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Resources Management and Risk Efficiency of Crop Rotation Systems in Sudan Gezira Scheme

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Abstract

Risk is an important factor in crop rotation systems and cropping system management studies. The study uses stochastic simulation techniques and Stochastic Efficiency with Respect to Function (SERF) to evaluate five crop rotations risk-efficiency and economic sustainability in Sudan Gezira Scheme. Price and yield risk for five crops were simulated to calculate whole-scheme net return. The analysis shows with the present irrigation system capacity 4 course rotation is the most preferred at lower (ARAC) and the 5 Course rotation (B) with 53% land use intensity achieve water distribution equity and is the most risk efficient crop rotation at upper (ARAC). It is downside risk oriented and resilience crop rotation. The area allocated in 5 Course rotations (B) for cotton crop is 17%, wheat 7%, sorghum 60%, groundnut 4% and fodder crops 12%. Fodder can be grown two times in summer and winter season without creating water shortage problems. However, this will increase net return and increase soil fertilities within the selected crop rotation. The result also shows that return pack to night storage irrigation system needs a risk premium of 36 Million (SDG). The techniques used in this study could be used with any distribution estimates for the uncertain variables to incorporate new crop varieties and research recommendation packages. They also could be modified to account for new information contribution during the decision process and account for dynamic effects and policy adjustment and modification.

Keywords: crop rotation, risk-efficient alternative, SERF analysis, simulation model, risk and uncertainty

1. Introduction

The Sudan Gezira Scheme is the largest farm under one management in the world. It occupies 2.1 million acres and one hundred thousand farmers. The scheme accounts for 50% of the total irrigated land of Sudan. The Gezira scheme slopes gradually from south to north and is irrigated by thousands of kilometers of main canals and subsidiary field canals. The scheme provides a livelihood for two million people living within it is boundaries. The scheme is a joint venture between government, management and farmers and each party has specific duties and cost in production. The General Director of Irrigation provides water up to the miner canals and from that point onward water distribution is operated by Sudan Gezira Scheme staff.Figure

The main objective of the scheme is to develop and promote resources to achieve maximum socioeconomic benefit for farmers and people living within the scheme. In year 1991/1992 the Scheme translates government policy to achieve food security and reduce cash crop area (cotton and groundnuts) and increase food crop area (wheat and sorghum). The area of cotton crop of season 1991/1992 was reduced by 45% and cereals crops increased by 100%.

The Government is responsible for maintaining main canals and irrigation operation up to minor canals. The maximum area can be irrigated is one half of the Scheme which is equal to 1.5 million acres each year. The Government is also responsible for importing all chemicals and inputs and marketing cotton and determining cotton and wheat farm gate price. The Sudan Gezira Board (SGB) is responsible for determining crop area to be cultivated each year and land leveling and preparation using scheme machineries, maintaining subsidiary field canals. The Scheme provides agricultural inputs and supervises farmers operation and maintains the scheme fixed assets. The Sudan Gezira Board (SGB) also keeps all financial records of the scheme and individual farmer accounts and at the end of the cropping season the scheme services cost detected from farmers' individual account and balance dispersed to farmers. The farmers are responsible for agricultural operation such as planting and irrigation and harvesting and paying other duties costs not paid by scheme.

The scheme continuously operated for 75 years and during the period many changes have taken place especially in soil, canalization systems, agricultural environment and scheme farmers' themselves. Studies on these issues have to be conducted to investigate the extent of changes on productivities and improve operation, argued Muddathir A. Ahmed, (2004).

The irrigation system of the scheme is a huge network of main, branch, major, minor and field canals. The irrigation system comprises two main canals length is 261 km, 11 branch of a total length of 651 km, 107 major canals with a length of 1,652 km and 1,498 minor canals with a length of 8,119 km. The field canals consist of 29,000 (Abu XX) with a total length of 40,000 km and 350,000 (Abu VI) with 100,000 km length and a capacity of 50 Lit / second. The design objective of the irrigation system is to provide adequate water supply to cultivated crops and the reliability of water supply irrespective of time and location within the scheme. During 1989/1990 season a study on irrigation system performance indicated that the conveying performance of the head and middle of the major and minor canals is good but the tail of the tail major, middle and tail of the minor performance were unsatisfactory and supply 20% less the target quantities of water as stated by (Shafique, M. S., 2008). However, with the existing canals siltation and weed infestation the unattended irrigation practices increased. The night storage irrigation system turned to continuous irrigation system and irrigation schedule and timing deteriorated. The irrigation of "Number" a land of 90 acres take more time than the design irrigation frame time and the whole operation of the irrigation system could not be maintained.

The scheme management (SGB) implemented new strategy and crop rotation and reduced total cultivated area and land use intensity to cope with limited water resources and irrigation problems especially during 1990s. The problems of irrigation have been covered in detail in many studies, A. M. Eldaw (2004); Muddathir A. Ahmed (2004).The cash crops i.e. cotton and groundnuts area reduced by 45% and 75%, respectively. Food crops such as sorghum crop area increased by 100% to achieve food security policy. The crop rotation modifications have been imposed on the farmers who have a little choice to decide on which crops to grow. Farmer has a right to decide the crop he wants to cultivate only on 6% of his land area such as vegetable and fodder crop. This land tenure system discourages farmers from investment and improves productivity. Farmer's participation in Field School and WUA (Water Union Association), location of the farm, land tenure system are the main factors influencing on the technical inefficiency for the cultivated crops in the Gezira scheme argued Fadelmola M. Elnour and Abbas E. M. Elamin (2014).

Agricultural management decisions are most always made in the face of uncertain variables and consequences. Crop planting areas are generally made before a price for the crop has been set and long time before yields are determined. Inputs required for farming are also uncertain in term of quantities and value. Following Hardaker et al. (1997), uncertain outcome especially unfavorable ones are broadly defined as risk. Hardaker et al. (1997) divide risk sources into five categories: production risk, price and market risk, institutional risk, human or personal risk, and financial risk. The production risk in the scheme refers to uncertain crop yields due to quantity and time of inputs application, rainy season and pest infestations. Price or market risk refers to uncertain input and output prices and institutional risk arises from changes in government policies and irrigation water availability in main canals and field canals. Crop rotation risk analyses using stochastic efficiency with respect to function (SERF) have been covered in many studies Ascough II. et al. (2009); G. Lien et al. (2007). These studies use experimental and field plot data which is different from what is obtained in farmers' field. The (SERF) was introduced by Hardaker et al. (2004).

Farmers in the scheme face operation and activities delay due to un-availability of inputs and irrigation water in canals, which is the main source of risk that should be considered in comparing crop rotation performance in the scheme. Comparing different cropping systems needs a whole-farm budget approach and not partial budget analysis, since factors interact, argued G. Lien, et al. (2005). In this study we use historical data from scheme collected by Socio-Economic Research Unit (SERU) and consider yield and price risk for each crop rotation in the analysis and whole scheme net returns for each crop rotation approach.

Farmers are generally risk averse and are willing to give up some expected returns from cash crops return such as cotton and groundnuts for a reduction in risk due to water shortage. However, the amount farmers would be willing to give up depends on farmers preferences. There are many ways that farmer in Sudan Gezira Scheme can deal with risk. They use to reduce or eliminate risk by collecting information to reduce uncertainty, by finding less risky ways to produce cash crop such as cotton, or by building flexibility into their operations allowing them to rapidly respond to changing conditions. Alternatively, they can transfer risk to others by using futures markets agreements. Financial tools such as (Shail agreement) are used at the scheme. In this case the money lender provides advance loans to farmers who pledge the delivery of a specific quantity of output equivalent to the value of the loan at the time of harvest.

In analyzing cropping systems, it is important to understand sources and effects of risk and how farmers respond to risk. The approach in this paper is to use land and water resources as an example of risk in cropping systems to illustrate some useful tools for analyzing risk and to understand the ways risk can affect farmers and Scheme decision makers' behavior.

The study investigated five crop rotations with different land use intensities to identify yield and price risk on scheme net return and determine risk efficient crop rotation and land use intensity.Figure

2. Materials and Methods

2.1 Stochastic Budgeting – Crop Rotation Systems Analysis

To evaluate risk, we need to identify the distribution of possible outcomes under uncertainty. A useful tool is stochastic budgeting approach which allows uncertainty in some variables to be included in calculating potential outcomes. Although stochastic budgeting approach has been used for several years, it has become now much easier to use due to the development of spreadsheet software add-ins such as @RISK (Palisade, 2010) and Simetar (Richardson et al., 2003) to automate stochastic simulation. The approach in stochastic budgeting is just like constructing a deterministic budget with some uncertain variables. The stochastic nature of the budget is captured by specifying probability distributions for the uncertain variables. Using a Monte Carlo procedure, random samples are drawn from these distributions and used to evaluate the budget. The results are recorded, another sample is drawn, and the results are again recorded. This simulation continues for a sufficiently large number of samples to generate a stable distribution of outcomes. The procedure is general enough to be used with almost any type of budget including enterprise budgets, or whole-farm budgets. In this study the whole scheme budgeting approach will be used.

2.2 Simulated Net Returns and Data Analysis

The study identified 5 crop rotations imposed at Sudan Gezira Scheme during 1960 and 2002. Net return for each crop rotation alternative is considered as the key output variable. To simulate net returns one or more of the input variables of the model (exogenous variables) should be considered as stochastic. This study considers average annual crop yield and price received by farmers as stochastic variables. Historical data of yield and crop price for different crops in each crop rotation were collected for 13 years (1981-1994) from Socio-Economic Research Unit at Sudan Gezira Board and simulated to generate stochastic yields and prices. Linear correlation matrix is used to simulate correlated uniform standard deviates (CUSDs), which can then use in the Simetar probability distribution functions to simulate probability distributions. The key output variables (KOVs) for different crops are generated by Simetar and calculated summary and statistics over the 500 iterations are produced.

Yields, input types and rates, and field operations cost data were also collected from Socio-Economic Research Unit at Sudan Gezira Board. The SERU staff monitors a sample of 25 farmers at each part of the scheme. Production costs are based on actual field operations and input rates. The cost information is used with yield and price data to calculate net returns and simulate a distribution of net returns for each strategy and crop rotation imposed by SGB. Enterprise budgets that include one or more stochastic variables are called stochastic budgets. Net returns estimated from these budgets are simulated for 500 iterations generating 500 possible net returns for each crop rotation alternative.

2.3 Stochastic Efficiency with Respect to a Function

Stochastic efficiency with respect to a function (SERF) is used to order a set of risky alternatives in terms of certainty equivalents (CEs) for a range of risk preferences (Hardaker et al., 2004). SERF ranks and orders preferred alternatives in terms of CEs as the degree of risk aversion increases. Crop rotations with higher CEs are preferred to those with lower CEs. The CE of a risky crop rotation and strategy is the amount of money at which the decision makers at SGB are indifferent between the certain crop rotation (generally lower) net return value and the expected value of the new crop rotation strategy (Lien et al., 2007). For a risk-averse decision maker, the estimated CE is typically less than the expected value of the risky strategy.

The calculation of the CE depends on the utility function specified. A negative exponential utility function used in the SERF analysis conforms to the hypothesis that managers prefer less risk to more given the same expected return. This functional form assumes managers have constant absolute risk aversion. Under this assumption, managers view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth.

The simulated net return data for each strategy is sorted into cumulative probability distribution functions (CDFs) which are used in the SERF analysis. Decision makers with RACs greater than zero exhibit risk-averse behavior.

The actual RACs used in the final analysis range from 0.00 to 8.78E-9 because the rankings do not change for RACs above that level for different land use intensity strategies and crop rotation examined.

A utility weighted risk premium (RP), when risk aversion is considered, can be calculated by subtracting the CE of a less preferred strategy from the preferred strategy. The RP, a utility weighted risk premium for a risk-averse decision-maker, reflects the minimum amount of money that will have to be paid to a decision maker to justify a switch from one crop rotation alternative to the other. The risk premium generally increases with degree of risk aversion increases.

2.4 StopLight Analysis

StopLight analysis relies on CDF information and generates the probability of exceeding a target net return value for the whole Sudan Gezira Scheme. The upper cutoff net return value and lower cutoff value is decided and dictated by policy makers at SGB. The StopLight chart has three ranges colors, red presents the probability of net returns less than the lower cutoff value, the yellow colors are the probability of net returns between the upper and lower cutoff values, while the green colors are the probability of net returns exceeding the upper cutoff value.

2.5 Data Collection and Crop Rotation

The crop rotation in Sudan Gezira Scheme started with a three crop rotation in 1925 as (cotton–fallow–fallow-cotton-fallow-sorghum-lubia/fallow-fellow) with land use intensity of 43.75%. After 1960 intensification started and groundnut and wheat were introduced and the crop rotation changed to (cotton–wheat–sorghum/groundnuts- fallow) with land use intensity of 75%. In the 1990s food security policy was imposed by the Government and cash crop area was reduced and sorghum crop area increased by 196%. Table 1 below summarize crop rotations and land use intensity considered in the study.

Table 1. Crop rotation alternatives and land use intensity policy considered in the analysis

No	Rotation designation	Crop rotation description	Years	Land use intensity %
1	3 course R	Cotton- Wheat- Sorg/Gnut- Fallow	1965	47%
2	4 course R	Cotton- Wheat- Sorg/Gnut- Fallow	1975	75%
3	5 course R Org.	Cotton- Wheat- Sorg/Gnut- Fodder – Fallow	1990	79%
4	5 course R Act (A)	Cotton- Wheat- Sorg/Gnut- Fodder/Fallow- Fallow	1993	72%
5	5 course R Act (B)	Cotton- Wheat- Sorg/Gnut- Fodder/Fallow- Fallow	2002	53%

Formed by the Author.

Crop rotation and land use policy implemented at Sudan Gezira Scheme (1965-2002) :

- 3 course rotation, before intensification policy and joint account system.
- 4 course rotation, after individual account & intensification policy implementation.
- 5 course rotation original, present land use intensity maximization with individual account & intensification policy original 5 course rotation, which has been applied for two seasons only.
- 5 course rotation actual (A), food security policy increase sorghum land use intensity to 41% and cash crop area (Cotton and groundnut) reduction with individual account & intensification policy was implemented.
- 5 course rotation actual (B), land use intensity reduction (wheat, Groundnuts) to cope with water resources with individual account & intensification.

The study compares alternative land use intensity for each crop rotation and total cultivated area for each crop in the rotation. The Sudan Gezira Board and Ministry of Agriculture every year announces total crop area to be cultivated within the scheme according to agriculture policy and irrigation water availability. The standard tenancy is 40 acres, but mostly half of the area is cultivated due to irrigation system capacity. According to crop rotation, the tenants are placed in equal plots at different Number (90 acres in a rectangular plot) i.e. three numbers for three crop rotation and four numbers for four crop rotation. The water and land resources management in the scheme depend on many factors such as irrigation water availability, total cultivated area, crop sowing dates, crop growing stage and crop season duration. Table 2 below summarized allocated crop area and land use intensity for each crop rotation tested in this study and resources management during 1965-2002.

SGB reduced cotton crop area from 51% to 17%, and increased sorghum area from 26% to 60% of total cultivated area due to irrigation system deterioration.

Table 2. Allocated crops area in (Acres) and land use intensity policy

No	Crop rotation	Cotton	Wheat	Sorghum	Groundnut	Fodder	Area/fed	% Total area
1	3 course R	507 000	75 000	255 000	60 000	95 000	992 000	45.1%
	Land use %	51%	7%	26%	6%	9%	100%	
2	4 course R	603 000	428 000	154 000	361 000	49 000	1 595 000	72.5%
	Land use %	38%	27%	9%	23%	3%	100%	
3	5 course R Org.	420 000	420 000	210 000	210 000	420 000	1 680 000	76.4%
	Land use %	25%	25%	13%	13%	25%	100%	
4	5 course R Act (A)	175 000	514 034	621 736	163 814	52 000	1 526 584	69.4%
	Land use %	11%	34%	41%	11%	3%	100%	
5	5 course R Act (B)	190 000	81 000	679 000	45 000	130 000	1 125 000	51.1%
	Land use %	17%	7%	60%	4%	12%	100%	

Calculated by the Author.

The study included five crop rotation system combinations: 3 course rotation with land use intensity 47% (3 course R), 4 course rotation with land use intensity 75% (4 course R), original 5 course rotation with land use intensity 79% (5 course R Org.), 5 course rotation with land use intensity 72% (5 course R Act A) and 5 course rotation with land use intensity 53% (5 course R Act B). The study also included input levels and costs of production for each crop which optioned from (SERU) at Sudan Gezira Board (SGB).

For this analysis, the effects of uncertain prices and yields on returns for the alternative crop rotation systems have been evaluated. Simetar (2011) was used to simulate cumulative distribution functions (CDF) for each crop rotation based on stochastic annual yields and prices for 14 years.

Since yield distributions for each crop were driven at least in part by rainy season weather and irrigation system conditions, it is likely they were not stochastically independent. Moreover, it is possible that crop yields and prices may not be stochastically independent due to the possibility of rainy weather influences over large area (whole scheme) which may affect crop supplies. To fully account for this effect, it would be necessary to estimate a joint distribution function for the uncertain variables. However, this would be difficult at best. To account for some of the interdependence, Simetar allows correlations between each of the uncertain variables to be included in the sampling procedure. A correlation matrix was estimated for yields and prices based on the 1982-1994 observations and MVE probability distribution method was used to estimate parameters and simulate probability distribution. Enterprise budgets were constructed to calculate whole-scheme net return for alternative crop rotations.

3. Results and Discussion

3.1 Water and Land Resource Management

The monthly and total crop water requirements (CWR) for each crop rotation calculated and represented in Table (3). Monthly CWR for each crop multiplied by crop cultivated area to have monthly water requirement. The analysis indicates high water demand observed in June, August, September and October months. The 5 Course Act (B) rotations consumes low irrigation water around the season compared to other crop rotations as it avoids high water demand for growing groundnut in June and peak demand in October for the cotton crop.

The crop intensification program, expansion of the irrigation system, breakdown of the telecommunications system, and insufficient funds available for irrigation system maintenance, resulted in improper use of water and land resources and result in inadequate irrigation system control. The deterioration of the communication system cause instability of water levels in the major canals, and it became difficult to maintain the intended discharge into the minor canals. Moreover, the high degree of siltation of some minor canals creates problems such that little water reaches the tail end farmers at “Numbers” and some areas are out of production, (Kheiry et al., 1991).

Return to traditional night storage irrigation system could improve irrigation equity and reliability of water deliver as urged by Ahmed et al. (2002), but it should be remembered that traditional irrigation system was practiced with low cropping intensity, and low irrigation labour cost at the scheme. The present system (continuous irrigation) is more adaptable to the crop water requirements at different crop growing stages and preferred by the tenants as it is low irrigation cost method.

Table 3. Monthly and total crop water requirement for each crop rotation in Million M³

Month	3 Course R	4 Course R	5 Course Org	5 Course Act A	5 Course Act B
January	541	837	1,144	600	358
February	124	124	277	63	94
March	0	0	0	0	0
April	0	0	0	0	0
May	0	0	0	0	0
June	392	619	927	761	758
July	372	505	693	563	580
August	647	833	947	848	868
September	648	847	957	871	885
October	603	856	655	623	502
November	500	817	649	493	222
December	586	870	1,159	585	372
Total	**4,412**	**6,308**	**7,407**	**5,409**	**4,639**

Calculated by the Author.

Although the 3 Course R, 4 Course R and 5 Course Org. crop rotation had a higher net return income than other crop rotation system as shown in Table 4, but they are more risky due to irrigation water shortage especially during groundnut and sorghum crop growing season (June- July-August- September) as four crops at this time needs to be irrigated. As a result, SGB reduced groundnut area in 5 course R Act (A) to 163 814 acres to cope with water shortages risk during groundnut crop grown season. However, this indicates that crop area reduction policy provides more water for irrigation at high level of risk aversion.

Table 4. Summarized net return in Million (SDG) for each crop rotation in Sudan Gezira Scheme

Rotation	3 Course R	4 Course R	5 Course Org	5 Course Act A	5 Course Act B
Mean	57.828	68.766	47.897	19.923	21.667
SD	211.193	251.182	174.953	72.773	79.145
Skewness	0.16889	0.16889	0.16889	0.168889	0.16889
Kurtosis	-0.22335	-0.22335	-0.22335	-0.22335	-0.22335
Min	(497.761)	(592.012)	(412.347)	(171.517)	(186.538)
Max	715.391	850.850	592.632	246.508	268.095

Calculated by the Author and Simetar.

3.2 Stochastic Budgeting Simulated Net Returns

Because Simetar is an Excel add-in, there is considerable flexibility in setting up different crop rotation scenarios to be evaluated. Five different scenarios are presented in this analysis and in each scenario; both yields and prices were stochastic. All five scenarios were run simultaneously using 500 random samples from the multivariate yield and price distribution. The analysis and summaries are presented in Table (4).

3.3 Cumulative Distribution Function (CDFs) analysis

The Cumulative Distribution Function (CDFs) analysis performed to illustrate the range and probabilities of scheme net returns for different crop rotation scenarios. Figure 1 shows the net return CDF's for the five crop rotation treatments under the current irrigation system. Although a risk preference is vary from farmer to farmer, the CDF's can be used to identify the crop rotation that would be preferred by decision maker within a range of preferences using stochastic dominance analysis (Meyer, 1977). The simplest form of stochastic dominance is first-degree stochastic dominance. Among crop rotations tested in this study no rotation was first-degree stochastically dominant as their CDFs lines crossed each other and no clear ranking under different generalized stochastic dominance is possible. However, a more improved technic, Stochastic Dominance with Respect to a Function analysis preformed and indicates that 4 Course R is most preferred rotation at lower ARAC (0.0) and 5 Course R (A) is the most preferred rotation at upper ARAC level (8.78E-9).

Stochastic Efficiency with Respect to a Function analysis was used to rank alternative crop rotation risk efficiently within specific range of ARAC values (0.0 – 8.78E-9). Four observations can be drawn from Fig.1. First, the 3 Course R, 4 Course R and 5 Course Org. systems had a higher net return income than other crop rotation systems. Second, the net return income from the 3 Course R, 4 Course R and 5 Course Org. system were described as the most risky rotation, since the CDFs for them were less steep than 5 Course R (A) and 5 Course R (B). The standard deviation (SD) in yields was in general highest for the 3 Course R, 4 Course R and 5 Course Org. systems (Table 4). Third, under existing irrigation system conditions; all of the crop rotation systems had a small probability of generating negative net returns (less than 42%). The last point is that 5 Course R (A) and 5 Course R (B) are downside risk oriented.

The expected mean annual net return income for 4 Course rotations is the most risk efficiency rotation up to 0.0000000011 risk aversion, after that 5 Course Org. is a risk efficient rotation with net return of 20.5 Million. At 0.0000000026 risk aversion 5 Course R (B) was risk efficient rotation with 13.7 Million (SDG), and 13.2 Million (SDG) for 5 Course R (A). In other words, the 5 Course R (A) and 5 Course R (B) systems had almost the same expected income and risk efficient at higher ARAC. The analysis indicates net return income of crop rotation are higher if more land allocated to cash crop such as cotton crop, but these rotation are more risky crop rotation as water resource availability in canals to irrigate all area simultaneously is difficult to achieve under current situation.

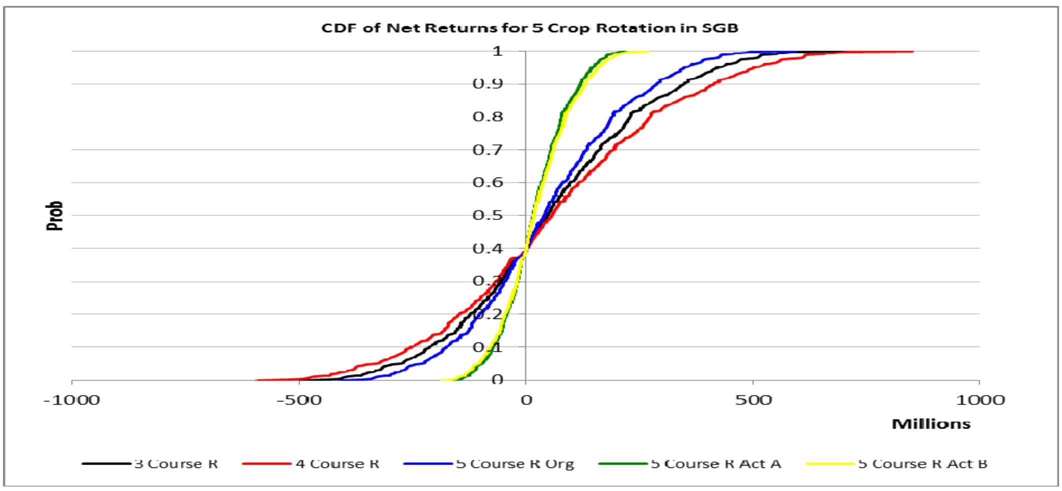

Figure 1. Cumulative probability distribution of net returns for 5 crop rotations in Sudan Gezira Scheme

Comparison of 5 Course R (A) and 5 Course R (B) rotation system shows that they have a slightly different risk profile; where 5 Course R (B) is the most risk efferent. Which of these two alternatives the SGB and farmers would prefer, depends on their degree of risk aversion, which can be identified by SERF analysis?

3.4 Stochastic Efficiency with Respect to a Function

To rank the risk-efficient of crop rotation alternatives, the SERF approach performed and result shown in Figure 2. A risk-neutral decision maker and farmer ranking five crop rotations and land use intensity were tested in this study. The result shows that 4 Course R is risk efficient at risk neutral ARAC level and after 0.0000000022 5

Course R (B) and 5 Course R (A) are the most risk efficiency rotation with 14.878 Million and 14.178 Million (SDG) net return CEs respectively, as shown in Figure (2).

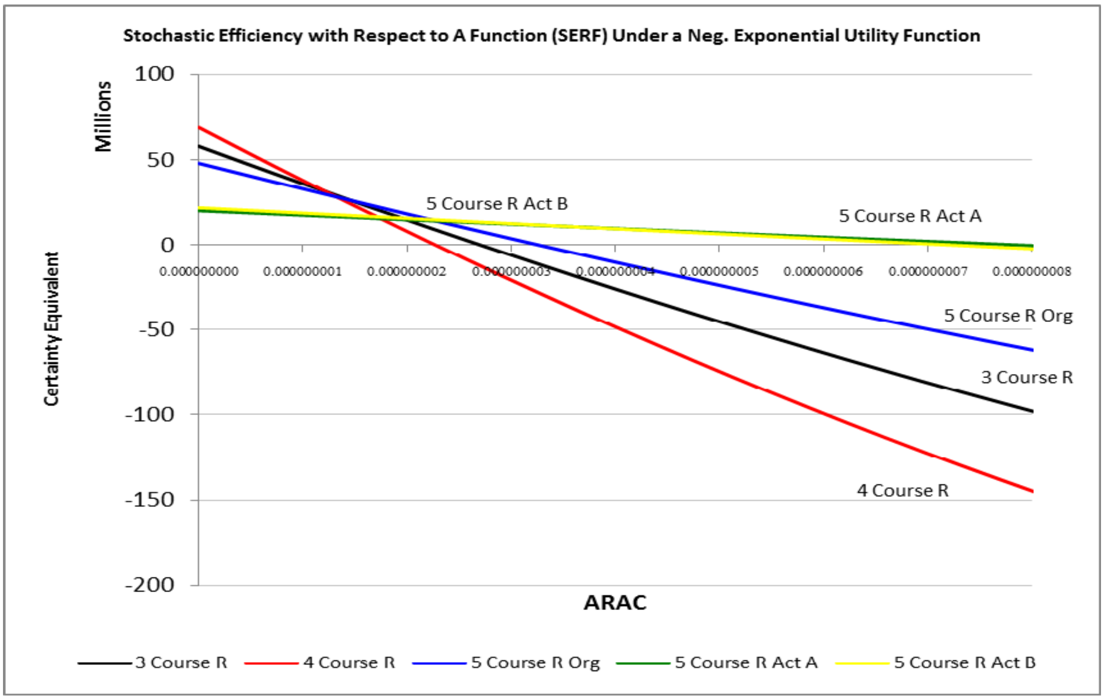

Figure 2. The net return CE results for all ARAC's for five crop rotation system alternatives

The results show that the rankings change as risk aversion increases and that the (5 Course R Act B) crop rotation system with 53% land use intensity is preferred at high range of risk aversion. Adam Elhag Ahmed, (2011) used variance and the expected income–variance risk analysis to identify crop combination and land use intensity under risk consideration and tenants' preference and found that 53% land use intensity is the most preferred alternative. For extreme risk aversion level with 0.0000000037 ARAC the (5 Course R Act A) with 72% land use intensity is the most risk preferred crop rotation.

In reality, SGB and farmers have options to reduce the price and production risk shown in the 4 course rotation and 5 course Org. rotation scenarios. The cash crops area and also land use intensity have been reduced to cope with water resources shortage and current irrigation system capacity.

In year 1993 at 5 course rotation (A) farmer planted 621 736 acres with sorghum crop with an additional 467 736 Acres compared to the 4 course rotation in 1975, which allocated 154 000 acres only to sorghum crop. Essentially all of the additional sorghum area came at the expense of a decrease in cash crops area such as groundnut 42% and cotton crops area 58%. Consequently, the land planted with continuous sorghum crop increased remarkably and might cause weed problem and reduce yield and increase cost of production. However, this indicates, some farmers are willing to accept the known risks associated with growing sorghum in place of groundnut area in order to avoid the uncertain risks associated with water deficit from increasing groundnut production area (Ishag et al., 1980).

Richardson et al. (2006) used stochastic efficiency with respect to function (SERF) analysis to rank strategies by using the certainty equivalent (CE) results. The risk premium RP can also be calculated by subtracting the CE of a baseline crop rotation (3 Course Rotation - often a less preferred rotation) from the CE of a preferred alternative (5 Course R (B) -often a preferred strategy). The RP for a risk-averse decision maker reflects the minimum amount of money that would have to be paid to a decision maker to justify a switch from less preferred rotation alternative to a preferred rotation.

Table 5. Ranking of risk-efficient crop rotation by CE and ARAC of net return in Million (SDG)

Risk	Risk Neutral		Normal Risk		Rather Risk		Extremely Risk	
ARAC	0.00000000		0.0000000033		0.0000000055		0.0000000088	
Rank	Alternative	CE	Alternative	CE	Alternative	CE	Alternative	CE
1	4 Course R	68.7	5 Course R (B)	11.54	5 Course R (A)	5.79	5 Course R (A)	(2.30)
2	3 Course R	57.8	5 Course R (A)	11.35	5 Course R (B)	4.99	5 Course R (B)	(4.59)
3	5 Course Org.	47.9	5 Course Org.	(0.48)	5 Course Org.	(30.3)	5 Course Org.	(71.0)
4	5 Course R (B)	21.7	3 Course R	(12.0)	3 Course R	(54.2)	3 Course R	(110)
5	5 Course R (A)	19.9	4 Course R	(29.0)	4 Course R	(86.7)	4 Course R	(161)

Calculated by the Author & Simetar.

Table 5 shows that to switch from (5 Course R B) crop rotation to (5 Course R A) with high land use intensity i.e.72% a risk premium of 1.8 Million (SDG) needs to be paid to farmers with risk neutral risk aversion coefficient. The result also shows that night storage irrigation system (3 Course R) is not preferred for normal and rather risk aversion coefficient. However, increasing cash crop area such as cotton crop from 11% to 25% is difficult under present irrigation system situation as cotton crop needs 12-13 numbers of irrigation compare to sorghum crop which needs only 4-5 irrigation and almost half of sorghum CWR covered by rainfall. Moreover, the irrigation cycle of 14 day and 5000 cubic meters of water per day which is sufficient to irrigate 12 Acres per day and a crop number of (90 acres) in 7.5 day will not be applicable with present irrigation canal capacity. The introduction of new cotton verities with high yield and reasonable cost of production will increase scheme net return without increasing land use intensity.

3.5 StopLight Analysis

The Stoplight analysis relies on CDF information but is a more visually appealing depiction of probabilistic information. The Stoplight analysis uses the stimulated net income distribution to calculate the probability of whole-scheme net return exceeding an upper cutoff value of 25 Million (SDG), being less than a lower cutoff value of (0) net return, or it can have a value between the upper and lower cutoff values. The Stoplight analysis is performed to identify the probability of getting positive whole-scheme net returns for five crop rotations in the scheme. Figure 3 shows that the scheme will get 25 Million (SDG) or more with a probability of 55% for 4 course rotation and getting positive net return with 61% probability for all crop rotations. Red color represents the probability of having negative returns, which is 39% for all crop rotations. The yellow represent the probability of returns from (0) to 25 Million (SDG). The green color represents probability of having net returns more than 25 Million (SDG). The (4 Course R) and (3 Course R) crop rotation have the highest probability of making return between (0) and 25 Million (SDG).

However, SGB policy makers should select crop rotation which achieves equity water distribution among all scheme farmers with less net return i.e. 5 Course R (B) and 5 Course R (A) rather than targeting higher net returns crop rotation.

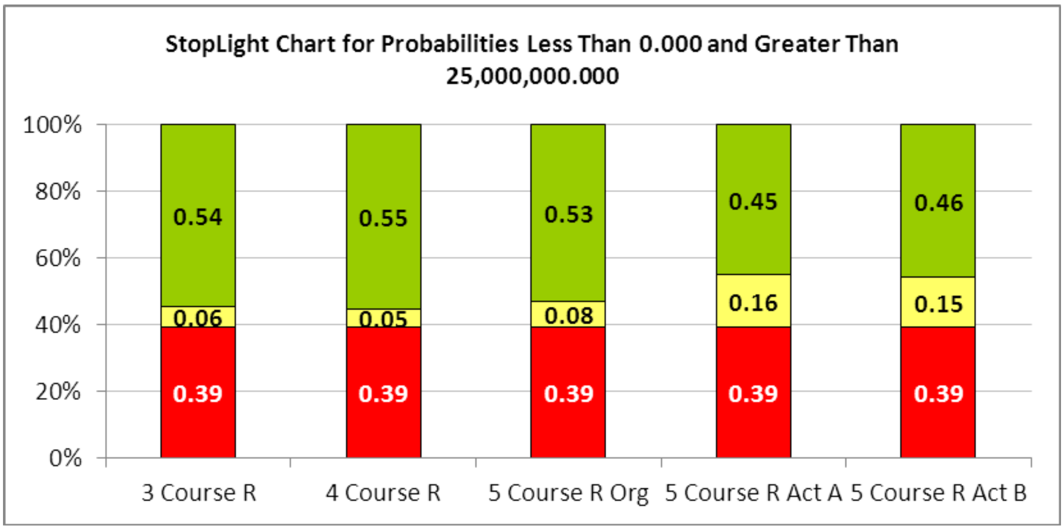

Figure 3. Probabilities of whole-scheme net returns for five course crop rotations in Sudan Gezira Scheme

4. Conclusion

The study use stochastic simulation techniques to evaluate five crop rotations risk-efficiency and economic sustainability in Sudan Gezira Scheme. Price and yield risk for five crops were simulated to calculate whole-scheme net return. The analysis shows with the present irrigation system capacity and continuous irrigation practices the 5 Course rotation (B) with 53% land use intensity is the most risk efficiency crop rotation to be followed and implemented in the scheme with normal risk aversion coefficient. In this recommended crop rotation equity water distribution achieved and area allocated to cotton crop is 17%, wheat 7%, sorghum 60%, groundnut 4% and fodder crops 12%. Fodder crop can be grown two times in summer and winter season without creating water shortage problems. However, this will increase net return and increase soil fertilities within the selected crop rotation.

The analysis shows that 5 Course rotation (A) is the second preferred crop rotation with land use intensity of 72%. The techniques used in this study can be used to investigate source of risk and analyze the impact of alternative management options and policy. Both the available management tools and sources of risk can significantly change the riskiness of alternative cropping systems.

The SGB have to maintain and monitor annual canals maintenance to keep sufficient water to implement 5 Course (B) crop rotation and land use intensity of 53%, as the return to night storage irrigation system will get a negative net returns. New high yield varieties have to be introduced at the scheme to replace loss from area reduction for cash crop and increase net return. The SGB also have to provide inputs to farmers for all crops cultivated within 5 course rotation (B) with a reasonable cost and treat all crops in the selected crop rotation with same support.Figure

In order to utilize stochastic simulation techniques the study use data from farmer's field, it is critical that there is enough information to characterize the distributions of the uncertain variables. The distributions of uncertain variables in this analysis were estimated based on historical data; however historical distributions may not be the best representation of potential outcomes. As a result, the techniques used in this study could be used with any distribution estimates for the uncertain variables incorporating such things as new crop varieties and research recommendation packages. They also could be modified to account for the new information effect during the decision process and account for dynamic effects to develop sharp policies.

Competing interests

The author declares that he has no competing interest.

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References

Ahmed, A. E. (2011). Risk sources and attitude among the tenants of the Gezira Scheme–Sudan. *Journal of the Saudi Society of Agricultural Sciences, 10*(2), 71-75. http://dx.doi.org/10.1016/j.jssas.2011.03.006

Ahmed, M. A. (2004). Effective farm management decision-making in the Gezira Scheme. Irrigation Management in Sudan, International Irrigation Management Institute.

Ascough II, J. C., Fathelrahman, E. M., Vandenberg, B. C., Green, T. R., & Hoag, D. L. (2009). Economic risk analysis of agricultural tillage systems using the SMART stochastic efficiency software package. In *18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009*. Retrieved from http://mssanz.org.au/modsim09

Eldaw, A. M. (2004). The Gezira Scheme, Perspectives for Sustainable Development, University of Gezira, Reports and Working Papers 2/2004.

Elnour, F. M., & Elamin, A. E. (2014). Status of on-Farm water use efficiency and source of inefficiency in the Sudan Gezira Scheme. International Working Paper Series NAF-IRN Paper No. 14/1. Heep://economia.unipv.it/naf/

Hardaker, J. B., Huirne, R. B., Anderson, J. R., & Lien, G. (1997). *Coping with Risk in Agriculture* (p. 274). CAB International, Wallingford, UK.

Hardaker, J. B., Richardson, J. W., Lien, G., & Schumann, K. D. (2004). Stochastic efficiency analysis with risk aversion bounds: a simplified approach. *Australian Journal of Agricultural and Resource Economics, 48*(2), 253-270. http://dx.doi.org/10.1111/j.1467-8489.2004.00239.x

Ibrahim, A. A., Stigter, C., Adam, H. S., & Adeeb, A. M. (2002). Water-use efficiency of sorghum and groundnut under traditional and current irrigation in the Gezira scheme, Sudan. *Irrigation Science, 21*(3), 115-125. http://dx.doi.org/10.1007/s00271-002-0057-z

Ishag, H. M., Ali, M. A., & Ahmadi, A. B. (1980). Groundnut production and research problems in the Sudan. Pages 282-284 in Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, India. Pataacheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Ishag, K., Thornton, D., Tiffen, M., & Upton, M. (1991). Farm location and farmers' performance on the Hamza minor canal. *International Journal of water Resources Development, 7*(1), 2-15. http://dx.doi.org/10.1080/07900629108722486

Lien, G., & Hardaker, J. B. (2001). Whole-farm planning under uncertainty: impacts of subsidy scheme and utility function on portfolio choice in Norwegian agriculture. *European review of agricultural economics, 28*(1), 17-36. http://dx.doi.org/10.1093/erae/28.1.17

Lien, G., Hardaker, J. B., & Flaten, O. (2007). Risk and economic sustainability of crop farming systems. *Agricultural Systems, 94*(2), 541-552. http://dx.doi.org/10.1016/j.agsy.2007.01.006

Meyer, J. (1977). Choice among distributions. *Journal of Economic Theory, 14*(2), 326-336. http://dx.doi.org/10.1016/0022-0531(77)90134-X

Palisade Corporation. (1997). Guide to Using @RISK Risk Analysis and Simulation Add-In for Microsoft Excel or Lotus 1-2-3, Window Version. Newfield, NY, USA.

Richardson, J. W. (2003). Simulation for Applied Risk Management. Department of Agricultural Economics, Texas A&M University, August 2003.

Richardson, J. W., Schumann, K. D., & Feldman, P. A. (2006). Simulation and Econometrics to Analyze Risk: Simetar_c Inc. 2006 User's Manual. College Station, Texas.

Richardson, J. W., Schumann, K., & Feldman, P. (2003). Simetar Simulation for Excel to Analyze Risk User's Guide. Agricultural and Food Policy Center, Texas A&M University, College Station, TX, USA.

Shafique, M. S. (2008). Performance of the Gezira canals, International Irrigation Management Institute.

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