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BREAD PRICES IN THE SUDAN

VOLUME II

RESOURCE ALLOCATION IN THE GEZIRA SCHEME:

A SENSITIVITY ANALYSIS

Raleigh, North Carolina
April 1983

SIGMA ONE CORPORATION

Consumption Effects of Agricultural Policies: Bread Prices in the Sudan

Volume II

Resource Allocation in the Gezira Scheme: A Sensitivity Analysis

FINAL REPORT

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PREFACE

This study was originally undertaken to develop certain inputs for the wheat import demand model, an important element of the policy scenarios that were analyzed in Consumption Effects of Agricultural Policies: Bread Prices in the Sudan. A primary objective of the present study was to estimate the potential output of wheat from the Gezira Scheme under alternative technology packages. As work progressed, information and insights were developed that were not directly applicable to modeling the demand for wheat imports. In particular, the present analysis highlighted the dependence of resource allocation among crops on the choice of an objective function for the scheme and the potential conflict between the objective functions of management and tenants. Consequently, the present study is being issued as a separate report.

After this study was conducted in July and August, 1982, the input costs were updated and the analysis was extended to crops grown in traditional and mechanized rainfed farming systems. The results of this study, Comparative Advantage of Agricultural Products (Ministry of Finance and Economic Planning (Planning), Khartoum, April 1983), do not significantly alter the basic conclusions of this report.

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SECTION 1: INTRODUCTION

1.1 Setting

The Gezira Scheme is the linchpin of the Sudanese economy. It has historically accounted for one-half of the country's export revenues through the production of and trade in long- and medium-staple cotton and groundnuts. It also provides 75 percent of total wheat production in the Sudan. In short, it plays a significant role both in Sudan's foreign trade position and in vital domestic policies, namely the export diversification program and the drive to achieve food self-sufficiency. If the rainfed agricultural sector is the backbone of the national economy, the two-million feddan Gezira Scheme is the agricultural showcase of the country.

The steady deterioration of agricultural output from this scheme is partly the cause and partly the effect of the financial and economic crises that have been plaguing the Sudan in recent years. Lacking the foreign exchange needed to purchase spare parts, machinery, and other agricultural inputs, the Sudanese government and the Sudan Gezira Board (SGB) have not been able to perform the necessary maintenance and to replace or rehabilitate the existing equipment required to attain the relatively high yields realized in the past. At the same time, production declines in cotton and groundnuts have decreased export revenues, while declining wheat yields have forced the government to expend scarce foreign exchange reserves to import wheat or to rely on concessional wheat imports, primarily from the United States.

Attempts are now underway to break this cycle. The objective of the Agricultural Rehabilitation Program, of which $36.8 million has been allocated to the Gezira Scheme, and of the Gezira Rehabilitation Project, is to increase yields to those realized in the early 1970's. The government's Export Action Program, while ostensibly concerned with improving the performance of both the irrigated and rainfed agricultural sectors, is more specifically directed to rehabilitating the publicly-controlled irrigated schemes.

While studies have been conducted to support and to provide information for those investment and policy reform programs that affect the Gezira Scheme [2, 4], the determination of an optimal cropping pattern has not been addressed. Either a cropping pattern has been assumed in analyzing financial, economic, and agricultural problems facing the scheme [2] or a determination has been made that certain crops should or should not be grown on those schemes based on measures of international competitiveness [3]. A recent study conducted by the Ministry of Finance and Economic Planning [4] presented estimates for the 1980/81 crop year of foreign exchange dependence, international competitiveness, and private profitability for major crops produced in the rainfed sector and in the Gezira and Suki irrigation schemes. While these studies contain much of value, they do not incorporate the effects of variations in world and producer prices, yields, and input costs on resource allocation decisions. This study analyzes the sensitivity of several indicators for

five crops grown in the Gezira Scheme to changes in yields, input costs, border and producer prices, and exchange rates. These indicators are foreign exchange dependence, value added, domestic resource cost coefficients, and private profitability. It builds on the analysis in Study of Cost of Production and Comparative Advantage of Crops in the Sudan (SCP) by using the cost of production data as the basis for a sensitivity analysis of the results and conclusions of that study.

This study originally had two purposes. The first was to determine the amount of wheat that would be produced in the Gezira under different optimal allocations of resources among all crops. This information would then be used as an input to the import demand model being developed in a related project, Consumption Effects of Agricultural Policies: Wheat Bread Pricing in the Sudan. The second purpose of this study was to develop a portfolio of alternative allocations of water among five crops: long- and medium-staple cotton, wheat, sorghum, and groundnuts. Each alternative would have an associated probability of success and would be a solution of a linear program that maximized net foreign exchange earnings subject to constraints on water availability, availability of foreign exchange to purchase the imported inputs, and contraints on private profitability. The results of the sensitivity analysis would be used as inputs to the linear program. Since each value would have a distribution based on the assumed distributions of yields and border and producer prices, probabilities could be determined for each value used in the linear program. These

probabilities would then be combined to calculate an overall probability of success for each allocation of water. This analysis would permit an assessment of levels of risk of each cropping alternative.

Upon completion of the sensitivity analysis, two things became apparent. First, all solutions of the linear program were trivial; that is, all constraints on water availability for each crop would be binding and a corner solution would result (see Appendix A). For example, if a solution existed at all, it always called for planting the maximum allowable area in medium-staple cotton, the minimum allowable area in long-staple cotton, and the maximum area in wheat; some solutions allocated the maximum area to sorghum, while others allocated the maximum area to groundnuts and the minimum to sorghum.

The second consideration was that the estimates of domestic resource cost coefficients (a measure of comparative advantage) raised serious doubts about the appropriateness of defining maximization of net foreign exchange earnings as the objective function of the SGB. While foreign exchange earnings would be enhanced, there would be an efficiency cost to the country. Because the SGB would be directing resources towards those crops that generated the most foreign exchange rather than towards those crops that it could produce most efficiently (as measured by international standards of comparative advantage), domestic resources would be misallocated. Although the level of Sudan's foreign exchange reserves is cause for concern, the issue of

efficient domestic resource allocation is at least of equal importance.

For these reasons it was appropriate to change the emphasis of the study from producing a portfolio of water allocations to a more detailed examination of the results of the sensitivity analysis. The trivial nature of the linear programming solutions and the implications of the results of the sensitivity analysis for policies that affect not only the Gezira Scheme but also the entire agricultural sector justify this change of emphasis.

1.2 Background*

The Gezira Scheme is the major economic enterprise in the Sudanese economy. The output of the scheme generates between 7 to 10 percent of the GDP; the contribution of the entire agricultural sector is about 40 percent. In the 1979/80 crop year, it produced over 80 percent of the long-staple cotton grown in the country, about 40 percent of the medium-staple cotton, 75 percent of the wheat, and over 30 percent of the groundnuts. Exports of long-staple cotton from the Gezira Scheme accounted for 45 percent of Sudan's total export revenues; when revenues from groundnuts exports and the foreign exchange savings from wheat production were included, the Gezira Scheme generated one-half of total export revenues in 1978/79 (approximately LS.110 million). In the same year, it accounted for 4 percent (LS.18 million) of Sudan's import bill, mostly in expenditures on cotton fertilizers

*The material in this section is taken from Euroconsult, Gezira Rehabilitation and Modernization Project I [2].

and spraying.

The Gezira Scheme is a mainstay of the public sector and employs a significant proportion of the labor force. It contributes to government revenues through export and import duties, taxes, and the government's share of the operational surplus. Its 10 year annual average contribution of LS.8.4 million is greater than that of the public banks and of all the public corporations combined. Over 490,000 people, approximately 7 percent of the labor force, are directly employed in the scheme. Between 1.2 and 1.5 million people are dependent on the scheme, either directly or indirectly.

The Gezira Scheme comprises 2.1 million feddans between the Blue and White Niles, and is under the management of the Sudan Gezira Board (SGB). The land is farmed by 102,000 tenants. The SGB determines the cropping pattern and maintains the main canal and the minor canals. It provides extension services, all agricultural inputs (seeds, fertilizers, herbicides, and spraying), and most of the mechanized land preparation for cotton and wheat. In addition, it is responsible for an extensive credit program that supports the production and marketing of cotton and wheat, including cash advances to the tenants to cover the costs of cotton picking. It is responsible for transporting cotton from the collection centers to the ginneries, ginning the cotton, and selling the lint to the Cotton Public Corporation. The tenants are responsible for maintaining the field canals, some of the land preparation, and the sowing, weeding, irrigation, and harvesting of the crops.

The four major crops grown in the scheme are cotton, wheat, sorghum, and groundnuts. The SGB is heavily involved in the production and marketing of cotton and wheat. There is very little involvement in groundnuts production and marketing, in which sharecropping is common, and in sorghum production, which is a consumption good rather than a source of cash income. Although there is an official market in which tenants can sell their wheat (minus a deduction for costs of production incurred by the SGB), 70 to 80 percent of the wheat produced is sold by the tenants in unofficial markets. Even if net revenues per feddan are low, wheat production is also attractive to the tenants because of its low labor requirements (land preparation and harvesting is almost completely mechanized).

The crops are grown in a four-course rotation in the Gezira (1.1 million feddans) and in a three-course rotation in the Managil extension (1 million feddans). The average size of a tenancy in Gezira is 20 feddans, in which 5 feddans are planted in cotton, 5 in wheat, 5 in sorghum and groundnuts, and 5 in fallow. In the Managil extension, there is no fallow, so the average tenancy has 15 feddans with 5 planted in cotton, 5 in wheat, and 5 in sorghum and groundnuts. The cropping intensity in the scheme is currently 65 to 70 percent (approximately 1.4 million feddans cropped) because of the fallow in the Gezira rotation and limitations on the water supply delivered by the Main Canal.

The planting and harvesting times for the four crops

primarily determine the competition for resources. Cotton has the longest growing period; land preparation and sowing begin in late July and the crop is picked by the end of March. The summer crops, groundnuts and sorghum, are planted in early June and harvested in later October and early November. The amount of water allocated for cotton production determines what is available for production of sorghum and groundnuts and, consequently, wheat. Thus, wheat, a winter crop, is planted in late October or early November and harvested in April. Thus, given the current cropping intensity, once the allocation of irrigation water for cotton has been determined, the amount of water for the remaining three crops is determined residually. The competition for irrigation water is particularly critical in October and November, when groundnuts and sorghum are being harvested and wheat is being planted.

Given the biological characteristics of the crops, the planting and harvesting times reported above represent the optimal times for these activities. In practice, delays in seed bed preparation and sowing intensify the natural competition for resources and result in reduced yields of all crops. In particular, late planting of cotton increases the competition for water required for irrigating groundnuts and sorghum. The resulting delay in harvesting groundnuts and sorghum means that these crops compete for irrigation water required for wheat. Wheat planting is also regularly delayed because there is a shortage of equipment used for ploughing. The late planting of groundnuts and sorghum also compounds the labor required for cotton picking,

which must be deferred until the groundnuts and sorghum are harvested.

SECTION 2: METHODS AND ASSUMPTIONS

2.1 Output Variables

This section describes the variables whose sensitivity to changes in exchange rates, border and producer prices, yields, and input costs were analyzed. The following variables were analyzed for each of the five crops: domestic resource cost coefficient, value added, foreign exchange dependence, and private profitability coefficient.

The domestic resource cost coefficient (DRC) is a measure of comparative advantage. For an exportable commodity, it measures the amount of foreign exchange earned when a unit of domestic resources is committed to its production; for an import substitute, it gives the amount of foreign exchange saved when a unit of domestic resources is used to produce that good. Since domestic resources are measured in the local currency and foreign exchange earnings or savings in foreign currencies, the DRC is an exchange rate measured in LS./$ that applies to the production of a particular commodity. When the DRC is divided by the real price of foreign exchange, it becomes a unitless number. If it is less than one, the country or region has a comparative advantage in its production because it can exchange domestic resources for foreign exchange at a rate below that at which the economy as a whole converts domestic resources into foreign exchange; a DRC greater than one implies a comparative disadvantage*.

*Alternatively, the DRC in LS./$ can be compared with the real price of foreign exchange, also given in LS./$. If the DRC is less than the real price of foreign exchange, a comparative advantage exists.

The DRC coefficient is directly related to the coefficient of international competitiveness (CIC) that was calculated in the SCP. The CIC is measured in units of dollars per Sudanese pound, the DRC is given in units of Sudanese pounds per dollar; that is, the DRC is the reciprocal of the CIC. To determine whether there is a comparative advantage, the CIC is compared with the real exchange rate, also given in dollars per Sudanese pound; a comparative advantage exists if the CIC is greater than the real price of foreign exchange. The unitless DRC is presented in this study because the comparison with the real exchange rate is built into the estimate.

The DRC coefficient for a commodity is given by the following equation:

(1) $$DRC = \frac{d - v}{(p_b \cdot y - m)X}$$ where

d = value of the domestic resources used in production of the commodity (LS./feddan)

v = value of any joint product (LS./feddan)

p_b = border price of the commodity ($/unit of output)

y = realized yield of the commodity (output/feddan)

m = value of the traded inputs used in the production of the commodity ($/feddan)

X = real exchange rate (LS./$)

Without an estimate of the real price of foreign exchange (the shadow exchange rate), in calculating the DRC's in Section 3 it

is implicitly assumed that each of the exchange rates used in the analysis is the shadow exchange rate. Thus, no inferences can be drawn regarding the effects of an overvalued exchange rate. Each scenario stands alone and any comparisons among the DRC's calculated at the different exchange rates are not valid.*

Two other output variables subjected to the sensitivity analysis, value added and foreign exchange dependence, are directly related and are discussed together. Value added for any commodity is given by the following equation:

(2) $VA = p_b y - m$ where

VA = value added in \$/feddan and all other variables are defined in equation (1).

Foreign exchange dependence (FED) is given by:

(3) $FED = \frac{m}{p_b y}$.

Both measures convey information about the contribution to foreign exchange earnings (or savings) resulting from the production of a particular commodity. Both measures are presented in this analysis because both are needed if the objectives of the SGB are to be defined in terms of maximizing net foreign exchange earnings or minimizing expenditures on imported inputs. For example, while an FED = 0.4 implies that for every dollar of

*Since the exchange rate reflects prevailing conditions in the domestic economy relative to its major trading partners, it is not treated as an explicit policy instrument in this study. Given a fixed exchange rate system, a change in the price of foreign exchange will not change the underlying conditions in the economy. It can, however, reflect a change in those conditions.

foreign exchange earned by exporting a particular commodity, 40 cents are expended on the imported inputs used in its production, it does not necessarily follow that the production of this commodity should be encouraged over that of another commodity with an FED = 0.6 if the objective of the SGB is to maximize net foreign exchange earnings. In this case, value added has to be the choice variable. It is possible that the commodity with an FED = 0.6 contributes $100 per feddan in value added while the commodity with an FED = 0.4 only contributes $20 per feddan. Similarly, if the objective is to minimize expenditures on imported inputs, the measure of FED is not sufficient to insure this. Two commodities could have identical FED's, but utilize different levels of imported inputs. Thus, it is the absolute magnitudes of the value of traded inputs and the value of output that are relevant to resource allocations rather than the ratio of these magnitudes.

The final variable subjected to the sensitivity analysis was the coefficient of private profitability, PPC:

(4) $PPC = \frac{P_p y + v}{(mX + d) - ry}$ where

P_p = producer price per unit of output (LS.)

r = all costs incurred beyond the farmgate (LS./unit of output).

All other variables are defined in equation (1). The numerator is the total value of output per feddan received by the producer (tenant) and the denominator is the total cost of production per feddan at the farmgate incurred by the producer (tenant). If

the PPC is greater than one, the producer is making a profit; if the PPC is less than one, he is incurring a loss.

The PPC is a critical consideration in any allocation of water resources made by the SGB, because it is a primary determinant of the tenant's response to those allocations. It is possible that the objectives of the SGB might conflict with the objectives of the tenant.* For instance, an allocation of resources by the SGB toward crops that might be unprofitable to the tenant could mean that the SGB would have to subsidize the production of the commodity either on the input side by lowering costs or on the output side by increasing the price received by the producer. This would not be a satisfactory solution in the long run, however. In this regard, efforts to increase yields and to encourage more effective input use through agricultural research and extension activities would be more appropriate.

The data needed to conduct a sensitivity analysis on the four output variables are presented and discussed in the following sections. These include border and producer prices for each crop, the input costs of each agricultural technology, and the expected yields from each technology. Variations in border and producer prices, exchange rates, yields, and input costs are then analyzed and discussed in Section 3.

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*The organization of the Gezira Scheme can be viewed as two decision makers, the SGB and the tenants, in a hierarchical relationship. The problem of determining an optimal allocation of resources given two objective functions can be solved by multilevel programming and has been addressed in another study [1].

2.2 Border and Producer Prices

The border prices for each crop were chosen to reflect as closely as possible reasonable deviations from the prices realized for the 1980/81 harvest season. A probability was assigned to each price to reflect the likelihood of occurrence of a particular price in an attempt to simulate the dynamics of world market conditions. The border prices and associated probabilities are presented in Table 1.

To calculate producer prices, import or export parity pricing was assumed. This involved converting the border prices, which were given in U.S. dollars per unit of output, to Sudanese pounds per unit of output and netting out an efficient marketing margin. These margins were determined using the difference between the border and producer prices in the SCP. For wheat, sorghum, and groundnuts, fixed percentage margins of 8 percent, 43 percent, and 35 percent, respectively, were deducted from the converted border prices. For long- and medium-staple cotton, the marketing margin varied depending on which border price was used: 45 percent for the low border price, 40 percent for the medium border price, and 35 percent for the high border price. The results are shown in Table 1.

Producer prices in this study are not only a function of the border price but also a function of the conversion factor used to simulate different real exchange rates. As the conversion factor increases from $1.11/LS.1.00 to $0.80/LS.1.00, the price realized by the producer also rises significantly for a given border

Table 1. Border and Producer Prices

	Low		Medium		High	
	Price	Probability[a]	Price	Probability[a]	Price	Probability[a]
Wheat[b]						
Border ($/sack)	20.00	0.20	23.20[f]	0.60	35.00	0.20
Producer (LS./sack)						
$1.11 = LS.1	16.58	0.20	19.23	0.60	29.01	0.20
$1.00 = LS.1	18.40	0.20	21.34	0.60	32.20	0.20
$0.80 = LS.1	23.00	0.20	26.68	0.60	40.25	0.20
Sorghum[c]						
Border ($/sack)	15.90	0.25	21.80	0.25	27.70[f]	0.50
Producer (LS./sack)						
$1.11 = LS.1	8.17	0.25	11.20	0.25	14.22	0.50
$1.00 = LS.1	9.07	0.25	12.44	0.25	15.79	0.50
$0.80 = LS.1	11.34	0.25	15.55	0.25	19.74	0.50
Groundnuts[d]						
Border ($/sack)	9.60	0.30	12.30	0.30	15.00[f]	0.40
Producer (LS./sack)						
$1.11 = LS.1	5.60	0.30	7.20	0.30	8.80	0.40
$1.00 = LS.1	6.22	0.30	7.99	0.30	9.77	0.40
$0.80 = LS.1	7.77	0.30	9.99	0.30	12.21	0.40
Medium-staple cotton[e]						
Border ($/kantar)	75.00	0.25	104.00[f]	0.625	125.00	0.125
Producer (LS./kantar)						
$1.11 = LS.1	37.16	0.25	56.22	0.625	73.20	0.125
$1.00 = LS.1	41.25	0.25	62.40	0.625	81.25	0.125
$0.80 = LS.1	51.56	0.25	78.00	0.625	101.56	0.125
Long-staple cotton[e]						
Border ($/kantar)	99.00	0.33	132.00[f]	0.50	145.00	0.17
Producer (LS./kantar)						
$1.11 = LS.1	49.05	0.33	71.36	0.50	84.91	0.17
$1.00 = LS.1	54.45	0.33	79.20	0.50	94.25	0.17
$0.80 = LS.1	68.06	0.33	99.00	0.50	117.81	0.17

[a]Probabilities of occurrence are intended to represent expectations about world prices. Probabilities were based on World Bank Commodity Price Projections as a reference.

[b]Border prices of wheat in $/MT converted to per sack prices using 10 sacks = 1 MT. Producer prices were calculated by converting the border price to LS./sack and subtracting a fixed margin of 8 percent, which was the margin in the SCP at $1.11 = LS.1.

[c]Border prices of sorghum in $/MT converted to per sack prices using 11 sacks/MT. Producer prices were calculated by converting the border price to LS./sack and subtracting a fixed margin of 43 percent, which was the margin in the SCP at $1.11 = LS.1.

[d]Border price of groundnuts in $/MT converted to per sack prices using 36.6 sacks/MT. Producer prices were calculated by converting the border price to LS./sack and subtracting a fixed margin of 35 percent, which was the margin in the SCP at $1.11 = LS.1.

[e]Producer prices were calculated by converting the border price to LS./kantar and deducting the following margins from the border price: (1) low border price, 45 percent (2) medium border price, 40 percent (3) high border price, 35 percent.

[f]Price used in Study of Cost of Production (1982).

price. The table also illustrates how different levels of the real exchange rate affect the producer. In particular, if the current exchange rate is $1.11/LS.1.00 while the equilibrium rate is $0.80/LS.1.00, then the overvaluation of 39 percent represents an implicit tax levied on the producer. This is not to say that the exchange rate is overvalued, nor should the results of the study be interpreted as advocating exchange rate reform. The prices presented in Table 1 do, however, illustrate the effects of different real exchange rates. These effects also enter into the results presented in Section 3 and have implications for resource allocation decisions in the Gezira.

2.3 Agricultural Technologies and Production Costs

The sensitivity analysis was conducted on production cost data, which are described in this section. The production costs were based on the data in the SCP, but were modified in consultation with officials from the Ministry of Finance and Economic Planning. These costs define four agricultural technologies, each of which has a different yield distribution associated with it. The analysis based on these data is intended to illustrate the effects on allocation decisions that could occur given reasonable improvements in agricultural research and extension services and in more effective input use.

The major change made in the SCP data was identifying and adjusting those input costs that would directly affect yields. The result of this effort was the specification of four technologies and the classification of the cost of each input as a productivity cost, a fixed cost, or a variable cost. The

technologies are mainly distinguished by differences in the productivity costs; an increase in the use of a productivity-related input, such as land preparation, was assumed to raise the average yield. Thus, a distribution of yields is associated with each technology, although there is considerable overlapping of the distributions because of uncontrollable factors (storm and pest damage, for example) that affect yields. Fixed costs do not vary with output, while variable costs, such as expenditures on sacks and string, vary directly with the amount produced. Tables 2 through 6 present the technology costs for the five crops.

Although the costs for Technologies 1 and 2 are identical, different yield distributions were assumed for each. For Technology 1, the range of yields reported for each crop in the SCP were used in conjunction with the modified costs. This part of the analysis was conducted to determine the robustness of the results reported in the SCP. When compared with the results based on Technology 2, it also illustrates how a bad harvest year can generate results much different from those anticipated when the resources were allocated or how the expectation of a poor harvest could result in a significantly different allocation of resources. Under Technology 2, the higher yields would reflect the adoption of new seed varieties and improved agronomic practices which might be developed in an experiment station and provided to the tenants through agricultural research and extension services.

Technology 3 is similar to the second one, except that

Table 2. Input Costs for Wheat

	Traded Component(%)[a]	Technology 1,2	3	4
Productivity Costs (LS./feddan)[b]				
Land preparation	50	7.49	8.61	9.36
Agricultural operations	45	4.87	5.60	6.09
Fertilizer	87	0.00	15.84	23.76
Others	20	0.35	0.40	0.44
Fixed Costs (LS./feddan)[c]				
Spraying	87	1.36	1.36	1.36
Seeds	87	10.66	10.66	10.66
Land and water charges	45	18.00	18.00	18.00
Variable Costs (LS./sack)[d]				
Harvesting and transport to market[e]	48	2.30	1.65	1.16
Sacks and strings	87	0.70	0.70	0.70
Shelling[f]	0	0.00	0.00	0.00
Transport and handling[f]	60	2.71	2.71	2.71
Marketing[f]	10	1.60	1.60	1.60

[a]Reflects the proportion of each input that is tradeable. Source: Ministry of Finance and Economic Planning, Study of Cost of Production and Comparative Advantage of Crops in Sudan, May 1982.

[b]Costs of land preparation, agricultural operations, and others for Technologies 1 and 2 assumed to be equal to the medium yield costs in SCP; 15 percent and 25 percent were added to these costs to obtain costs for Technologies 3 and 4, respectively. No fertilizer use was assumed for 1 and 2; fertilizer cost for Technology 3 assumed to equal that in SCP; 50 percent was added to this amount to obtain fertilizer cost for Technology 4.

[c]Costs for spraying and land and water charges taken from SCP Cost of seeds for high yield farms in that study was assumed to be fixed for all technologies.

[d]Costs of all items except harvesting and transport to market taken from SCP.

[e]Table entries calculated from the following equation using the average yield (Table 7) for each technology:

$$H = 3.853 - 0.327\ Y \text{ where}$$

H = cost of harvesting and transport to market in LS./sack

Y = yield in sacks/feddan.

The equation was estimated using data for 37 individual farms. For each farm, the costs for manual harvesting, mechanical harvesting, threshing, packing, cleaning, and transport to market were summed and treated as a single cost item, harvesting and transport to market.

[f]Costs incurred beyond the farmgate.

Table 3. Input Costs for Sorghum

	Traded Component(%)[a]	Technology 1,2	3	4
Productivity Costs (LS./feddan)[b]				
Land preparation	40	7.09	8.15	8.86
Agricultural operations	14	18.07	20.78	22.59
Spraying	87	0.00	0.68	1.36
Fertilizer	87	0.00	7.92	15.84
Others	20	0.16	0.18	0.20
Fixed Costs (LS./feddan)[c]				
Seeds	87	2.33	2.33	2.33
Land and water charges	45	7.00	7.00	7.00
Variable Costs (LS./sack)[d]				
Harvesting and transport to market[e]	18	3.96	3.28	2.40
Sacks and strings	87	0.73	0.73	0.73
Shelling[f]	0	0.00	0.00	0.00
Transport and handling[f]	60	1.83	1.83	1.83
Marketing[f]	10	5.43	5.43	5.43

[a]Reflects the proportion of each input that is tradeable. Source: Ministry of Finance and Economic Planning, Study of Cost of Production and Comparative Advantage of Crops in Sudan, May 1982.

[b]Costs of land preparation, agricultural operations, and others for Technologies 1 and 2 assumed to be equal to the medium yield costs in SCP; 15 percent and 25 percent were added to these costs to obtain costs for Technologies 3 and 4, respectively. No fertilizer use or spraying was assumed for Technologies 1 and 2; fertilizer and spraying costs for Technology 4 were assumed to equal those for wheat given in SCP; 50 percent of these amounts were assumed to represent the costs for Technology 3.

[c]Land and water charges taken from SCP. Cost of seeds for medium yield farms in that study was assumed to be fixed for all technologies.

[d]Costs of all items except harvesting and transport to market taken from SCP. Cost of sacks and strings for medium yield farms was used for all technologies.

[e]Table entries calculated from the folowing equation using the average yield (Table 7) for each technology:

$H = 6.295 - 0.354Y$ where

H = cost of harvesting and transport to market in LS./sack

Y = yield in sacks/feddan.

The equation was estimated using data for 38 individual farms. For each farm, the costs for manual harvesting, mechanical harvesting, threshing, packing, cleaning, and transport to market were summed and treated as a single cost item, harvesting and transport to market.

[f]Costs incurred beyond the farmgate.

Table 4. Input Costs for Groundnuts

	Traded Component(%)[a]	Technology 1,2	3	4
Productivity Costs (LS./feddan)[b]				
Land preparation	35	7.01	8.06	8.76
Agricultural operations	13	29.32	33.72	36.65
Fertilizer	87	0.00	0.00	0.00
Others	20	0.37	0.43	0.46
Fixed Costs (LS./feddan)[c]				
Herbicides	87	0.00	7.60	7.60
Seeds	87	7.36	7.36	7.36
Land and water charges	45	14.00	14.00	14.00
Variable Costs (LS./sack)[d]				
Harvesting and transport to market[e]	18	1.79	1.35	0.84
Sacks and strings	87	0.57	0.57	0.57
Shelling[f]	55	0.30	0.30	0.30
Transport and handling[f]	60	0.80	0.80	0.80
Marketing[f]	10	2.28	2.28	2.28

[a]Reflects the proportion of each input that is tradeable. Source: Ministry of Finance and Economic Planning, Study of Cost of Production and Comparative Advantage of Crops in Sudan, May 1982.

[b]Costs of land preparation, agricultural operations, and others for Technologies 1 and 2 assumed to be equal to the medium yield costs in SCP; 15 percent and 25 percent were added to these costs to obtain costs for Technologies 3 and 4, respectively. No fertilizer is used in groundnuts production.

[c]Land and water charges taken from SCP. Cost of seeds for medium yield farms in that study was assumed to be fixed for all input mixes. No herbicide use was assumed for Technologies 1 and 2; the cost of herbicides for medium-staple cotton grown in the Suki scheme was used for Technologies 3 and 4.

[d]Costs of all items except harvesting and transport to market taken from SCP. Cost of sacks and strings for medium yield farms was used for all technologies.

[e]Table entries calculated from the following equation using the average yield (Table 7) for each technology:

$$H = 3.679 - 0.126Y \text{ where}$$

H = cost of harvesting and transport to market in LS./sack

Y = yield in sacks/feddan.

The equation was estimated using three observations, the averages for the low, medium, and high yield farms in the SCP. For each observation, the costs for manual harvesting, mechanical harvesting, threshing, packing, cleaning, and transport to market were summed and treated as a single cost item, harvesting and transport to market.

[f]Costs incurred beyond the farmgate.

Table 5. Input Costs for Medium-Staple Cotton

	Traded Component(%)[a]	Technology 1,2	3	4
Productivity Costs (LS./feddan)[b]				
Land preparation	50	11.24	12.93	14.05
Agricultural operations	14	28.84	33.17	36.05
Other operations	20	0.00	0.00	0.00
Fertilizer	87	9.33	18.66	27.99
Fixed Costs (LS./feddan)[c]				
Seeds	87	1.96	1.96	1.96
Herbicides	87	7.60	7.60	7.60
Spraying	87	31.88	31.88	31.88
Land and water charges	45	28.50	28.50	28.50
Miscellaneous services	40	3.52	3.52	3.52
Variable Costs (LS./kantar)[d]				
Picking and transport from field[e]	16	5.33	5.20	5.05
Sacks and string	87	1.33	1.33	1.33
Transport to ginneries	60	2.10	2.10	2.10
Insurance and others	0	8.00	8.00	8.00
Ginning[f]	60	7.32	7.32	7.32
Transport to Port Sudan[f]	60	1.39	1.39	1.39
Marketing[f]	10	11.54	11.54	11.54

[a]Reflects the proportion of each input that is tradeable. Source: Ministry of Finance and Economic Planning, Study of Cost of Production and Comparative Advantage of Crops in Sudan, May 1982.

[b]Costs of land preparation, agricultural operations, and other operations for Technologies 1 and 2 assumed to be equal to the medium yield costs in SCP; 15 percent and 25 percent were added to these costs to obtain costs for Technologies 3 and 4, respectively. Fertilizer cost for Technology 3 assumed to equal the cost given in SCP; 50 percent of this amount was used to obtain fertilizer cost for Technologies 1 and 2 and 50 percent was added to the cost for Technology 3 to obtain the fertilizer cost for Technology 4.

[c]Costs for seeds, spraying, land and water charges, and miscellaneous services taken from SCP. Cost of herbicides for medium-staple cotton in the Suki scheme was used for all technologies.

[d]Costs of all items except picking and transport from field taken

from SCP.

[e]Table entries calculated from the following equation using the average yield (Table 7) for each technology:

$$H = 5.850 - 0.100\ Y \text{ where}$$

H = cost of picking and transport from field in LS./kantar

Y = yield in kantars/feddan.

The equation was estimated using three obervations, the averages for the low, medium, and high yield farms in the SCP. For each observation, the costs for picking and transport from field were summed and treated as a single cost item.

[f]Costs incurred beyond the gin gate.

Table 6. Input Costs for Long-Staple Cotton

	Traded Component(%)[a]	Technology 1,2	3	4
Productivity Costs (LS./feddan)[b]				
Land preparation	50	16.18	18.61	20.23
Agricultural operations	14	35.91	41.30	44.89
Other operations	20	2.70	3.11	3.38
Fertilizer	87	9.33	18.66	27.99
Fixed Costs (LS./feddan)[c]				
Seeds	87	1.96	1.96	1.96
Herbicides	87	7.60	7.60	7.60
Spraying	87	31.88	31.88	31.88
Land and water charges	45	28.50	28.50	28.50
Miscellaneous services	40	3.52	3.52	3.52
Variable Costs (LS./kantar)[d]				
Picking and transport from field[e]	15	8.43	7.17	5.91
Sacks and string	87	1.33	1.33	1.33
Transport to ginneries	60	2.10	2.10	2.10
Insurance and others	0	8.00	8.00	8.00
Ginning[f]	60	7.32	7.32	7.32
Transport to Port Sudan[f]	60	1.39	1.39	1.39
Marketing[f]	10	14.13	14.13	14.13

[a]Reflects the proportion of each input that is tradeable. Source: Ministry of Finance and Economic Planning, Study of Cost of Production and Comparative Advantage of Crops in Sudan, May 1982.

[b]Costs of land preparation, agricultural operations, and other operations for Technologies 1 and 2 assumed to be equal to the medium yield costs in SCP; 15 percent and 25 percent were added to these costs to obtain costs for Technologies 3 and 4, respectively. Fertilizer cost for Technology 3 assumed to equal the cost given in SCP; 50 percent of this amount was used for Technologies 1 and 2 and 50 percent was added to the cost for Technology 3 to obtain the fertilizer cost for Technology 4.

[c]Costs for seeds, spraying, land and water charges and miscellaneous services taken from SCP. Cost of herbicides for medium-staple cotton in the Suki scheme was used for all technologies.

[d]Costs of all items except picking and transport from field taken

from SCP.

[e]Table entries calculated from the following equation using the average yield (Table 7) for each technology:

$$H = 12.833 - 1.258\ Y \text{ where}$$

H = cost of picking and transport from field in LS./kantar

Y = yield in kantars/feddan.

The equation was estimated using three observations, the averages for the low, medium, and high yield farms in the SCP. For each observation, the costs for picking and transport from field were summed and treated as a single cost item.

[f]Costs incurred beyond the gin gate.

higher levels of input use, especially tenant labor devoted to land preparation and agricultural operations, result in higher average yields. Technology 4 embodies very intensive use of inputs; its very high average yields reflect an optimistic scenario that could occur only under significant improvements in the structure of incentives, the agricultural research program, and the delivery of the results to the tenants. If this were to occur, it could imply significant changes in the cropping patterns.

2.3.1 Productivity Costs

The bulk of the productivity costs are accounted for by the labor committed to land preparation and agricultural operations and by the cost of fertilizer. These are ex ante costs; that is, the tenant commits his resources and incurs the costs before any yields are realized. Although it was assumed that increasing the use of these inputs would, on average, increase the yield, the effect of factors beyond the tenant's control (climatic conditions, pest and insect damage, etc.) could result in yields above or below the average. There would be a distribution of yields about the mean associated with each technology. The minimum and maximum yields, the average yield, and the standard deviation are shown for each crop in Table 7.

An important feature of the productivity costs is that the SGB cannot directly control the tenant's commitment of his time in the way that it controls the allocation of water and the purchases of material inputs. Thus, while the SGB could purchase enough fertilizer to meet the requirements of Technology 4, the

Table 7. Yield Distributions by Technology

	Technology 1[a]			
	Minimum	Average	Maximum	Standard Deviation
Wheat (sacks/fed.)	0.5	2.75	5.00	0.75
Sorghum (sacks/fed.)	0.5	3.50	6.50	1.00
Groundnuts (sacks/fed.)	2.0	12.00	22.00	3.33
Long-staple cotton (kantars/fed.)	0.5	2.25	4.00	0.583
Medium-staple cotton (kantars/fed.)	0.5	2.75	5.00	0.75

	Technology 2[b]			
	Minimum	Average	Maximum	Standard Deviation
Wheat (sacks/fed.)	2.00	4.75	7.50	0.917
Sorghum (sacks/fed.)	2.20	6.60	11.00	1.467
Groundnuts (sacks/fed.)	5.00	15.00	25.00	3.333
Long-staple cotton (kantars/fed.)	1.50	3.50	5.50	0.667
Medium-staple cotton (kantars/fed.)	2.00	5.25	8.50	1.083

Table 7. Yield Distributions by Technology (continued)

	Technology 3[b]			
	Minimum	Average	Maximum	Standard Deviation
Wheat (sacks/fed.)	3.50	6.75	10.00	1.083
Sorghum (sacks/fed.)	3.85	8.53	13.20	1.558
Groundnuts (sacks/fed.)	7.00	18.50	30.00	3.833
Long-staple cotton (kantars/fed.)	2.50	4.50	6.50	0.667
Medium-staple cotton (kantars/fed.)	3.00	6.50	10.00	1.167

	Technology 4[b]			
	Minimum	Average	Maximum	Standard Deviation
Wheat (sacks/fed.)	4.50	8.25	12.00	1.250
Sorghum (sacks/fed.)	5.50	11.00	16.50	1.833
Groundnuts (sacks/fed.)	10.00	22.50	35.00	4.167
Long-staple cotton (kantars/fed.)	3.50	5.50	7.50	0.667
Medium-staple cotton (kantars/fed.)	4.00	8.00	12.00	1.333

[a]Minimum and maximum yields for each crop were those reported in SCP (1982). The midpoint of the range was taken as the average. All yields were assumed to be normally distributed. All observed yields were assumed to

fall within plus or minus three standard deviations from the mean; thus, the standard deviations given in the table were obtained by dividing the range of yields by six (standard deviations).

[b]The minimum and maximum yields were provided by Dr. Abdus Sattar of the UNDP/IBRD Planning Assistance and Training Project/Sudan. The midpoint of the range was taken as the average. All yields were assumed to be normally distributed. All observed yields were assumed to fall within plus or minus three standard deviations from the mean; thus, the standard deviations given in the table were obtained by dividing the range of yields by six (standard deviations).

structure of incentives facing the tenant might be such that he is only willing to commit resources equivalent to those of Technology 1 or 2. It is assumed throughout this study that the incentives facing the producer are structured to elicit the level of effort required by the technology the SGB ultimately selects. This is perhaps the most crucial assumption underlying the analysis, because these inputs are the only ones that directly affect yields.

The costs of all labor inputs in Technologies 1 and 2 were assumed to be equal to those of the medium yield farms in the SCP. Increments of 15 and 25 percent were added to these amounts to obtain the costs for Technologies 3 and 4, respectively. The methods used to estimate the cost of fertilizer are described in the footnotes to the cost table for each crop.

2.3.2 Fixed and Variable Costs

The fixed costs from the SCP shown in the cost tables are constant across different output levels. Although the use of these inputs is necessary to obtain some output, it is assumed that increasing their use would not increase yields.

All variable costs begin to be incurred when the crop is ready for harvesting. With the exception of harvesting costs, expenditures on variable inputs are given on a constant per sack or per kantar basis; thus, total expenditures for variable inputs depend solely on the yield. Some of the variable costs, notably shelling or ginning, transport and handling, and marketing, are incurred beyond the farmgate or gin gate. Though these items do

not affect private profitability through the cost side, they do constitute part of the marketing margin for each commodity and therefore affect profitability through the price the tenant receives for his output. With the exception of harvesting costs, all variable costs were taken directly from the SCP.

Harvesting costs are a quasi-variable cost, that is, they contain a fixed component and a variable component. Consequently, the cost per unit of output declines as yields rise. Because hundreds of yields were used in calculating the coefficients, a function was estimated for each crop relating harvesting (or picking) cost per unit of output to the yield. For wheat and sorghum, data for almost 40 individual farms each were used to estimate the functions. Individual farm data were not available for groundnuts, long-staple cotton, and medium-staple cotton, so the averages for the low, medium, and high yield farms reported in SCP were used. Harvesting costs for wheat, sorghum, and groundnuts include expenditures on manual and mechanical harvesting, threshing, packing, cleaning, and transport to market. For long- and medium-staple cotton, expenditures on picking and transport from the field were summed.

The estimating functions are reported in the footnotes to the cost table for each crop; the harvesting costs reported in the tables were calculated from these functions using the average yield for each input mix.

2.3.3. Traded Component of Input Costs

The calculation of DRC coefficients, foreign exchange dependence, and value added requires that input costs be decomposed

into their traded and nontraded (domestic) components. This classification is based on an opportunity cost concept. For an input to be considered a tradeable does not necessarily mean that it is imported or exported, merely that it could be. For example, all the seed required for a particular crop might be produced in the Sudan. The large tradeable component of seed cost (87 percent), however, reflects the real cost of domestic production, namely that the demand for seed could have been filled through purchases in the world seed market. In other words, domestic resources were foregone to produce seeds; 87 percent of those resources were traded in international markets.

The tradeable component of each input is given in the cost table for each crop. These percentages are identical to the ones used in the SCP. The traded component of harvesting costs is a weighted average of the proportions assigned to the individual cost items that were aggregated.

2.4 Summary of Methods

In the sensitivity analysis, yields were assumed to be normally distributed around the mean. For each crop, one hundred yields were randomly selected from this distribution. Each yield was combined with a border and producer price which was determined using the probabilities of occurrence given in Section 2.2; these data and the relevant production costs were then used to calculate each of the four output variables described in Section 2.1. The results of this analysis are presented and discussed in Section 3.

SECTION 3: RESULTS OF SENSITIVITY ANALYSIS

This section presents the results of the sensitivity analysis. The discussion of the results has two parts. The first part is an analysis of each agricultural technology (Section 3.1) that illustrates how critical the choice is of an objective function. The choice of an objective function must also take into account the responses of the tenants to resource allocations made by the SGB. The second part of the analysis presents estimates of the responsiveness of each of the output variables to changes in exchange rates, border prices, and yields (Section 3.2). This part of the analysis reveals some important considerations regarding the relative efficacy of policies that affect producer prices, yields, and exchange rates.

3.1 Analysis of Agricultural Technologies

Tables 8 through 10 are a summary of the results of the sensitivity analysis. Given an exchange rate, each table gives the 5th, 50th, and 95th percentile values of the DRC coefficient, value added, FED, and the PPC for each crop and agricultural technology package. Percentile values, rather than the means and standard deviations, were used to represent the distributions of the coefficients, because it is more representative of the probability that a particular outcome would occur.

The following four sub-sections are a discussion of each technology package in terms of how resources would be allocated using two criteria, maximization of net foreign exchange earnings (value added) and maximization of comparative advantage (DRC

Table 8. Distributions of Coefficients by Technology Package if Real Exchange Rate=$1.11/LS.1.00

Technology Package	Crop	Domestic Resource Cost Percentile Values[a]			Value Added Percentile Values ($/Feddan)			Foreign Exchange Dependence Percentile Values			Private Profitability Percentile Value[b]		
		5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%
1	Wheat	0.40	1.05	3.19	7.1	26.3	71.3	0.36	0.59	0.83	0.72	0.97	1.54
	Sorghum	0.53	0.94	2.12	18.1	49.0	109.3	0.21	0.33	0.53	0.59	0.76	1.00
	Groundnuts	0.60	0.86	1.67	43.8	102.4	176.5	0.23	0.29	0.44	0.52	0.76	0.96
	Medium-staple cotton	0.51	0.88	2.19	46.7	156.8	343.9	0.26	0.40	0.66	0.42	0.71	0.96
	Long-staple cotton	0.60	0.91	3.96	30.6	173.5	321.5	0.27	0.38	0.76	0.36	0.72	0.98
2	Wheat	0.23	0.50	0.89	33.0	67.7	153.2	0.24	0.41	0.55	1.04	1.35	2.22
	Sorghum	0.41	0.56	0.99	66.9	115.4	189.0	0.17	0.22	0.33	0.70	0.97	1.16
	Groundnuts	0.48	0.73	1.46	61.2	137.4	229.0	0.19	0.26	0.41	0.55	0.85	1.13
	Medium-staple cotton	0.42	0.56	0.96	190.2	376.0	616.8	0.20	0.26	0.39	0.62	0.96	1.30
	Long-staple cotton	0.46	0.63	1.09	143.9	304.6	475.2	0.21	0.28	0.42	0.57	0.90	1.21
3	Wheat	0.20	0.45	0.81	47.5	92.8	209.3	0.25	0.43	0.58	1.04	1.37	2.27
	Sorghum	0.39	0.54	1.04	75.9	154.7	229.9	0.19	0.24	0.38	0.67	0.95	1.16
	Groundnuts	0.43	0.68	1.33	78.3	161.1	286.2	0.19	0.27	0.41	0.58	0.87	1.21
	Medium-staple cotton	0.42	0.51	0.86	274.8	509.2	738.1	0.19	0.23	0.35	0.64	1.02	1.28
	Long-staple cotton	0.44	0.56	0.96	216.1	400.9	612.3	0.20	0.26	0.38	0.61	0.96	1.24
4	Wheat	0.19	0.41	0.75	55.9	109.3	239.2	0.25	0.42	0.57	1.07	1.42	2.29
	Sorghum	0.35	0.47	0.91	104.1	214.0	318.5	0.18	0.23	0.37	0.70	1.01	1.22
	Groundnuts	0.41	0.60	1.09	109.1	205.8	364.2	0.18	0.25	0.36	0.65	0.95	1.28
	Medium-staple cotton	0.41	0.50	0.81	348.7	592.6	894.7	0.19	0.23	0.33	0.67	1.02	1.29
	Long-staple cotton	0.40	0.50	0.82	296.9	522.1	717.3	0.19	0.23	0.34	0.67	1.05	1.33

[a]DRC less than one implies a comparative advantage; DRC greater than one implies a comparative disadvantage.

[b]PPC less than one means producer incurs a loss; PPC greater than one means producer makes a profit.

Source: Sigma One Corporation

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Table 9. Distributions of Coefficients by Technology Package if Real Exchange Rate=$1.00/LS.1.00

Technology Package	Crop	Domestic Resource Cost Percentile Values[a]			Value Added Percentile Values ($/Feddan)			Foreign Exchange Dependence Percentile Values			Private Profitability Percentile Values[b]		
		5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%
1	Wheat	0.32	0.85	4.48	3.0	28.0	76.8	0.32	0.55	0.90	0.68	1.03	1.71
	Sorghum	0.47	0.68	1.63	21.7	62.3	113.3	0.19	0.26	0.46	0.63	0.89	1.08
	Groundnuts	0.52	0.79	1.42	52.9	102.7	174.1	0.20	0.27	0.40	0.56	0.80	1.07
	Medium-staple cotton	0.48	0.69	1.56	64.9	182.3	322.4	0.24	0.34	0.56	0.49	0.83	1.08
	Long-staple cotton	0.50	0.78	1.78	58.9	180.4	322.4	0.24	0.35	0.60	0.46	0.77	1.14
2	Wheat	0.20	0.46	0.79	34.3	67.8	160.8	0.22	0.39	0.52	1.09	1.42	2.47
	Sorghum	0.35	0.49	0.95	55.8	118.9	204.5	0.15	0.20	0.32	0.72	1.03	1.30
	Groundnuts	0.41	0.65	1.18	68.6	138.4	247.4	0.17	0.24	0.36	0.62	0.91	1.29
	Medium-staple cotton	0.36	0.48	0.81	195.3	398.4	634.7	0.17	0.23	0.35	0.68	1.08	1.47
	Long-staple cotton	0.41	0.60	0.81	200.8	315.1	498.7	0.19	0.26	0.33	0.69	0.92	1.33
3	Wheat	0.21	0.39	0.64	53.1	92.6	179.1	0.25	0.40	0.52	1.16	1.48	2.25
	Sorghum	0.32	0.46	0.92	75.2	150.3	260.5	0.16	0.21	0.35	0.71	1.05	1.32
	Groundnuts	0.41	0.61	1.06	85.8	170.3	270.4	0.18	0.25	0.36	0.66	0.94	1.28
	Medium-staple cotton	0.34	0.44	0.74	281.8	535.9	790.9	0.16	0.21	0.32	0.71	1.14	1.53
	Long-staple cotton	0.38	0.47	0.72	279.3	455.1	623.1	0.18	0.22	0.31	0.73	1.11	1.42
4	Wheat	0.17	0.31	0.47	81.2	129.1	239.5	0.23	0.36	0.46	1.32	1.65	2.50
	Sorghum	0.32	0.43	0.90	88.3	200.3	296.1	0.17	0.22	0.37	0.70	1.06	1.31
	Groundnuts	0.37	0.53	0.86	127.1	208.8	357.0	0.17	0.22	0.31	0.75	1.04	1.37
	Medium-staple cotton	0.33	0.43	0.73	324.9	634.7	919.8	0.16	0.20	0.31	0.71	1.16	1.54
	Long-staple cotton	0.36	0.45	0.72	304.3	512.7	766.6	0.17	0.22	0.31	0.73	1.12	1.48

[a]DRC less than one implies a comparative advantage; DRC greater than one implies a comparative disadvantage.

[b]PPC less than one means producer incurs a loss; PPC greater than one means producer makes a profit.

Source: Sigma One Corporation

Table 10. Distributions of Coefficients by Technology Package if Real Exchange Rate=$0.80/LS.1.00

Technology Package	Crop	Domestic Resource Cost Percentile Values[a]			Value Added Percentile Values ($/Feddan)			Foreign Exchange Dependence Percentile Values			Private Profitability Percentile Values[b]		
		5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%
1	Wheat	0.26	0.61	1.88	9.5	34.0	81.1	0.26	0.46	0.73	0.82	1.24	2.08
	Sorghum	0.36	0.51	1.32	18.5	60.6	117.5	0.15	0.21	0.42	0.69	1.05	1.30
	Groundnuts	0.39	0.61	1.16	42.7	107.7	196.6	0.16	0.22	0.36	0.63	0.97	1.35
	Medium-staple cotton	0.38	0.54	1.04	86.5	181.0	328.6	0.21	0.29	0.45	0.60	0.98	1.38
	Long-staple cotton	0.39	0.57	1.08	90.5	201.0	345.2	0.20	0.28	0.44	0.61	0.97	1.35
2	Wheat	0.16	0.30	0.52	42.2	82.2	153.9	0.18	0.29	0.42	1.33	1.87	2.91
	Sorghum	0.28	0.36	0.68	63.0	125.9	200.7	0.12	0.15	0.25	0.87	1.30	1.54
	Groundnuts	0.34	0.50	0.89	71.4	149.0	229.7	0.15	0.20	0.30	0.74	1.10	1.48
	Medium-staple cotton	0.28	0.36	0.61	215.9	411.0	658.8	0.14	0.18	0.28	0.82	1.35	1.83
	Long-staple cotton	0.30	0.41	0.65	192.7	338.2	534.4	0.15	0.21	0.30	0.80	1.25	1.70
3	Wheat	0.14	0.26	0.45	61.1	116.1	220.9	0.19	0.30	0.43	1.38	1.93	3.05
	Sorghum	0.26	0.38	0.63	91.4	157.9	258.3	0.13	0.18	0.27	0.86	1.20	1.57
	Groundnuts	0.29	0.45	0.75	95.9	186.1	302.9	0.14	0.19	0.29	0.82	1.19	1.65
	Medium-staple cotton	0.26	0.34	0.55	305.4	549.9	878.4	0.13	0.17	0.26	0.88	1.41	1.95
	Long-staple cotton	0.29	0.35	0.52	288.4	477.6	642.3	0.14	0.18	0.24	0.93	1.38	1.76
4	Wheat	0.13	0.22	0.31	100.5	145.7	264.8	0.18	0.28	0.35	1.69	2.06	3.16
	Sorghum	0.24	0.33	0.60	109.8	206.2	320.7	0.13	0.18	0.28	0.87	1.27	1.61
	Groundnuts	0.28	0.42	0.75	110.4	214.9	360.5	0.13	0.18	0.28	0.82	1.25	1.72
	Medium-staple cotton	0.26	0.32	0.50	412.4	698.2	967.2	0.13	0.16	0.23	0.94	1.47	1.89
	Long-staple Cotton	0.29	0.33	0.50	369.2	567.2	744.5	0.14	0.17	0.23	0.96	1.45	1.76

[a]DRC less than one implies a comparative advantage; DRC greater than one implies a comparative disadvantage.

[b]PPC less than one means producer incurs a loss; PPC greater than one means producer makes a profit.

Source: Sigma One Corporation

coefficient). The private profitability of the crops produced by each technology is examined to determine the extent to which the tenants would support a particular allocation of resources by the SGB.

3.1.1. Technology Package 1

This technology and its associated yields roughly approximate the conditions that prevailed in the Gezira in the 1980/81 harvest year. At the prevailing exchange rate ($1.11 = LS.1.00), Table 8 shows that if the crops are ranked at the median (50th percentile) by value added, long-staple cotton generates the highest net foreign exchange earnings, followed by medium-staple cotton and groundnuts. This order is reversed if the DRC is used as the ranking criterion. Wheat generates the smallest value added and is the only crop in which a comparative disadvantage exists in more than 50 percent of the cases. However, it is the most profitable crop for the producer; almost 50 percent of the PPC's are greater than or equal to one. Less than five percent of the producers of long- and medium-staple cotton and groundnuts would break even.

An examination of Tables 9 and 10 shows that similar results are obtained for alternative values of the real exchange rate. When ranked by value added, the two types of cotton are first and second, followed by groundnuts. When ranked by the DRC coefficient, sorghum has the greatest comparative advantage in at least 75 percent of the cases analyzed, followed by medium-staple cotton, long-staple cotton, and groundnuts. Under the alterna-

tive exchange rates of $1.00 = LS.1.00 however, the private profitability coefficients indicate that producers of sorghum would earn a profit in 25 percent of the cases analyzed, and producers of medium- and long-staple cotton and groundnuts would earn a profit in only 10 percent of the cases analyzed. Although private profitability improves overall at an exchange rate of $0.80 = LS.1.00, wheat and sorghum are the only crops in which the producers make a profit at least 50 percent of the time.

Although wheat consistently ranks last in terms of both value added and comparative advantage, it would be the crop of choice among the tenants, since its production yields a profit at least 50 percent of the time regardless of what the real exchange rate might be. The results also clearly illustrate the conflict that exists between the objective functions facing the SGB and the objective function of the tenants. Any allocation of resources utilizing this technology would have to incorporate some type of subsidy program to compensate the tenants for the losses they would incur if the allocation program were to achieve its intended objective.

3.1.2. Technology Package 2

This technology is very similar to Technology Package 1, except that on average higher yields are realized through more effective input use and the availability of improved agricultural inputs (Table 7). Inspection of the median values of value added shown in Tables 8 through 10 shows that the ranking of crops based on this criterion is identical across exchange rates. In descending order, this ranking gives medium-staple cotton, long-

staple cotton, groundnuts, sorghum, and wheat. The ranking based on comparative advantage is also identical across exchange rates, although significantly different from that obtained using value added as the criterion. From the greatest comparative advantage to the least, the order is wheat, medium-staple cotton, sorghum, long-staple cotton, and groundnuts.

That wheat is first when ranked by comparative advantage is interesting for two reasons. First, other studies have consistently demonstrated that the Sudan is at a significant comparative disadvantage in the production of wheat [3, 4, 5]. This study shows a clear comparative advantage in wheat production across exchange rates for all cases analyzed. If the technology costs are accurate, this result reflects the importance both of increased wheat yields in the determination of comparative advantage. The second reason this result is of interest is that if resources were allocated according to comparative advantage rather than by value added, the objective functions of both the SGB and the tenants would not conflict.

The private profitability coefficients show that across exchange rates, wheat producers would make a profit in almost 100 percent of the cases analyzed. It is also the most profitable of the five crops. Although profits accruing to the producers of the other four crops are higher under Technology 2 than under Technology 1, some producers would incur losses. At an exchange rate of $1.11 = LS.1.00, producers of medium- and long-staple cotton, groundnuts, and sorghum would not be able to cover their

costs more than 50 percent of the time. If the real exchange rate were $0.80 = LS.1.00, roughly 75 percent of the producers of crops other than wheat would either break even or make a profit. In this case, a ranking based on private profitability from highest to lowest gives wheat, medium-staple cotton, sorghum, long-staple cotton, and groundnuts.

Under this technology, an allocation of resources based on maximizing net foreign exchange earnings would favor the cash crops (cotton and groundnuts) over the food crops (wheat and sorghum). The objective function of the tenants (maximization of private profitability) would conflict with this allocation for two reasons. First, these results show that the production of food crops are more profitable for the tenants than are the cash crops. Second, the existence of an unofficial market for wheat and the use of sorghum as a staple food grain makes their production more attractive than the production of cotton which is purchased from the tenants only through official markets. A final consideration is that any significant allocation of resources directed towards the production of wheat because of its comparative advantage must be carefully examined to determine the consequences for Sudan's foreign exchange reserves. Wheat consistently has the lowest value added and the highest foreign exchange dependence of all crops across the exchange rates. Since the Gezira Scheme is both a major supplier and user of foreign exchange, any significant change in resource allocation in this scheme must be evaluated in view of the potential impacts to the domestic economy and to Sudan's foreign trade position.

3.1.3. Technology Package 3

The ranking of crops by value added is identical across exchange rates. In descending order, the ranking is medium-staple cotton, long-staple cotton, groundnuts, sorghum, and wheat. If comparative advantage is the criterion, a different ranking is obtained, but one which is essentially the same across exchange rates. In descending order, wheat always ranks first, followed by medium-staple cotton, sorghum or long-staple cotton, and groundnuts. The private profitability coefficients show that the tenants always make the greatest profits in the production of wheat. At an exchange rate of $1.11 = LS.1.00 only medium-staple cotton is profitable at least 50 percent of the time; the median values for long-staple cotton, sorghum, and groundnuts are less than one. At an exchange rate of $1.00 = LS.1.00, all crops except groundnuts are profitable in at least 50 percent of the cases analyzed. Private profitability peaks at an exchange rate of $0.80 = LS.1.00 where all crops are profitable at least 50 percent of the time and all crops except sorghum have a PPC of one or greater in 75 percent of the cases.

If this technology package is applied, an allocation of resources based on comparative advantage would coincide with the incentives facing producers; wheat and medium-staple cotton are the most profitable crops for the tenants and are also the ones that exhibit the greatest comparative advantage. Since the production of groundnuts has the least comparative advantage (at the prevailing exchange rate, a comparative disadvantage exists in at

least 20 percent of the cases) and its profitability to producers is also low, any allocation of resources to its production under this technology should be closely examined, especially since groundnuts production has a significant comparative advantage in the rainfed sector [4]. This example also highlights the necessity of considering the relationship between the irrigated and rainfed sectors when allocating resources in the Gezira Scheme.

3.1.4. Technology Package 4

The results based on this technology, which embodies the most optimistic expectations regarding yields, generally supports the conclusions reached in the analysis of Technologies 2 and 3. Cotton is the largest contributor to net foreign exchange earnings and wheat is the smallest across the exchange rates. When ranked according to comparative advantage, the results vary more with the real exchange rate than do those of the other technologies, although wheat always exhibits the greatest comparative advantage and groundnuts the least. Sorghum production ranks second in comparative advantage at exchange rates of $1.11 = LS.1.00 and $1.00 = LS.1.00. At the highest real exchange rate, medium-staple cotton ranks second and long-staple cotton and sorghum, with the same DRC's, rank third.

Wheat produced with this technology package remains the most profitable across all exchange rates; in all cases analyzed, profits significantly exceeded the break even point. At the prevailing exchange rate, median values of the PPC for sorghum and long- and medium-staple cotton are just above the break even

point. Profits are very high at an exchange rate of $0.80 = LS.1.00; in the cases analyzed, over 80 percent of the PPC's for medium-staple cotton were greater than one, over 75 percent for long-staple cotton and groundnuts, and almost 75 percent for sorghum. These results illustrate the potential for realizing significant producer profits given very effective and very intensive use of superior agricultural inputs and an improved structure of incentives.

3.2 Effects of Exchange Rates, Prices, and Yields

As the analysis in Section 3.1 showed, domestic resource cost coefficients, value added, foreign exchange dependence, and private profitability coefficients are sensitive to changes in several factors. The primary ones are exchange rates, border prices, and yields. Although production costs were varied in the analysis, they were directly related to changes in the average yield levels through the productivity costs. Producer prices were also varied in the sensitivity analysis, but these were calculated from the border prices. This section analyzes the responsiveness across all agricultural technologies of the coefficients to changes in exchange rates, border prices, and yields.

This information shows the impact of changes in factors over which policy makers have little or no control and of those over which they do have influence. This, in turn, enables policy makers to formulate reasonable expectations about the potential effects of their actions. Since changes in the real exchange rate are exogenous to the SGB, it is not considered an SGB

policy instrument in this analysis. For all crops except long-staple cotton, the Sudan is a price-taker in world markets. Accordingly, the border price is not a policy instrument either. Producer prices, however, can be affected by policy-makers. Policies that cause the producer price to diverge from its import or export parity equivalent could have significant impacts on the results and conclusions presented in this study. The third factor, yields, can also be affected through government and SGB policies, particularly the allocation of resources to agricultural research and extension services and the provision of yield-increasing inputs such as appropriate fertilizers, improved seed varieties, etc.

Values of each coefficient from the four technology packages were regressed on the exchange rate, the border price, and the yield. Since logarithms of the variables were used in the estimation procedure, the coefficients of the independent variables can be interpreted as elasticities. That is, each coefficient gives the percentage change in a particular output variable caused by a one percent change in the relevant independent variable. The results are given in Table 11*.

The absolute values of the coefficients in Table 11 show that yield changes have a much smaller impact on all output variables except value added than do changes in the exchange rate

*Variable components analysis of the data set yielded results that were very similar to those obtained in the regression analysis. The coefficient estimates are presented because their interpretation is more intuitive.

Table 11. Elasticity Estimates of Exchange Rates, Border Prices, and Yields[a]

Crop	Independent Variable	Output Variable: Domestic Resource Cost	Value Added	Foreign Exchange Dependence	Private Profitability Coefficient
Wheat	Exchange Rate	1.66	-0.66	0.99	-0.94
	Border Price	-1.59	1.60	-1.00	0.95
	Yield	-1.04	1.43	-0.43	0.44
Sorghum	Exchange Rate	1.30	-0.30	0.98	-0.79
	Border Price	-1.34	1.34	-0.98	0.78
	Yield	-0.50	1.11	-0.27	0.21
Groundnuts	Exchange Rate	1.33	-0.33	1.00	-0.95
	Border Price	-1.34	1.34	-0.99	0.94
	Yield	-0.70	1.16	-0.42	0.46
Medium-staple cotton	Exchange Rate	1.34	-0.34	1.00	-1.00
	Border Price	-1.40	1.40	-1.01	1.30
	Yield	-0.56	1.25	-0.56	0.38
Long-staple cotton	Exchange Rate	1.42	-0.41	1.02	-1.00
	Border Price	-1.37	1.38	-0.98	1.36
	Yield	-0.76	1.34	-0.60	0.45

[a]Table entries represent the percentage change in each output variable given a one (1) percent change in the associated independent variable. A minus sign indicates a response in the output variable that is opposite to the direction of change in the independent variable.

Source: Sigma One Corporation

and the border price for all crops. For example, a one percent increase in wheat yields would decrease the DRC coefficient by one percent, whereas a one percent increase in the border price would result in a 1.6 percent decrease in the DRC. Similarly, a one percent increase in the exchange rate would reduce the DRC by almost 1.7 percent. That changes in yields have less effect on the private profitability coefficient than do changes in the exchange rate and the border price illustrates the importance of the assumption of import or export parity pricing that was used in this study. Although efforts made to increase yields through the dissemination of agricultural research results and better inputs would increase producer profits, domestic policies that ultimately affect the exchange rate at which the border price is converted and exogenous changes in the border price have a much greater impact. While changes in the border price cannot be controlled, policies that cause producer prices to diverge from the import or export parity prices would have much larger impacts on private profitability (and correspondingly on producer incentives) than would attempts to increase yields.

Value added is more responsive to changes in yields and border prices than to changes in the exchange rate. The reason is that the exchange rate is used to convert the value of traded inputs in Sudanese pounds to dollars whereas changes in either the border price or yield affects the total value of output.

These results show that producer incentives, as reflected in the border price coefficient, are a critical ingredient

reconciling the objectives of the tenants and of the SGB. The magnitude of this effect relative to the yield coefficients supports this conclusion. Although this study did not model producer behavior, it is reasonable to assume a link between producer prices and realized yields. That is, the availability of better agronomic practices and improved agricultural inputs is not sufficient to insure their adoption. The proper structure of incentives creates the conditions under which producers would want to increase yields and would adopt better practices and inputs if they were available.

SECTION 4: SUMMARY AND CONCLUSIONS

The importance of the Gezira Scheme to the economy of Sudan means that SGB resource allocations among the five primary crops must be carefully evaluated to insure that the objectives of the three partners in the scheme, the government of Sudan, the SGB, and the tenants, mesh. This study analyzed the sensitivity of four possible decision variables to changes in real exchange rates, border and producer prices, input costs, and yields. These variables were the domestic resource cost coefficient, value added, foreign exchange dependence, and the private profitability coefficient. For each crop, four agricultural technologies were specified and costed. Technology 1 represents the current situation in the Gezira. Implicit in the remaining technologies is the assumption that further investment in agricultural research and extension services, more effective and more intensive input use, and significant improvements in the structure of incentives will result in increasingly greater yields.

Under current cost levels and yields, all crops are unprofitable to the producer a majority of the time. The production and export of cotton would generate the most foreign exchange and wheat would generate the least. The greatest comparative advantage is in irrigated groundnuts production (although the comparative advantage of rainfed grounds is greater), while a comparative disadvantage exists in wheat production most of the time. The application of Technologies 2,

3, or 4 significantly increase both the comparative advantage and the private profitability of wheat production. The production of medium-staple cotton would earn the most foreign exchange and would rank second behind wheat in comparative advantage and private profitability.

The analytical results based on Technologies 2, 3, and 4 depend on the validity of one key assumption. The SGB, given constraints on the resources available to it, can choose a technology package. However, if the expected yields are to be achieved, the structure of incentives must be such that the tenants would respond positively to the resource allocations made by the SGB. Only if this is done will the objectives of the SGB and the tenants be compatible and thus lead to the outcomes presented in this study.

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APPENDIX A: SOLUTIONS TO THE LINEAR PROGRAMMING PROBLEM

The purpose of this appendix is to present the solutions to two of the least restrictive linear programs (LP) originally proposed for this study, and to demonstrate that, because of the nature of the problem, its solution was a trivial one, i.e., a corner solution always obtained.

The problem can be stated as follows:

$$\text{maximize } FEX = MC\cdot(VA_{MC}) + LC\cdot(VA_{LC}) + W\cdot(VA_W) + S\cdot(VA_S) + G\cdot(VA_G)$$

subject to the following constraints on water availability:

$$LC \geqslant 280$$

$$MC \geqslant 20$$

$$300 \leqslant LC + MC \leqslant 600$$

$$S \geqslant 50$$

$$0 \leqslant S + G \leqslant 1000 - (LC + MC)$$

$$100 \leqslant W \leqslant 1000 - (LC + MC)$$

where FEX = net foreign exchange earnings, MC = area planted in medium-staple cotton, LC = area planted in long-staple cotton, W = area planted in wheat, S = area planted in sorghum, G = area planted in groundnuts, VA = value added for each crop (\$/feddan).

An additional constraint was imposed on private profitability to define the first LP problem:

$P_{MC}, P_{LC}, P_W, P_S, P_G \geqslant 1.00$ at the 50th percentile where the P's are private profitability coefficients.

This constraint was made more restrictive in the second LP

problem:

P_{MC}, P_{LC}, P_W, P_S, $P_G \geqslant 1.20$ at the 50th percentile.

No constraints were imposed on the availability of foreign exchange to purchase imported inputs.* Thus, in the solutions to these problems it is implicitly assumed that the necessary amount of foreign exchange will be available and forthcoming.

Table A.1 presents a summary of the solutions to these problems. Tables 8 through 10 from Section 3.1 were used to obtain these solutions by inspection. As Table A.1 shows, no solution was possible in many cases, because no feasible set existed. That is, there were no values that met the constraints on private profitability.

In those cases where a solution existed, it was a trivial, or corner, solution. The values for value added (net foreign exchange earnings) were such that the maximum allowable area was always allocated to medium-staple cotton, and the minimum allowable area was always allocated to long-staple cotton. Because of this, the maximum allowable area was always allocated to wheat. The only allocations that varied were those for sorghum and groundnuts; if the maximum was allocated to one, the minimum was allocated to the other.

*Originally, an upper limit on foreign exchange availability, expressed as a percentage of total F.O.B. production costs, had been proposed. However, adding this constraint would have further restricted the feasible set and fewer solutions would have been obtained.

Table A.1. Summary of Solutions to Linear Program (000 feddans)[a]

	Exchange Rate		
	$1.11=LS.1.00	$1.00=LS.1.00	$0.80=LS.1.00
Technology 1			
Constraint set A[b]	N/S	N/S	N/S
Constraint set B[c]	N/S	N/S	N/S
Technology 2			
Constraint set A[b]	N/S	N/S	MC=320, LC=280 S=50, G=350 W=400
Constraint set B[c]	N/S	N/S	MC=320, LC=280 S=400, G=0 W=400
Technology 3			
Constraint set A[b]	N/S	MC=320, LC=280 S=400, G=0 W=400	MC=320, LC=280 S=50, G=350 W=400
Constraint set B[c]	N/S	N/S	MC=320, LC=280 S=400, G=0 W=400
Technology 4			
Constraint set A[b]	MC=320, LC=280 S=400, G=0 W=400	MC=320, LC=280 S=50, G=350 W=400	MC=320, LC=280 S=50, G=350 W=400
Constraint set B[c]	N/S	N/S	MC=320, LC=280 S=50, G=350 W=400

[a]Notation:
N/S = no solution
MC = area planted in medium staple cotton
LC = area planted in long-staple cotton
S = area planted in sorghum
G = area planted in groundnuts
W = area planted in wheat

[b]Constraint set A has the following constraints on water availability and private profitability:

$$LC \geq 280$$
$$MC \geq 20$$

$$300 \leq LC + MC \leq 600$$
$$S \geq 50$$
$$0 \leq S + G \leq 1000 - (LC + MC)$$
$$100 \leq W \leq 1000 - (LC + MC)$$
$$P_{LC}, P_{MC}, P_S, P_G, P_W \geq 1.00 \text{ at the 50th percentile where}$$
$$P = \text{private profitability coefficient}$$

[c]Constraint set B used the water availability constraints for set A, but imposed a stricter constraint on private profitability:

$$P_{LC}, P_{MC}, P_S, P_G, P_W \geq 1.20 \text{ at the 50th percentile.}$$

Source: Sigma One Corporation