MODELING EFFICIENT RESOURCE ALLOCATION PATTERNS FOR ARABLE CROP FARMERS IN NIGER STATE, NIGERIA: A LINEAR PROGRAMMING APPROACH

By

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ABSTRACT

This study examined the resource use pattern for small scale arable crop-based farmer in Niger State, North central Nigeria during the 2009 cropping season considering available resources. Linear Programming model was used for optimizing gross margins. The results revealed a considerable divergence between the existing and optimum plans under both limited and borrowed capital situations. Results indicated that resources were not optimally allocated and after optimization, gross margins could be increased. Cereal-legume cropping patterns showed dominance in both the existing and optimum plans. As a result of inter variation in capital resource endowment and management, the gross margins were higher in the borrowed capital (₦87,322.89/ha) as compared to the limited capital situation (₦51,211.54/ha). The optimum plans prescribed more of cash-crop-based enterprises. The study recommended that farmers should organize farm resources as prescribed by the optimum plans. This should be complemented with strong financial support, farm advisory services and adequate supply of modern inputs at fairly competitive prices would enhance the prospects of the small holder farmers.

Keywords: efficient, resource allocation, optimization, linear programming, gross margin.

INTRODUCTION

Countries in the African continent face an ever-worsening food crisis as the growth rate of the effective demand for food in these countries continues to outpace the growth rate of food production. Cereal imports in Nigeria for instance have tended upwards in recent years due mainly to high population growth and changing consumption pattern. Imports of cereal mostly wheat and rice are estimated at about 4.33 million tonnes in 2004, up from 4.07 million tonnes in 2003. This is against the backdrop that agriculture has remained the backbone of many developing countries because it plays important role largely through improving food security, export earning and accounting for between 30% and 60% of their Gross Domestic Product (GDP) as well as employing as much as 70% of the labour force and providing income to a vast majority of the population (World Bank, 1996). A sectoral analysis in 2006 of the real GDP indicated that the agricultural sector contributed to about 42 percent of the GDP compared with 41.2 percent in 2005 (CBN, 2006). The growth rate of the contribution of the agricultural sector to the GDP at 1990 constant basic prices grew from 4.2 percent in 2002 to 7.2 percent in 2006.

The agricultural sector also employed over 60 percent of the total labor force in Nigeria in 1999 (Adeoti, 2002).

The advent of oil in the early 1970s made Nigeria highly dependent on oil revenue, with the performance of the agricultural sector declining over the years. Though the growth rate in the agricultural sector in Nigeria increased from an average of about 3 percent in the 1990s to about 7 percent in mid 2000, the food security/sufficiency status of Nigerians continued to decline (Adeoti, 2002). The dismal performance of the agricultural sector in terms of its contribution to Nigeria's yearly total revenue in the last three decades prompted the government to initiate several agricultural schemes and programs to enhance agricultural productivity, which include the following: the River Basin Development Authorities, the National Accelerated Food Production Project, the Agricultural Development Project, Operation Feed the Nation, the Green Revolution, the National Directorate of Food, Roads and Rural Infrastructure, the Agricultural Credit Guarantee Scheme Fund, the National Special Programme for Food Security, Root and Tuber Expansion Project, and the National Fadama I and II programs.

The domestic economy where agriculture thrives must therefore be improved upon and sustained and if possible its external sector impact enhanced. This is because, indication of high potential for increased food production in Nigeria is glaring given that Nigeria has a land area estimated at about 98.3 million hectares out of which about 71.2 million hectares accounting for about 70% are cultivable while only about 34 million hectares accounting for one third of total land area are under cultivation (Onyenweaku *et al*., 2008). Increasing sustainability and targeting small-scale farmers who constitute the bulk of agricultural practitioners should be the principal policy issues directed towards agricultural development (Udoh, 2000) and obviously, the panacea in meeting the food need of the nation and raising the income level of small holder farmers. A typical farmer anywhere in the world is faced with a myriad of choices for allocating scarce resources between crop and livestock production activities to optimize his/her production objectives (Olayemi and Onyenweaku, 1999). Agricultural production planning apart from shedding light on efficient utilization of resources in the farm, makes possible the charting of those courses of action for attaining maximum net returns. Identifying the best farm plan is a difficult task for any farmer, but it is especially difficult for small scale farmers with little or no formal education. Thus, if agricultural policy is to be relevant and to raise the income levels and subsequently the living standards of the many small-scale farmers who produce the bulk of the food consumed in the country, optimum farm plans must be formulated for them by region or locality. These plans could also help policy-makers predict farmers' responses to policy alternatives thereby sharpening the policy decision-making process. Studies in optimum resource allocation in a regional framework using the linear programming approach have been attempted in many countries (Shahidullah, *et al* 2006; Hassan, 2004; Hassan *et al*, 2005; Alam *et al.*, 1995; Sama, 1997; Alam, 1994; Uddin *et al* 1994; Onyenweaku, 1980; Schipper *et al*., 1995; Dipeolu *et al*., 2000; Tanko, 2004, Adejobi *et al*., 2003; Klein and Narayan 2008).

Up to now, little attention has been devoted to the role of farm planning in the resolution of the food crisis and raising income earnings of smallholder farmers. Formulating optimum farm

plans for small holder farmers could lead to the resolution of the food crisis and consequently improve on their living standards. Knowledge of the optimal enterprise combination and of the influence of changes in production and prices associated with it may support farmers in taking important management decisions which will translate into increased output and improve the earning power of households. Given the prevailing farming systems, it is imperative to seek out profit minded agricultural producers and encourage them with necessary incentives while convincing them of the profitability of specific enterprises based on research results. The prototype enterprise combinations that were developed in this study could be useful in a wide variety of ways.

The specific objectives of this study are to develop optimum enterprise combination patterns and efficient resource allocation that would maximize the total gross margin of farms in the study area.

METHODOLOGY

Study area

The study area is Niger State of Nigeria. The State is located in North-central Nigeria between Latitudes 8˚20´N and 11˚30´ N and Longitudes 3˚30´ E and 7˚20´E with a total land area of 76,363 square kilometers and a population of 4,082,558 people (Wikipedia, 2008). Agriculture is the predominant source of livelihood; 80% to 90% of the population reside in farm households. Mixed farming is widely practiced. The animals provide energy for ploughing, while their droppings are used for manuring the soil. Thus, the animals aid in mechanization and encourage intensification of land use. The State is well suited for production of a wide variety of crops such as yam, cassava, maize, millet, rice, cowpea, tomato, etc because of the favourable climatic condition. The annual rainfall is between 1100 and 1600mm with average monthly temperature ranging from 23˚C to 37˚C (NSADP, 1994). The vegetation consists mainly of short grasses, shrubs and scattered trees. The State covers a land area of 80,000 square kilometers or 8 million hectares constituting 8 percent of the total land area of the country. About six million hectares, representing 85% of the total land area is arable.

Sampling technique

The sampling frame for this study comprised of all the crop farmers in Niger State. The data used for this study were mainly from primary sources collected from farmers who were selected using multi-stage sampling. The three Agricultural Development Project (ADP) Zones in the State, namely, Bida, Kontagora and Kuta were considered for the study. The first stage involved random selection of two LGA's each from the ADP zones as follows: Lavun and Bida were randomly chosen from Bida Zone, Mariga and Kontagora from Kontagora Zone, as well as Shiroro and Paiko from Kuta Zone. In the second stage, two villages were selected randomly from each of the LGA's giving a total of twelve (12) villages. The third stage involved random selection of eighteen (35) farm households from each of the villages bringing the total sample size to 420. The data were collected using well structured questionnaire. Extension Officers resident in each of the locations as well as well trained enumerators assisted the researchers in

data collection. Data collection lasted for five months (August-December, 2009) using the limited cost-route approach to data collection. Data collected for this study include input information such as farm size in hectares, human labour input in man days, animal traction input in cattle days, tractor hiring in number of hours utilized, quantity of fertilizers in kilogrammes, cost of agrochemicals in naira, depreciation on farm tools and equipment etc., input and output prices, socio-economic characteristics of farmers such as years of schooling, farming experience, age, household size, etc. as well as output information.

The empirical model

A linear programming model essentially similar to that of Alam *et al* (1995) and Tanko (2004) was used to achieve the objectives of this study. The objective function (equation 1) is to maximize total gross margin of producing the crops less costs of hired human labour, bullock labour, hired tractor/power tiller, capital borrowing and marketing. The constraint equations 2-6 (i.e for land, human labour, bullock labour, tractor/power tiller, and capital, respectively), require that the amount of a resource required to produce the n crop activities must not exceed the available. The model is specified as follows:

$$\text{Maximize } Z_0 = \sum_{J=1}^{n} P_j X_j - \sum_{t=1}^{5} WhL_t - \sum_{t=1}^{n} WbK_t - \sum_{t=1}^{3} WdR_t - \sum_{k=1}^{n} P_k Y_k - \sum_{t=1}^{3} M_t \quad \text{--- (1)}$$

Subject to:

$$\sum_{j=1}^{n} ljs\, X_j \leq L_s \quad \text{(Land)} \quad (s = 1, 2, \ldots, 72) \quad \text{--- (2)}$$

$$\sum_{j=1}^{n} aj_t\, X_j - L_t \leq H_t \quad \text{(Human labour)} \quad (t = 1, 2, 3, 4, 5) \quad \text{--- (3)}$$

$$\sum_{j=1}^{n} b_{jt}\, X_j - K_t \leq B_t \quad \text{(Bullock labour)} \quad (t = 1, 2, 3, 4, 5) \quad \text{--- (4)}$$

$$\sum_{j=1}^{n} d_{jt}\, X_j - R_t \leq S_t \quad \text{(Tractor/power tiller)} \quad (t = 1, 2) \quad \text{--- (5)}$$

$$\sum_{j=1}^{n} c_{jt}\, X_j - M_t \leq C_t \quad \text{(Capital)} \quad (t = 1, 2, 3) \quad \text{--- (6)}$$

$$\sum_{j=1}^{n} f_k\, X_j \geq F_{(min)} \quad \text{(Minimum subsistence farm-family cereal/legume requirement)} \quad \text{--- (7)}$$

$$X_j, L_t, K_t, R_t, P_k, M_t \geq 0 \quad \text{--- (8)}$$

Where; Z_o=Total gross margin of the farm in Naira; X_j=Units of the j^{th} crop activity in hectares; P_j = Gross value of output per ha of the j^{th} crop activity in Naira; Wh = Wage rate per unit of hired human labour in Naira; L_t = Number of hired human labour in t^{th} period; Wb = Wage rate

per unit of bullock labour in Naira; K_t = Number of hired bullock labour in t^{th} period; Wd = Wage rate per unit of tractor/power tiller; R_t = Tractor/power tiller hired in t^{th} period; P_k = Marketing expense per unit of the product sold in t^{th} period; Y_k= Units of crop products sold in t^{th} period; r = Rate of interest for six months; M_t = Capital borrowed in Naira in t^{th} period; f_k = Food production in tons/hectare of k^{th} cereal/legume activity; L_s = Total available land in hectares for the crops with (s) restrictions; H_t = Total man-days of family labour owned by the farmer in t^{th} period; B_t = Total bullock labour owned in t^{th} period; S_t = Total tractor/power tiller owned in t^{th} period; C_t = Total working capital owned/available in Naira in t^{th} period; $F_{(min)}$= minimum quantity of cereal/legume required by the farm family per annum in tons; 1_{js} = Input coefficient of land which is one hectare with s restrictions; a_{jt} = Input coefficient of human labour (in mandays) for j^{th} crop activity in t^{th} period. b_{jt} = Input coefficient of bullock labour for j^{th} crop activity in t^{th} period; c_{jt}= Amount of capital used in producing one hectare of j^{th} crop activity in t^{th} period and $\sum$ = Summation of j^{th} crop activities (j =1 to n);

Activities in the model and the price coefficient "P_j"

The activities in the models can broadly be grouped into crop production activities, labour (human, bullock, tractor) hiring activities, capital borrowing and product selling activities. The crop production activities are broadly grouped into sole crops and crop mixtures. For each of the crop production activities the unit of activity is one hectare. The price coefficient "Pj" of a production activity in the model is the gross margin per hectare (total revenue less total variable costs of production). For a human labour hiring activity, the price coefficient is the ruling wage rate (naira per man day). The price coefficient of a bullock labour hiring activity is the wage rate per cattle day in naira. The price coefficient of a tractor hiring activity is the wage rate per hour of tractor hiring. For a capital borrowing activity, the price coefficient is the prevailing market rate of interest, while for a selling activity, the price coefficient is the marketing expense per unit of the product sold. The selling activity facilitates the sale of the final output realized from the various cropping activities. Each production activity may have more than one selling activity depending on whether such activity is sole or mixed. Transfer activities (rows) provide a vehicle whereby the services or output of one activity may be transferred in the model to another activity. Hence, to ensure fuller utilization of capital and labour, capital and labour transfer activities were incorporated in the model. They ensure the transfer of capital and labour from one period to another period provided it is profitable.

Input coefficients

The input coefficients refer to the requirement of a crop activity in respect of the inputs of the different resources measured on per hectare basis (unit of land). The input coefficients for all the crop activities were calculated on the basis of the actual quantities of different resources used for those crop activities. For instance, the input-output coefficient for human labour are denoted by ajt's and they refer to the amount of human labour in man days used in producing a hectare of the j^{th} crop activity in t^{th} period. The input-output coefficients (aij's)are the averages for all the farmers in each category

Resource restrictions in the model

Six restrictions/constraints were incorporated in the model. These are: Land (with 24 restrictions i.e. two types of land restriction, namely: irrigated and non-irrigated) were considered. Twelve months of land restrictions were considered. Human labour (with five restriction periods namely: land preparation, planting, first weeding, second weeding and harvesting). Labour requirement is characterized by certain peak operational periods which would require the hiring of casual labour to accomplish farm operations. Bullock labour(with two restriction periods of first weeding and second weeding). Tractor/power tiller(three restriction periods of May, June and July). Capital (three restriction periods namely: April-June, July-September and October-December). Capital was considered to be working capital required for meeting day to day farm expenses both in cash and in kind as well as Cereal/legume requirement constraints. Minimum Cereal/Legume Requirement refers to family food supply, another possible constraint in farm planning (Alam *et al*., 1995). Subsistence farmers cultivate land area enough with cereal/legume crops needed to fulfill their home consumption requirement. Their production is less market-oriented.

RESULTS AND DISCUSSION

Socioeconomic profile of respondents

A summary of the statistics of farmers in the study area is presented in Table 1.

	Minimum	Maximum	Mean	Std. Deviation	Variance
Age	27.00	67.00	43.63	9.89	97.96
Marital status	0.00	1.00	0.90	0.29	0.08
Household size	3.00	14.00	9.18	2.64	6.97
Farm size	0.00	4.00	1.06	1.00	1.00
Education	0.00	12.00	6.18	4.05	16.48
Labour	35.00	220.00	99.66	31.91	1018.74
Experience	10.00	35.00	24.01	5.39	29.15
Cooperative	0.00	1.00	0.39	0.48	0.24
Credit	0.00	80000.00	12600.00	22271.25	4.96
Tenurial status	0.00	1.00	0.75	0.43	0.18
Ext. contact	1.00	3.00	2.02	0.77	0.60

Source: Field survey data, 2009.

Results in Table 1 show that a typical farmer sampled is about 44 years old, married, had nine family members, had attained at least primary level of education and cultivated1.06 hectares of land. The typical farm household head had 24 years of experience in farming, owned the land he/she cultivated, belonged to a cooperative society and had at least two contacts with an extension agent during the 2009 cropping season. A typical respondent with access to credit received at least ₦12,000.00 as loan. As the age of the farmer increases, the adoption of agricultural technology will likely decrease while sensitivity to risk will increase. Older farmers are more risk averse. The preponderance of experienced farmers in the state will make planning

imperatives worthwhile. Previous experience enables the farmer set realistic time and cost targets by identifying production risks and constraints with ease. A large family size provides a ready source of cheap family labour. Small holder farmers over rely on meagre household resources and would strive to ensure minimum usage of paid labour as a result of the paucity and dearth of resources. Education plays a crucial role in technology dissemination and adoption. The ability of the farmer to cope with complexities of new innovations, the intricacies of the product and factor markets increases as the level of education increases. Smallness of cultivated land is a common feature in small holder agriculture. Farmers usually own several plots devoted to crops in scattered locations, the average in the study area being two, each less than one hectare.

Farm Income

The annual incomes of the farmers are mainly from two sources, namely, farm activities and off-farm activities. The annual net income for a typical farmer is shown in Table 2, while the income derived from various sources expressed as percentage of total income is presented in Table 3. Table 2 shows that cropping enterprises constitute the main source of a typical farmer's income, constituting an average of ₦152,800.38 which represents 56.66% of the total income. Farmers with access to capital borrowing realized higher incomes as compared to those without access.

Table 2: Average annual income of farmers in Niger State

Farmer category	Crops (₦)	Income source Livestock (₦)	Off-farm activities(₦)	Total
With borrowed capital	185,600.75	58,600.40	60,315.60	304,516.75
Without borrowed capital	120,000.00	53,442.15	55,720.00	229,162.15
Average for the state	152,800.38	56,021.28	58,017.80	266,839.45

Source: Computed from field survey data, 2009.

Table 3: Farmer's income from various sources expressed as percentage of total income

Farmer Group	Crops (% of total)	Livestock (% of total)	Off-farm activities (% of total)	Total
With borrowed capital	60.95	19.24	19.81	100.00
Without borrowed capital	52.36	23.32	24.31	100.00
Average for the state	56.66	21.28	22.06	100.00

Source: Computed from field survey data, 2009.

Farm Resource Allocation under Existing and Optimum Cropping Patterns

Existing land use pattern

The existing land use in terms of hectarage allocation for the various basic activities are presented in Table 4. Small holder farmers usually cultivate several plots (average of two), usually less than one hectare in size devoted to different crops in scattered locations. Results in Table 4 indicate that farmers with limited capital devoted maximum area to Maize/Groundnut/Cowpea enterprise in the highland situation which accounted for about 13.52% of the total cropped area. The next predominant cropping pattern was Maize/Groundnut which occupied about 10.03% of total cropped area in the highland situation. For this category of

farms, cereal-legume based cropping enterprises were the predominant cropping patterns. A greater proportion of the farm land (i.e. 68.94%) was devoted to cereal-based mixed cropping enterprises. Sole crops accounted for only 31.06% of total cropped area.

Similar cropping patterns were adopted by farmers with access to capital borrowing in the existing plan. The most predominant cropping pattern for this group was Maize/Groundnut which accounted for about 11.21% of total cropped area in the highland situation. The next important cropping pattern was Maize/Groundnut/Cowpea which occupied 9.46% of total cropped area. The cropping patterns adopted by the two groups are indicative of their resource endowment. The cropping patterns adopted by these farmers tended more towards commercial/cash crop production. Cereal-legume based cropping enterprises dominated the farming systems. Mixed cropping is founded on sound biological principles.

Optimum land use pattern under limited capital situation

The results in Table 4 show that optimization and reallocation of existing resources brought about notable changes in the existing land use pattern. As a result of optimization, melon/okra was the most dominant cropping pattern in the highland situation accounting for an overwhelming 71.05% of the total cropped area. The second and the last cropping pattern prescribed by the optimum plan under this scenario was sorghum/cowpea/groundnut under the highland situation. As a result of capital scarcity, only two cropping enterprises appeared in the plan. Optimum plan with limited capital indicates lower land use by perhaps keeping the land seasonally fallow as available resources could not permit increasing the scale of operation. Consequently, optimization suggested a decrease in the allocation of area to crop enterprises. A cursory look at the optimized plans also reveals that under the existing technology, mixed cropping enterprises are more favoured whereby, all the land (i.e. 100%) in the optimum plan, was allocated to mixed cropping patterns which are cereal-legume based enterprises. Commercial crops such as melon and okra were important as they were included in the plans. Due to optimization, the cultivated area of optimized plans under limited capital situation decreased as compared to the existing plan.

Optimum land use pattern under borrowed capital situations

The results in Table 4 also show that the relaxation of the capital input, by allowing capital borrowing resulted in an increase in the cultivated area. Results show that melon/okra was the most dominant cropping pattern in the highland situation which occupied about 67.70% of total cropped area. The next cropping pattern prescribed by the optimum plan was sorghum/cowpea/groundnut under the highland situation which accounted for about 24.70% of total cropped area. A third crop enterprise, namely, maize/cowpea occupying 7.60% of total cropped area under highland situation was included in the optimized plan. This suggests that cropping patterns under borrowed capital were more cash generating as the number of crops included in the optimum plans were observed to have increased. Credit plays a crucial role in smallholder agriculture as it enables the farmer to purchase production inputs and hire more

labour to accomplish farm operations. The optimum plans also devoted the total cropped area to mixed cropping enterprises.

Activities included in the optimum plans under borrowed and limited capital situations

The following activities presented in Table 5 were prescribed by the optimum plans under the borrowed and limited capital situations.

Table 4: Existing and optimum cropping patterns under borrowed and limited capital situations in Niger State, Nigeria, 2009.

Cropping patterns	Existing plan		Optimum plans	
	FWLC	FWBC	FWLC	FWBC
1. Maize (HL)	-	0.95	-	-
		(6.66)		
2. Cowpea (HL)	0.44	0.62	-	-
	(4.65)	(4.34)		
3. Sorghum (LL)	0.25	0.87	-	-
	(2.64)	(6.10)		
4. Groundnut (HL)	0.39	0.99	-	-
	(4.12)	(6.94)		
5. Millet (LL)	0.71	-	-	-
	(7.50)			
6. Rice (LL)	-	0.45	-	-
		(3.15)		
7. Yam (HL)	0.62	0.80	-	-
	(6.55)	(5.61)		
8. Melon (LL)	-	0.28	-	-
		(1.96)		
9. Sweet potato (LL)	0.03	-	-	-
	(0.32)			
10.Cassava (LL)	0.05	0.06	-	-
	(0.53)	(0.42)		
11.Maize/Cowpea (HL)	-	0.89	-	0.32
		(6.24)	-	(7.60)
12. Maize/Groundnut (HL)	0.95	1.60	-	-
	(10.03)	(11.21)		
13. Maize/Sorghum (HL)	0.75	0.34	-	-
	(7.92)	(2.38)		
14.Maize/Groundnut/Cowpea (HL)	1.28	1.35	-	-
	(13.52)	(9.46)		
15.Sorghum/Maize/Cowpea (HL)	0.88	0.91	-	-
	(9.29)	(6.38)		
16.Millet/Cowpea (HL)	-	0.67	-	-
		(4.70)		
17.Yam/Okra (HL)	0.78		-	-
	(8.24)	-		
18.Yam/Maize (HL)	0.45	0.70	-	-
	(4.75)	(4.91)		
19.Sorghum/Cowpea (LL)	0.90	1.01	-	-
	(9.50)	(7.08)		
20.Melon/Okra (HL)	0.02	0.04	2.85	2.85

	(0.21)	(0.28)	(71.07)	(67.70)
21.Sorghum/Cowpea/Groundn (HL)	0.65	0.90	1.16	1.04
	(6.86)	(6.31)	(28.93)	(24.70)
22.Sorghum/Groundnut (HL)	0.32	0.84	-	-
	(3.38)	(5.89)		
Total cropped area	9.47	14.27	4.01	4.21
	(100.00)	(100.00)	(100.00)	(100.00)
% Sole crops	31.06	35.18	0.00	0.00
% Crop mixtures	68.94	64.82	100.00	100.00

Source: Computed from field survey data, 2009.

Note: HL=Highland; LL=Lowland; FWLC=Farmers with limited capital; FWBC=Farmers with access to capital borrowing. Figures in parentheses are the respective percentages.

Table 5: Activities included in the optimum plans under borrowed and limited capital situations

No.	Activity name	Unit of activity	Optimal value/Activity levels	
			Borrowed capital	Limited capital
1.	Maize/Cowpea	Hectares	0.32	-
2.	Melon/Okra	Hectares	2.85	2.85
3.	Sorghum/Cowpea/Groundnut	Hectares	1.04	1.16
4.	Capital Borrowing	Naira	1,823.50	-
5.	Maize selling	Naira	606.80	-
6.	Cowpea selling	Naira	113,877.20	113,877.20
7.	Sorghum selling	Naira	49,160.59	54,578.00
8.	Groundnut selling	Naira	64,781.22	71,920.00
9.	Melon selling	Naira	243,475.50	-
10.	Okra selling	Naira	297,759.50	286,197.00
	Max. Objective		₦87,322.89	₦51,211.54

Source: Computed from field survey data, 2009.

Results in Table 5 indicate the dominance of mixed cropping enterprises in the optimized plans. Cash crops also exhibited dominance under both capital situations.

Table 6: Minimum cereal/legume requirements by household (in tons), in the existing and optimum plans.

Farmer Category	Quantity required (in tons)		Decrease over existing plan (%)
	Existing plan	Optimum plans	
FWLC	2.57	2.16	-15.95
FWBC	2.57	2.51	-2.33

Source: Field survey data, 2009.

Note: FWLC and FWLC are as previously defined.

Gross Margin per Hectare in Naira in the Existing and Optimum plans

The gross margins for the existing and optimum plans under different capital situations are presented in Table 7.

Table 7: Gross margins per hectare realized by farmers in the borrowed and limited capital situations

Farmer Category	Gross margin/ha Existing plan(₦)	Gross margin/ha Optimum plans(₦)	Increase over existing plan	% increase over existing plan
FWLC	45,026.10	51,211.54	6,185.44	12.08
FWBC	63,800.25	87,322.89	23,522.64	26.94
Average	54,413.18	69,267.22	14,854.04	19.51

Source: Field survey data, 2009.

Note: FWLC and FWLC are as previously defined.

Results in Table 7 indicate that optimum plans under both limited and borrowed capital situations resulted in an increase in gross margins over the existing plan by 12.08% and 26.94% respectively. Marked disparity in gross incomes was witnessed in both category of farms. Access to adequate and timely credit is likely to raise farm incomes, improve the livelihoods of the farmers by raising their purchasing power to be able to acquire more productive inputs, hire labour, etc.

Status of resource constraints in the optimum plans

The status of available resources in the optimized plans under limited and borrowed capital scenarios are presented in Tables 8 and 9, respectively. Results show that the only resource that constrained the attainment of the objective function is land.

Table 8: Resource constraints for farmers with access to capital borrowing

No	Constraints	Status	Original value	Shadow price	Slack or surplus
1.	Human Labour (Land preparation)	Loose	175.00	0.00	75.77
2.	Human Labour (Planting)	Loose	162.00	0.00	55.34
3.	Human Labour (First weeding)	Loose	186.00	0.00	29.54
4.	Human Labour (Second weeding)	Loose	180.00	0.00	75.74
5.	Human Labour (Harvesting)	Loose	150.00	0.00	42.59
6.	Land I (Highland)	Tight	1.16	10,142.69	0.00
7.	Land II (Highland)	Tight	2.85	13,840.71	0.00
8.	Bullock labour	Loose	21.00	0.00	14.16
9.	Tractor Hiring	Loose	8.50	0.00	8.50
10.	Transfer row maize	Loose	0.00	0.00	0.00
11.	Transfer row cowpea	Tight	0.00	0.05	0.00
12.	Transfer row sorghum	Tight	0.00	0.10	0.00
13.	Transfer row groundnut	Tight	0.00	0.05	0.00
14.	Transfer row millet	Tight	0.00	0.06	0.00
15.	Transfer row rice	Tight	0.00	0.05	0.00
16.	Transfer row yam	Tight	0.00	0.07	0.00
17.	Transfer row melon	Tight	0.00	0.11	0.00

18.	Transfer row potato	Tight	0.00	0.09	0.00
19.	Transfer row cassava	Tight	0.00	0.10	0.00
20.	Transfer row okra	Tight	0.00	0.07	0.00
21.	Yam minimum	Loose	7,620.00	0.00	7,620.00
22.	Rice minimum	Loose	2,360.00	0.00	2,360.00
23.	Cowpea minimum	Loose	4,598.84	0.00	4,598.84
24.	Millet minimum	Loose	3,680.00	0.00	3,680.00
25.	Sorghum minimum	Loose	3,728.84	0.00	3,728.84
26.	Maize minimum	Loose	3,400.00	0.00	3,400.00
27.	Groundnut minimum	Loose	280.00	0.00	278.84

Source: Computed from field survey data, 2009.

Sensitivity analysis

The results indicated that land acted as a severe constraint to production. The emerging farm plans were subjected to sensitivity analysis to observe the sensitivity of the optimum plans to changes in a predetermined variable, namely land. Cultivated land area by a typical respondent was increased by one hectare, that is from 1.16ha to 2.16ha (in the case of lowland) and from 2.85 to 3.85 (in the case of highland) in the programming matrix in each case for the two categories of farmers, respectively.

Table 9: Resource constraints for farmers with limited capital

No	Constraints	Status	RHS constants	Shadow price	Slack or surplus
1.	Human Labour (Land prep.)	Loose	175.00	0.00	75.76
2.	Human Labour (Planting)	Loose	162.00	0.00	55.34
3.	Human Labour (1st weeding)	Loose	186.00	0.00	29.54
4.	Human Labour (2nd weeding)	Loose	180.00	0.00	75.74
5.	Human Labour (Harvesting)	Loose	150.00	0.00	42.59
6.	Land I (Highland)	Tight	1.16	10,142.69	0.00
7.	Land II (Highland)	Tight	2.85	13,840.71	0.00
8.	Bullock labour	Loose	21.00	0.00	14.16
9.	Tractor Hiring	Loose	8.50	0.00	8.50
10.	Transfer row maize	Loose	0.00	0.00	0.00
11.	Transfer row cowpea	Tight	0.00	0.05	0.00
12.	Transfer row sorghum	Tight	0.00	0.10	0.00
13.	Transfer row groundnut	Tight	0.00	0.05	0.00
14.	Transfer row millet	Tight	0.00	0.06	0.00
15.	Transfer row rice	Tight	0.00	0.05	0.00
16.	Transfer row yam	Tight	0.00	0.07	0.00
17.	Transfer row melon	Tight	0.00	0.11	0.00
18.	Transfer row potato	Tight	0.00	0.09	0.00
19.	Transfer row cassava	Tight	0.00	0.10	0.00
20.	Transfer row okra	Tight	0.00	0.07	0.00

21.	Yam minimum	Loose	7,620.00	0.00	7,620.00
22.	Rice minimum	Loose	2,360.00	0.00	2,360.00
23.	Cowpea minimum	Loose	4,598.84	0.00	4,598.84
24.	Millet minimum	Loose	3,680.00	0.00	3,680.00
25.	Sorghum minimum	Loose	3,728.84	0.00	3,728.84
26.	Maize minimum	Loose	3,400.00	0.00	3,400.00
27.	Groundnut minimum	Loose	278.84	0.00	280.00

Source: Computed from field survey data, 2009.

Effect of increasing area under cultivation

Increasing the area under cultivation in the case of farmers with access to capital borrowing resulted in the following cropping enterprises namely millet/cowpea (0.028ha), melon/okra (3.094 ha) and sorghum/cowpea/groundnut (0.728ha) being included in the optimum plan. This is an improvement over plan I whereby total land allocated to crops was lower on a comparative basis suggesting that prospects abound if cultivated land is increased. Results in Table 10 show that optimum gross margin increased from ₦87,322.89 to ₦99,343.02 an increase of 13.77% over the initial plan (plan I). Large farm sizes coupled with efficient utilization of resources and appropriate management practices should translate into increased outputs and/or farm income. Under the limited capital scenario, land was similarly parametized. The following cropping enterprises, namely, yam/okra (1.205ha) and melon/okra (3.850ha) were prescribed by the optimum plan. Results in Table 10 also show that optimum gross margin increased from ₦51,211.54 to ₦65,196.91, representing an increase of ₦13,985.37 (27.31%) over the initial plan (plan II). However, despite the increase in gross margin, the same number of crop activities were included but at higher levels of employment of land further suggesting that land constrained optimum enterprise combination.

Table 10: Comparison of the optimum gross margins of programmes I and II, when land was increased by one hectare

Category	Optimum gross margins from plans I and II (₦)	Optimum gross margins from present plan (₦)	Increase in farm income (₦)	Percentage change
FWLC	51,211.54	65,196.91	13,985.37	27.31
FWBC	87,322.89	99,343.02	12,020.13	13.77

Source: Field survey data, 2009.

Note: FWLC and FWLC are as previously defined.

CONCLUSION AND POLICY IMPLICATIONS

Complexities abound in traditional agriculture that has manifested in food supplies not keeping pace with demand. This study has shown that given the existing level of technology, farm resources were not optimally allocated. Tractor hiring and bullock labour utilization increased under borrowed capital situation, suggesting that lack of capital severely constrained production.

Capital borrowing increased even at higher rates of interest. Cereal based cropping enterprises laced with legumes showed dominance in both the existing and optimum plans. The observed differences in gross margins by the groups of farms investigated was mainly attributable to variation in resource endowment and management.

Under the existing level of technology and resource availability, crop mixtures were in a better competitive position than sole crops. Gauging the sensitivity of the plans to increase in land under cultivation indicated that agricultural land acted as a constraint to production. This is likely to hamper production activities of farmers.

Based on the findings of this research, certain policy instruments and their implications are identifiable. The existing land use pattern was found to be sub-optimal, thereby suggesting more scope for farm management. The prototype combinations of enterprises could be found useful in the extension education package of Niger State Agricutural Development Project (ADP) and the Niger State Fadama Coordination Office (NSFCO). Effective extension programmes and farm advisory services that will educate the farmers on efficient allocation of resources should be further strengthened. This has the propensity to improve the livelihoods of the smallholder farmer, curb the incidences of widespread hunger, unemployment and poverty. The optimum combination of enterprises, in addition to increasing gross margins were also capital intensive as capital investments were observed even at higher rates of interest. Adequate supply of agricultural credit, modern production inputs at terms and times convenient and at fairly competitive prices should be made available to practicing farmers.

Results also show that increasing the area under cultivation resulted in increase in gross margins. This suggests that more arable land should be employed in crop production. A trend towards specialization was indicated by the plans. This however is in conflict with the concept of diversification. There is need to give special attention to minor crops in developing improved varieties with higher profitability, dissemination of technology to the farmers and improvement in the post harvest processing and utilization. For the goals of food security, increased income and reduced farm production costs, farmers should allocate farm resources as prescribed by the plans.

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