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Original Research Article

Simulation Model of Risk Management in the Gezira Scheme, Sudan

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ABSTRACT

Studies involving risk analysis could be most useful in a wide range of production optimization problems. The results of such studies could be valuable to private and public decision makers. Gezira scheme has a high potential of building national food security and foreign exchange earnings in the economy of Sudan. Tenant in the Gezira scheme face unstable farm income due to uncontrollable weather conditions and unpredictable input and output prices. The quadratic risk programming model was developed and used in this study to simulate the scheme according to expected income by different risk attitude. Primary data were collected from a random sample of 150 farmers in the scheme; secondary data were collected from relevant formal sources. The results showed that Groundnut is the most risky crop in the scheme followed by Sorghum, Cotton and Wheat. Reducing risks need sacrifice of relatively little expected income, so achieving higher income means being more risky. Management of agricultural risks contributes substantially to farm income stability.

Keywords: expected income, risk, quadratic risk programming model, Gezira scheme, Sudan.

I. INTRODUCTION

Agriculture is subject to a considerable element of uncertainty in all its aspects and relationships. [1] It is susceptible to all the social and economic uncertainties which any other similar enterprise, such as mining or industry is called upon to face. In developing countries where farming is particularly weather-dependent, farmers face substantial risk of farm income fluctuations originated mainly from yield and price uncertainties. Therefore, risk considerations in these areas are more important especially for poor farmers. Moreover, increased income risk is considered itself a loss of welfare to risk-averse farmers. It might make modern crop technology less attractive to farmers and hence decelerate agricultural development. Grouped sources of risk in agriculture into production, marketing, financial, legal and human risks. [2] The major source of production risks are weather, pests, diseases technology, genetics, machinery efficiency and the quality of inputs. Unanticipated force such as weather or government action, can lead to dramatic changes in prices. [3] Stated that the risk management process could be divided into a series of individual steps that must be accomplished in managing risks. The six steps in the risk management process are: determination of the objectives, identification of the risk, evaluation of the risk, considering

alternatives and selecting the risk treatment device, implementing the decision and evaluation and review. [1] stated that there are three principal ways of mitigating agricultural risks which are: avoidance, prevention and assumption. On the other hand [2] stated that, there are five main methods to deal with and manage risk and uncertainty indecision making which are: (1) Retain risk with no protection from downside risk. (2)Shift risk by using a contractual arrangement such as insurance. (3) Reduce risk, keep fences in good repair. (4) Self-insurance. Maintain emergency reserves funded from previous years profits. (5) Avoid risk by not selecting a particular enterprise. Gezira scheme is the largest irrigated scheme under on management in the world. The prevailing farming systems in the scheme aim to produce food and high value export crops for self-sufficiency and for export respectively. One of the scheme main objectives is to promote social development of the tenant as well as people residing in the scheme area through better schooling, medical care, and creation of job opportunities and the sense of security through better settlement. [4] It represent about a quarter of all irrigation area in Sudan and half the area of irrigation schemes drawing water from the Nile system. It uses about 35% of Sudan's current allocation of Nile water. [5] The scheme contributed 58 % of cotton, 46 % of wheat, 23 % of groundnut and 12 % of sorghum of the total production of Sudan. [6] Despite the economic importance of the scheme, crop production in the Gezira scheme has production, market and financial risks. Production risks included drought, flood, pests and diseases…etc. that creates variability in yields. Market risk result from fluctuating output prices. Both risks cause a considerable reduction in producer incomes. Financial risks arise from high dependence of farmers on borrowed funds. Other institutional risks are associated with changes in the policy framework (agricultural and other policies). The presence of different agricultural risks had resulted in low and variable productivity and producer prices in the Gezira scheme. So low farm income and other financial difficulties are common among farmer as a result. This paper aims to classify tenant's risk attitudes (risk averse, risk indifference and risk preference), simulate different scenarios according to expected income by risk attitude.

II. METHODOLOGY

2.1 Data collection source

The survey was conducted between June and October 2009 in The Gezira scheme, Sudan. During this time both primary and secondary data were collected. Secondary data was obtained from references, annual reports, published and unpublished materials and previous studies from relevant institutions. Primary data were collected by direct interview with the respondents. A structured questionnaire covering the relevant aspects was designed and distributed to respondents. Basic information derived from an interviewed-based sample survey includes:

- Socioeconomic characteristics of farm households like age, level of education, household size, sex, marital status, etc,
- Cost of production, crop return, farm income and off farm incomes.
- The major agricultural problems of the sample communities.
- Information about farmers' insurance status and their opinion on the different aspects regarding agricultural insurance.

2.2 Sampling procedure

The surveyed sample consists of 150 farm households, which were selected through stratified random sampling technique, as there no significant differences within the farming system regarding farmer's decisions on crop mix, yield and production were shown. For the purpose of the study, 2 groups of the 18 groups of the scheme were selected, and from each group 5 blocks are selected from each block 15 tenants are selected randomly to obtain a sample size of 150 respondents. The data collected were analyzed using descriptive

statistical analysis and quadratic risk programming model.

2.3 The study area

The study area is located about 115 kilometers south of Khartoum, central Sudan. It covers a net cultivable area of little less than one million hectares (about 2.1 million feddans). Gezira scheme consists of two main parts: Gezira main with an area of 1.1 million feddan and Managil extension of 1.0 million feddan. [7] It has a population of about 2.9 million people either live in the scheme and depend on it for their livelihood as tenants, sharecroppers, agricultural laborers, traders or providers of various services. [5]

2.4 Analytical tool

To achieve the stated objectives, a quadratic risk programming model was developed, using non-linear programming. The first attempts to take explicit account of risk in mathematical programming formulations of the whole farm planning problem were by quadratic risk programming. In this formulation risk is considered only in relation to activity net revenues, the constraints still being regarded as deterministic. It used to assume that the activity net revenues follow a multivariate normal distribution. The relevant statistics are the mean, variances and covariance of the activity net revenues. These are commonly estimated from trend-corrected historical data [8,9] reported that quadratic risk programming has been used to generate e set of farm plans lying on the mean-variance (E, V) efficient frontier. E, V efficiency rule is based on the proposition that if the expected value of alternative A is greater than or equal to the expected value of alternatives B, and variance of A is less than or equal to the variance of B, with at least one strict inequality, then A is preferred to B by all decision makers. The model used in this study, of the E, V problem whose objective function is to minimize the variance subject to a given level of the expected income is written as follows: [8]

$$Min\ V = \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma ij x_i x_j \quad (1)$$

Subject to:

$$\sum c_j x_j - f = E \quad (2)$$

$$\sum_{i=1}^{n} a_{hj} x_j \leq b_h \rightarrow \text{All h} \quad (3)$$

$$x_j \geq 0 \rightarrow \text{All j} \quad (4)$$

Where:

V: Variance of the total gross margin of the current plan

σ_{ij}: Covariance of gross margins between the j_{th} and i_{th} activity (σ_{ij}) will be the variance when j = i

x_j: Level of the j_{th} activity

c_j: Expected net revenue per unit of the activity j.

E: Expected gross margin (profit)

a_{hj}: Technical input-output coefficient specifying the amount of the h_{th} resources required for a unit of product from the j_{th} activity.

B_h: The available stock of the h_{th} resources.

f : The fixed costs (since the fixed costs do not very with the level of the activity, they can be omitted from the model formulation).

The resources constraints and the coefficient matrix are assumed to be deterministic, the coefficient matrix represents per feddan amount of the resources which is required for each crop production activity included in the model table (1).

The gross margins of the major crops produced in the scheme during the period (1990/91-2008/09) were used to calculate the gross margins variance and covariance used in the model. The expected incomes used are assumed to be the expected incomes for different scenarios given the producer available resources. These targeted incomes include:

(1) Income from the field survey results as a target income (US$ 641).
(2) Income for the insured farmers whom are diversified their income sources (US$992). (3) Income for the noninsured and diversified farmers (US$ 1124).
(4) Income for the insured and non diversified farmers (US$ 328).
(5) Income for the non insured and non diversified farmers (US$ 175).

Table (1): Resources constraints and the coefficient matrix

	Unit	Cotton	Wheat	Groundnut	Sorghum	RHS
Land	Feddan	1	1	1	1	<= 20
Labor	Man days	48	11	33	30	<= 537
Capital	US $	260	156	136	107	<= 2391
Water	Cubic meter	4377	2555	2877	2558	<=46468.63

RHS=Right hand said

Solving this model requires access to software capable of solving non-linear problems. There are several software packages that are used to do these jobs. For this study the model was solved using GAMS (General Algebraic Modeling System) that incorporates several powerful non-linear programming packages.

III. RESULTS AND DISCUSSION

Table (2): Variance and covariance of gross margin for the major crops, Gezira scheme (1990/91 – 2008/09)

Variance	Cotton	Wheat	Groundnut	Sorghum
Cotton	5581	2148	2884	345
Wheat	2148	4127	5625	2577
Groundnut	2884	5625	21136	8956
Sorghum	345	2577	8956	7968

Source: model results

To identify the risky crop, the quadratic risk programming model results indicated that groundnut was the most risky crop and Wheat was the less risky crop in the scheme (table 2). Although sorghum was a risky crop, it is still an important for the tenant being the main source of staple food crop in the scheme. The crop residues of sorghum were also used for animals

3.1 Crop combination and land use intensity under the E.V. concept in Gezira scheme

Three categories of risk attitudes had been classified which were: Risk averse category which included (insured and diversified farmers, noninsured and diversified farmers, insured and non diversified farmers), risk preference category which included farmers whom were not insured or diversified their income sources and risk indifference (no one).
Five scenarios for different expected net incomes were used in order to obtain a good indication of the solutions likely to be of interest to the farmer, and to determine the area allocation for different crops and the expected income variances for the different amount of income that can be achieved under the variable resources. While scenario 1 represents the risk preference farmers, scenario 2, 4 and 5 represent the risk averse farmers. Scenario 3 is used as target income from the field survey.

Table (3): Change of basic solution for the quadratic risk programming (QRP) formulation, Gezira scheme

Item \ Scenario		Non insured and non diversified	Insured and non diversified	field survey	Diversified and insured	Diversified and non insured
		1	2	3	4	5
Income (US$)		175	328	641	992	1124
Variance($\$^2 10^9$)		0.2747	0.9652	3.6863	10.2010	15.5844
Crop (feddan)	Cotton	1.412	2.646	5.171	4.578	2.785
	Wheat	0.124	0.233	0.456	0.00	0.00
	Groundnut	0.00	0.00	0.00	0.656	1.762
	Sorghum	1.299	2.434	4.756	9.595	11.418
Total land use (fed.)		2.835	5.313	10.383	14.829	15.965
Land use intensity %		14	27	52	74	80

Source: model results

Table (3) shows changes of basic solutions for the quadratic risk programming formulation under the E.V. concept. It showed that through all five scenarios, the variance of the expected income increases as income increases (Correlation=0.959). This indicates that achieving higher income means bearing more risk. The results also reflect positive correlation between the income and the land use intensity (0.997), as income increases the crop area increases. Throughout all of the scenarios of income cotton and sorghum has the highest area allocation. For wheat crop, although it was less risky the area allocated to it not exceeded 0.5 feddan, for scenario 4 and 5 the area allocated to wheat was zero perhaps due to its high cost of production and low gross margin value compared to the other crops. For groundnut, which was the most risky one, its area allocated was zero for scenario 1 up to 3. For 4 and 5 some area was allocated to groundnut. The area allocated to groundnut and sorghum increased associated with higher level of income. Tenants with higher level of income seemed to be more risk prone, and therefore expand their area under these risky crops.

3.2 Impact of changes in relative prices of cotton and wheat

Table (4): Change of the (QRP) formulation when prices of wheat and cotton are changed, Gezira scheme.

Scenario / Item		Non insured and non diversified	Insured and non diversified	field survey	Diversified and insured	Diversified and non insured
		1	2	3	4	5
Income (US$)		175	454	820	1283	1124
Variance($\$^2 10^9$)		0.2747	1.8492	6.0473	24.5522	15.5844
Crop (feddan)	Cotton	1.412	3.662	6.306	3.545	2.785
	Wheat	0.124	0.323	0.405	0.204	0.00
	Groundnut	0.00	0.00	0.00	3.100	1.762
	Sorghum	1.299	3.369	6.433	10.544	11.418
Total land use (fed)		2.835	7.354	13.144	17.393	15.965
Land use intensity %		14	37	66	87	80

Source: model results

The prices of wheat and cotton increased due to government support for price of wheat to 100 SDG/sack and increasing of international price of cotton. Therefore cotton price increased by 100% and price of 100 SDG/sack for wheat was used and then the five scenarios were developed. As shown in table (4) for scenario 1 and 5 farmer income, land use intensity and the area allocated to different crops remained the same when compared to the basic solution. Those scenarios represent non insured farmers (They do not grow cotton and wheat). For scenario 2, 3 and 4 farmers income and land use intensity are increased. The area allocated to cotton increased in scenario 2 and 3 and decreased in scenario 4 as the tenant with the higher level of income preferred the risky crops. However, despite of the high new price (100 SDG/sack) for wheat, no farmers attempted to increase area under wheat.

3.3 Impact of increasing cost of production of different crops

This case was conducted by increasing the costs of production of the different crops due to increased fuel and other input prices.

Table (5): Change of (QRP) formulation with increase costs of production by 20%, Gezira scheme

Scenario / Item		Non insured & non diversified	Insured & non diversified	field survey	Diversified & insured	Diversified & non insured
		1	2	3	4	5
Income (US$)		113	218	462	724	902
Variance($\$^2 10^9$)		0.1145	0.4263	1.9149	4.7028	7.5947
Crop (feddan)	Cotton	0.912	1.759	3.727	5.841	5.815
	Wheat	0.080	0.155	0.329	0.515	0.00
	Groundnut	0.00	0.00	0.00	0.00	0.00
	Sorghum	0.838	1.618	3.428	5.372	8.215
Total land use (fed)		1.83	3.532	7.484	11.728	14.03
Land use intensity %		9	18	37	59	70

Source: model results

Table (6): Change of (QRP) formulation with increase costs of production by 40%, Gezira scheme

Scenario / Item		Non insured & non diversified	Insured & non diversified	field survey	Diversified & insured	Diversified & non insured
		1	2	3	4	5
Income (US$)		72	108	281	451	680
Variance($\$^2 10^9$)		0.0465	0.1046	0.7084	1.8248	4.1485
Crop (feddan)	Cotton	0.581	0.871	2.267	3.638	5.486
	Wheat	0.051	0.087	0.200	0.321	0.484
	Groundnut	0.00	0.00	0.00	0.00	0.00
	Sorghum	0.534	0.801	2.085	3.346	5.046
Total land use (fed.)		1.166	1.759	4.552	7.305	11.016
Land use intensity %		6	9	23	37	55

Source: model results

The costs of production of different crops increased by 20% and 40% respectively, and then the five scenarios were developed, Tables (5, 6). The result indicates that by increasing costs of production farmer income and land use intensity to different crops decreased. Also for all different scenarios the area allocated to groundnut is zero and the area allocated to sorghum decreased. For cotton and wheat the area allocated to them decreased in scenario 1,2 and 3, in scenario 5 the area allocated to cotton increased. Increasing cost of production has great effect on groundnut as it was completely removed out in the different scenarios. The reduction in area allocation to Sorghum would be larger than that in case of the other two crops. It may be concluded that sorghum would be more affected by increasing cost of production than wheat and cotton.

3.4 Impact of reducing cost of production of different crops

This case was conducted by decreasing the costs of production of the different crops assuming support of agricultural production through tax and customs exemption. Therefore costs of production of different crops decreased by 20% and 40%, and then the five scenarios were developed. The result indicated that by decreasing costs of production both of farmer's income and land use intensity increased than that in basic solution. For wheat crop the area allocated to it increased greater than that in the basic solution but it still very little. The area allocated to groundnut remain zero for scenario 1, 2 and 3, in scenario4 and 5 it shows greater increase than that in the basic solution, a greater increase in area allocated to sorghum than that in the basic solution is also shown, Tables (7, 8).

Table (7): Change of (QRP) formulation with reduce costs of production by 20%, Gezira scheme

Scenario / Item		Non insured & non diversified	Insured & non diversified	Field survey	Diversified & insured	Diversified & non insured
		1	2	3	4	5
Income (US$)		236	439	825	1273	1346
Variance($\$^2 10^9$)		0.4996	1.7290	6.1280	23.9072	29.3106
Crop (feddan)	Cotton	1.904	3.541	6.281	0.690	0.00
	Wheat	0.168	0.312	0.370	0.182	0.205
	Groundnut	0.00	0.00	0.00	3.017	5.512
	Sorghum	1.751	3.257	6.544	13.410	11.762
Total land use (fed)		3.823	7.11	13.195	17.299	17.479
Land use intensity %		19	36	66	86	87

Source: model results

Table (8): Change of (QRP) formulation with reduce costs of production by 40%, Gezira Scheme

Scenario / Item		Non insured & non diversified	Insured & non diversified	Field survey	Diversified & insured	Diversified & non insured
		1	2	3	4	5
Income (US$)		298	549	1006	1367	1468
Variance($\$^2 10^9$)		0.7967	2.7041	10.6841	31.8836	54.8296
Crop (feddan)	Cotton	2.404	4.429	4.388	0.00	0.00
	Wheat	0.212	0.390	0.158	0.137	0.192
	Groundnut	0.00	0.00	0.774	7.249	10.065
	Sorghum	2.211	0.390	9.630	9.876	7.198
Total land use (fed.)		4.827	5.209	14.95	17.262	17.455
Land use intensity %		24	26	75	86	87

Source: model results

It can be concluded that groundnut and sorghum was more affected by decreasing cost of production than cotton and wheat. In scenario 4 and 5 the area allocated to cotton and wheat decreased and the area allocated to sorghum and groundnut increased as the tenant with the higher level of income preferred the risky crops.

3.5 Impact of increasing yields of different crops

This case was conducted by increasing yields of different crops by 20%. After developing the different scenarios the result indicated that farmer income and land use intensity of different crops increased than that in basic solution. For cotton crop the area allocated to it increased in scenario 1, 2 and 3 in scenario 5 and 6 the area allocated to it droped to zero. For wheat crop the area allocated to it increased greater than that in the basic solution but it still very little. The area allocated to groundnut remain zero for scenario 1, 2 and 3, in scenario 4 and 5 it shows greater increase than that in the basic solution. The area allocated to sorghum increased in scenario 1 to 4 than that in the basic solution and decreased in scenario 5. Also it is concluded that sorghum and groundnut have been more affected by increasing yield compared to cotton and wheat table (9).

Table (9): Change of (QRP) formulation with increasing crop yields by 20%, Gezira scheme

Scenario / Item		Non insured & non diversified	Insured & non diversified	Field survey	Diversified & insured	Diversified & non insured
		1	2	3	4	5
Income (US$)		241	472	920	1359	1453
Variance ($\$^2$ 10^9)		0.5210	1.9987	8.0406	30.8261	50.2021
Crop (feddan)	Cotton	1.944	3.808	5.356	0.00	0.00
	Wheat	0.171	0.336	0.471	0.163	0.183
	Groundnut	0.00	0.00	0.00	6.587	9.705
	Sorghum	1.788	3.502	8.531	10.594	7.627
Total land use (fed)		3.903	7.646	14.358	17.344	17.515
Land use intensity %		20	38	72	87	88

Source: model result

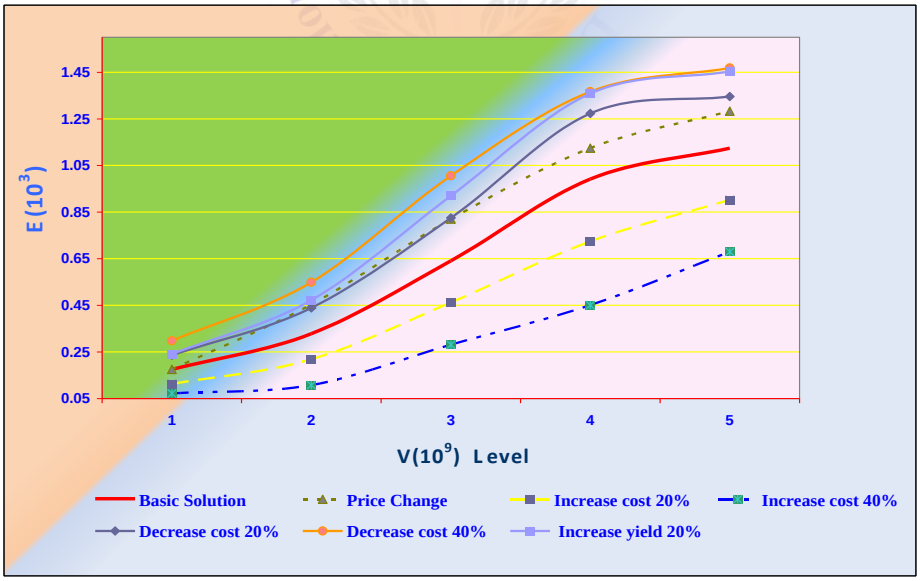

Figure (1): E, V efficient frontier for the (QRP) formulation, comparing the basic solution with different changes, Gezira scheme
Source: model results

Figure (1) compared the six strategies of changes in prices, cost of production and yield with the basic solution, all graphs show that to achieve a significant reduction in variance (reducing risk) need sacrifice of relatively little expected income. Also the figure indicates that while the graphs of increasing cost of production strategies lie below the basic solution, the graphs of cost of production reduction,

increasing yield and increasing prices of cotton and wheat strategies lie above the basic solution graph. The strategies which lie above the basic solution are dominating that which lies below it as they reduce the risk and increase farmer income.

IV CONCLUSION

Groundnut is the most risky crop in the scheme followed by sorghum, cotton and wheat. Although sorghum was a risky crop, it is still an important for the tenant being the main source of staple food crop in the scheme. The crop residues of sorghum are also used for animals. Wheat crop was not preferred to the Gezira tenant for its high cost of production and its low gross margins. Reducing risks need sacrifice of relatively little expected income, so achieving higher income means being more risky. Therefore the area allocated to the risky crops is increased with the higher level of incomes. Management of agricultural risks positively affected the farm income. These recognize the need for more modern risk management systems to prevent the economic losses which negatively affected production in order to stabilizing their incomes.

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