were employed to administer the questionnaires.

2.4. Analytical Technique

2.4.1. Descriptive Statistics

This involved the use of means, frequency distribution tables and percentages to examine the socio economic characteristics of the crop farmers and also discuss the constraints associated with food crop production by the farmers.

2.4.2. Inferential Statistics

The linear programming technique was employed to determine the optimal farm plan and resource allocation in food crop production by gender in the study area. The model equation is represented as:

$MaxZ = \sum ajxj$ ..... (3) (3)

Subject to: $bijxj \leq Gi$

and $xi \geq 0$

where $i = 1, 2, 3, \ldots, m$

and $j = 1, 2, 3, \ldots, n$

where:

Z = Net gross margin/ha to be maximized which is the objective function

a_j= Gross margin of the i^{th} enterprise/ha

bij = Input-output coefficients or the quantity of a resource i required to produce a unit of an activity j

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

x_j= Decision variables to be maximized which are the different activities or enterprises.

Input coefficients: This refers to the requirement of a crop activity in respect of the inputs of the different resources measured on per hectare basis. The input coefficients for all the crop enterprises were calculated on the basis of the actual quantities of different resources used for the particular crop enterprise. For instance, the input-output coefficient for hired labour refers to the amount of hired labour in man-days used in producing a hectare of that particular crop enterprise.

Resource constraints/restriction in the model: Six constraints were incorporated in the model. These are land (in hectares), inorganic fertilizer (in kg), seed (in kg), hired labour (in man-days), family labour (in Man-days) and agrochemicals (in litres).

Enterprises/activities in the model: Food crop production was grouped into sole cropping and mixed cropping. For each of the crop production activity, the unit of activity is one hectare.

The linear programming input matrix used for the optimization iteration is given by:

Maximize $a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6 + a_7x_7 + a_8x_8 + a_9x_9$ .....(4)

$a_1 - a_9$ = Corresponding gross margins per hectare for the nine food crop enterprises

Subject to: $b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 + b_8x_8 + b_9x_9 \leq .$ G .....(5)

Where:

- → X_1 = Sole maize enterprise
- → X_2 = Sole rice enterprise
- → X_3 = Sole sorghum enterprise
- → X_4 = Maize/rice enterprise
- → X_5 = Rice/sorghum enterprise
- → X_6 = Maize/sorghum enterprise
- → X_7 = Maize/rice/sorghum enterprise
- → X_8 = Maize/rice/vegetables enterprise
- → X_9 = Maize/vegetables enterprise

b_1–b_9 = Input-output coefficients such as land (in hectares), hired labour in (man-days/ha), inorganic fertilizer (in kg/ha), seed (in kg/ha), family labour (man-days/ha) and agrochemicals (in litres/ha). They were measured in terms of quantity required to produce a hectare of that particular crop enterprise.
G = Total amount of that particular input used in production by the crop farmers.
The linear programming equation for the male respondents is given by:
Maximize $71{,}808.4x_1 + 90{,}960x_2 + 26{,}600x_3 + 76{,}383.8x_4 + 93{,}342.9x_5 + 52{,}817.5x_6 + 88{,}781.1x_7 + 111{,}583.9x_8 + 155{,}940.4x_9$ ....(6)
Subject to:
Land constraint (ha) $1.75x_1 + 0.47x_2 + 0.5x_3 + 2.49x_4 + 0.98x_5 + 1.96x_6 + 3.38x_7 + 3.13x_8 + 4.15x_9 \leq 459$ ....(7)
Labour constraint (md) $61.69x_1 + 271.84x_2 + 147.2x_3 + 40.99x_4 + 52.20x_5 + 52.73x_6 + 49.67x_7 + 51.38x_8 + 178.80x_9 \leq 154.47$ .....(8)
Agrochemicals constraint (lt) $4.35x_1 + 5.6x_2 + 4.0x_3 + 4.11x_4 + 4.13x_5 + 3.85x_6 + 5.23x_7 + 2.44x_8 + 6.67x_9 \leq 10.91$ .....(9)
Fertilizer constraint (kg) $157.14x_1 + 280x_2 + 200x_3 + 154.46x_4 + 219.04x_5 + 156.36x_6 + 179.28x_7 + 199.27x_8 + 255.28x_9 \leq 450.14$ .... (10)
Seed constraint (kg) $19.12x_1 + 48x_2 + 30x_3 + 28.88x_4 + 41.9x_5 + 19.05x_6 + 19.45x_7 + 7.14x_8 + 19.88x_9 \leq 56.77$ ....(11)

Similarly, the linear programming equation for the female respondents is given by:
Maximize:
$57{,}938.5x_1 + 48{,}368.2x_2 + 33{,}600x_3 + 62{,}039.5x_4 + 8{,}236.9x_5 + 69{,}200x_6 + 72{,}547.9x_7 + 85{,}888.9x_8 + 66{,}889.7x_9$ .. ..(12)
Subject to:
Land constraint (ha) $1.08x_1 + 1.22x_2 + 1x_3 + 2.33x_4 + 0.81x_5 + 1.26x_6 + 2.55x_7 + 2.25x_8 + 3.63x_9 \leq 186.25$ .....(13)
Labour constraint (md) $33.25x_1 + 43.7x_2 + 67.25x_3 + 37.84x_4 + 87.88x_5 + 37.62x_6 + 58.46x_7 + 329.44x_8 + 124.5x_9 \leq 114.16$..... ...(14)
Agrochemicals constraint (lt) $3.84x_1 + 4.18x_2 + 5x_3 + 4.13x_4 + 4x_5 + 3.47x_6 + 6.21x_7 + 13.33x_8 + 6x_9 \leq 9.67$ .....(15)
Fertilizer constraint (kg) $130.8x_1 + 195.5x_2 + 150x_3 + 159.1x_4 + 276.9x_5 + 193.33x_6 + 265x_7 + 488.8x_8 + 237.9x_9 \leq 396.9$ .....(16)
Seed constraint (kg) $19.23x_1 + 39.09x_2 + 1x_3 + 27.96x_4 + 51.54x_5 + 29.87x_6 + 30.94x_7 + 36.44x_8 + 19.59x_9 \leq 1089.1$ .....(17)
The SIMPLEX method was used in obtaining the optimal solution and the iteration was done using the linear programming module TOS (TORA Optimization System, version 2.00)

3. Results and Discussions

3.1. Socio-economic Characteristics
The distribution of the socioeconomic characteristics of respondents is presented on Table 1. The age distribution shows that about 45% of the male and 34% of the female fadama crop farmers were between 31-40 years while only about 3% of male and 5% of female respondents were above 60 years of age. The mean age for the male and female respondents was about 40 years and 41 years respectively. This implies that most of the farmers participating in fadama crop production in the study area were within the active age group that provided manpower for agricultural activities. This agrees with the findings of Ajibefun *et al*. (2006) who observed that age has an inverse relationship with productivity of farmers.
The distribution of respondents according to farm size revealed that 30% of male respondents had farm size of less than one hectare as compared to the female respondents (39%) that had farm size of less than one hectare. The result also revealed that about 79% of the male and about 95% of the female respondents cultivated farmlands below three hectares while about 21% of the male and only about 5% of the female respondents cultivated farm lands above three hectares. The mean farm size of the male respondents is 1.89 while that of the female respondents is about 1.39 hectares. This is an indication that fadama crop farmers are small scale farmers which is a general characteristics of subsistence farming as reported by Amujoyegbe and Elemo (2011) that the poor resource small holder farmer cultivates between 0.05 - 3 hectares of farmlands and usually scattered over a wide expanse of land area.
The result also showed that about 52% male respondents acquired their land through family inheritance and 42% through leaseholds while majority (85.3%) of the female respondents acquired their land through leaseholds. The acquisition of farm lands through inheritance favoured more male respondents (52%) than their female counterparts (11.6%) in the study area. The ownership of, or access to agricultural land by farmers could determine to a large extent the scale of farm operations undertaken by them. The implication of this is that gender disparity in terms of land acquisition was prevalent in the study area and this will limit the productivity of the female fadama crop farmers. This agrees with the findings of Amaza *et al*. (2006) who reported that farm size, fertilizer and hired labour were major factors associated with changes in the output of food crops.

In terms of access to extension services, the result reveals that about 88 % male and 83% female respondents had contact with extension agents who are called facilitators under the project to train and provide technical assistance to the beneficiary-communities through access to a diversified menu of farm/enterprise advisory services, including the knowledge, technology, information and guidance with regard to the technical and economic management of specific crop and livestock enterprises.This is an indication that majority of the respondents had contact with project facilitators. The implication is that both the male and female fadama crop farmers had access to proven and relevant agricultural innovations thereby increasing food crop production. This agrees with the findings of Ambali *et al.* (2012) that extension service to farmers is an important incentive in farm production as it aids information dissemination and adoption of innovation thereby increasing food crop production.

The result also showed that 51% of the male and 74.2% of the female respondents got support from Fadama III project. Also 47% of the male and 17.2% of the female respondents depended on their personal savings apart from the support from the project, only 1.7% of the male and 1.6% of the female respondents got loans from the Banks apart from the support from the project to finance production. The dependence of the respondents on the support from the project might be responsible for their involvement in small scale production which is one of the characteristic feature of subsistence farming. Farmers with access to finance tend to be more productive due to enhanced ability to finance mechanization, purchase inputs, and hire labour. The findings agree with Kolawole and Ojo (2007) who reported that one of the constraints faced by farmers in the production process was limited access to funds.

Variable	**Male**		**Female**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Age in years				
≤ 30	24	13.1	17	17.9
31-40	82	44.8	32	33.7
41-50	53	28.9	27	28.4
51-60	18	9.8	14	14.7
61 and above	6	3.4	5	5.3
Total	183	100	95	100
Minimum	24		20	
Maximum	61		66	
Mean	40		41	
Farm size (Ha)				
< 1.0	55	30.0	36	37.8
1.0-2.0	61	33.3	40	42.1
2.1-3.0	28	15.4	24	14.8
3.1-4.0	24	13.1	3	3.2
4.1-5.0	9	4.9	6	2.1
> 5.0	6	3.3	-	-
Total	183	100	95	100
Maximum	6.5		3.0	
Minimum	0.5		0.25	
Mean	1.89		1.39	
Sources of Land Acquisition				
Purchase	13	7.1	3	3.1
Inheritance	95	51.9	11	11.6
Rented/leased	75	42.0	81	85.3
Total	183	100	95	100
Access to Extension Services				
Yes	161	87.9	79	83.2
No	22	12.1	16	16.8
Total	183	100	95	100
Sources of Fund				
Support from fadama	183	51.0	95	74.2
Loan from banks	6	1.7	2	1.6
Personal savings	169	47.0	22	17.2
Friends and relatives	1	0.3	9	7.0
Total	359*	100	128*	100

Table 1: Distribution of Socio-economic Characteristics of Food Crop Farmers
Source: Field Survey, 2014
**Multiple response*

3.2. Linear Programming

The result of Linear Programming technique as applied to the male and female fadama crop farmersis presented in Table 2. Out of the nine basic activities included in the model for the male crop farmers, four activities entered the programme. The four enterprises are rice/sorghum, maize/rice/sorghum, maize/rice/vegetable and maize/vegetable. The existing farm plan allocated 1.0, 3.4, 3.8 and 3.1 hectares respectively while the optimal plan obtained from the programming output recommends 0.7, 1.0, 0.3 and 0.3 hectares respectively. Similarly, for the female farmers, out of the nine basic activities included in the model, three activities entered the programme. The recommended enterprises are sole maize, rice/sorghum and maize/sorghum. The existing farm plan allocated 1.1, 0.8 and 1.3 hectares respectively while the optimal plan obtained from the programming output recommends 0.8, 0.6 and 0.8 hectares respectively.

The optimal farm plan recommends that the male fadama crop farmers should allocate their resources in such a way that the four crop enterprises are produced according to these hectares allocations to maximize total gross margin of ₦233,246.32 while for the female fadama crop farmers, the optimal plan recommends that they should allocate their resources in such a way that the three crop enterprises are produced according to these hectares allocations to maximize total gross margin of ₦153,833.05.

The non basic activities for the male farmers as shown include sole maize, sole rice, sole sorghum, maize/rice, and maize/sorghum while that of the female farmers are sole rice, sole sorghum, maize/rice, maize/rice/sorghum, maize/rive/vegetable and maize/vegetable. The marginal opportunity cost signifies by how much the programme value will decrease if any of the of the non basic activities, which erstwhile did not enter the programme, is forced into the programme. That is, when one hectare of the non basic activities is forced into the plan, the optimal cost of production will increase by the margin equal to the marginal opportunity cost value. The marginal opportunity cost therefore shows the gains as well as the penalty for adoption. This therefore means that sole rice with marginal opportunity cost of ₦125,995.09 and maize/rice/vegetable with marginal opportunity cost of ₦108,075.39 have the highest penalty for adoption for the male and female farmers respectively, while maize/rice have the least penalty for adoption in both male and female farmers with marginal opportunity cost of ₦8,584.84 and ₦33.24 respectively.

Enterprise	**Solution**		**Objective value contribution (₦)**		**Marginal opportunity cost (₦)**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Sole maize	0.00	0.80	0.00	47,319.61	13,713.10	0.00
Sole rice	0.00	0.00	0.00	0.00	125,995.09	24,429.54
Sole sorghum	0.00	0.00	0.00	0.00	85,279.72	22,681.58
Maize/rice	0.00	0.00	0.00	0.00	8,584.84	33.24
Rice/sorghum	0.69	0.64	63,872.31	50,203.91	0.00	0.00
Maize/sorghum	0.00	0.81	0.00	56,309.51	27,485.46	0.00
Maize/rice/sorghum	1.03	0.00	92,177.22	0.00	0.00	28,103.33
Maize/rice/vegetable	0.28	0.00	31,005.36	0.00	0.00	108,075.39
Maize/vegetable	0.30	0.00	46,091.43	0.00	0.00	37,094.74
Maximized objective			233,246.32	153,833.05		

Table 2: Linear Programming Result for Male and Female Fadama Crop Farmers
Source: Field survey, 2014

3.3. Gross margin per hectare in the existing and optional plan among male and female fadama crop farmers

The male farmers gross margin per hectare of the existing and optimal farm plan in Table 3 shows that the existing rice/sorghum, maize/rice/sorghum, maize/rice/vegetable and maize/vegetable enterprise had ₦93,342.86, ₦88,781.07, ₦111,583.92 and ₦155,940.36 respectively while the maximum surplus were ₦115,115.56, ₦119,612.48, ₦139,621.79 and ₦251,861.21 respectively. This indicates an increase of 23.3%, 34.7%, 25.1% and 61.5% respectively from the existing plan.

Enterprise	**Existing plan**	**Optimal plan**	**Increase**	**Percentage**
Rice/sorghum	93,342.86	115,115.56	21,772.70	23.3
Maize/rice/sorghum	88,781.07	119,612.48	30,831.41	34.7
Maize/rice/vegetable	111,583.92	139,621.79	28,037.87	25.1
Maize/vegetable	155,940.36	251,861.21	95,920.85	61.5

Table 3: Gross Margin (₦) per Hectare of the Existing and Optional Plan among Male Fadama Crop Farmers
Source: Field survey, 2014

Comparing this with the female farmers, gross margin per hectare of the existing and optimal farm plan in Table 4 shows that the existing sole maize, rice/sorghum and maize/sorghum enterprises had ₦57,938.46, ₦78,236.92 and ₦69,200.00 respectively while the maximum plan were 88,999.86, 141,988.00 and 72,261.00 respectively. This also signifies an increase of 53.6%, 68.3% and 4.42% respectively from the existing plan. This therefore implies that for the male farmers, maize/rice/sorghum enterprise brings the highest profit than the other enterprises while for the female farmers, rice/sorghum enterprise brings the highest profit than the other enterprises.

Enterprise	Existing plan	Optimal plan	Increase	Percentage
Sole maize	57,938.46	88,999.86	31,061.40	53.6
Rice/sorghum	78,236.92	141,988.00	63,751.08	68.3
Maize/sorghum	69,200.00	72,261.06	3,061.06	4.42

Table 4: Gross Margin (₦) per Hectare of the Existing and Optional Plan among Female Fadama Crop Farmers
Source: Field survey, 2014

3.4. Resource allocation and use pattern among male and female fadama crop farmers

The result on the resource utilization pattern for the male farmers presented on Table 5 shows that four of the resource constraints (inputs) were fully utilized in arriving at the optimal solution. These inputs are labour, agro-chemicals, inorganic fertilizer and seeds. The dual (shadow) prices of the fully utilized resources indicate the amount by which the objective function will increase if these inputs are increased by one unit. That is, total gross margin will increase by ₦369.32, ₦3384.95, ₦200.31 and ₦864.91 for one-man day increase in labour, one litre increase in agro-chemicals, one kilogram increases in inorganic fertilizer and one kilogram increase in seed respectively.

Similarly, for the female farmers, resource utilization pattern also showed three of the resource constraints were fully utilized in arriving at the optimal solution. These inputs are labour, agro-chemicals and inorganic fertilizer. The dual (shadow) prices of the fully utilized resources indicate the amount by which the objective function will increase if these inputs are increased by one unit. This means that total gross margin will increase by ₦65.57, ₦3671.84 and ₦279.27 for one-man day increase in labour, one litre increase in agro-chemicals and one kilogram increase in inorganic fertilizer respectively. The non fully utilized resources among the male farmers was land (452.72 ha) while the non fully utilized resources among the female farmers were land (183.83 ha) and seeds (1,016.02 kg), indicating that these resources were in-efficiently utilized by the male and female fadama crop farmers in the study area

Resource (Constraint)	Use Status		Slack		Dual Shadow Price	
	Male	Female	Male	Female	Male	Female
Land (ha)	Not fully utilized	Not fully utilized	452.72	183.83	0.00	0.00
Labour (md)	Fully utilized	Fully utilized	0.00	0.00	369.32	65.57
Agrochemicals (lts)	Fully utilized	Fully utilized	0.00	0.00	3,384.95	3,671.84
Inorganic fertilizer (kg)	Fully utilized	Fully utilized	0.00	0.00	200.31	279.27
Seeds (kg)	Fully utilized	Not fully utilized	0.00	1,016.02	864.91	0.00

Table 5: Resource Allocation and use Pattern among male and female fadama crop farmers
Source: Field survey, 2014

3.5. Constraints to Food Crop Production by Male and Female Fadama Farmers

Identifying problems associated with male and female fadama farmers will improve the use of inputs associated with crop production that results in increased yield. Table 6 shows the problem of inadequate/high cost of fertilizer was found to be the major constraints as it was ranked first with about 20% and 25% for both male and female respondents respectively. This was followed by high cost of paid labour and clashes with pastoralists as the 2nd and 3rd constraints for the male respondents with 16.5% and 14.4% respectively while for the female respondents, high cost of transportation and lack of access land was ranked 2nd and 3rd with 20.8% and 13.6% respectively.

Other important constraints identified as affecting crop production by the male respondents in the study area were high cost of transportation, poor access road and lack of access to land which were ranked 4th, 5th and 6th respectively in order of severity. On the other hand, high cost of paid labour, low fertility status of land and lack of marketing facilities were ranked 4th, 5th and 6th respectively in order of severity among the female respondents.

However, the result showed that female respondents in the study area were more affected by these constraints than their male counterparts. For example, the percentage of the female respondents affected by inadequate and high cost of fertilizer were 24.7 while for the male respondents it was 19.9%. The implication of this is that gender inequality still remains an important factor in understanding the challenges facing farmers. Women farmers suffer more limitations in accessing inputs for agricultural production than their male counterparts. This agrees with the findings of Baret *et al.* (2009) as reported by Adebayo *et al.* (2011) that men and women had different access to farm inputs resulting in different yield levels with women's yield being lower than men's. The differences were not as a result of inefficiency on the part of the women but resulted from women's low access to farm inputs.

Constraints	Male			Female		
	Frequency	%	Ranking	Frequency	%	Ranking
Inadequate and high cost of fertilizer	174	19.9	1st	82	24.7	1st
Lack of improved seeds	27	3.1	9th	15	4.5	7th
Clashes with pastoralists	126	14.4	3rd	13	3.9	8th
High cost of paid labour	144	16.5	2nd	38	11.5	4th
Attack by pests and diseases	57	6.5	7th	11	3.3	9th
Low fertility status of farmlands	42	4.8	8th	27	8.2	5th
High cost of transportation	124	14.2	4th	69	20.8	2nd
Lack of access to land	64	7.3	6th	45	13.6	3rd
Poor access roads	98	11.2	5th	9	2.7	10th
Lack of marketing facilities	17	1.9	10th	22	6.6	6th

Table 6: Constraints to Food Crop Production by Male and Female Fadama Crop Farmers
Source: Field Survey, 2014

4. Conclusion and Recommendations

The result of Linear Programming showed that four activities entered the programme for the male farmers while three activities entered the programme for the female farmers. The optimal farm plan recommends that the male and female fadama crop farmers should allocate their resources in such a way that the four crop enterprises and the three crop enterprises are produced to maximize total gross margin of ₦233,246.32 and ₦153,833.05 respectively. The result on the resource utilization pattern for male farmers showed that four of the resource constraints were fully utilized in arriving at the optimal solution. These are labour, agro-chemicals, inorganic fertilizer and seeds. The dual (shadow) prices of the fully utilized resources indicate the amount by which the objective function will increase if these inputs are increased by one unit. That is, total gross margin will increase by ₦369.32, ₦3384.95, ₦200.31 and ₦864.91 for one-man day increase in labour, one litre increase in agro-chemicals, one kilogram increases in inorganic fertilizer and one kilogram increase in seed respectively. Similarly, for the female farmers, resource utilization pattern also showed three of the resource constraints were fully utilized in arriving at the optimal solution. These inputs are labour, agro-chemicals and inorganic fertilizer. This also means that total gross margin will increase by ₦65.57, ₦3671.84 and ₦279.27 for one-man day increase in labour, one litre increase in agro-chemicals and one kilogram increase in inorganic fertilizer respectively. The non fully utilized resources among the male farmers was land (452.72 ha) while the non fully utilized resources among the female farmers were land (183.83 ha) and seeds (1,016.02 kg), indicating that these resources were in-efficiently utilized by the male and female fadama crop farmers in the study area. The study recommended that a prototype combination of crop enterprises that emanated from the linear programming should be integrated into the extension education package of the male and female fadama farmers to enable them improve on their farm income.

Based on the findings of the study, the following recommendations are made:

i. Farm income of the male and female farmers would be improved upon if a prototype combination of crop enterprises that emanated from the linear programming could be integrated into the extension education package of the farmers within the study area.

ii. The current extension system where facilitators work with the male and female fadama III crop farmers should be sustained and expanded to cover non fadama communities as it is geared towards increasing the knowledge level of farmers in order to improve productivity.

iii. Training of farmers on latest agronomic practices and record keeping should be encouraged so as to help them monitor activities of their groups towards ensuring that project support for inputs are actually put into production thereby increasing efficiency.

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