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Analysing Optimum and Alternative Farm Plans for Risk Averse Grain Crop Farmers in Kaduna State, Northern, Nigeria

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Abstract: It has been argued that the limited success of Nigeria in rural development programmes could be due to absence of a prior analysis of attitudes towards, risk inherent in traditional agriculture. This paper was therefore conceived to explain farmers' cropping patterns vis-à-vis their attitudes towards risk. The paper applied an analytical procedure that made use of the conventional linear programming, and the Target Minimization of total absolute deviations (Target MOTAD) as the major toosl. Results indicate that farmers' existing and profit maximizing crop plans are risk inefficient. They also show that there are increasing levels of risks of the farm plans as the farm size decreases. Sustainable farm plans that minimize risk and can ensure desirable returns (gross margins) are suggested for the three identified categories of farers that were surveyed for the analysis. The study provides a critical methodological framework that can help understand the alternative ways in which these farmers actually manage risk, particularly in a complex and unstable economic environment such as Nigeria.

Key words: Risk aversion · economic Optimum · Northern Nigeria

INTRODUCTION

In Nigeria, the deteriorating condition of the agricultural sector that has led to the declining trend of domestic food production has been attributed to several factors. Prominent among these factors was the discovery of oil resources [1]. Other factors contributing to this situation as described by [2] are: farmers operating very small farms in scattered plots using primitive tools and traditionally low yielding inputs; farms that were managed by aged, uneducated but rational farmers. Other factors are poor soil conditions, unstable government policies, mismanaged agricultural subsidy regime and bad export crop pricing schedules.

Coupled with the above problems however, farmers' attitudes towards risks remain one of the most outstanding factors inhibiting increased agricultural productivity. It is not in any way difficult to point out that the observed factor use of farmers reveals the underling degrees of risk preferences. Researches, e.g. [3, 4] have also revealed that this inherent inability to choose based on risk preferences affected farmers' adoption of technology. It has been argued [5, 6] that the limited success of Nigeria in rural development programmes is due to the absence of a prior analysis of attitudes towards risk inherent in new technologies and the inability to ascertain the farmers' trade-off between risk and return in traditional agriculture. In the last decade, attitudes towards risk on decision-making by farmers were evidenced by a lot of studies e.g. [7-9]. The efforts that have resulted in the empirical findings from these studies are commendable in three ways: one, positive application of risk theory that explain farmers' behaviour detection; two, decision makers are better empowered in their planning, given their feeling towards risks; and three, the combination of these, form prospective criteria for aiding diffusion of new technologies among farmers [10-14].

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However, most of these studies on risk are not typical of small-holder (or subsistence) agriculture as it is characteristic of farmers in sub-Sahara Africa, especially Nigeria. This study therefore employed the risk attitudes of grain crop farmers in the dry savanna zone of Nigeria, modeled together with their resource endowment to generate alternative, optimal and sustainable grain crop farm plans (crop patterns) for identified risk averse farmers.

This paper is divided into five sections. The next section presents the theoretical background upon which the analytical and empirical models for the study are based. Section three is on research methodology, which includes the description of the study area, data collection and sampling. The fourth section discusses explicitly the results of the research. Section five draws some policy relevance based on the research findings to make vital recommendations and conclusion.

ANALYTICAL AND EMPIRICAL MODELS

Analytical framework: This study stems from the simple assumption of additivity, linearity, divisibility, finiteness and single valued expectations of the linear programming (LP) model [15]. The analytical framework used is a "hybrid" of the conventional LP. Here, the outputs from the LP models are parameterized and transformed into new input-output matrices. These matrices are made up of income deviations and food self sufficiency variables (risk variables). In this way, the Target Minimization of Total Absolute Deviations (T-MOTAD) [16, 17] evolves. The results are then modeled to generate alternative optimal farm plans for the identified risk averse farmers. Some of these techniques have been applied to stochastic and multi-objective farm planning in Africa, e.g. mean-variance analysis [18].

In the MOTAD Programming, the variance constraint of Quadratic Programming (QP) is replaced with a constraint on the mean absolute deviations of net income. The advantage of MOTAD over QP is that mean absolute deviations can be obtained as a linear expression, therefore requiring only LP to find solutions. The T-MOTAD formulation generates expected income (E, M) that approximates the mean-variance (E, V) frontier but as the latter is generally not stochastically efficient, the E, M. efficient frontier is slightly less likely to contain the utility maximizing solution for the farmer. These theoretical limitations can however be overcome while retaining the advantages of the LP formulation. The target MOTAD programming, developed by Tauer [16] is one of such modifications [19]. It entails imposing a constraint on income deviation, from a target level of income. In other words, the mean deviation, (E.d) efficient set of solutions is obtained for a given level of *t*, the target income, where *d* is the deviation from the target. The main advantage is that solutions are second-degree stochastically dominant (regardless of the distribution of income) and so are efficient for risk-averse decision makers. In essence, this paper relies on the conceptual framework of linear programming to explain generated results for the farmers with differing risk attitudes.

The solution procedure for this study generates first, optimal farm profits as necessary bases for which MOTAD formulation is specified as follows:

Maximize $$G = cx - f^{+} \qquad (1)$$

+ No Fixed or overhead costs were considered in this study. Costs of farm implements are calculated on rental basis to give yearly variable cost as part of the cross-sectional data for the study. (Equation I) therefore reduces to maximize G = x

Subject to

$$Ax \leq b \qquad (2)$$

$$^{++}Cx - Iy \leq -ut \qquad (3)$$

++ The matrix C is based on adjusted historical data.

$$Py \leq d,\ d\ \text{var}\ \textit{ied} \qquad (4)$$

and $$x, y \geq 0$$

Where G is expected profit (gross margin), c is a 1 by n vector of activity expected net returns, x s an n by 1 vector of activity levels, f is fixed or overhead costs, A is an m by n matrix of technical coefficients and b is an m by 1 vector of resource stocks. C is an s by n matrix of activity net revenues by state (row) and activity (column), I is an s by s identity matrix, y is an s by 1 vector of activity levels measuring negative income deviations by state. Furthermore, u is an s by 1 vector of ones, t is the target level of total revenue; P is a 1 by s vector of state probabilities and d is deviation from the target.

Empirical model:

$$. \mathrm{Max}\, E(G) \sum_{k=1}^{3} \sum_{j=1}^{10} C_{kj} V_{kj} \qquad (5)$$

Subject to:

$$\sum a_{ij} V_j \,£\, b_i \; (j=1 \text{ to } 10 \text{ and } i=1 \text{ to } 20) \qquad (6)$$

and

$$V \geq 0, \qquad (7)$$

With V_j as a vector of 10 farming enterprises and b_I a vector of 20 constraints (see Appendix for detailed matrix of constraints).

In the above empirical model, the ten major farming activities (enterprise) were found to be either sole maize or maize with other grain crops. Activities in the models include crops, sole maize (mz): maize, cowpea, groundnut (mz/cp/gn); maize guinea corn, millet (mz/gc/milt); maize, millet, groundnut (mz/gc/cp); maize, rice, soybean (mz, rc, sb); maize, guinea corn, groundnut (mz/gc/cp); maize rice soybean (mz, rc, sb); maize, guinea corn, round nut (m/gc/gn). Other activities include family labour, hired labour, own capital and off-farm activities. The set of constraints included land, family and hired labours, household, own and borrowed capital and off-farm activities. The set of constraints included land, family and hired labours, household food sufficiency, own and borrowed capitals, non-negatively and risk constraints (the details of equations for constraints are in the appendix). The means of achieving increased farm income (profit) are examined and assessed for two important sets of objectives for the resources employed in the production process. The first set is the profit maximization (economic optimum) from the farmer's present average level of cultivation. The second set is the generation of farm income equal t or higher than a specifically set income threshold. This income threshold is usually set just to meet or satisfy the basic subsistence needs of the farm's family. Such income threshold was calculated for an average risk-averse farmer that was sampled, based on Selley's [20] procedure. The optimum plans are thus discussed under these two sets of objectives.

Grain/cereal farmers of the study area were initially classified into three groups (groups I, II and III farmers). This classification was based on the risk aversion index, k or factor [21]. Group 1 is made of low-risk averse farmers. Group II is made of medium-risk averse farmers; and groups III is made of high risk averse farmers. Details on the typology of farmers are as described by Olarinde [22]. The corresponding average farm sizes were 6, 4 and 3.5 hectares respectively. Cross-sectional data generated were used to estimate the appropriate coefficients for the linear programming equation to represent the different scenarios considered for this study. Optimal returns from the programme solutions were then compared with the earlier estimated gross returns for each of the representative cropping patterns that were found to be mostly adopted by farmers in the study area.

This paper however presents results for farmers group I and III, which show the best contrast in the strategies adopted between low and high-risk averse farmers.

SOURCES OF DATA

Area studied: The study was carried out in Kaduna State, Northern Nigeria. It lies on longitude 6.13°E-8.70°E and latitude 9.30°N-11.60°N, with a rainfall range of 950mm-150mm and a growing period of 6-8 months. The ecology of the zone favours the cultivation of staple crops, especially grains and other cereals. Prominent crops grown include grain, maize, millet, cowpea, soybean, groundnut and rice. Roots and tubers are also grown and they include yam, cocoyam, cassava, potatoes and ginger. The dominant farming system is mixed cropping, livestock production also occupies every important position as the rearing of large and small ruminants are widely practiced.

Sampling: A multistage stratified sampling procedure was adopted to select 400 farmers required for this study. The basis for the stratification was the Kaduna State Agricultural Development Project (KADP) [23] zones which were obviously structured and demarcated along the lines of their ecologies. Fifteen (15) Local Government Areas (LGAs) were randomly selected from 23 LGAs that make up the four ADP zones. The proportions of farm families from the four ADP zones were determined and used to represent the weight of each ADP zones in the final sample. The percentage of farm families from each LGA in an ADP zone was calculated and used to determine the sample size from that LGA. Finally, respondents from each LGA were selected at random from the list of cereal and grain legume growers in that LGA. Effectively, 348 questionnaires were used for the analysis. Some were either not returned or were discarded for their inconsistent responses.

Data collection: Primarily and secondary data were used for this study. The primary data collection was achieved with the aid of well-structured questionnaire administered on the farmers. Data on farm outputs, family and hired labour and their wage rate, tractor and animal (traction) use, other farm implements, fertilizers and other chemicals were collected. Data on market prices, household food requirements, crop hectarages and farm diversification patterns were equally obtained. To supplement the primary data, relevant secondary data were also gathered. These included historical yield and prices of major crops and price indices. These were collected from the (KADP), Federal Office of statistic (FOS) [24] and the central bank of Nigeria (CBN) [25].

RESULTS AND DISCUSSION

(a) Existing and optimal farm plans with minimized risks for group I farmers: The results are condensed in Table 1 for the farmers' existing plan, which represents the average farm plan as is being practiced and the plan obtained from profit maximization technique only and for risk minimizing alternative plan (I-IV). Plans I to IV are based on a decreasing total absolute deviation of income (TAD). Expected returns decreased from plans I to IV. The expected incomes were N42, 571.01, N42, 552.50, N40,893.14 and N38,177.55 respectively. The corresponding enterprises (activities) in the programme solutions are sole maize;mz/gc/rc; mz/gc/mlt; mz/gc/sb and mz/rc/sb in all the plans. Mz/mlt/sb and mz/gc/gn were not part of any plan; mz/mlt/gn is contained in the existing plan I while mz/gc/cp entered plans, II, III and IV. In plans I to IV there are consistent accompanying decreases in the programme value and the cropped areas. The results obtained here indicate that for the group I farmers, the crop mixtures that are not in the parametric programming solutions are not efficient farm plans and with the prevailing farm environment, they are also not risk minimizing strategies with optimum income.

The trade-off between risk and return (captured by the coefficient of variation) (Table 2) indicates that as the coefficient of a variation reduces, expected returns also decrease. This implies that risk per Naira of return to resources is reduced. The minimum variability in return to farm resources (indicated by the standard deviation) is obtained in plan I and II and since the tendency is always to avert risk, farmers in this group can shift to enterprises mix between plans I and II. This will enable farmers to increase their profit level with minimum risk.

(b) Existing and optimal farm plans with minimized risks farm plans for group III farmers: The expected income (Table 3) were N19,021.79, N18,240.77, N17,848.40 and N17,456.02 respectively for the risk minimized plans. For all the plans, mz/gc/cr, mz/cp/gn and mz/rc/sb entered none but the programme solurion for the profit maximizing plan. Sole maize, mz/gc/mlt and mz/gc/cp are in all but the profit-maximizing plan. Mz/gc/sb entered plans, II, III, IV and the profit maximizing plan. The deductions that can be made from these results are that sole maize, mz/gc/mlt and mz/gc/cp are better risk minimized combinations. These generate ideal and quite optimum income with their risk levels. Other combinations that are found in the programme solution in II, III and IV are also risk minimized combinations, but can be riskier than those which are found in all the plans.

Table 1: Summary of existing and optimal farm plans with minimized risks for group I farmers

	Farmers' plan		Risk minimized and efficient (Alternative) farm plans			
Enterprises	Existing plan	Profit maximizing plan	I	II	III	IV
Net return	60,623.07	38,177.55	69,009.59	42,571.01	42,522.50	40,893.14
Mz (Ha)	0.94 (15.67)	0.55 (9.17)	1.12 (18.67)	0.94 (15.67)	0.92 (15.33)	0.73 (13.0)
Mz/gc/rc (Ha)	0.31 (5.17)	0.10 (1.67)	0.44 (7.33)	0.30 (5.00)	0.30 (5.00)	0.22 (3.67)
Mz/mlt/sb (Ha)	0.15 (2.50)	-	0.14	-	-	-
Mz/cp/gn (Ha)	1.10 (1.67)	1.00 (1.67)	(2.33)	1.10	1.10	1.10 (1.67)
Mz/cp/mlt (Ha)	0.12 (2.00)	0.12 (2.00)				1.12 (2.00)
Mz/rc/sb (Ha)	0.01 (0.17)	-				-
Mz/gc/cp (Ha)	0.25 (4.17)	0.23 (3.83)				0.24 (4.0)
Mz/rc/sb (Ha)	0.35 (5.83	0.29				0.11
Mz/gc/gn (Ha)	0.13 (2.17)	(4.83) 0.34				(1.83) 0.22
Mz/gc/gn (Ha)	0.35 (.83	(5.67)				(3.67)

₦ Naira (Nigerian currency. As at the time of the research, One Naira exchanged for 0.1125 US. Dollars)

Ha: Hectare ( ): Percentage cropped ared

Source: Estimated from LP results

Table 2: Risk and return levels of different farm plans for Group I Farmer

Management strategies	Farmers' plan		Risk minimized and efficient farm plans			
	Existing plan	Profit maximizing plan	I	II	III	IV
(a) Return to resources (₦)	60,623.07	69,009.59	42,571.01	42,522.50	40,893.14	38,177.55
(b) minimized standard deviation (SD)	8.528	6,035	8,528	9,846	9,846	9,846
(c) Coefficient of variation, CV (%)	25.79	24.08	23.15	14.07	14.07	8.73NNaira

Source: Estimated form LP results

Table 3: Existing and optimal farm plans with minimized risks for group III farmers

Enterprises	Farmers' plan		Risk minimized and efficient (Alternative) farm plans			
	Existing plan	Profit maximizing plan	I	II	III	IV
Net return	51,545	71,180.44	19,021.79	18,240.77	17,848.40	17,456.02
Mz (Ha)	0.940.08 (2.29)	-	0.08 (2.29)	0.09 (2.57)	0.10 (2.86)	0.11 (3.14)
Mz/gc/rc (Ha)	1.10 (31.43)	0.98 28.0)	1.10 (31.43)	1.04 (29.71)	1.01 (28.80)	0.98 (28.00)
Mz/mlt/sb (Ha)	0.15 (4.30)	-0.55 (15.71)	-	-0.10	-0.56	-0.02
Mz/cp/gn (Ha)	0.18 (5.14)	1.00 (28.57)	0.18 (5.14)	(2.86) 1.41	(16.0) 1.34	(0.57) 1.28
Mz/cp/mlt (Ha)	1.54 (44.0)	-	1.54 (44.0)	(40.29)-	(38.29)-	(36.57)-
Mz/rc/sb (Ha)	0.05 (1.43)	-	-	0.13	0.19	0.26
Mz/gc/cp (Ha)	0.45 (12.89)	0.58 (16.57)	-	(3.71) 0.41	(5.43) 0.45	(7.43) 0.48
Mz/rc/sb (Ha)	0.34 (9.71)	-	0.34 (9.71)	(11.71) 0.32	(12.86) 0.35	(13.71) 0.38
Mz/gc/gn (Ha)	0.26 (7.43)	0.37 (10.57)	0.26 (7.43)			
Mz/gc/gn (Ha)	0.25 (7.16)	-	-	-	-	-

( ) percentage of cropped area Source: Estimated from LP data

Table 4: Risk and return levels of different farm plans for group III farmers

Enterprises	Farmers' plan		Risk minimized plans			
	Existing plan	Profit maximizing	I	II	III	IV
(a) Return to resources (₦)	51,545	71,180.44	19,021.70	18,240.77	17,848.40	17,848.40
(b) Minized Standard Deviation (SD)	10,235	10,814	10,235	10,525	10,525	10,525
(c) Coefficient of Variation, CV(%)	60.29	60.13	57.82	57.70	57.70	53.81

Source: Estimated from LP results

Table 5: Generated and suggested sustainable alternative risk minimized and efficient grain crop farm plans

Risk averse farmer groups	Suggested sustainable plans
Low risk	II, III (₦4,851)
High risk	II, IV (N392.37)

( ) Figures in parenthesis are values of least income variability

Noticeably, the trade-off between risk and return to resources show increasing levels of risks of the farm plans from groups I to III. Return decreases with each decrease in the coefficients of variation (Table 4). In this group, however, the standard deviation which indicates the extent of variability of the return to farm resource is not decreasing significantly. There appears to be a consistent variation in the risk levels of farm plans. The best plan however can be chosen from plans II and III.

The variability in expected return from the risk minimized farm plan and for the two categories of farmers formed the basis for the suggested alternative farm plan that farmers in the study area can adopt. Depending on the risk preference of farmers, one from each of the two pairs of suggested farm plans can be made sustainable by a risk averse farmer (Table 5).

It is important to note that the initial optimal (Profit maximizing) plans, which formed the basis for the subsequent flexible plans were generated as the best achievable plans when profit maximization was the only objective. However, with the introduction of quantified risk levels of crops and farm plans, the alternative farm plans offered lower income. They are nonetheless realistic solutions that are efficient in term of resource-use and sustainability.

Comparable results were found by Adubi and Daramola [26]; Abudulkadri and Ajebefun [1] and Umoh [27]. In their studies, the risk minimized and efficient crop plans were generalized for farm sizes and unspecified risk averse farmers. The results of this present study are however distinct in the sense that they are specified according to the risk preferences and attitudes of different categories of farmers in the study area. The suitability of the present approach is found in its ability to identify individual farmers with respect to their risk preferences and bearing abilities. This is necessary for the advocacy of farm plans which can best be sustained.

SUMMARY OF FINDINGS, RECOMMENDATION AND CONCLUSION

In the study area, farmers employed about 10 major diversification crop farm plans to manage risk. These include sole maize and maize with at least two of guinea corn, rice, millet, soybean, cowpea and groundnut. The analysis shows that risk minimized and efficient farm plans varied by the risk aversion level of the farmer (i.e. low. medium and high risk averse farmers) and the crops constituting each plan in the alternative plans. Results in the models for the two groups of risk averse farmers show that farmers' existing and profit maximizing plans are risk-inefficient, indicating that risk can be kept at a minimum while maintaining smaller reductions in returns to resources between the plans.

The study has also been able to show that there are increasing levels of risks of the farm plan from the low (group 1) to the high-risk (group III) averse farmers. For the two groups of farmers however, a positive trade-off is observed between risk and returns to farm resources. As the risk level of farm plans increase, expected returns to farm resources also increase. This supports the theory that highly risky enterprises have attached to them, a commensurate high income. However, sustainable farm plans that minimize risk and can ensure desirable net returns are also suggested for the two categories of farmers.

The model for farmers' existing plans, together with the profit maximizing and risk minimizing efficient plans have important implications for strategies to increase crop production. These ultimately result in efficient use of resources and returns to farmers' resources. The risk minimized farm plans for the two categories of farmers in this study can be sustained if their resource requirements are consistent. Resources like labour, own and borrowed capitals could be allocated in diverse ways for all the flexible plans and for the two groups of risk averse farmers (based on the projected resource allocation patterns). However, such resources are sometimes difficult to actualize in the real sense of it. There is need for research to focus critically on simple implements that can perform tasks like weeding, planting, harvesting and so on. Such implements will remove the physical stress of labour and because of the simplicity of their nature; farmers in the study area would be able to afford them. Government and other stakeholders should also expand avenues for credit to farmers to supplement farmers' meager equity. Higher risks accompanied higher returns to farm resources. In spite of these higher returns however, reduction in risk was not consistent with the variability in returns. This was due to further drop in yields from plan to plan. It is therefore recommended that policies that will minimize or stabilize the effect of market forces on the prices of crop be put in place. For example, attractive input prices can be set by government. This will increase their use thereby resulting in increased crop yields. This situation has the capability of mitigating disequilibrium between demand and supply.

There are possibilities for expanding the area under crop production in the study area. These can equally expand the flexibility levels of the risk minimized farm plans, thereby raising the maximum risk-return efficiency frontier confronting the farmers. The effect of such expansion strategy on marketed output however could be limited, due to low yields. Since in this study, plans have been developed within which farmer can minimize risk and remain efficient, new technologies and policies that would make farmers operate within those plans can be made available through the mutual efforts of government, research and extension agencies.

In conclusion, this research provides a critical methodological framework that can help understand the alternative ways in which small-holder farmers actually manage risk particularly in a complex and unstable economic environment such as Nigeria.

Appendix: Detailed Matrix of Constraints

$\sum_{j=1} a_{1j} v_j < b_1$ Land (hectares) (1)

$\sum_{j=1} a_{2j} v_j < b_2$ Family Labour (labourdays) (2)

$\sum_{j=1} a_{3j} v_j < b_3$ Hired Labour (labour days) (3)

$\sum_{j=1} a_{4j} v_j < b_4$ Owned Capital (Naira) (4)

$\sum_{j=1} a_{5j} v_j < b_5$ Borrowed Capital (Naira) (5)

$\sum_{j=1} a_{6j} v_j < b_6$ Off-farm Activities (Naira) (6)

$\sum_{j=1} a_{7j} v_j < b_7$ (Deviation, 1996, in Naira) (7)

$\sum_{j=1} a_{8j} v_j < b_8$ (Deviation, 1997, in Naira) (8)

$\sum_{j=1} a_{9j} v_j < b_9$ (Deviation, 1998, in Naira) (9)

$\sum_{j=1} a_{10j} v_j < b_{10}$ (Deviation, 1999, in Naira) (10)

$\sum_{j=1} a_{11j} v_j < b_{11}$ (Deviation, 2000, in Naira) (11)

$\sum_{j=1} a_{12j} v_j < b_{12}$ Minimum Absolute Deviation (O-M) (12)

$\sum_{j=1} a_{13j} v_j < b_{13}$ Mimimum Maize (Tonne) (13)

$\sum_{j=1} a_{14j} v_j < b_{14}$ Minimum Guinea Corn (Tonne) (14)

$\sum_{j=1} a_{15j} v_j < b_{15}$ Minimum Rice (Tonne) (15)

$\sum_{j=1} a_{16j} v_j < b_{16}$ Minimum Cowpea (Tonne) (16)

$\sum_{j=1} a_{17j} v_j < b_{17}$ Minimum Millet (Tonne) (17)

$\sum_{j=1} a_{18j} v_j < b_{18}$ Minimum Soybean (Tonne) (18)

$\sum_{j=1} a_{19j} v_j < b_{19}$ Minimum Groundnut (Tonne) (19)

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