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POLICY ANALYSIS OF SUDAN'S IRRIGATED SUBSECTOR: THE CASE OF GEZIRA IRRIGATION SCHEME

By

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ABSTRACT

POLICY ANALYSIS OF SUDAN'S IRRIGATED SUBSECTOR: THE CASE OF GEZIRA IRRIGATION SCHEME

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This study analyzes changes in resource use, enterprise mix and farm income on a typical Gezira tenancy, and assesses the impact of government policy on farm productivity. The study has five objectives: 1) describe the Gezira farming system; 2) identify main constraints facing tenants; 3) evaluate the viability of the Gezira Scheme; 4) evaluate alternative policies designed to raise productivity; and 5) draw policy implications from the study's results.

The study was based on both primary and secondary data. Secondary data was obtained from published reports and studies. Primary data was obtained from a survey of 96 Gezira farm households for 1989/90 cropping season. Information collected on farm operations and socioeconomic characteristics of the farm households was used to develop farm enterprise budgets, descriptive statistics and domestic resource cost ratios. A static linear programming model was formulated to maximize total gross margin subject to minimum sorghum consumption requirements of the tenant households. Optimum farm plans were generated using the farm survey data. Sensitivity analysis was used to determine the impact of alternative technologies, policies, and resource levels on cropping pattern, resource use, farm productivity and farm income.

The results showed that: Sudan has a comparative advantage in production on the Gezira Scheme of long-staple cotton, medium-staple cotton, wheat and groundnuts, and a comparative disadvantage in production of sorghum. The optimum base plan includes medium-staple cotton, wheat and sorghum, and excludes long-staple cotton and

groundnuts. Both long-staple cotton and groundnuts face high costs of production and groundnuts lacks an adequate market infrastructure.

Labor, capital and water were binding during the peak production periods. Sensitivity analyses indicate that increases in crop yields and prices, improved supply of irrigation water, and elimination of the mandated cropping pattern will result in higher resource productivity, and higher output and farm income.

Government policy should focus on the design and improvement of crop marketing, input supply and utilization; elimination of the mandated cropping pattern; reduction of production costs; efficient water distribution; provision of credit, research and extension services; and the formulation of monetary, fiscal and trade policies that will spur economic development.

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DEDICATION

To my dear parents Estere Mude and Elisa Lemi

Who laid the foundation for my Education.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Sudan has an area of 2.25 million square kilometers, a population of 25.8 million people growing at the rate of 2.8 percent per annum, and an inflation rate of 56 percent per annum (1991). Sudan is heterogenous in climate, geography, history, peoples and religions. Table 1.1 reveals that there are 84 million hectares of arable land but only 9 million hectares are under production. The high potential remain underutilized because of counterproductive macroeconomic policies, government mismanagement, drought and civil war.

The Sudanese economy is dominated by the services sector which contributes 50 percent to GDP. Agriculture contributes 35 percent to GDP, generates 60 percent of government revenue, 81 percent to export earnings and 75 percent of the economically active population is engaged in agriculture. Livestock contributes about ll percent and forestry about 3 percent. Secondary production contributes about l6 percent: manufacturing 9 percent, construction 5 percent and public utilities 2 percent (World Bank, 1990a).

The performance of the Sudanese economy has been very disappointing; declines in per capita income and output, stagnation in exports, deterioration in infrastructure, health and education, services; and a mounting external debt. The economy can be characterized by l) production below capacity in both agriculture and manufacturing with much variability due to the influence of weather in agriculture; 2) stagnation in real exports due to low productivity and inappropriate trade policies; and 3) an expanding

financial imbalance. Foreign debt, including payment of arrears, and government deficits have both increased sharply. The mounting arrears on foreign debt have reduced Sudan's access to foreign finance; and the monetization of the government deficits have contributed to high and rising domestic inflation. Because of the above mentioned factors; savings and investments have been very low, and productive and supportive infrastructure have been decaying from the lack of maintenance that makes it difficult for the country to maintain production and export sectors.

GNP grew at the rate of 2.1 percent a year. With the population growing at the rate of 2.8 percent a year, the poor performance of the GNP implies an 11 percent reduction in real per capita GNP over a 20-year period. The slow trend growth in GDP reflects a uniformly slow growth in all sectors of the economy. Value added in agriculture

TABLE 1.1 LAND UTILIZATION IN THE SUDAN 1975 AND 1985.

LAND USE	1975	1985
TOTAL AREA	250,540	250,540
Land Area	237,560	237,560
Area under water	12,980	12,980
AGRICULTURAL AREA	84,200	84,200
Cultivated	7,848	9,600
Cropped:	7,008	8,800
-Irrigated	(1,565)	(1,680)
-Rainfed	(5,443)	(7,120)
Fallow	840	800
PASTURE LAND	22,740	20,000
FORESTS	91,500	70,000
OTHER UNCULTIVATED	38,100	63,369
Area in hectares '000' 1 Feddan (Fed) = 0.42 (Ha) = 1.036 Acres		
Source: Brandt et al., 1987.		

manufacturing and services grew at 1.5, 4.5, and 2.3 percent a year, respectively. The overall growth in GDP mirrors the extreme variability in the agriculture sector. Export volumes have varied annually with a growth trend of -1.4 in the 1980's; cotton exports declined at the rate of 0.4 percent a year. Gum arabic exports also fell. Sorghum exports have been erratic with a trend growth rate of 1.5 percent a year. Sudan's total world market share in merchandise exports fell by about 46 percent over the ten year period.

1.2 PROBLEM SETTING

In the last 20 years, Sudan has been experiencing economic crises. The major causes of these crises include: poor economic policies, drought and civil war. External factors also aggravated the impact of the bad domestic policies. Per capita income decreased by an annual rate of 1.9 percent. Balance of payments deficit has been increasing at the rate of 9 percent per annum. The external debt has risen from $3.8 billion in 1978 to $15 billion in 1992.

In the 1970s, Sudan was viewed as the Bread Basket of the middle East. Its vast agricultural potential coupled with the petro dollars from the Gulf states were thought to be an ideal combination to supply the food needs of the Middle East. Development projects were based on the "Breadbasket strategy". However, rapid declines in the second half of the 1970's led to concentration on the rehabilitation of the existing schemes rather than opening new ones. There was a sharp decline in the volume of Sudan's traditional cash crops: long-staple cotton, sesame and groundnuts.

In 1983-1985 Sudan experienced its worst food crisis as a result of drought, bad agriculture policies, civil war and high oil prices. These problems are closely linked to the performance of the irrigated subsector which is oriented towards the production of

cotton for export with the government being an active participant. The irrigated subsector has demonstrated a high productivity potential that can only be realized through the use of good government policies.

Major problems that plague the irrigated subsector since the 1970's include poor maintenance, bad management, high administrative costs, shortage of skilled manpower, price controls, shortage of equipment, late delivery of inputs and lack of proven technology for wheat, groundnuts and sorghum. The irrigated subsector faces the most government intervention, including mandating of enterprise mix and crop rotation, provision of irrigation water, land preparation, fertilizer application, and setting of input and output prices.

This study will examine resource allocation in the Gezira Scheme in order to determine resource use, crop productivity and farm income; and an evaluation of financial profitability for cotton, wheat, groundnuts and sorghum in the Gezira. The key research questions are: 1) do government policies encourage efficient resource allocation; 2) does the present incentive structure stimulate high productivity; and 3) what policy changes can facilitate further development of the irrigated subsector?

1.3 RESEARCH OBJECTIVES

1. To describe the farming system of the Gezira Scheme.
2. To identify the main economic constraints facing the tenants in increasing food production and farm income in the Gezira Scheme.
3. To evaluate alternative policy scenarios which can lead to more efficient resource use in the Gezira Scheme.

4. To evaluate the economic viability and Sudan's comparative advantage of the crops grown in the Gezira.

5. To draw policy implications for raising crop productivity in the Gezira Scheme.

1.4 RELATED STUDIES

Technical aspects of the irrigated subsector have been extensively analyzed but very little research has been done on economic aspects.

Acharya (1979) examined the role of a wide range of policy interventions in determining the overall incentive framework influencing the allocation of resources in the Sudan. He concluded that the incentive framework confers widely divergent rates of effective protection to different agricultural activities and that the overall incentive framework is biased against agriculture in favor of industry and is also biased in favor of import substitution and against exports. Acharya advocated a set of policy reforms in favor of comparative advantage. The study did not pay much attention to the implications of the incentive structure for resource allocation within the irrigated subsector where most of the exports originate.

Faki (1982) built a linear programming model to examine the economics and management of irrigation water in the Gezira Scheme. Faki's model had 85 activities and the main constraints were land, water, labor and machinery. He ran the model at varies canal capacity levels and found: 1) an irrigation water deficit in October and November; 2) high returns to irrigation water; 3) cotton realized the highest benefits, followed by sorghum and groundnuts, while the net benefit for wheat was negative; 4) maximum cropping intensity was only 65 percent as compared to the planned 75 percent; and 5) an

increase in canal capacity increases demand for seasonal labor. Faki suggested a water rate system which would differ by the crop.

Sattar (1982) presented estimates for the 1980/81 cropping season of foreign exchange dependence, international competitiveness, and private profitability for all crops grown in rainfed and irrigated subsectors. This study did not incorporate the effects of variations in world and producer prices, yields, input costs on resource allocation decisions. The study showed that concentrations on investments on the rehabilitation of existing projects was a step in the right direction, and there were relatively high profits on rainfed crops. The study emphasized the need for agricultural research on cultural practices and new production technology.

Youngblood et al. (1982) examined the structure of incentives facing Sudanese rainfed farming. They analyzed the effect of policy changes in tax structures, the exchange rate, agricultural pricing and marketing, and government intervention on productivity in the rainfed subsector and its potential for improving the economy. They concluded that whereas the policy reforms have led to gains in the rainfed subsector, much remains to be done in the area of tax reform, agricultural research, and improvements in the marketing system. They did not estimate the impact of policy changes on the irrigated subsector.

The Youngblood and Leonard (1983) study builds on the cost of production data in Sattar's (1982) study as a basis for sensitivity analysis. They analyzed the sensitivity of several indicators for crops grown in the Gezira 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. The study concluded that under current cost levels and yields, all crops are unprofitable

to the producers most of the time. The production and export of cotton would generate the most foreign exchange, and wheat would generate the least. Irrigated groundnuts has the greatest comparative advantage and wheat has the greatest comparative disadvantage most of the time.

Chhibber and Hrabovsky (1983) examined several aspects of agricultural prices and investment policy in the Sudan using a linear programming framework. They concluded that: 1) the price elasticities of supply for important agricultural products in the Sudan are very low ranging from 0-0.5 except for sorghum; 2) rates of return for major purchased agricultural inputs were well above their market value; and 3) plans for the expansion of irrigated land were adequate. They made no attempt to include a subcomponent into the linear programming model to deal with the impact of policy changes on the irrigated subsector.

D'Silva and McKaig (1985) focused on the effects of the Blue Nile flow during the 1984 drought by analyzing alternative crop production scenarios and their implications for water use and food crop production in the Gezira scheme. The analysis shows that reducing the area under cotton by 200,000 acres could lead to increases in cereal output of between 240,000 and 390,000 tons depending upon the assumptions. Reallocating areas would also lead to savings in water on both an annual and seasonal basis. Reduction in cotton production would have little effect as Sudan had not been able to market all its cotton. They concluded that the increase in grain production would lower domestic prices, increase consumer's purchasing power, while at the same time reducing food aid needs.

D'Silva (1986) examined policy issues in the irrigated subsector and its role on Sudan's agricultural economy. He contended that the present system of production leads

to an inefficient utilization of scarce resources like fertilizer. D'Silva proposed an evaluation of changes in cropping patterns, institutions and production technologies to help generate foreign exchange, government revenue and farm income.

Brandt et al. (1987) examined the prospects of the Gezira scheme's contribution towards strengthening the overall national grain supplies through import substitution of wheat and/or production for local consumption and export of surplus sorghum. They concluded that whereas it is feasible to intensify wheat production with seed and fertilizer application; an increase of sorghum production beyond subsistence is not economical.

Jansen (1986) provided a framework for the analyses of crop profitability for major crops in the Sudan. Her analysis of Sudan's comparative advantage in the production of the different crops can be of a tremendous use to policy makers in their establishment of support prices and the formulation of agriculture policy for all crops grown. The agricultural policy making considerations can determine the crops the Government should encourage. For instance, if the government wishes to encourage groundnuts production, it can do so by the alteration of subsidy, an increase in price or subsidization of the costs of production.

Plusquellec (1990) focused on the extent to which the design of the Gezira irrigation system fosters effective water management and provides equitable, reliable, timely water distribution to farms. He analyzed water efficiency, effectiveness of maintenance and cost recovery; and concluded that water distribution from the Gezira system to the field is efficient, timely and reliable as long as the canal system is adequately maintained.

1.5 AN OVERVIEW OF THE RESEARCH APPROACH

The study uses both primary and secondary data. The secondary data on the macroeconomy, agriculture sector and the irrigated subsector is used to assess the possible effects of government intervention on agricultural production and trade. Studies on Sudan's comparative advantage in the four crops grown in the Gezira will be reviewed thoroughly on the basis of the domestic resource cost ratios calculated by Youngblood (1983) and Jansen (1989). Domestic resource cost ratios will be calculated for the 1989/90 survey season.

Primary data was collected for the 1989/90 cropping season. The information collected on the socioeconomic conditions of the tenants and their farming environment will be used in the development of a linear programming model for the "representative farm" (Model farm) in the Gezira. The cropping activities in the model include medium and long-staple cotton, wheat, groundnuts and local and hybrid sorghum, and the resources are land, labor, irrigation water and operating capital.

The Gezira model attempts to evaluate whether the production resources are allocated optimally and the prospect of policy reforms that would create a favorable incentive structure so as to stimulate high productivity and foster further development of the Gezira Scheme and the irrigated subsector in general.

1.6 ORGANIZATION OF THE STUDY

Chapter II deals with the methodological approaches to the research, it outlines the conceptual framework, research questions, choice of the research area, sampling procedures, data collection and data utilization.

Chapter III outlines Sudan's national policy failures that have had deleterious effects on the important irrigated subsector on which Sudan's economy depends. It attempts to trace the workings of the agricultural policy instruments and their impact on the agriculture sector and food system. It ends with an examination of the allocation of the Nile water resource under the 1929 and 1959 Nile waters agreements between Sudan and Egypt.

Chapter IV outlines the socioeconomic, physical and policy environment of the Gezira Scheme. With a special attention being paid to climate, land tenure, cropping pattern, production system, resource use, agricultural research and crop marketing services.

Chapter V describes the household characteristics and constraints facing the survey tenants. It places a lot of emphasis on the utilization of land, labor, water, capital and production technology, and ends with a discussion of crop enterprise budgets for long-staple cotton, medium-staple cotton, wheat, groundnuts, local sorghum and hybrid sorghum.

Chapter VI provides a framework for the analysis of crop profitability, reviews studies on comparative advantage in the production of crops in the Gezira, and presents domestic resource cost ratios for medium-staple cotton, long-staple cotton, wheat, groundnuts and sorghum for the 1989/90 survey season.

Chapter VII presents the structure of the linear programming model for the Gezira that employs land, labor, irrigation water and capital resources for the production of medium-staple cotton, long-staple cotton, wheat, groundnuts and sorghum. The discussion includes mathematical representation, model assumptions and the model components: objective function, activities, restrictions and the righthand side.

Chapter VIII discusses the results of the Gezira model applicable to resource use, cropping patterns, farm profitability and farm income. It includes an evaluation of information on the objective function, enterprise mix, shadow prices, cost of forcing excluded activities into the model and the stability limits.

Chapter IX summarizes the research findings, draws conclusions and policy implications, indicates the limitations of the study; and gives suggestions for future research.

CHAPTER II

RESEARCH METHODOLOGY

2.1 CONCEPTUAL FRAMEWORK

The agricultural sector is particularly sensitive to macroeconomic policies, and many food and agricultural policies are inextricably linked with macro policies since the Sudanese economy is predominantly agricultural. The important policy issues comprise: the tax system, exchange rate policies, production policies, input and output policies and trade policies.

The single most important agriculture policy issue is: how to resolve the demands of both rural producers and urban consumers. A healthy agricultural sector should be able to provide a basic supply of food at prices within reach of urban consumers while at the same time generating adequate levels of income, employment and foreign exchange. But Sudan's weak agriculture sector does not produce sufficient quantities of agricultural products to support the population. Shortfalls are then met through imports while prices are controlled through subsidies. Food rationing and the attendant hardships are the norm. The policies that favor consumers tend to reduce the incentives to producers for increased growth in agricultural production. Decreased growth in food production exacerbates the food shortage problem thereby causing an increase in imports of food and fiber. Depending upon the international price levels for the imported goods, subsidies may also be needed to make the food affordable. Balance of payments and external debt problems could become more severe. The net effects of monetary, fiscal, trade and agricultural policies could produce net positive/negative protection rates.

Subsidies will lower farm incomes as well as reducing incentives to adopt improved techniques of production. Macroeconomic distortions in the economy can impose an implicit tax on agriculture leading to the distortion of resource allocation and loss in economic welfare.

The theoretical approach in this study is to employ: l) domestic resource cost (DRC) ratios to review and evaluate the comparative advantage of crop production in the Gezira, and 2) linear programming (LP) model of the Gezira Scheme to obtain optimum farm plans under the existing resources constraints. This information is central to developing production and trade strategies for the irrigated subsector in general and the Gezira in particular.

2.1.1 DOMESTIC RESOURCE COST RATIOS

The domestic resource cost ratio is the ratio of the factor costs to value added in economic prices. Because this ratio includes domestic factor costs, it measures not only policy effects on tradable inputs and outputs, but the opportunity costs of using domestic factors in production and can therefore serve as a measure of comparative advantage. The costs of domestic factors are essential in determining economic profitability and the domestic resource cost mesurement allows economic profitability to be compared across commodities. An economically profitable commodity will produce more than enough value added to remunerate labor and capital and reimburse capital owners (Jansen, 1989).

Bruno (l972) brought the concept of domestic resource cost ratios into common use for the purpose of measuring comparative advantage. A product has a comparative advantage if, at equilibrium domestic prices, the domestic resource cost ratio is equal to or lower than the prevailing exchange rate. For a given country one product would be

more competitive in international markets than another product because the first requires fewer domestic resources per unit of foreign exchange earned or saved. Domestic resource cost ratios apply to goods that are tradable or potentially tradable. The domestic cost items have to be distinguished from the imported ones. Net foreign exchange earnings or savings are defined by netting out the cost of imported inputs from the value of the output. The net foreign exchange cost per unit of output is then divided into the sum of the domestic costs of production to give an expression for the cost in "domestic resources" of earnings or savings of foreign exchange. If the domestic resource cost ratio is less than one, it means the country has a comparative advantage in the production of a particular commodity because it can exchange domestic resources for foreign exchange at a rate below that at which the economy as a whole converts the domestic resources into foreign exchange. If the domestic resource cost ratio is greater than one, it implies that the country has comparative disadvantage in the production of the particular commodity for export or as an import substitute.

The domestic resource cost ratio has a useful interpretation. It tells how much of the economy's domestic resources are being spent to earn or save a dollar of foreign exchange. If this number is greater than the exchange rate for a given product then it is evident that the product should not be promoted for export or import substitution. The policy usefulness of the domestic resource cost arises in practice because in many occasions when there is a violation of the above rule, pointing it out in an objective, quantative terms will highlight the need for policy change. When the domestic resource cost indicates comparative advantage in more than one product, other factors should enter the deliberations about which product to promote. These important factors include profit margins and distributional effects of policy (Norton, 1988).

2.1.2 LINEAR PROGRAMMING MODEL

Linear programming deals with the problem of allocating limited resources among competing activities in the most optimal way possible. One must select the level of alternative activities that can compete for the scarce resources. Linear programming has been applied to answer questions in agriculture policy in the less developed countries for the last twenty years. Linear programming will be used to find the optimal combination of farm activities to maximize farm income for given prices, input-output coefficients and resource constraints. Less binding constraints that reflect incentive effects can then be introduced into the model to find the plan that indicates optimal changes in the cropping patterns, resource productivity and farm income.

Producers tend to maximize profits within some given constraints. The farmer's objective function could be to maximize profits subject to obtaining a plentiful supply of food for the family for the entire year. The mathematical formulation of linear programming has three main features: l) an objective function to be maximized or minimized; 2) resource constraints; and 3) the activity set. The expressions of the equations are given below in matrix notations.

The objective function is in the form:

$$\text{Max.} \quad Z - C'X$$

where Z represents the returns to be maximized, and X are the decision variables. C' measures the marginal contribution of each decision variable.

The linear restrictions are of the form are:

$$aX \leq b$$

where: a represent how much of a resource is required for each unit of activity, X are the decision variables and b represent the total amount of resource available.

$$X \geq 0$$

specifies that only non-negative levels of each decision variable will be subject for examination.

Linear programming provides the means to find the levels of decision variables that would maximize the objective function subject to the fixed conditions on the farm and non-negativity requirements.

2.2 RESEARCH QUESTIONS

The lack of adequate research and an appropriate technology suitable to the local environment, as well as inappropriate economic development policies, have impeded increased agriculture production and the provision of adequate food supplies. Sudan attempted to mobilize revenue for economic development through high taxes on agricultural output and income, especially on export crops whose prices are easily subjected to official controls. The misguided belief was that an increased government role in production and development would improve the economy. In the Gezira Scheme, excessive government involvement in production and input procurement decisions hamper the ability of the tenants to produce efficiently. The government preference for controls prevents the private sector to compete with or complement the inefficient state monopolies.

The excessive state controls have depressed the prices of domestic agriculture commodities relative to manufactures, discouraged increased agriculture production and reduced farmers incentives to produce. The stagnant agriculture has failed to generate foreign exchange, cheap food supplies and aggregate savings that can be used to spur the growth of the domestic markets and the economy.

The specific issues this study seeks to address include the following:-

1. The excessive government controls of cropping pattern, resource use, production and marketing decisions that hamper the ability of the Gezira tenants to produce efficiently.
2. Lack of technology suitable to the Gezira environment has impeded increases in agricultural productivity.
3. Lack of support services has contributed to the decline in agricultural production at the Gezira Scheme.

2.3 CHOICE OF THE STUDY AREA

The following factors were instrumental in selecting the Gezira irrigation Scheme as a study area:

1. It is the backbone of the Sudanese economy.
2. It is the oldest and largest irrigation Scheme in the Sudan.
3. It is the basis of the design of the other irrigation Schemes.
4. Many of the irrigation problems facing the Gezira Scheme are similar to those of the smaller Schemes.

2.4 SAMPLING TECHNIQUES

The main Gezira tenants are organized into 7 groups, 51 blocks, 48,350 tenancies and an average farm size of 20 feddans each. A sample of 96 tenants were selected at a random. Table 2.3 presents the sample selection procedures where four blocks were randomly selected from the seven groups. Wad Numan from the South group, Tayba from the Elmesselemia group, Turis from the Wad Shair group and Loata from the

TABLE 2.1 SAMPLE SELECTION IN THE MAIN GEZIRA.

	GROUP\TENANT	NUMBER BLOCKS	NUMBER TENANTS	SELECTED BLOCKS	NUMBER TENANTS	SAMPLE SIZE
1	South	7	6,577	Wad Numan	879	24
2	Center	8	5,640			
3	Elmesselemia	9	5,121	Tayba	1,011	24
4	Wad Habouba	6	7,009			
5	Wad Shair	6	6,803	Turis	1,233	24
6	North	7	7,902	Loata	1,661	24
7	Northwest	8	9,298			
	TOTAL	51	48,350	4	4,784	96

Source: Sudan Gezira Board.

North group. The total number of tenants in the four administrative blocks is 4,772. Two to three minor canals were selected at random from each block and a sample of 24 tenants was selected systematically taking into consideration the position of the tenancy along the minor canal. The sample of 96 tenants was deemed adequate for the planned study given the financial and logistical limitations.

2.5 DATA COLLECTION

Data were collected from both primary and secondary sources. Primary data were collected by interviewing the 96 tenants in the four blocks. The purpose was to obtain information on the socioeconomic characteristics, and farm and non-farm activities. The information sought was on the socioeconomy and kinds of farm operations: number of household members, age, level of education, farm work, frequency of irrigation, timing of different cultural operations, costs of production, available labor,

available capital, subsistence requirements, yield history, farming strategies, farm profitability, land, labor, capital and water constraints and government policy on the farm.

The field data collection was from June 1989 to May 1990. Eleven experienced Socioeconomic Unit, Sudan Gezira Board enumerators who reside 2-3 persons in each of the four selected blocks filled in the questionnaire. They obtained the information on monthly basis throughout the whole 1989/90 cropping season. The main difficulty faced was translation of questions from English to Arabic and vice versa. Shortages of vehicle spare parts and gasoline as well as rains in August and September prevented the researcher from making frequent visits to the research sites.

2.6 DATA UTILIZATION

The cropping activities include medium-staple cotton, long-staple cotton, wheat, groundnuts and sorghum; and resources and their constraints include land, labor, capital and irrigation water.

The information collected from the field together with the secondary information from Agricultural Research Corporation, Sudan Gezira Board, Ministry of Agriculture and Ministry of Irrigation was used to develop crop labor requirements per month, average labor and crop prices per season, supply and demand for irrigation water, and enterprise budgets.

The data was used in the development of a linear programming model to obtain optimal farm plans in the Gezira Scheme under the existing resource constraints. Postoptimality analyzes were conducted where less binding constraints that reflect incentive effects were then introduced into the model to determine their impact on

cropping patterns and resource profitability. The data was also used to calculate domestic resource cost ratios for the crops grown in the Gezira in the 1989/90 survey season.

CHAPTER III

NATIONAL POLICIES

3.1 FRAMEWORK FOR POLICY ANALYSIS

The framework for policy analysis regards the goal of government as that of maximizing social welfare, and it chooses target variables which it sets out to achieve in the pursuit of this overall goal. Thus it selects the best policy instruments to achieve the goals given constraints, uncontrollable factors and side effects that could be detrimental. The major components are goals, constraints, instruments and side effects (Ellis, 1992).

The two major objectives are efficiency and equity. Efficiency deals with the attainment of economic optimum levels of commodities and services from a set of given resources. Equity deals with the distribution of the total output between individuals and social groups within the society. Policy instruments designed to increase output will have varying effects on income distribution and those designed with equity considerations in mind will have direct or indirect effects on output. Efficiency is objective and equity subjective, and the two may conflict.

Important constraints such as shortage of foreign exchange, budget deficit or low world export prices are relative to existing technology that can improve resource productivity or make new resources available. Policies that seek to accelerate technological change directly or indirectly are necessary.

The government uses policy instruments to implement its policies. A single policy instrument could accomplish more that one objective or a set of policy instruments on a set of policy goals. These policy instruments will have impact on the small farm systems.

Pareto optimum, Pareto criterion and compensation criterion are the key concepts in welfare economics. Pareto optimum is defined for society as a whole in which it is not possible to make one person better off without making another person worse off. A Pareto criterion states that a policy change is desirable if no one is made worse off by the change, and a compensation criterion states that a policy change may be worth considering provides that the gainers could potentially compensate the losers and still be better off than they were before the change.

The partial equilibrium analysis concepts of producer surplus and consumer surplus enable the compensation criterion to be made operational. The change in the economic variables and the knowledge of the elasticities of supply and demand in markets affected by the policy changes are important for the measurements of the effects of the policy. The gains and losses from policy are measured in financial and, economic prices that represents the opportunity cost to society of farm inputs and outputs. Domestic resource cost ratios can be used to measure the divergence between the financial prices induced by policy intervention, and the economic prices represented by world prices for tradable inputs and outputs.

3.2 MACROECONOMIC POLICIES

Sudan is plagued by macroeconomic policy failures apparent in high inflation, overvalued currency, high unemployment, excessive bureaucracy, government budget deficits, trade deficits, mounting international debt, and economic and related political instability.

Political instability has had an important impact on the economy. Political factionalism has plagued the country for the most part since independence in 1956.

Factionalism among the political parties paved the way for four military coups in 1958, 1969, 1985 and 1989. The civil war that erupted in 1983 not only cost much in human lives and those displaced; it has also drained economic resources and manpower away from economic development. High expenditures to finance the war contributed a great deal to a large monetary expansion and an acceleration of inflation. Sudan has also been affected by major exogenous shocks that include drought in 1983/85 and 1990, as well as floods and locusts in 1988. These shocks have had a severe adverse impacts on agricultural output, and consequently on GNP. Table 3.1 shows the percentage share of GNP by sector.

TABLE 3.1 PERCENTAGE SHARE OF GDP BY SECTOR, 1984/5-1988/90.

SOURCE \ PERIOD	1984/85	1985/86	1986/87	1987/88	1988/89
PRIMARY PROD.	29.3	35.6	34.8	30.8	36.1
Agriculture	29.3	35.6	34.7	30.7	36.0
Mining	0.0	0.1	0.1	0.1	0.1
SECOND PROD.	16.3	15.2	15.2	15.8	14.5
Manufacturing	8.8	8.6	8.7	8.8	8.2
Construction	5.8	4.8	4.7	5.1	4.6
Public Utilities	1.9	1.8	1.8	1.9	1.8
SERVICES	54.4	49.2	50.0	53.4	49.4
Trans & Storage	8.6	9.5	10.0	9.9	9.4
Commerce & Hotel	22.7	13.0	13.9	16.2	13.9
Finance & Estate	13.2	12.1	12.7	13.4	12.7
Govt Services	8.2	12.8	11.6	11.9	11.6
Personal service	1.7	1.8	1.8	1.9	1.8
GDP-FACTOR COST	100.0	100.0	100.0	100.0	100.0

Source: Ministry of Finance, 1989.

Government performance in revenue collection has been very poor because of: 1) a narrow tax base structure -- the introduction of islamic tax (zakat) in 1985 for conventional income taxes reduced revenue as well as eliminating excise duties on a number of products; 2) price controls and exchange rate overvaluation; 3) poor performance of the parastatal corporations; and 4) disruptive tax policies.

Twenty eight percent of the annual credit flows from the banking system goes to the public corporations. The rapid growth in money supply results in high inflation rates, negative real interest rates and high commodity prices. Private savings average about 7 percent of GDP but government savings registered negative rates for all the 1980's. Remittances from the 350,000 Sudanese nationals working in the Gulf countries have not helped because: 1) government exchange rates, trade, investment and financial policies have not been conducive to attracting remittances; and 2) the large foreign interest obligations on government debt reduces national savings on a commitment bases. Investment has fallen from 22.8 percent of GDP in 1982 to a mere 9.1 percent in 1989. New investment has been discouraged by cumbersome investment regulation processes and lack of long-term finance from the domestic financial systems.

Table 3.2 presents Sudan's balance of payments. Growth in imports have been rapid, financed by foreign aid, Arab fund, remittances from Sudanese nationals working abroad; and foreign commercial borrowing in the late 1970's. Exports on the other hand have declined due to; 1) over-regulation of irrigated agriculture; 2) inefficiencies in parastatal monopolies in charge of export marketing; 3) excessive licensing requirements and setting of minimum prices for exporters 4) unpredictable bans on exportation of particular products eg. sorghum; and 5) inappropriate exchange rate policy. The overvaluation of the exchange rate discriminates major export products (cotton, gum

TABLE 3.2 BALANCE OF PAYMENTS, 1984/85-1988/89. 1/					
SOURCE \ PERIOD	1984/5	1985/6	1986/7	1987/8	1988/9
Exports & NFS	800	702	702	661	750
Imports & NFS	1,395	1,338	1,132	1,456	1,560
Deficit (-)	-594	-636	-431	-795	-810
Net factor income	-478	-556	-522	-649	-706
Curr Private Trans	430	350	250	445	297
CURR ACCT BALANCE	-642	-842	-703	-999	-1,216
Official Transfers	288	412	280	369	271
Bal curr Accounts	-354	-430	-423	-630	-945
Net M&LT Loans	-322	-477	-232	-230	-329
Errors & Omissions	-189	-145	-191	-193	-36
OVERALL BALANCE	-865	-1,052	-846	-1,053	-1,309
Net reserve changes	100	-13	220	280	177
Capital flows	257	270	110	13	00
Net arrears changes	508	795	516	760	1,132
1/ Millions of US Dollars.					
Source: World bank, 1990a.					

arabic) while favoring cheaper imports into the country. This shifts Sudan towards negative balance of trade. The ratio of imports of goods and non factor services to GDP in real terms increased from 18 percent in 1976 to 30 percent in 1983 while that of exports decreased from 16 percent to 13 percent. The real ratio of imports to GDP fell from 30 percent in 1984 to 19 percent in 1989. External terms of trade increased at a trend growth rate of 0.6 percent a year from 1976 to 1982, and 2.6 percent a year from 1982 to 1989.

The external debt has risen from $3.8 in 1978 to $ 15 billion in 1992. Arrears constitute about 60 percent of the outstanding debt, rising from $1.5 billion in 1985 to $8.4

billion in 1990. The external debt now stands at over 1,500 percent of exports of goods and services, and about 150 percent of GDP. It represents $500 of debt to every Sudanese, compared to the Sub-Saharan Africa per capita external debt average of about $296. Sudan's debt service for 1989 has averaged about 115 percent of the value of exports of goods and services (World Bank, 1990a)

3.3 AGRICULTURAL POLICIES

Policy interventions attempt to alter the allocative position of farmers by changing the relative prices of inputs and outputs; and the technical production frontier by raising the productivity of existing resources. Price, marketing, input, credit, mechanization, land tenure, research and irrigation are the most important agricultural policy instruments.

Price policy: Farm prices allocate resources between outputs, distribute income and determine the rates of return to agriculture. Governments do influence the three roles that farm prices play. Price stabilization programs have been confined to a few strategic crops, around a long run trend and on flexible import policies so as to supplement buffer stocks.

Marketing policy: Governments have the tendency to intervene in agricultural marketing channels. Monopoly marketing parastatals tend to fail because of high overhead costs, poor capacity utilization, poor performance, and residual producer price determination. The main function of the state is to provide price monitoring and market information services of a kind that the private sector cannot supply.

Input policy: The state intervention has been in the form of price, subsidies and delivery systems to replace the private sector in farm inputs. Subsidy on fertilizers can

increase its utilization. The quantity and the timeliness of farm input delivery can be critical. Regulation of agricultural chemicals that can be hazardous and the transmission of information on the use of new inputs in order to avoid mistakes and waste scarce resources.

Credit policy:: The traditional approach is to supply subsidized credit to farmers at low interest rates. The main emphasis needs to be on the creation of viable private and public credit institutions. These credit institutions should charge real interest rates that reflect the opportunity cost of funds, thus encouraging savings and lending.

Mechanization policy: Prices should fully reflect social opportunity cost. The pace of mechanization should reflect the true underlying changes in resource scarcities in agriculture, not the artificial lowering of machinery prices resulting in an inefficient substitution of machines for labor. The role of the state is to ensure that machinery prices are reasonable, encourage the development of a much wider range of mechanical technologies at the labor using end of the range of technical alternatives.

Land tenure: Economists do recognize the rationale for both efficiency and equity gains from equal size distribution of farms but may oppose the property rights involved. Experiences with cooperatives, communal and state farms have not been encouraging. The institution of freehold in place of previous village or community land allocation is a continuing process. Successful land reform creates a freehold or leasehold small-farm structure as a results of the reform.

Research policy: This is about the generation and diffusion of new technology to farmers. Research policy is a public good to be funded and conducted by the state. Higher returns to research call for strong emphasis being placed on participation and

interaction with farmers. It concerns with technical rather than allocative efficiency at the farm level.

Irrigation policy: Irrigation policy is about the role of the state in promoting or providing irrigation technology, management of large-scale irrigation schemes and ways of charging the cost of water as an input to farmers. Canal irrigation is a public good, its operation involves certain kinds of market failure. We need to improve the recurrent operations and maintenance of irrigation canal. Income of water management agencies should depend on service fees paid by farmers with mechanisms for increasing the interdependence and trust between both parties.

Sudan's agricultural policy goals include: the generation of employment and income, government revenue, and the achievement of food security, political stability and economic development. The poor performance of the agriculture sector could be an indication that these policies may not be well articulated.

Table 3.3 presents the operations of agricultural policy instruments on crop production, consumption and marketing. The production system of major cereals can be characterized by low trend growth rates and sharp annual fluctuations. Sorghum is usually in surplus, wheat in deficit and millet in balance. Sudan has never been self-sufficient in cereals since 1985. Production variability is high depending on weather, labor availability, transport and storage infrastructure. Food insecurity is felt through fluctuations in food availability, food prices and agricultural employment.

The consumption pattern is such that the urban high income group show preference for wheat and sugar in their diets. In the rural areas, the farmers derive their income primarily from farming; and landless laborers and pastoralists depend on wages. The demand for food crops is differentiated by income groups as well as by the

TABLE 3.3 OPERATIONS OF THE AGRICULTURE POLICY AND FOOD SYSTEM

AGRIC POLICY INSTRUMENTS	COTTON	WHEAT	PEANUTS	SORGHUM
PRODUCTION				
Credit Subsidy	X	X	X	
Exchange rate Subsidy	X	X	X	X
Fixed Price	X	X		
Floor Price			X	X
CONSUMPTION				
Consumer Subsidy		X		X
Ration System		X		
MARKETING				
Government Monopoly	X	X	X	
Strategic Reserve				X
Buffer Stock				X
Trade Controls	X	X	X	X
PRODUCTION - FOOD SYSTEM				
Traditional Farmers			X	X
Mechanized Farmers				X
Irrigated Farmers	X	X	X	X
CONSUMPTION - FOOD SYSTEM				
Urban High Income		X		X
Urban Middle Income		X		X
Urban Low Income			X	X
Rural High Income		X	X	X
Rural Low Income			X	X
Rural Landless			X	X
Rural Pastoralists		X	X	X
MARKETING - FOOD SYSTEM				
Segmented Markets	X		X	X
Formal Markets	X	X	X	X
Informal Markets			X	

Source: World Bank, 1990b.

type of commodities they consume. Wheat is consumed by all classes of urban consumers, while sorghum and millet are mainly consumed by rural households. The bulk of peasant consumption is met from their own production; while urban consumption is met through surpluses from large farms of the mechanized subsector. Most of the surplus is transported and marketed by private sector merchants. Trade flows are from the surplus areas to the food deficit urban centers but this movement is constrained by high transport costs such that many households lack access to food when they need it. The Sudanese grain market is divided into two sectors; an open market and a government run concessional food supply system. However, most of the wheat under the government distribution system goes to the urban population. Approximately 75 percent of the rural population have no access to the government subsidized food. Thus they are not served by the system.

Two policy issues are excessive government control and an inappropriate exchange rate. Sudan maintains a dual exchange rates; an official exchange rate of LS 4.5/$ and a commercial exchange rate of LS 12/$. These rates are used to value different commodities eg. agricultural inputs are valued at the official rate and cotton exports at the commercial rate. This affects decision making on imports, and provides a disincentive to producers and exporters. The government extracts surplus through low crop prices, marketing monopolies, export taxes and duties.

Excessive government involvement in production and input procurement hampers the ability of the tenants to function efficiently. They should be free to combine the resources at their disposal to produce the goods and services for which local and external markets exist. Improvements in the entrepreneurial and management ability of the tenants, adjustment in the structure of incentives plus improvements in extension,

marketing and credit facilities can lead to an expansion of personal enterprises leading to an increase in productivity. The government preference for control means that the private sector cannot compete with the overstretched inefficient monopolies. There is need to replace the controls with a minimum core of regulations on production and exports; and an exchange rate policy that truly reflect the scarcity of foreign exchange in the economy and actual production costs on exports.

High producer prices lead to increases in domestic production, consumer prices, reduces consumption and increases imports. Consumer prices and government revenue will increase.

3.4 AGRICULTURAL SECTOR

The Agriculture sector consists of three subsectors (traditional rainfed, mechanized rainfed, and irrigated) each of which produce both food and export crops.

3.4.1 The **traditional** rainfed subsector of 9.8 million feddans produces sorghum, millet, sesame and groundnuts mainly for subsistence and gum Arabic for export. Cattle, sheep, goats and camels are raised on the vast pastures of this subsector. The bulk of the small farmers are found in the traditional subsector. The smallholders lack access to inputs, credit, markets, proven technology and transport. The traditional subsector uses no modern inputs such as fertilizers, insecticides, herbicides and machinery; and production is oriented towards meeting subsistence needs.

3.4.2 The **mechanized** rainfed subsector of 9 million feddans and 1,000-1,500 feddan individual holdings is operated by the private sector with the government providing inputs and credit. Sorghum and sesame are the major crops grown for both domestic consumption and export. Sorghum contributes 4 percent and sesame 7 percent to export

TABLE 3.4 TOTAL CROP AREA, OUTPUT AND AVERAGE YIELDS.

CROP\PERIOD	1984/85	1985/86	1986/87	1987/88	1988/89
COTTON					
Area	876	807	851	772	792
Output	4,016	2,881	3,931	3151	3494
Yield	4.6	3.5	4.6	4.1	4.4
WHEAT					
Area	115	397	282	343	393
Output	79	186	157	181	247
Yield	687	469	557	528	628
GROUNDNUTS					
Area	1,758	951	1,290	1,629	1,625
Output	386	274	364	432	587
Yield	220	288	282	265	361
SORGHUM					
Area	8,159	13,155	11,805	8,069	13,279
Output	1,097	3,595	3,277	1,363	4,421
Yield	134	274	289	169	311
MILLET					
Area	1,853	2,474	2,233	2,285	2,795
Output	133	132	216	233	195
Yield	72	53	97	102	70
GUM ARABIC					
Output	16	18	25	26	35

Area: '000' Feddan; Output: '000' Mt; Yield: Kg per Feddan

Cotton: Output '000'Kantars; Yield: Kantars per Feddan.

Source: Ministry of Agriculture, 1990.

earnings. The farmers face yield variability, input scarcity, low level of cultural practices, and lack of improved technology. Shifting cultivation and cultivation of fallow land not only degrade the soil but also encroach on land for traditional farming and livestock raising; monocropping of sorghum also worsens the situation. Pastoralists and small farmers are being pushed to the marginal lands. Pastoralists could graze their livestock on crop residues and the small farmers provide the seasonal labor but the marginalization of the pastoralists outweighs the benefits.

3.4.3 **Irrigated** subsector covers 4.4 million feddans comprising of the large scale irrigation schemes and small scale pump schemes on the Blue and White Niles. Cotton, wheat, groundnuts and sorghum are the major crops grown. These schemes are owned by public corporations. Tenants experience some limited access to inputs and credit, poor management and incentive structure, high transport costs and government over-regulation. Table 3.5 shows the area, output and yield of the crops grown in the irrigated subsector.

The area in the irrigated subsector is under flood, pump and gravity irrigation from the Nile waters. When Sudan became independent in 1956 approximately two million feddans were under gravity irrigation in the Gezira scheme and the remainder was on the flood and pump irrigation of the Nile waters.

The government doubled the area under irrigated agriculture after independence. Table 3.6 shows that the period between 1978-1986 witnessed the establishment of seven irrigation schemes:- Rahad, Abu Naam, El Suki, Hagar Asalaya, Kenana and pump schemes along the Blue and White Niles. Fortunately, the location of these schemes to the south of Sennar dam where the precipitation is more than 400 mm helps reduce the strain on the Nile waters. The schemes under gravity irrigation are the most important

TABLE 3.5 TOTAL AREA, OUTPUT AND YIELD OF IRRIGATED CROPS.					
CROP \ PERIOD	1984/85	1985/86	1986/87	1987/88	1988/89
COTTON					
Area	747	796	729	725	722
Output	2,790	3,828	3,130	3,387	3,217
Yield	3.5	4.6	4.1	4.4	4.3
WHEAT					
Area	397	282	343	393	500
Output	186	157	181	247	320
Yield	469	557	528	628	640
GROUNDNUTS					
Area	146	234	251	217	156
Output	94	171	198	189	137
Yield	644	731	789	871	878
SORGHUM					
Area	1,123	822	711	846	791
Output	658	454	352	468	441
Yield	586	552	485	553	558
Area: '000' Feddan; Output: '000' Mt; Yield: Kg per Feddan					
Cotton: Output '000'Kantars; Yield: Kantars per Feddan.					
Source: Ministry of Agriculture, 1990.					

and are state owned. They include Gezira, Rahad and New Halfa, which together make up for 60 percent of the total irrigated area in the Sudan. However, the 2.1 million feddan Gezira scheme irrigated by the Sennar dam on the Blue Nile is the oldest and most dominant. Ninety eight percent of Sudan's cotton, 100 percent of the wheat, 55 percent of the groundnuts and 26 percent of the sorghum is produced in the irrigated

TABLE 3.6 MAJOR IRRIGATION SCHEMES IN THE SUDAN.

SCHEMES	TENANTS	AREA	CROPS	CROP %	WATER	SOURCE
BLUE NILE						
Gezira	48,350	1135400	C-W-S/G-F	75	4,000	G
Gezira*	53,900	946,300	C-W-S/G-F	75	3,600	G
Rahad	12,000	300,000	C-S-G	100	1,139	P/G
Pump B		245,418	C-S/G-F	67	876	P
Pump N		103,729	C-S-G-F	67	---	
Suki		86,920	C-S/G-F	67	330	P
Private		63,500	C-S/G-F	---	165	P
Guneid	2,000	45,400	C-W-S/G	83	180	P
Guneids	2,320	38,700	Sugar/G	67	230	P
Sennars		32,500	Sugar	Perm	388	P
Abunaam		30,000	Kenaf	100	100	P
Seleit		20,000	Fodder		---	P
Sennar		16,661	C,Sugar		---	
Sub Tot		3064528			11,008	
WHITE NILE						
Pump		530,000	C-W-S/G	75	900	P
Kenana		81,000	Sugar	Perm	968	P
Asalaya		35,000	Sugar	Perm	363	P
Sub Tot		646,000			2,231	
ATBARA						
Girba	22,000	350,000	C-W-S/G	100	1180	G
MAIN NILE						
Pump		351000	W,S,D,CR		1200	P
Total		4411528			15619	

Key: Crops: C=Cotton W=Wheat G=Groundnuts S=Sorghum F=Fallow

Water Sources: P=Pump G=Gravity P/G=Pump/Gravity *=Managil Extention

Source: Ministry of Irrigation, 1990.

subsector. The irrigated subsector contributes 9.9 percent to GDP. The pattern of production relations at the Gezira scheme serves as a model for most of the gravity irrigated schemes where the government provides irrigation water, the parastatal Sudan Gezira Board provides inputs, and the tenants provide labor.

3.5 THE NILE WATERS

The Water utilization is governed by the 1929 and 1959 Nile waters agreements between Sudan and Egypt. The yield of the river Nile as measured at Aswan is 84 billion cubic meters of water. The actual mean flow is 84 billion cubic meters but evaporation accounts for losses of 10 billion cubic meters.

Table 2.8 shows the water shares under the 1929 and 1959 Nile waters agreements that govern the water allocations between Egypt and Sudan. Under the 1929 Nile waters agreement, Sudan was allocated only 4 billion cubic meters and Egypt 48 billion cubic meters. Sudan was to irrigate the Gezira during the winter months of July to December. The 1959 Nile waters agreement raised Sudan's share to 18.5 billion cubic meters. A Permanent Joint Technical Commission (PJJC) was established to plan for Nile basin development, data collection and supervision of construction projects. Sudan's current water usage is 15.6 billion cubic meters per annum of which the share of the Gezira Scheme is 7.6 billion cubic meters of water. An expansion of irrigated agriculture to tap into the remaining 3 billion cubic meters can only come about with high level of management. Competition for water could become a very serious bottleneck in the near future.

Ahmed et al. (1988) believe that the 10 billion cubic meters reserved for evaporation at Lake Nasser is too high. Sudan's storage capacity is approximately 3

TABLE 3.7 NILE WATERS AGREEMENT 1929 AND 1959.		
SHARES * \ YEAR	1929	1959
Egypt	48.0	55.5
Sudan	4.0	18.5
Unallocated	32.0	----
Storage Losses	----	10.0
TOTAL	84.0	84.0
* Billion Cubic Meters of water		
Source: Gaitskell, 1959.		

billion cubic meters. Most of the dams have lost their original storage capacity to sediment deposition.

Sudan's consumption is calculated at Sennar and Aswan, the difference is accounted for by losses due to evaporation. Water consumption has been increasing steadily indicating that the 18.5 billion cubic meter allocation will be fully utilized by the year 2000. This occurrence could be averted by; 1) increases in the storage capacity; 2) improvements in water management; and 3) increases in the yield of the Nile.

CHAPTER IV

CHARACTERISTICS OF AGRICULTURAL PRODUCTION IN THE GEZIRA

4.1 HISTORICAL DEVELOPMENT

In 1908 a pump scheme was established at Tayba for the production of cotton under the management of Sudan Productions Syndicate (SPS). In 1925, the Sennar dam on the Blue Nile, financed by a loan from the British government, was completed. Crop production under gravity irrigation was started in the Gezira. Cotton was the main crop but sorghum and beans were included in the rotation for subsistence and fodder. The initial 300,000 feddans had expanded to 700,000 feddans by 1931 (Gaitskell, 1959).

The 1913 Gezira tenancy agreement established a triple partnership - government, syndicate and tenants. The agreed upon production relationship specifies the responsibilities of each of the three partners in the production process. The government leases the land, builds and maintains the irrigation canals; the syndicate suppies credit and management; and the tenant suppies labor, tools and undertakes field operations. The profit from cotton production were distributed to the three partners according to a prescribed formula (Tenancy agreement, 1927).

Following the nationalization of the Gezira Scheme in 1950, the Sudan Gezira Board was established to replace the Syndicate. The area under irrigation was expanded and crop production was diversified and intensified. Cotton continued to be grown as a main source of foreign currency earner. Wheat was introduced as an import substitute and groundnuts for export, domestic consumption and the maintenance of soil fertility. Sorghum continues to be grown as a subsistence crop. Gezira produces 47 percent of

Sudan's cotton, 11 percent sorghum, 60 percent wheat and 28 percent groundnuts. About 1.5 million people depend on the Gezira Scheme for their livelihood. With an area of 2 million feddans and a cropping intensity of 57 percent, the Gezira is "the largest farm in the world under a single management" (Jaffe, 1992). Figure 4.1 presents the main irrigation network in the Gezira Scheme.

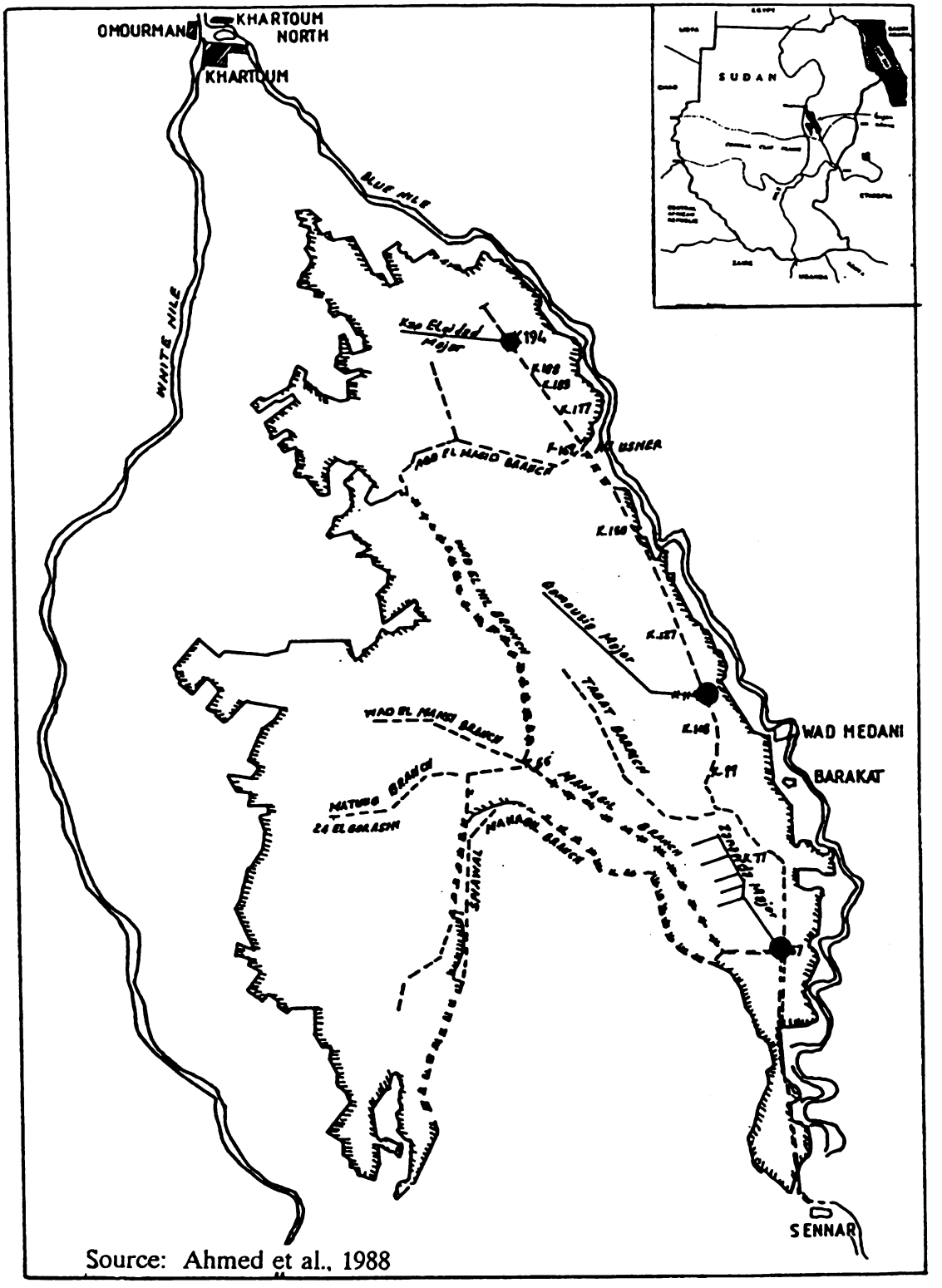
4.2 CURRENT SITUATION AND ORGANIZATION

The Gezira Scheme lies between the Blue and the White Niles. The 5 million feddans Gezira plain is suitable for irrigation because the gentle slope of 15 cm per kilometer towards the White Nile requires little investment in levelling and canal lining; and the clay soils allows little water loss through seepage. The erratic rainfall could only support the production of short maturing drought-resistant sorghum combined with semi-nomadic herding of cattle, sheep and goats.

The Gezira irrigation Scheme is fed by gravity irrigation from the Blue Nile. The total area is 2.1 million feddans, 1.2 million feddans in the main Gezira and 0.9 million feddans in the Managil extension established in 1957 following the construction of the Roseires dam. The Gezira Scheme represents 47 percent of the total irrigated area and 10 percent of the total arable area under crop production in the Sudan.

The management of the Gezira Scheme is divided between the Ministry of Irrigation (MOI) which is responsible for the irrigation network and the Sudan Gezira Board which is responsible for agricultural operations and for determining the irrigation water requirements. Figure 4.2 shows a typical irrigation shedule layout of a ten feddan hawasha.

FIGURE 4.1 MAIN IRRIGATION NETWORK IN THE GEZIRA.



Source: Ahmed et al., 1988

The Ministry of Irrigation staff involved in the management is 3,200 persons of whom 18 are University graduates and 78 technicians. The Ministry of Irrigation is organized into 7 divisions, each under the control of a division engineer (DE), 23 subdivisions under the control of assistant division engineers (ADE) and 56 sections under the control of assistant engineers (AE). Each subdivision controls an area of 90,000 feddans. The ADE handles water control and the AE handles maintenance operations. The main maintenance activities including silt and weed clearance are carried out by two parastatal corporations: l) Earthmoving Corporation (EMC), and 2) Irrigation Works Corporation (IWC). They act as contractors to the Ministry of Irrigation for maintenance work in the Gezira. The two corporations have a staff of 4,000.

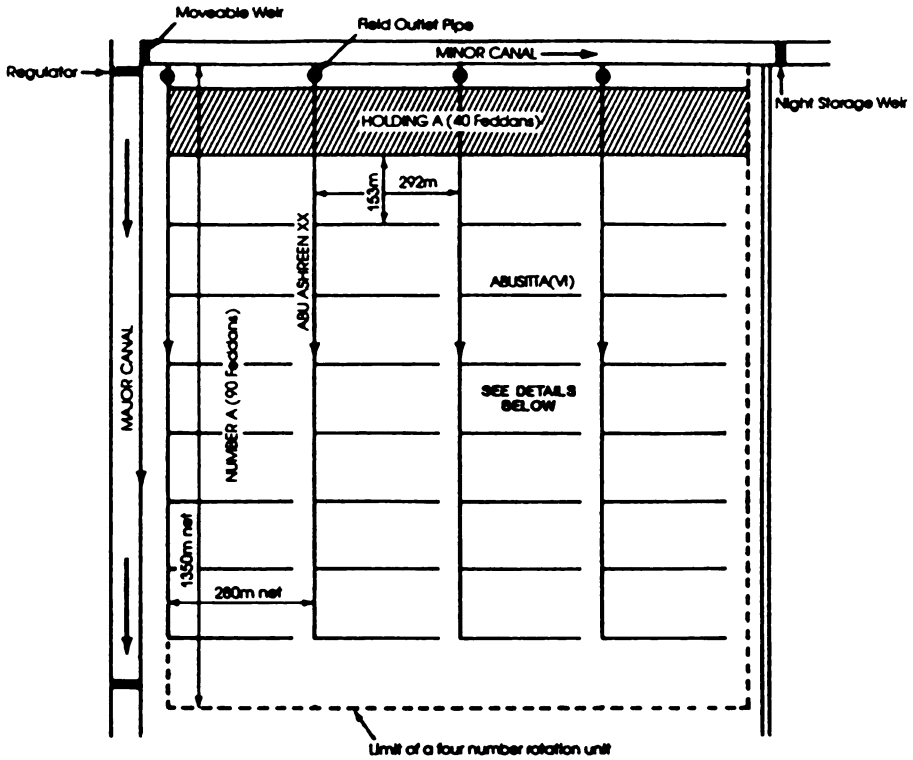
The Sudan Gezira Board is responsible for the agricultural management of the Scheme. These functions include administration, accountancy, technical, field and social services.

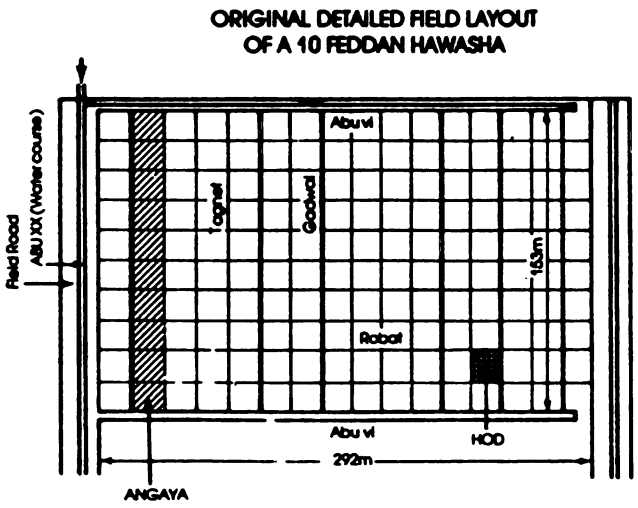
Figure 4.3 shows the area under irrigation divided into l4 groups and further subdivided into l03 blocks of about 20,000 feddans each, with the size and location dependent on topographical and locational factors. Each block has a block inspector with 2-3 field inspectors who are responsible for the supervision of production. Samads (Sub-inspectors) chosen among the tenants assist the field inspectors.

Figure 4.4 shows the tenancies arranged in "Numbers" of 90 feddans each cultivated by one crop. Usually there are l8 "hawashas" of five feddans in each number. The 4-course rotation is across four adjacent numbers and each tenancy will have a "hawasha" in each of the four numbers (Sudan Gezira Board, 1990).

The Scheme employs 2l3,000 people of whom 2,200 are classified officials and half a million permanent and casual laborers. The Scheme's problems include lack of

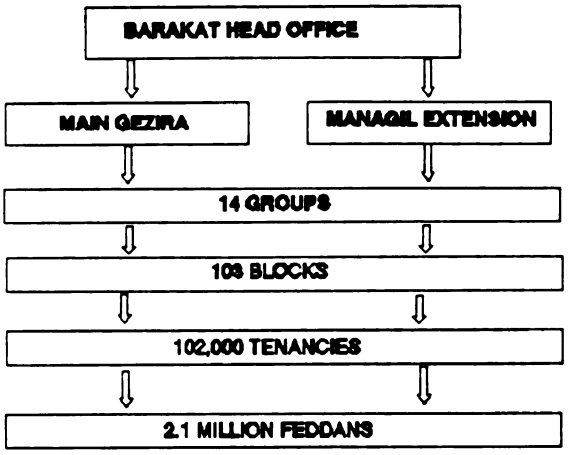
FIGURE 4.2 A TYPICAL IRRIGATION SHEDULE LAYOUT.





Source: Plusquellec, 1990.

FIGURE 4.3 ORGANIZATION OF THE GEZIRA SCHEME



Source: Sudan Gezira Board.

trained agriculturalists, motivation, machinery and spare parts (Plusquellec, 1990).

The social services department of Sudan Gezira Board supplies social services such as schools, adult education, drinking water and health clinics. The Board is responsible for the maintenance of the infrastructure which includes roads and a railway network of 1,050 Km in length used for transporting cotton. The literacy rate in the Gezira is 53 percent as compared to the national rate of 35 percent.

The Tenants Union whose membership is open to all the tenants caters for the interests of the tenants. The tenants are represented in the Board of Directors (which is the highest policy making body of the Scheme) by five members. The tenants are supposed to be full participants in the decision making process. However, because of the important role the Gezira Scheme plays in the country, directives have tended to come from the top to the tenant without a feedback.

FIGURE 4.4 ORGANIZATION OF HAWASHAS IN A 90 FEDDAN NUMBER.							
NUMBER 1		NUMBER 2		NUMBER 3		NUMBER 4	
A1		A2		A3		A4	
B1		B2		B3		B4	
C1		C2		C3		C4	
D1		D2		D3		D4	
E1		E2		E3		E4	
F1		F2		F3		F4	
G1		G2		G3		G4	
H1		H2		H3		H4	
I1		I2		I3		I4	
A1 + A2 + A3 + A4 = 20 Feddan Gezira Tenancy = 4 Hawashas.							
Source: Field Survey, 1989/90.							

4.3 CLIMATE AND SOILS

The vertisol soils of the Gezira plain crack widely, are fairly uniform, have a clay content of 60 percent and a high cation exchange capacity. Water movement in the soil is very slow. The soil moisture content remains constant at a depth of a few meters with no downward percolation of irrigation water. However, water penetrates to a good depth on the cracks to be followed by plant roots. The cotton soils show a high tendency to waterlogging with the attendant bad aeration and yield reduction.

The climate is arid characterized by low annual precipitation and considerable yearly fluctuations in magnitude, intensity and distribution of rainfall. There are three distinct seasons: a short rainy season from July to September, during which the temperature is moderate and humidity high; a cool dry winter season from November to

TABLE 4.1 METEOROLOGICAL DATA FOR WAD MEDANI, 1941-75.

PERIOD	RAINFALL	TEMPER	HUMIDITY	WIND SP	EVAPOR
UNIT	(mm)	(Cent)	(%)	(m/s)	Penman
JAN	---	23.7	18.0	3.6	177
FEB	---	25.1	13.0	4.0	189
MAR	---	28.3	10.0	3.6	247
APR	3	31.0	9.0	4.5	256
MAY	13	32.7	15.0	4.5	280
JUN	27	32.1	23.0	4.5	282
JUL	94	29.0	39.0	4.5	244
AUG	96	29.3	51.0	4.0	206
SEP	57	28.5	42.0	3.1	206
OCT	8	29.7	27.0	2.2	204
NOV	1	27.2	19.0	3.1	180
DEC	---	24.1	19.0	4.0	171
ANNUA	299	28.3	24.0	3.6	2,632

Source: Sudan Gezira Board.

February; and a hot summer from April to June.

The mean annual rainfall ranges from 160 mm near Khartoum to 470 mm at the headwork of Sennar dam, and is distributed over three months from July to September. The relative humidity fluctuates from 20 percent to 70 percent and temperature varies from 5^0 C in December to over 45^0 C in April, with an annual mean of 28^0 C. The evaporation EO (Penman) at Wad Medani varies from 5.5 mm per day in December to 9 mm per day in June. Salinity is not a problem except for the fringe areas at the northern part of the Scheme south of Khartoum.

4.4 LAND TENURE

At the inception of the Gezira Scheme, the original landowners were compelled to lease their land to the government at the nominal rate of one Sudanese pound per annum for fifty years. They were given the right to become tenants on their own land up to a limit of one tenancy of 40 feddans and they could nominate tenants to their property exceeding this amount. The remaining land was allotted to landless peasants (Gezira Land Ordinance, 1927). The land required for permanent works such as irrigation canals and building structures was bought outright by the government from the owners.

Tenancies were allotted to both male and female adults but male relatives were appointed as responsible tenants on behalf of the females. Minors were also allotted tenancies but adult uncles have to work the farm until they come of age. The original distribution of land was as follows: the original land holders 40 percent, tenants nominated by the original landowners 14 percent and others 46 percent (Gaitskell, 1959). The allotment of land to the original landowners and their relations, those who were paying taxes on rainfed crops and laborers in the area preserved some property rights.

The tenancy is allocated on individual basis and is automatically renewable annually. Tenant evictions have been about one percent per annum (Socioeconomic Unit, 1988). The standard tenancy of 40 feddans was thought to provide adequate living for a family that would cultivate sorghum for its subsistence requirements and cotton as a cash crop. Labor was supposed to be provided by the tenant's family. However, family labor participation in the Gezira is only 31 percent (Brandt et al., 1987).

Culwick (1955) found that the standard tenancies of 40 feddans were only 35 percent, half tenancies of 20 feddans had increased to 62 percent and 60-80 feddan

tenancies were 3 percent of all tenancies in the Gezira. The significant increase in the number of half tenancies can be attributed to inheritance law that entitles an heir to receive a piece of land. A 20 feddan tenancy is the minimum parcel allowed by the Sudan Gezira Board.

In the Managil extension, tenancy size is only 15 feddans, deemed an optimum size for a tenant and his family to work without hired labor. The small holdings were to accommodate more tenants.

The Gezira Scheme has 102,250 tenancies: 48,350 in the main Gezira and 53,900 in the Managil extension with an average tenancy size of 20 feddans in the main Gezira and 15 feddans in Managil extension.

4.5 CROPPING PATTERN

4.5.1 CROP ROTATION

The main crops grown in the Gezira include cotton, wheat, groundnuts and sorghum. Cotton and wheat are the "government" crops while groundnuts and sorghum are the "tenant's" crops. In the typical four course rotation, three numbers are planted and one is left under fallow. Cotton is grown in the first number, wheat in the second, groundnuts and/or sorghum in the third and the fourth is left fallow. Each tenant's 20 feddans are split across four numbers with each "hawasha" occupying a fixed site on the number.

The rotation system is imposed on the tenants by the Sudan Gezira Board. It only takes into consideration technical rather than economic factors. Yet the tenants are expected to influence crop yields. The only decision left to the tenants is whether to grow groundnuts or sorghum in the third "hawasha". Some of the tenants grow vegetables

mainly tomatoes, onions, eggplants and cucumbers on fields adjacent to the main irrigation canals. This is offered as an incentive only to good cotton producers. Some tenants keep livestock for the production of milk for home consumption.

In the Managil extension, a three course rotation has been in practice until the 1985/86 cropping season. A gradual change to a four course rotation has been completed by the 1986/87 cropping season. The cropping intensity has decreased from the planned 100 percent to 75 percent with the area under fallow increasing from zero to 25 percent. The introduction of fallow is intended to: 1) reduce noxious weeds; 2) give enough time for land preparation; 3) reduce demand for limited water supply; and 4) provide grazing for livestock.

Table 4.2 shows the crop rotation in the main Gezira has undergone many changes based on policy and economic considerations. The initial three course rotation (1925-1933) was changed to a eight course rotation (1934-1961), to a seven course rotation (1962-1975), to the present four course rotation. In the 1960's wheat and groundnuts were introduced into the Gezira Scheme. The most intensive crop rotation started in the 1974/75 to take advantage of the abundant fallow land in the proceeding eight course rotation. However, this intensification took place without changes in the canal capacity such that the subsequent shortage of irrigation water has hindered the achievement of high crop productivity.

4.5.2 CROPPING CALENDAR

Figure 4.5 shows the cropping calendar in the Gezira. The growing season starts in May with the clearance of cotton stalks, ridging of groundnuts and sorghum plots. Groundnuts are sown the second week of June and sorghum the fourth week of June. Sowing of medium-staple cotton from July 15 to July 31 and long-staple cotton from July

TABLE 4.2 DEVELOPMENT OF CROP ROTATION IN THE GEZIRA.		
SEASON	ROTATION	CROP INTENSITY %
1925 - 1930	C-S/L-F	66.30
1931 - 1932	C-F-F	33.30
1933 - 1960	C-F-F-C-F-S-L/F-F	44.75
1961 - 1974	C-W-F-C-G-L/F-F	69.75
1975 - 1991	C-W-G/S-F	75.00
Key: C = Cotton W = Wheat G = Groundnuts		
S = Sorghum F = Fallow L = Legume		
Source: Sudan Gezira Board records.		

20 to August 15. Irrigation takes place throughout the season. Weeding of sorghum and groundnuts takes place in August and harvesting occurs in November. Fertilizer application and spraying of cotton in September. Land preparation for wheat takes place at the end of September and sowing in October. Groundnuts harvesting starts on November 15, and continues until December 31; medium-staple cotton from December to March, long-staple cotton from January to April and wheat in March. The tenants grow the cotton, groundnuts and sorghum in the summer and wheat in the winter.

4.6 PRODUCTION RELATIONS

Under the 1913 agreement, the Gezira Scheme established a joint account system on cotton production between the government, Syndicate and the tenants. Groundnuts, sorghum and vegetables belong to the tenants. Production costs of cotton and other crops were deducted from the gross revenue of cotton and the net revenue of cotton was distributed as follows: government 35 percent, Syndicate 25 percent and tenant 40 percent

FIGURE 4.5 GEZIRA CROPPING CALENDARS.

OP	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
COTTON												
P	XX											
S			XX	XX								
I		XX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
W					XX	XX						
H								XXX	XXX	XXX		
C										XX	XX	
WHEAT												
P				XX								
S					XX							
I					XX	XXX	XXX	XXX	XXX			
W												
H										XXX		
C											XX	
GROUNDNUTS												
P	XX											
S		XX	XX									
I		XX	XXX	XXX	XX							
W		XX	XXX	XX								
H						XX	XX					
C							XX					
SORGHUM												
P	XX											
S		XX										
I		XX	XXX	XXX								
W			XX	XXX								
H					XX	XXX						
C						XX	XX					

P = Cleaning canals S = Sowing I = Irrigation W = Weeding

H = Harvesting C = Land clearance OP = Operations

Source: Gezira Research station

TABLE 4.3 RESEARCH RECOMMENDED SOWING AND HARVESTING DATES.		
CROP \ DATES	SOWING DATES	HARVESTING DATES
Cotton MS	July 20, - August 8	March 31
Cotton LS	July 15, - July 31	March 31
Wheat	Oct 15, - Nov 15	February 28
Groundnuts	June 1, - June 15	October 20
Sorghum	June 15, - July 15	October
Source: Agricultural Research Corporation.		

Table 4.4 shows the distribution of the revenue from cotton among the three partners did not change until the 1950 cropping season. By the 1957 season, the local government, social development fund and tenant reserve fund were receiving 2 percent of the cotton revenue each. The changes in the share distribution continued until the 1981 season where the shares stood at: government 36 percent, Board 10 percent and tenant 47 percent. The reasons given for the triple partnership arrangement that involve close supervision include; 1) efficient control of water utilization, 2) maintenance of soil fertility by following strict rotation; 3) efficient utilization of machines in large adjacent land parcels; and 4) application of pesticide and herbicide sprays of cotton from the air.

The joint account began to face many difficulties over the years because as the costs of production were rising, the Board was charging more and more inputs on the joint account. Moreover, the average costs were charged across the board and the efficient tenants received no reward for better management. The Board deducts the cost of providing services for the production of cotton, wheat, groundnuts and sorghum from cotton proceeds: Because groundnuts and sorghum are privately marketed and the input

TABLE 4.4 PERCENTAGE DISTRIBUTION OF NET REVENUES.

PERIOD \ SHARE		GOVT	SGB	TENANT	LOCAL	DEV	RES
BEGIN	END				GOVT	FUND	FUND
1925/26	1949/50	35	25	40			
1950/51	1955/56	40	20	40			
1956/57	1962/63	42	10	42	2	2	2
1963/64	1964/65	40	10	44	2	2	2
1965/66	1968/69	36	10	48	2	2	2
1969/70	1980/81	36	10	47	2	3	2

Source: Sudan Gezira Board.

costs cannot be recovered at sale, cotton became less attractive to the tenants since it has to bear the burden of the land and water charges of groundnuts and sorghum. The Sudan Cotton Company could not sell all the cotton due to the presence of honey dew in the lint and low world demand for long staple cotton.

These problems led the tenants to neglect their duties and by 1980/81 the yield of all crops had declined drastically; cotton from 3.6 Kantars per feddan in 1974 to 2.2 Kantars per feddan, wheat 455.2 Kg per feddan to 297.5 Kg per feddan, groundnuts 335.2 Kg per feddan to 227.9 Kg per feddan and sorghum from 425.4 Kg per feddan to 281.4 Kg per feddan. An individual account system was introduced in the 1980/81 cropping season in an attempt to arrest the decline. The Board deducts the costs of providing services from the tenant's individual account. The tenant keeps the net revenue from the sale of cotton and wheat but has to pay land and water taxes for each of the four crops he grows.

The Gezira rehabilitation project brought about some improvements in crop yields that peaked by the 1988/89 cropping season: cotton 4.5 Kantars per feddan, wheat 628 Kg per feddan, groundnuts 361 Kg per feddan and sorghum 333 Kg per feddan. Cotton returns have improved because all costs are no longer debited to the cotton account and high-yield tenants reap benefits.

The land and water taxes are uniform across the board regardless of tenant access to water and land inputs which means that low yielding tenancies are penalized as compared to high yielding tenancies.

4.7 AGRICULTURE PRODUCTION

The yields of the four main crops hit rock bottom in the 1980/81 season but by 1988/89 they attained the previous levels. The decline can be attributed to decreasing soil fertility, machinery shortage that leads to delayed and inadequate timing of agricultural operations and lack of incentives to motivate tenants.

The change of the rotation in the Managil extension from a three course to a four course rotation has resulted in 1) reduction of potential cropping intensity from 86 percent to 75 percent; 2) the area under fallow increased from 236,000 feddans to 530,000 feddans per annum; 3) reduction of the total area available for crops to 1.59 million feddans; and 4) the area available for cereal production decreased to 530,000 feddans. The actual cropping intensity declined from 75 percent in the 1978/79 season to 60 percent in the 1988/89 season. The gap between the potential and actual cultivated crop areas has decreased indicating a positive impact of the rehabilitation program. Yields have tended to decrease from South to North except for wheat which gives high yields at the northern part of the Gezira. Water availability and climatic factors may

TABLE 4.5 CROP AREA, OUTPUT AND YIELD IN THE GEZIRA SCHEME.

	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
COTTON *						
Area	498	465	401	415	383	405
Output	2,454	2,427	1,419	2,048	1,752	210
Yield	4.93	5.22	3.45	4.93	4.57	5.20
WHEAT						
Area	266	---	244	180	252	274
Output	103,099	---	97,387	95,908	119,568	1,475
Yield	0.39	---	0.40	0.44	0.47	0.56
GROUNDNUTS						
Area	137	213	102	152	159	11
Output	92	109	56	91	96	67
Yield	0.67	0.51	0.55	0.60	0.60	0.60
SORGHUM						
Area	411	420	579	448	390	427
Output	216	147	318	179	141	215
Yield	0.53	0.35	0.55	0.40	0.36	0.50

Area: '000' Feddans. Output: '000' Mt. Yield: Kg/Fed.

* Output: '000' Kantars. Yield: Kantars/Fed.

Source: Socioeconomic Unit, Sudan Gezira Board.

explain the difference. Also, the distance of the hawasha from the field-outlet could have some marked effect on yield, which tends to decline towards the tail end of the irrigation system. This can be explained by the differences in the availability of the irrigation water which influences the timeliness of water delivery as well as its adequacy (Faki et al., 1984).

4.7.1 INPUT SUPPLY

The Board determines the area, varieties and timing of all field operations and supplies most of the material inputs (seeds, fertilizers, pesticides) as well as undertaking all the mechanical services such as land preparation, seed propagation, fertilizer application, transport, storage, ginning and grading of cotton. The tenants perform sowing, weeding, irrigation, harvesting, clearing and transportation. The Board advances cash for land preparation, canal opening, ridging, picking and stalk pulling labor.

The Board also participates in wheat production by providing the material inputs, mechanical services and the tenant's role is confined to land preparation, weeding and irrigation. The tenant has to provide all the material inputs, mechanical services and labor inputs for groundnuts and sorghum but must observe the general rules of cultivation. The Board does not make fertilizers and pesticides available for groundnuts and local sorghum.

There are several committees that decide on production inputs. The Ministry of Finance considers requests for inputs only on a quarterly basis, and the Bank of Sudan releases foreign currency for a new request only after a full account is given of the utilization of supplies secured in the previous quarter. Release of funds for inputs tends to be tied to the success of fund-raising efforts with donors. Thus, top management of the Gezira Scheme spends much time in Khartoum on the follow-up of these funds instead of managing the Scheme in order to improve production efficiency. Critical inputs like sacks often arrive late leading to significant losses in output.

4.7.2 COST OF PRODUCTION

Material production inputs for cotton and wheat are provided by Scheme management and their costs are charged to the individual account. Inputs for groundnuts

TABLE 4.6 WATER RATES BASED ON ACTUAL CULTIVATED AREAS, 1988.					
CROP \ AREA	CULTIVATED	COMPUTED	RECOVERABLE AMOUNT		RATES
UNIT	(Fed)	(LS/Fed)	(LS)	(%)	($/Ha)
Cotton	384,000	46.07	17,690,850	49.60	27.61
Wheat	300,000	28.80	8,639,000	24.30	17.26
Groundnuts	159,000	23.04	3,662,330	10.30	13.81
Sorghum	397,000	11.52	4,572,415	12.80	6.90
Vegetables	27,000	40.32	1,085,640	3.00	24.17
Source: Plusquellec, 1990.					

and sorghum are obtained privately at the prices ruling in the market.

Table 4.7 shows that production costs of all the crops have increased considerably over the years. Cotton from LS 108 per feddan in 1980/81 to LS 2,404 per feddan in 1989/90, wheat from LS 41 per feddan to LS 857 per feddan, groundnuts from LS 47 per feddan to LS 832 per feddan and sorghum from LS 24 per feddan to LS 689 per feddan. Soaring prices of agriculture inputs, high doses of insecticide application and rising wages of hired labor have contributed to the rising costs of production.

The tenants are charged for each input for each crop and they get the net revenue based on their productivity. Table 4.8 shows the land and water rates for all the crops. These rates are established to recover administrative and operating costs of the Board, and the Ministry of Irrigation; and their capital replacement and new investment costs. The rates established in 1981/82 are increased by a certain percentage for each crop annually.

Table 4.9 reveals that land and water charges collection rate is 70 percent in 1985/86, 81 percent in 1986/87 and 75 percent in 1987/88. Cotton has the highest collection

TABLE 4.7 COST OF PRODUCTION PER FEDDAN, 1981-1990.

PERIOD CROP	COTTON	WHEAT	GROUNDNUTS	SORGHUM
1980/81	107.9	40.8	46.9	24.4
1981/82	233.9	93.4	73.8	44.9
1982/83	293.9	124.3	90.5	56.0
1983/84	426.2	140.8	135.1	96.9
1984/85	443.6	----	132.8	102.3
1985/86	777.6	273.2	201.0	159.7
1986/87	834.9	275.8	262.7	158.7
1987/88	1,035.9	320.9	379.5	208.0
1988/89	1,580.7	558.7	480.9	367.7
1989/90 *	2,404.0	857.0	832.0	689.0

* 1989/90 cropping season covered by the field survey.

Source: Socioeconomic Unit, Sudan Gezira Board.

TABLE 4.8 LAND AND WATER RATES PER FEDDAN.

YEAR / CROP	COTTON	WHEAT	GROUNDNUTS	SORGHUM	VEGETABLES
1981/82	28.50	14.00	18.00	3.50	25.00
1982/83	28.50	14.00	18.00	7.00	25.00
1983/84	38.00	23.75	19.00	19.00	33.50
1984/85	50.50	31.00	25.00	25.00	44.00
1985/86	65.00	40.00	32.50	32.50	57.00
1986/87	80.00	49.00	40.00	40.00	70.00
1987/88	101.00	62.00	50.00	50.00	90.00
1988/89	130.00	95.00	55.00	55.00	130.00
1989/90 *	157.00	131.00	104.00	104	175.00

Source: Socioeconomic Unit, Sudan Gezira Board.

rate (90 percent) followed by wheat (80 percent) and; groundnuts, sorghum and vegetables 49-68 percent. The higher collection rates for cotton and wheat are because the Board has control over the sale of these crops whereas groundnuts and sorghum are marketed privately.

4.8 WATER RESOURCES

4.8.1 DISTRIBUTION SYSTEM

The Gezira Scheme consumes 7.6 billion cubic meters out of the l6 billion cubic meters of water allocated to all the existing Schemes. The capacity of the reservoir at the Sennar dam is 930 million cubic meters. Table 4.10 shows water distribution network in the Gezira. There are two main canals (main Gezira and Managil) from the dam, each supplies water to about half the Gezira Scheme. These canals feed ll branch canals. The branch canals feed 1,498 minor canals. From the minor canals, the water flows through

TABLE 4.9 ACTUAL EXPENDITURE AND RECOVERY RATES.

	1985/86	1986/87	1987/88
Ministry of Irrigation	28,670	32,909	35,650
Sudan Gezira Board	40,963	52,476	21,909
Total	69,633	85,383	107,559
Recovery	60,214	68,525	85,497
Average Recovery Rate %	86.5	80.2	79.5
Cotton recovery Rate %	88.0	93.00	90.0
Wheat recovery Rate %	74.0	25.0	80.0
Others recovery Rate %	49.0	68.3	54.1

Source: Plusquellec, 1990.

field outlet pipes (FOP) into tertiary canals called "ABU XX" (14,369 in main Gezira and 12,626 in Managil). The "ABU XX" supply water to plots of 90 feddans which are divided into 18 five feddan plots called "hawashas". The hawasha receive water through small field canals called "ABU VI" which are further divided into "gadwals" that alternate with "tagnats" (earth banks) that divide the tenancy into units called "angayas," of which there are 7 of them in each "hawasha". The "angayas" are further divided into small basins called "hods".

Water management is divided between the government, the Board and tenants. Ministry of Irrigation delivers the water up to the minor canals, Sudan Gezira Board provides the field level management and the tenants water their "hawashas". The Gezira is divided into 6 divisions that are further sub-divided into sub- divisions. The block inspector passes the water indents (orders) to the assistant engineers (AE) on weekly basis and the AE sums up the required discharge at each control point on the system in his subdivision. The indents are passed to the division engineer who makes corrections for water conveyance losses and passes the total to the chief engineer of the headwork at Sennar dam and the chief engineer adjusts the gates to give the discharge required. Water flow from the major to the minor canals is controlled by movable weirs, which provide water measurements.

The Ministry of Irrigation estimates the distribution efficiency at 93 percent. The high level could be due to: 1) impermeable clay soils; 2) low level of escapage and; 3) the storage role of the minor canals. Field efficiency (defined as the ratio of net crop requirements to releases at field outlet level) has been estimated at 70 percent. Water distribution has two dimensions: 1) a technical dimension that relates to the appropriateness of water distribution methods and their capacity to secure an optimum

TABLE 4.10 WATER DISTRIBUTION NETWORK IN THE GEZIRA SCHEME.		
CANAL \ LENGTH \ CAPACITY	LENGTH (Km)	CAPACITY (meters cube/s)
2 Main canals	261	354
11 Branch canals	651	25-120
1,498 Minor canals	107	1.5-15
29,00 Water courses 'Abu xx'	8,119	0.5-1.5
350,00 Field channels 'Abu VI'	40,000	0.12
Source: Ministry of Irrigation.		

match between supply and demand; and 2) a social/political dimension that concerns the capacity and the ability of officials to ration water equitably and resist powerful pressures to misallocate.

4.8.2 DEMAND FOR IRRIGATION WATER

The main Gezira canal conveys 15 million cubic meters and the Managil Canal 16 million cubic meters which corresponds to a monthly amount of 930 million cubic meters and 420 cubic meters per feddan respectively, taking into account transit losses. However, the actual amount released from the dam depends on the amount of water stored in the Sennar reservoir which is influenced by the flow of the Blue Nile.

The traditional method of determining crop water requirements estimates the requirement at 30 cubic meters per feddan per day exclusive of transit losses which corresponds to the traditional Gezira schedule of 420 cubic meters per feddan at fourteen day watering interval irrespective of the crop or season.

Research conducted since 1964 at Gezira Research Station has determined the values of crop water requirements according to the Penman method which meets the need

TABLE 4.11 MONTHLY WATER RELEASES FROM SENNAR DAM. *

MONTH \ YEAR	1984	1985	1986	1987	1988	MEAN
June	623.3	668.0	183.5	202.6	199.6	375.4
July	731.2	910.1	589.4	521.2	609.4	672.3
August	810.5	919	767.7	691.3	509.9	739.8
September	973.5	949.1	571	544.0	685.5	744.6
October	910.1	566.2	756.7	890.2	865.1	797.7
November	755.4	471.2	858.2	748.0	880.6	742.7
December	642.2	641.8	701.9	582.6	924.4	698.6
January	544.2	529.5	515.0	508.2	562.6	531.9
February	377.2	337.7	461.0	392.9	511.2	416.0
March	79.1	85.9	381.3	187.0	309.5	208.6
April	62.3	114.3	86.2	44.1	58.5	73.1
May	302.5	299.7	85.0	71.0	98.0	251.2
Total = S	6313.5	6448.0	6156.9	5383.1	6216.3	6103.6
Demand = D	6061.0	5757.0	5308.0	5415.0	5372.0	5582.6
Ratio S/D	1.04	1.12	1.16	0.99	1.16	1.09

* (Million Cubic Meters). S = Supply D = Demand

Source: Ministry of Irrigation.

of irrigated agriculture under the soil and climatic conditions of the Gezira plain. Farbrother (1977) determined the cropping factors for all the crops at the field outlet pipe level taking into account rainfall and transit losses. The definition of the crop water requirements at the Gezira are based on water losses below the field outlet pipe level because percolation water losses are very small. Nevertheless losses through evaporation, seepage, cracks and flooding of fallow numbers can be considerable. The water demand in

TABLE 4.12 CROP WATER REQUIREMENT FACTORS BY PENMAN METHOD.

PERIOD	COTTON MS	COTTON LS	WHEAT	PEANUT	SORGHUM
JUN 1				800 *	
JUN 2				0.50	
JUN 3				0.53	
JUL 1				0.59	800 *
JUL 2				0.68	0.50
JUL 3	600 *	600 *		0.78	0.55
AUG 1	0.50	0.50		1.91	0.70
AUG 2	0.50	0.50		1.01	0.94
AUG 3	0.53	0.57		1.09	1.10
SEP 1	0.58	0.67		1.10	1.14
SEP 2	0.65	0.85		1.07	1.08
SEP 3	0.81	0.99		1.03	0.93
OCT 1	1.01	1.20		0.89	0.80
OCT 2	1.10	1.20		0.80	0.70
OCT 3	1.13	1.21	400 *		
NOV 1	1.17	1.21	0.5		
NOV 2	1.20	1.11	0.66		
NOV 3	1.18	0.92	0.87		
DEC 1	1.16	0.75	1.07		
DEC 2	1.15	0.68	1.15		
DEC 3	1.11		1.18		
JAN 1	1.00		1.11		
JAN 2	0.95		0.95		
JAN 3	0.86		0.76		
FEB 1	0.77		0.60		
FEB 2	0.68		0.50		
FEB 3	0.68				

* Pre-Irrigation in millimeters (mm)

Source: Farbrother, 1977.

the period 1983-88 varies between 5.3 cubic meter per million and 6.1 cubic meters million (Plusquellec, 1990).

The original night storage system has given rise to a continuous twenty-four hour irrigation water delivery to the field known as the "grid system" which is not supervised by the tenants during the night. By adopting the continuous unattended irrigation, the tenants have considerably reduced labor costs for irrigation. They also appreciate the flexibility of the new system on which water is withdrawn on demand since they assume control of the opening of the field outlets. The departure from the originally planned method of watering has given rise to some management and water application problems. The new system results in loss of water, over watering and uneven watering with tenants at the tail end of the minor canal receiving less water than those at the head end. The water application problems have been aggravated by lack of funds, intensification of the cropping system, expansion of the system and poor management.

The poor performance of the export sector results in insufficient funds to finance the Scheme's recurrent operations and maintenance costs, and the replacement of machinery and equipment. The increase of the cropping intensity from 40 percent in 1964 to the present 60 percent combined with the increase in the area under irrigation resulted in a three-fold increase of water released through the irrigation system, and of the silt deposited into the canal system.

Water shortages are prevalent during the peak period from October to November when cotton, groundnuts and sorghum are maturing and wheat is being planted; and all the crops needing water. The outcome is the delay in irrigating some crops and less water per feddan per watering which has a negative effect on crop productivity.

Ahmed et al. (1988) maintain that improvements in water measurements, crop water requirement estimates, management control of irrigation water, removal of sediments and weeds could increase the supply of irrigation water by 2 million cubic meters. The seasonal variation of the Nile discharge ranges from over 10,000 cubic meter per second at the peak of the flood to 60 cubic meters per second in a very low year. The annual suspended solids of the Blue Nile is about 60 million tons. Silt content is high: 10 kg per cubic meters (Plusquellec, 1990).

Silt deposits and weed growth in the irrigation canals have become very serious problems in the Gezira, and the problem is getting worse every year. Cropping intensity is down from planned 75 percent to 62 percent, as nearly 300,000 feddans have to be taken out of production because silt and weeds in the canals have reduced the availability of water. The annual rate of silt deposits is estimated at 16.7 million cubic meters against the Earth Moving Corporations' removal capacity of 10.2 million cubic meters. Hence, each year another 6.5 million cubic meters are added to the back-log of 46.7 million cubic meters. The reduction in the cultivable area has resulted in stagnation of production in the irrigated subsector (World Bank, 1990a).

The dual management of the minor canals by the Board and Ministry of Irrigation, and the bureaucratic squabbles between these two arms of government have adversely affected the delivery of water to the tenants. There is a wide variability in the availability of water as well as the timing of other production operations leading to variability in crop yields with implications for cost recovery, production and exports. Improvement will include raising the Roseires dam to better control the flow of the Blue Nile; and replacement of pumps. Responsibility for the management of the minor canals

should be given to the Board with engineers from the Ministry of Irrigation on secondment to provide technical help (Plusquellec, 1990).

4.9 LABOR INPUT

The tenancy agreement stipulates that the provision of labor for all the field operations is the responsibility of the tenant. However, the Scheme management participates in the recruitment and financing of hired labor for land preparation, and picking and pulling of cotton stalks. The material inputs for wheat are supplied by the Board. The tenant's role is confined to land preparation, weeding and irrigation operations. The tenants have to provide all the labor for groundnuts and sorghum production with the Scheme only collecting the land and water taxes.

The size of the Gezira tenancy was thought to be big enough to provide a family with enough food and cash requirements and the household members were to provide most of the labor but the participation rate of family labor is very low. This could be due to low farm incomes and prospects of off-farm employment for the young males who tend to migrate out of their villages. Cultural and social values restrict the women of the family to housework.

Hired labor performs the bulk of the work in the Gezira Scheme. There are two sources of hired labor: labor settlements outside the tenant villages and seasonal laborers from outside the Scheme. The settlements are constituted by migrants from Kordofan, Darfur and west Africa who amount to about 15 percent of the Gezira Scheme population. The seasonal laborers are mainly peasants from the traditional subsector in western Sudan who wish to supplement their income to meet their basic subsistence. The number of available casual labor depends on the adequacy of rains in western Sudan.

Less labor migrates to the Gezira during the seasons with sufficient rainfall. The labor demand for the different crops appears to depend on the season and the degree of mechanization. The peak demand for labor is in November to December during cotton weeding and, groundnuts and sorghum harvesting. Cotton picking and wheat harvesting all require labor input. Wheat cultivation is mechanized except for land preparation, weeding and irrigation operations.

Both the Board and the Tenants' Union participate in the recruitment of seasonal labor in Western Sudan for Cotton picking. Wage rates are lower for the seasonal than for settled labor. The latter can enter into crop sharing relations with the tenants for the production of groundnuts and sorghum. However the standard of public health and drinking water facilities at the labor camps is very poor where bilharzia, malaria and diarrheal diseases predominate. Also, the illiteracy rate is very high.

In order to meet the labor requirements, the tenants are showing an increasing tendency towards share-cropping for groundnuts and sorghum. Sharecropping is forbidden under the tenancy agreement but the Scheme appears to show tolerance. The typical arrangement is for the tenant to pay the land and water taxes and provide seeds. The sharecropper has to provide all the labor and the gross proceeds have to be shared equally between the two parties. Vegetables assume a different kind of sharecropping where the tenant sublets the land to the sharecropper who finances all the costs of production and pays a fee for the use of the land. This is because vegetables require high capital to finance the costs of production.

4.10 PRODUCTION CREDIT

The Board finances cotton and wheat but no formal credit is available for

TABLE 4.13 COTTON PICKING LABOR, 1979-1989.

TYPE / SEASON	TENANT FAMILY	LOCAL LABOR	IMPORT LABOR	FLOAT LABOR*	TOTAL SUPPLY	TOTAL DEMAND
1978/79	132,703	69,116	252,877	7,877	462,578	460,296
1979/80	138,316	75,829	217,138	5,460	436,743	460,596
1980/81	131,627	77,473	186,018	5,161	400,279	410,513
1981/82	124,978	77,399	161,761	3,518	367,656	394,202
1982/83	145,719	86,380	203,659	3,209	438,967	466,185
1983/84	141,940	90,850	231,933	5,697	470,420	493,054
1984/85	141,505	94,078	214,862	1,3640	464,085	470,830
1985/86	132,421	87,584	173,024	11,505	404,534	402,790
1986/87	127,284	99,326	163,358	8,495	394,463	406,953
1987/88	124,399	89,874	144,526	7,517	366,316	383,015
1988/89	139,182	101,262	128,133	9,602	378,179	415,292

* Labor moving around in search of work in the peak periods.

Source: Socioeconomic Unit, Sudan Gezira Board.

groundnuts and sorghum production. The credit available for cotton and wheat production is for field operations. Most of the credit advances to the tenants is in-kind and the formal credit is inadequate.

The tenant has to rely on his own financial sources or the private sector to finance the cultivation of groundnuts and sorghum. Tenants need funds for the farm operations and family obligations - food bill, ceremonies and weddings. The informal sources of private credit include private moneylenders, "shail system" (a form of crop mortgage where a local merchant advances loans to the farmer who pledges to deliver to

him a specified amount of produce at harvest time), and off-farm employment. Informal credit accounts for about 60 percent of the total credit in the Gezira Scheme (Ahmed, 1979).

It is an obligation for family members to help the needy by offering cash in cases of illness, funerals and weddings. Loans given for the purchase of expensive consumer goods are usually on reciprocal basis with no interest payments. Tenants also borrow goods as well as cash from local shopkeepers.

Experiences with cooperatives in the early 1970s have been a failure because of dominance by local leaders, inadequate services and high administrative costs. The solution to this problem may involve changes in the Boards financing procedures on alternative credit sources (Brandt et al., 1987).

4.11 AGRICULTURAL RESEARCH

The Gezira Research Station founded in 1918 is responsible for the conduct of research in the Gezira Scheme. The Board has a small extension department which handles advisory services, demonstration plots and the preparation of literature for the tenants. The link between research and extension is very weak. Lack of appropriate technology suitable for the Gezira environment has impeded increases in agriculture productivity. Research is needed to improve the varieties of wheat, groundnuts and sorghum (World Bank, 1985).

Cotton research deals with breeding and the maintenance of the germaplasm material. The major challenges facing the cotton researchers include fusaria wilt, bacterial blight and whitefly infestation. Sudanese cotton sells at a discount of 10 cents per pound in the world market due to the presence of honeydew secreted by the cotton

white fly which causes stickiness of the lint cotton. The cotton research problems that need to be addressed include: soil nutrients, water requirements and weed and insect control. Improved technical packages for wheat are being tested to assess their suitability to the Gezira conditions. The main problems facing wheat production in the Gezira are: cultural practices, suitable varieties, harvesting, insects and diseases.

Groundnuts varieties are under trial but the research time allocated to it is inadequate. Research problems of groundnuts include: cultural practices, weeds, pests and diseases and aflatoxin contamination.

Hybrid sorghum variety known as Hageen dura-I, was released and approved for commercial production in 1983. Hageen Dura-l given the proper input combination, out-yields the local sorghum varieties by a factor of 6:1. However, the adoption rate of this technology has been very low. Farmers complain that the variety is not palatable, and food processors found that the seed breaks up during decortication even though it mixes very well to produce wheat/sorghum bread. Breeders will need to incorporate the lacking factors for it to succeed. The main problems facing sorghum production include: mixed varieties, poor cultural practices, weed control, striga infestation, pests and diseases.

The transfer of information and technology from the Gezira Research Station to the Agricultural Corporations is through the national committees dealing with crop husbandry, pests and diseases, cotton variety, and production and release. The information is received through meetings and reports and is conveyed to the tenants through the Board's inspectorate system. The information service is not capable of presenting the latest results from research work to the intended clients adequately. Agricultural Research Corporation annual reports are years behind schedule and technical reports are never published such that an improvement could only come about

with the strengthening of the information unit of the Agricultural Research Corporation and its linkages to extension.

Research and extension need to identify periods in which scarce water supplies exceed demand, and to devise cropping patterns that reduce underutilization of irrigation water to a minimum. The extension service lacks material, and both technical and communication skills. The low morale, low investment, and low pay leads to low performance. There is a need for resources, clear messages and a good program management system if the extension services is to enhance productivity and promote equity.

4.12 PRODUCE MARKETING

The whole of the cotton crop is delivered to the Board, where it is marketed by the Sudan Cotton Company (SCC), a parastatal company. Cotton prices are announced just before harvest, returns are to be paid out soon after harvest to effect cotton production but delays in payment are very common. The cotton price committee sets the prices according to variety, weight and grade. Tenants deliver the seed cotton to the collection centers then the Board transports it to the ginnery where a minimum of 1,500 sacks are required for an introduction into the ginnery. The Board operates 13 ginneries with a total production capacity of 900 tons of lint. Losses in the collection centers and ginnery compounds are very high.

The Sudan cotton company allocates 10 percent of the lint to the local textile mills that operate at 30 percent capacity because of shortages in power, spare parts and skilled manpower. The rest of the lint is transported to Port Sudan for export. The market has shifted from long to medium-staple cotton. There have been losses in the traditional

markets due to the problems of honey dew, and India and China have emerged from being net importers to net exporters of long-staple cotton.

Wheat is delivered to the Board against prices set by the Government. The tenant is only allowed to keep three sacks for every five feddan hawasha and is free to sell them in the open market. The government sets the prices for the wheat delivered to the mills and these prices are highly subsidized.

Sudan imports 80 percent of its total wheat supplies. 90 percent of wheat is distributed through official channels and 80 percent of the imports are on concessional terms. Wheat is available to urban consumers at low subsidized prices. Bread has displaced sorghum bread (Kisra) as the main staple and consumption of bread has been rising at about 7 percent a year since 1971 (World Bank, 1990a). Sudan has been unable to afford to import the increasing amounts of wheat. Similarly, reducing the gap between demand and supply through domestic production will be extremely difficult unless these are radical improvements in production and management at the Gezira Scheme. Wheat prices at the mills are set at LS 463 per metric ton. Millers supply at LS 689.14 per metric ton at the mill. They charge LS 300 per metric ton for bran. At an extraction rate of 80 percent, millers receive LS 110 per wheat plus revenue from bran sales. Flour is allocated to authorized bakeries at a controlled price (of LS 689.14 per metric ton in 1988). Baking costs of LS 54 per 120 Kg sack are allowed and bread is sold at official price and weight. The price of a 160 gm loaf has risen from LS 0.15 in 1988 to LS 0.24 in 1990 but the weight has fallen to 126 gm.

Tenants market the groundnuts and sorghum privately. The Ministry of Agriculture sets floor prices but the actual farm prices are determined by market conditions. Profits and margins depend predominantly on the trader's negotiating power,

the size of the market and the degree of competition. Sorghum in the Gezira is for subsistence consumption and enters the market only when there is marketable surplus or pressing household cash needs. It is sold in small quantities through informal household transactions. Lack of transport, storage, grading and financing limit groundnut marketing. Tenants sell their product at harvest time. Information on the market situation on a timely basis is lacking, even if information on prices was available; the product cannot be moved easily from low price to high price markets.

CHAPTER V

CHARACTERISTICS OF THE SURVEY TENANT HOUSEHOLDS

This chapter describes the household characteristics of the survey tenants. The main discussion covers the uses of land, labor and capital, and crop enterprise budgets. The information contained in this chapter forms the foundation of the domestic resource cost ratio computation presented in chapter VI, and the linear programming model presented in chapter VII.

5.1 REPRESENTATIVE FARM

Marshall (1920) defines a representative firm as "an average firm which we need to look into in order to see how the economics of the aggregate are performing". However, we need to exercise some caution since a representative firm might not reflect the aggregate of firms or households. Say (1963) questions the extent to which the component firms have to be similar in order for a single model to represent the aggregate of the individual decision problems without much distortion.

We do experience aggregation bias because all the farms are not exactly alike. Ideally, a model should be constructed for every individual farm, and all the individual models linked together to form the subsector model. However, it is not practical to model each individual farm, so the subsector model must be based on representative farms. The representative farm approach involves classifying the universe of farms into smaller numbers of homogeneous groups, and constructing a model for a representative farm from each group. The farms should have equal access to the same production technologies.

Say (1963) in Hazell and Norton (1986) shows that in order to avoid aggregation bias, farms grouped together have to satisfy three conditions:

1. Technological homogeneity - Each farm must have the same production possibilities, resource types and constraints, level of technology, and level of managerial ability.

2. "Pecunious" proportionality - Individual farmers in a group hold expectations about unit activity returns that are proportional to average expectations.

3. Institutional proportionality - The constraint vector of programming model for each individual farm should be proportional to the constraint vector of the average farm.

We can apply less stringent conditions based on the underlying reasoning that an optimal solution to a linear programming problem can be stable even when many of the coefficients are perturbed, i.e., there is a range for each coefficient over which it can be varied without inducing a change in the optimal basis. Buckwell and Hazell (1972) suggest grouping farms in agroclimatically similar areas and by the type of products produced to ensure a reasonable degree of conformity to Say's requirements of technological and pecunious homogeneity.

Collinson (1983) has discussed three alternative techniques for deriving representative farms. The alternative techniques are:

1. The identification of a particular farm as typical.
2. The use of an "average farm" (derived from the means of resources, input-output and net price coefficients of a sample of farms) as a representative farm.
3. The synthesis of a "typothetical" or composite farm from different components of the population.

An identification of a typical farm unit requires the consideration of a wide range of criteria but the selection of the criteria themselves may be difficult because data may

be unavailable or difficult to collect. The use of "average farm" brings with it the problem of aggregation bias that exists when the sum of the solutions from the individual farms in the set does not equal the estimate obtained by the optimum solution to the entire set directly. The synthesis of a composite farm reduces the aggregation bias but its practical weakness is that it is difficult to identify several institutional variables and human factors and their distributions within the population. These factors include institutional constraints, motivations, preferences and managerial ability that have an important impact on farm organization, product efficiency and farm earnings.

Choosing a "model farm" depends on the purpose for which the results of the study will be used. The purpose of this study is to identify resource constraints and farm adjustments and to estimate farmers' responses to input and output price changes such that the problems of aggregation bias and their control are not relevant, and there is justification for the use of the "average farm" approach. We can speak of a Gezira model farm because there is homogeneity with respect to important variables such as soils, climate, topography, input availability, management; and sociocultural setting. The information includes size of holding, mode of operation, availability of family labor, circulating capital, informal credit and subsistence needs. Much of the discussion that follows is based on the 1989/90 farm survey.

5.2 LAND USE

Table 5.1 presents the land use of an average Gezira tenancy. The mean tenancy area is 23.6 feddans per family. There appears to be little variation in the mean size of holding as 80 percent of tenants possess 20 feddans each, 17 percent have 40 feddans each, 2 percent 28 feddans each and only 1 percent has 18 feddans. The land was

allocated as follows: cotton, 5.9 feddans; wheat, 5.9 feddans; sorghum, 5.3 feddans and fallow, 6.5 feddans. Only 10 farmers cultivated groundnuts giving a mean area of 2.8 feddans. Three farmers in the Loata block did not cultivate any crops because the minor canal was covered with silt and weeds and could not convey water to their tenancies. A small fraction of the land under fallow was grown with vegetables.

The cropping intensity is 51 percent which falls short of the planned cropping intensity of 75 percent for the main Gezira. The main reason for the disparity is due to shortages of water, operating capital and other production inputs. Ninety two percent of the tenants stated that the size of their tenancies was adequate. However, the majority of tenants would like the Board to relax the institutional controls it imposes and allow them to choose their own crop mix. The choice would be dictated by product prices, crop labor requirements, duration of land occupation and the availability of produce marketing. The majority of the tenants prefer to cultivate more sorghum which is the major staple food that provides food security, in-kind payment for laborers, and stalks for building shelters and animal feed.

TABLE 5.1 LAND USE OF AN AVERAGE GEZIRA TENANCY, 1989/90.

CROP \ BLOCK	TAYBA		WAD NUMAN		TURIS		LOATA	
	No.	Fed.	No.	Fed.	No.	Fed.	No.	Fed.
Fallow		8.3		7.0		8.1		17.2
Cotton	21	5.9	18	5.6	17	5.9	10	6.5
Wheat	21	5.9	21	5.6	17	5.6	9	6.6
Groundnuts					8	3.0	2	2.0
Sorghum	22	3.5	21	5.4	23	5.1	20	6.2

Source: Computed from survey data.

Forty six percent of the tenants practice sharecropping, the majority of whom sharecrop sorghum. Three of the ten farmers who cultivated groundnuts sharecropped. A small percentage sharecrop cotton but wheat is not sharecropped because the Board picks up most of the production costs. The general conditions of sharecropping are: the tenant provides land and seeds and the sharecropper performs agricultural operations. The produce is divided equally between them. There are three reasons for sharecropping: l) it overcomes cash shortage and low supply of family labor; 2) it frees tenants to pursue off-farm activities; and 3) the household of the sharecropper becomes a potential source of wage labor for the rest of the tenancy.

Table 5.2 presents the yield performance under research and tenant conditions. The wide yield gap can be attributed to bad management of production resources on the farm. Crop trials at Gezira research station demonstrated that early sowing, furrow irrigation, shorter length of irrigation and pre-irrigation lead to significant improvements in yield.

Table 5.3 shows that the average yields vary from block to block depending on the level of management and water supply in the season. The factors affecting farm management include land preparation, sowing date, weeding, pests and diseases.

5.3 WATER USE

Supply and demand for irrigation water at the farm level is determined by canal capacity, crop water requirements, sowing dates and areas under individual crops. The crop water requirements are determined by a traditional uniform rate of 30 cubic meters per feddan per day excluding losses on transit. This corresponds to the traditional Gezira schedule of 420 cubic meters per irrigation per feddan at a two-week watering interval,

TABLE 5.2 CROP YIELDS UNDER RESEARCH AND TENANT CONDITIONS.			
CROP	UNITS	RESEARCH	TENANT
Cotton MS	Kan/Fed	12.0	6.8
Cotton LS	Kan/Fed	7.4	4.5
Wheat	Kg/Fed	1,000	550
Groundnuts	Kg/Fed	1,440	750
Sorghum	Kg/Fed	900	450
Source: Compiled from survey data.			

TABLE 5.3 AVERAGE YIELDS PER FEDDAN FOR SURVEY FARMS 1989/90.				
CROP \ BLOCK	TAYBA	WAD NUMAN	TURIS	LOATA
Cotton	7.1	3.1	4.1	4.2
Wheat	976	687	754	408
Groundnuts	---	---	770	923
Sorghum	790	542	355	383
Source: Computed from survey data.				

irrespective of the crop or season.

The 1989/90 cropping season gives average waterings of 11 for cotton, 7 for wheat, 7 for groundnuts and 6 for sorghum. This gives a season average of 7.8 waterings at the rate of 420 cubic meters per feddan per watering. This average is less than the traditionally stated number of average waterings of 8.4 at the rate of 420 cubic meters per feddan per watering (Faki, 1982). Groundnuts and sorghum production is supplemented by rainfall in August and September. Thirty percent of the survey tenants

TABLE 5.4 WATER REQUIREMENTS BY A 20 FEDDAN GEZIRA TENANCY					
MONTH \ CROP	COTTON	WHEAT	GROUNDNUTS	SORGHUM	TOTAL
June			420		420
July	420		420	420	1,260
August	420		420	420	1,260
September	840		840	840	2,520
October	840	420	840	420	2,520
November	840	840	420		2,100
December	840	840			1,680
January	840	840			1,680
Febuary	840	840			1,680
TOTAL	5,880	3,780	3,360	2,100	15,120
* Cubic meters of water per feddan.					
Source: Ministry of Irrigation.					

stated that they did not receive enough irrigation water, and 65 percent received some of their irrigations late. The researcher saw a sorghum crop in one 'number' along a minor canal at Wad Numan that had dried up after two irrigations because the canal was blocked with silt and weeds, and was not capable of conveying enough water.

There are two peak water demand periods under the traditional irrigation schedule; 1) July to September when cotton, groundnuts and sorghum are established in the field; and 2) October to November when cotton, wheat, groundnuts and sorghum all require irrigation. The first period is less critical because of the supplemental rainfall, which was adequate during the survey season but has been less predictable in some seasons. Problems of water logging and late sowing of crops are less critical. The second

peak demand period is more critical where irrigation was a real limiting factor. The area sown under wheat depends on the availability of water in the season.

Important aspects of irrigation management include: 1) pre-irrigation; 2) time of sowing; 3) method of water application; and 4) length of irrigation. Pre-watering has been on the decline because of lack of water and tenant interest. Crops were often sown late because of shortages in equipment with which to prepare the land and of water shortage for the first irrigation. Early crop establishment reduces the risk of interruption by the rains. The traditional method of field water application by basins promotes waterlogging. The network of cross-bunds of the "angaya" system prevents the removal of water which may stand for days. The tenants have to evacuate drains into the adjacent fallow since there is no field drainage at the lower end of the number. Late irrigation in February not only reduces land preparation for groundnuts but can introduce honeydew contamination and insect pest build-up.

5.4 FARM LABOR FORCE

5.4.1 HOUSEHOLD STRUCTURE

The average family size of the sample households was 7.3 persons. The range is from 1 to 17 persons per household; 12 percent are less than seven years old, 24 percent are eight to fifteen years and 64 percent are more than 15 years old. However, the average population is relatively young. Nineteen percent of the tenants are females. This proportion is much higher than the scheme average which is about 10 percent (Ismail and Khalid, 1989). The average age of the tenants is 50 years. 48 percent are above average and only 15 percent are less than 30 years old.

Illiteracy rate is 33 percent, "Khalwa" (Islamic school) education 41 percent, primary school 16 percent, intermediate school 7 percent and senior secondary school only 3 percent. The tenants value education such that most of them send their children to school. This is an important development as education could broaden a person's horizon thus enabling him to maximize the utilization of the scarce resources under his control leading to increases in farm productivity even though educated children tend to migrate to the urban centers or to the Gulf in search of government and private sector jobs.

The off-farm activities of the tenants are shopkeeping, trading in crops and livestock, money lending, local transport and laborers. Twenty two percent of the tenants have engaged in some form of off-farm employment. The types of work range from casual labor 20 percent, trading 27 percent, government employment 27 percent and others 26 percent. Those who work in the village are 29 percent, local towns 46 percent, Medani 12 percent and outside the Gezira 13 percent. The number of days worked ranges from 1 to 30 with about 45 percent working for the whole month. The average earnings was LS 436 per month.

5.4.2 FAMILY LABOR

Despite the large family size, very few family members are directly involved in farming activities. The average family labor available amounts to about 25 man-days per month. Thus, the available labor for any farm operation is about one person per household. When the tenant who mainly serves as a supervisor and may be involved in off-farm activities is excluded, then the amount of available labor is reduced to 15 man-days per month. Thus, not even one family member is fully engaged on the farm.

Family labor input tends to be high during the peak labor demand periods such as cotton picking in January to March. Reasons for the low family labor input are the low farm incomes and the availability of off-farm jobs. Demographic structure of the family and physical requirements of cultivation also determine the family labor input. Female members of the household are restricted to housework and there is a higher tendency among young people to move to town. Older tenants with working sons tend to supply less labor than younger tenant's. Family labor supply is also determined by the degree of mechanization and the pattern of cultivation.

Total average family labor as a percentage of total labor is 35 percent. Family labor contribution for the different crops is as follows: cotton 33 percent, wheat 49 percent, groundnuts 25 percent and sorghum 33 percent.

5.4.3 HIRED LABOR

Gezira tenants depend on hired labor for their farming activities. Labor is secured from labor camp settlements outside the village or through direct recruitment in western Sudan. Labor demand is throughout the season and is high during weeding and harvesting periods.

The 1989/90 survey reveals that 42 percent of the laborers are of local origin, 44 percent are from Western Sudan and the remaining 14 percent are from other regions of the Sudan and West Africa. Thirty percent of the tenants did not have enough labor.

The derivation of the labor coefficients was based on the 1989/90 survey data. The labor requirement for a given crop was derived as follows: records of the number of days spent on each of the crops each month were kept; when an operation overlaps a two-month period an estimate of the monthly labor distribution is used to allocate the

labor. The estimated total number of days each month were divided by the number of households per month. This yields the crop labor requirements in man-day per month.

The average coefficient per feddan was obtained by dividing the total number of days spent on an enterprise within a month by the total area of land in feddans allocated to the enterprise in question. The calculation was done for all crop production activities. Table 5.5 presents the crop labor requirements in Man-days per month per feddan in the main Gezira scheme.

Peak labor demand periods were the months of July, August, October, November, December and January. Labor costs which tend to vary with the activity and crop, are highest during these periods because both weeding and harvesting are tedious operations. Labor wage rates have been rising sharply during the last ten years, due perhaps to competition from new irrigation schemes, the mechanized subsector and the urban informal sector. The usual practice for a son over 18 years old is to receive wages for work performed on the farm, at a compensation equal to the prevailing market wage rate.

Labor hiring takes place throughout the season and its availability is constrained by operating capital. There are about 50 man-days of available labor per month that rises to 115 man-days in January, February and March due to the arrival of cotton pickers from Western Sudan.

5.5 FARM CAPITAL

Capital in farming refers to man-made assets that are produced for the purpose of being used in the process of agricultural production. It includes items such as machines, tools, roads, livestock, seeds, fertilizers, insecticides and herbicides. Capital

TABLE 5.5 MONTHLY CROP LABOR REQUIREMENTS, Md/Fed 1989/90.

MONTH \ CROP	COTTON	WHEAT	GROUNDNUTS	SORGHUM	TOTAL
June	1.6		2.5	0.6	4.7
July	2.7		7.6	3.3	13.6
August	4.4		6.1	4.1	14.6
September	5.4		2.5	0.8	8.7
October	1.3	0.8	1.8	6.4	10.3
November	1.1	7.6	4.5	3.1	10.3
December	3.7	1.1	8.8	0.5	14.1
January	7.4	0.8	5.7		13.9
February	7.3	0.6	0.9		8.8
March	5.1	1.1			6.2
April	2.9	0.5			3.4
May	2.2				2.2
TOTAL	45.1	6.5	40.4	20.5	112.5

Source: Computed from survey data.

assets are classified according to the length of their productive life into fixed capital and operating capital. Fixed capital consists of items with a production life that extends beyond one production cycle while operating capital consists of production items such as seeds and fertilizers that are used up in a single production cycle. The Gezira tenants have a low level of fixed assets. All tenants have hand tools and 66 percent keep some animals in their backyard. There are no buildings on the farm and there is limited storage space in the villages.

Operating capital items such as seeds, fertilizer and labor are purchased inputs and their use entails cash expenditures. The Sudan Gezira Board, personal savings,

livestock sales, credit from private moneylenders and remittances from relatives working abroad are the main sources of operating capital. Low levels of farm incomes restrict the level of savings. Institutional credit is non-existent although the Board prefinances most of the production costs for wheat and cotton. The local moneylenders charge high rates of interest for their financial services resulting in the tenants becoming indebted.

Table 5.6 presents cash expenditures of a representative 20-feddan Gezira tenancy on input purchases per month per crop. These are the actual Sudanese pounds spent on land preparation, labor and material inputs during the 1989/90 cropping season.

TABLE 5.6 CASH EXPENSES OF A GEZIRA MODEL FARM, 1989/90.

MONTH	COTTON MS	COTTON LS	WHEAT	PEANUTS	SORGHUM	TOTAL
Jun	281	281		172	66	800
Jul	61	25		103	54	243
Aug	61	45		93	79	278
Sep	236	236	177	10	67	726
Oct	489	189	101	10	85	874
Nov	10	466	163	316	119	1,074
Dec	210	15	30	24	115	394
Jan	150	205	10	104		573
Feb	270	175	20			465
Mar	180	350	200			730
Apr	240	260	156			656
May	157	157				314
TOTAL	2,345	2,404	857	832	689	7,127

Source: Computed from survey data.

The total cash expenses amounted to about LS 7,150. Cotton production is the most expensive followed by wheat, groundnuts and sorghum, respectively. The major cost items include land preparation, cultural operations, material inputs, harvest and others like services and land and water rates. The financial analysis enables us to compare the competitiveness of the crops grown in the main Gezira by their return to the operating costs of land, labor and irrigation water at the farm level.

5.6 PRODUCTION TECHNOLOGY

Table 5.8 presents two intensity levels specified for each of the crop enterprises. The first intensity level yields approximates the conditions that prevail in the main Gezira in the 1989/90 cropping season. Yields for this level are the average yields obtainable for five years, 1984/85-1988/89. The second intensity level involves the use of improved seed varieties, better land preparation, application of chemical fertilizers, pesticides and insecticides, better incentive structures and a strong research support. The potential yields for cotton and wheat could be attainable if farmers did not divert fertilizers to their sorghum crop. Yield assumptions for intensity level 2 are based on Gezira research station field trial results for all the crops. The highest yield trial results were excluded and 20 percent deducted in order to arrive at a moderate estimate concerning possible increases in crop yields attainable under the farm management conditions of the tenants. The trial results indicate that higher doses of fertilizer for cotton and wheat, and the application of fertilizer in groundnuts and local sorghum, show potential for increasing yields of all crops even further. Yields higher than those in intensity level 2 reflect an optimistic scenario that can only occur with significant improvements in agricultural research, delivery of research results and a proper structure

TABLE 5.7 FARM GATE PRICES IN THE GEZIRA, 1987/88 - 1989/90.				
CROP \ PERIOD	UNIT	1987/88	1988/89	1989/90
Cotton MS	LS/Kan	235	378	530
Cotton LS	LS/Kan	290	645	740
Wheat	LS/Kg	1.0	2.4	3.0
Groundnuts	LS/kg	1.4	1.4	2.8
Sorghum	LS/Kg	1.2	1.4	2.9
Source: Compiled from survey data.				

TABLE 5.8 AVERAGE CROP YIELDS IN THE MAIN GEZIRA.			
CROP	UNIT	INTENSITY 1	INTENSITY 2
Cotton MS	Kan/Fed	6.8	6.4
Cotton LS	Kan/Fed	4.5	5.8
Wheat	Kg/Fed	650	850
Groundnuts	Kg/Fed	750	1,200
Local sorghum	Kg/Fed	500	750
Hybrid sorghum	Kg/Fed	1,200	1,600
Source: Compiled from survey data.			

of incentives that could encourage tenants to adopt new technology.

5.7 ENTERPRISE BUDGETS

Enterprise budgets are estimates of costs and returns expected from crop or livestock enterprises. They contain information for the allocation of resources among the alternate crop enterprises and alternate uses. An enterprise budget is an estimate of the

costs of production per unit of land. Having the budgets on per feddan basis makes them easier to use in farm planning. Farm level decision makers need estimates about the profitability of alternatives. Enterprise budgets have value to many users other than farm level decision makers; for instance, lenders can use enterprise budgets to evaluate the viability of proposed farm investments, and farm policy analysts can use the information to determine the expected impact of policy alternatives.

This study uses the approach of average costs and returns that reflect the conditions of a typical 20-feddan Gezira tenancy. Tenants do not posses fixed assets, do not incur fixed costs nor pay water and land charges for land not brought under production.

Table 5.9 shows the division of responsibility over farm operations between the Board and the tenants. The Board determines areas, varieties, cultural practices, and cropping calendars. It also participates in some of the farm operations like land preparation and provides inputs for cotton and wheat.

Tables 5.10 to 5.15 present the gross margins per feddan for medium-staple cotton, long-staple cotton, wheat, groundnuts and sorghum. The operating costs tenants have to incur are for: 1) land preparation - plowing, levelling, split ridging, opening of irrigation canals, cross ridging and disk harrowing; 2) cultural operations - sowing, weeding, green ridging, thinning, canal cleaning and irrigation; 3) material inputs - seeds, fertilizers, insecticides, and sacks and strings; 4) harvest - local transport, picking, packing, stalk pulling and transport; and 5) other items -transport, services and land and water rates.

Table 5.10 shows the enterprise budget for two intensity levels of medium-staple cotton. The operating costs that rise with yields are for fertilizers, herbicides, sacks,

TABLE 5.9 BOARD AND TENANT RESPONSIBILITIES ON FARM OPERATIONS				
FARM OPERATIONS	COTTON	WHEAT	GROUNDNUTS	SORGHUM
LAND PREPARATION	B	B	T	T
CULTURAL PRACTICES	T	T	T	T
HARVEST OPERATIONS	T/B	B	T	T
INPUTS	B	B	T	T
TRANPORT	T/B	B	T	T
T = Tenant B = Board T/B = Tenant/Board				
Source: Compiled from Survey data.				

TABLE 5.10 ENTERPRISE BUDGET FOR MEDIUM-STAPLE COTTON.			
FARM OPERATIONS	UNIT	INTENSITY 1	INTENSITY 2
Yield	Kan/Fed	6.8	8.4
Price	LS/Kan	530	530
REVENUE	LS/Fed	3,604	4,452
LAND PREPARATIONS	LS/Fed	281	281
CULTURAL PRACTICES	LS/Fed	343	343
MATERIAL INPUTS	LS/Fed	559	764
HARVEST	LS/Fed	840	976
OTHER ITEMS	LS/Fed	322	344
TOTAL COST	LS/Fed	2,345	2,708
GROSS MARGIN	LS/Fed	1,259	1,744
Source: Computed from survey data.			

picking, packing, transport and services. Intensity level 1 costs LS 2,345 per feddan and gives a return of LS 1,259. Intensity level 2 costs LS 2,708 per feddan and gives a return of LS 1,744 per feddan.

Table 5.11 shows the enterprise budget for two intensity levels of long-staple cotton. The operating costs that rise with yields are for fertilizers, herbicides, sacks, picking, packing, transport and services. Intensity level 1, costs LS 2,404 per feddan and gives a return of LS 1,106 and intensity level 2 costs LS 2,832 per feddan and gives a return to operating capital of LS 1,692 per feddan.

Table 5.12 shows the enterprise budget for two intensity levels of wheat. The operating costs that rise with yields are for fertilizers, sacks, harvesting, transport and services. Intensity level 1, costs LS 857 per feddan and gives a return of LS 1,093 and intensity level 2 costs LS 1,142 per feddan and gives a return to operating capital of LS

TABLE 5.11 ENTERPRISE BUDGET FOR LONG-STAPLE COTTON.

FARM OPERATIONS	UNIT	INTENSITY 1	INTENSITY 2
Yield	Kan/Fed	4.5	5.8
Price	LS/Kan	740	740
REVENUE	LS/Fed	3,510	4,524
LAND PREPARATION	LS/Fed	281	281
CULTURAL PRACTICES	LS/Fed	353	353
MATERIAL INPUTS	LS/Fed	653	859
HARVEST	LS/Fed	810	1,005
OTHER ITEMS	LS/Fed	307	334
TOTAL COST	LS/Fed	2,404	2,832
GROSS MARGIN	LS/Fed	1,106	1,692

Source: Computed from Survey data.

TABLE 5.12 ENTERPRISE BUDGET FOR WHEAT.			
FARM OPERATIONS	UNIT	INTENSITY 1	INTENSITY 2
Yield	Kg/Fed	650	850
Price	LS/Kg	3.0	3.0
REVENUE	LS/Fed	1,950	2,550
LAND PREPARATION	LS/Fed	177	177
CULTURAL PRACTICES	LS/Fed	90	90
MATERIAL INPUTS	LS/Fed	254	441
HARVEST	LS/Fed	120	185
OTHER ITEMS	LS/Fed	216	249
TOTAL COST	LS/Fed	857	1,142
GROSS MARGIN	LS/Fed	1,093	1,408
Source: Computed from survey data.			

TABLE 5.13 ENTERPRISE BUDGET FOR GROUNDNUTS.			
FARM OPERATIONS	UNIT	INTENSITY 1	INTENSITY 2
Yield	Kg/Fed	750	1200
Price	LS/Kg	2.8	2.8
REVENUE	LS/Fed	2,100	3,360
LAND PREPARATION	LS/Fed	65	65
CULTURAL PRACTICES	LS/Fed	259	259
HARVEST	LS/Fed	288	359
MATERIAL INPUTS	LS/Fed	92	372
OTHER ITEMS	LS/Fed	128	137
TOTAL COST	LS/Fed	832	1,192
GROSS MARGIN	LS/Fed	1,268	2,168
Source: Computed from survey data.			

1,408 per feddan.

Table 5.13 shows the enterprise budget for two intensity levels of groundnuts. The operating costs that rise with yields are for fertilizers, sacks, harvesting, threshing and transport. Intensity level 1, costs LS 832 per feddan and gives a return of LS 1,268 and intensity level 2 costs LS 1,192 per feddan and gives a return to operating capital of LS 2,168 per Feddan.

Table 5.14 shows the enterprise budget for two intensity levels of local sorghum. The operating costs that rise with yields are for fertilizers, sacks, harvesting, threshing and transport. Intensity level 1, costs LS 689 per feddan and gives a return of LS 761 and intensity level 2 costs LS 958 per feddan and gives a return to operating capital of LS 1,217 per Feddan.

Table 5.15 shows the enterprise budget for two intensity levels of hybrid sorghum. The operating costs that rise with yields are for fertilizer, sacks, harvesting and transport.

TABLE 5.14 ENTERPRISE BUDGET FOR LOCAL SORGHUM.

FARM OPERATIONS	UNIT	INTENSITY 1	INTENSITY 2
Yield	Kg/Fed	500	750
Price	LS/Kg	2.9	2.9
REVENUE	LS/Fed	1,450	2,175
LAND PREPARATION	LS/Fed	66	66
CULTURAL PRACTICES	LS/Fed	215	211
MATERIAL INPUTS	LS/Fed	43	254
HARVEST	LS/Fed	221	263
OTHER ITEMS	LS/Fed	144	164
TOTAL COST	LS/Fed	689	958
GROSS MARGIN	LS/Fed	761	1,217

Source: computed from survey data.

TABLE 5.15 ENTERPRISE BUDGET FOR HYBRID SORGHUM.			
FARM OPERATIONS	UNIT	INTENSITY 1	INTENSITY 2
Yield	Kg/Fed	1,200	1,600
Price	LS/Kg	2.3	2.3
REVENUE	LS/Fed	2,760	3,680
LAND PREPARATION	LS/Fed	66	66
CULTURAL PRACTICES	LS/Fed	211	211
MATERIAL INPUTS	LS/Fed	221	449
HARVEST	LS/Fed	375	450
OTHER ITEMS	LS/Fed	224	264
TOTAL COST	LS/Fed	1,097	1,440
GROSS MARGIN	LS/Fed	1,663	2,240
Source: Computed from survey data.			

Intensity level 1, costs LS 1,097 per feddan and gives a return of LS 1,663 and intensity level 2 costs LS 1,440 per feddan and gives a return to operating capital of LS 2,240 per feddan.

Table 5.16 shows crop costs, revenue and net income for the 1989/90 cropping season. The main components of an enterprise budget are expected revenue, costs, and net returns. The production quantities and prices are indicative of what would occur on a typical Gezira farm. The yields are the long term average yields and the prices are the farmgate prices for the scheme. We multiply the yield with the price in order to get the revenue for the enterprise. In the operating inputs section, all the costs of the inputs per feddan are estimated and subtracted from the revenue to give the gross margin per feddan or the return to total operating costs. This returns figure is good for short term planning.

TABLE 5.16 CROP COSTS, REVENUE AND NET INCOMES, 1989/90.						
CROP	GROSS REVENUE		TOTAL COST		GROSS MARGIN	
INTENSITY	1	2	1	2	1	2
Cotton MS	3,604	4,452	2,345	2,708	1,259	1,744
Cotton LS	3,510	4,524	2,404	2,610	1,106	1,692
Wheat	1,950	2,550	857	1,142	1,093	1,408
Groundnuts	2,100	3,360	832	1,192	1,268	2,168
Sorghum	1,450	2,175	689	958	761	1,217
Source: Computed from survey data.						

These figures show that an adoption of a new technology will lead to significant increases in yield. Medium-staple cotton gives a return of LS 1,744 per feddan, long-staple cotton LS 1,692 per feddan, wheat Ls 1,408 per feddan, groundnuts LS 2,168 per feddan, and sorghum LS 761 per feddan.

CHAPTER VI

COMPARATIVE ADVANTAGE FOR GEZIRA CROPS

6.1 COMPARATIVE ADVANTAGE

Policy reforms designed to take advantage of comparative advantage in the 1980's in the developing countries include reduction of state participation in agriculture, liberalization of commodity trade, freeing of market forces to play a role in directing economic activity along efficiency lines, and cost-effective allocation of agricultural research funds (Morris, 1988).

Ricardo (1817) extended the optimization principle to define efficient choice of output by firms into the arena of international trade. He pointed out that a country can achieve net welfare gains by concentrating productive capacity on goods and services of which it is relatively an efficient producer and trading for the rest.

The domestic resource cost ratio is a measure of relative economic efficiency of productive resources that indicates production alternatives to the national income. We need to determine the set of alternative enterprises that are relatively more efficient. Relative efficiency (comparative advantage) depends on: 1) technology which determines production possibilities and influences rates of product transformation; 2) resource endowment which determines the value of domestic resources (land, labor, capital and water); 3) and world prices which determine the value of all inputs and outputs.

The economic efficiency measures have to be used with caution because they are sensitive to: 1) the specification of yields and world price levels that may not reflect long

run averages; 2) differences in regional border price equivalents and transportation costs; 3) the cost of nontraded inputs in domestic markets; and 4) the choice of exchange rate for the valuation of border prices.

The domestic resource cost ratio for a commodity is given by the following equation (Youngblood, 1983):

$$\text{The DRC} = \frac{D - V}{(PY - M)X}$$

where: D = Value of the domestic resources used in the production of the commodity (LS/feddan)

V = Value of any joint product (LS/feddan)

P = Border price of the commodity ($/unit of output)

Y = Yield of the commodity (Output/Feddan)

M = Value of traded inputs used in the production of the commodity ($/feddan)

X = Real exchange rate

It can be seen that the numerator is the cost of the purely domestic inputs and resources; and the denominator is the net foreign exchange earnings or net potential foreign exchange earnings. If the domestic resource cost ratio is less than one, the country has a comparative advantage in the production of the particular commodity because it can exchange domestic resources for foreign exchange at a rate below that at which the economy as a whole converts the domestic resources into foreign exchange. If the domestic resource cost ratio is more than one, it indicates that the cost of the domestic resource used in the production of a given commodity are more than the foreign exchange saved and hence it is not an efficient use of the resource to produce that commodity. This implies comparative disadvantage in the production of the commodity.

The main uses of DRC ratios are: 1) revelation of differences between private and social profitability; 2) comparative advantage between different crop enterprises, regions and technologies; and 3) setting agricultural research priorities.

6.2 THE EFFECTS OF POLICY

The calculation of economic profitability of crops is closely related to the measurement of the effects of economic policy. Crop profitability is looked at from the point of view of the nation using economic prices rather than from the point of view of the tenant or government budget using financial prices. A combination of trade restriction, price control, tax, subsidy, or exchange rate policies can cause divergences between financial and economic prices. If the financial prices are higher than market prices, then consumers have to pay higher than world price or the government treasury must subsidize the commodity. The tax system exerts both direct and indirect effects on exports, imports and domestic production. Taxes drive a wedge between supply and demand thus creating disincentives.

Since Sudan has no market power in respect to most agricultural commodities, macroeconomic and commodity policies have no significant effect on world prices and economic valuation of tradable commodities. An overvalued exchange rate depresses the prices of tradables relative to those of non-tradables and acts as a tax on all tradable activities and a subsidy on imports. Imports of petroleum products would be cheaper and exports of cotton would be more expensive. However, the tax effect on exports may be offset by the subsidization effect on the inputs. If the government employs a fixed exchange rate and chooses fiscal and monetary policies that permit rates of inflation higher than the average rate experienced in its trading partner countries, and changes

the exchange rate sufficiently to offset the loss of international competitiveness caused by the differential inflation, then the exchange rates will cause the financial prices of tradables to be higher or lower than efficiency levels in a manner that is directly analogous to the use of a trade restrictive policy for a given input or output (Jansen, 1986).

The economic prices of domestic factors are given by the determination of opportunity costs, which are reflective of the underlying supply and demand conditions in domestic factor markets. An enactment of tax or subsidy policies on any factor of production (land, labor and capital) creates a divergence between financial costs and economic costs resulting in a subsidy/tax to the system. Factor price policies (credit, subsidies, rationing, minimum wage and wage freeze laws) can cause financial factor costs to exceed or fall short of comparable opportunity costs. Consequently, financial profitability can be greater than, less than, or equal to economic profitability depending on whether the net effects of commodity and macroeconomic policy are subsidization, taxation or neutrality.

6.3 REVIEW OF COMPARATIVE ADVANTAGE STUDIES

6.3.1 Sattar (1982) calculated the coefficient of foreign exchange dependence, coefficient of international competitiveness and coefficient of private profitability for medium-staple cotton, long-staple cotton, wheat, groundnuts and sorghum grown in the Gezira in the 1980/81 cropping season. Table 6.1 presents these coefficients. The coefficient of foreign exchange dependence and the coefficient of international competitiveness are important indicators for national crop policy formulation. The coefficient of private profitability is of primary interest to the individual producer who

can only produce when the coefficient is favorable. The coefficient of private profitability represents local or regional economics of production and can therefore be in conflict with the other two coefficients.

The coefficient of foreign exchange dependence (CFED) is the percentage proportion of border value of one feddan's output of a crop which is used up in its production as a payment for imported inputs. The lower this coefficient is for a product the greater is its positive contribution to the balance of payments. It also indicates the extent to which the production of a crop would be sensitive to disruptions in imports or domestic distribution of imported inputs. Wheat has the highest (126) and groundnuts the lowest coefficient of foreign exchange dependence (32).

The coefficient of international competitiveness (CIC) represents the number of units of international value added by export or saved by substituting a local good for an import per unit of domestic resources used in its production. The coefficient of international competitiveness is a ratio of domestic resource costs of producing one feddan of a crop to the international value added from its production. The negative coefficient for wheat means that there is an outflow of foreign exchange because the cost of traded inputs in domestic production is more than border value of output, resulting in negative international value added.

The coefficient of private profitability (CPP) is the ratio of production costs to the value of a product at the producer level. The degree of profitability of the product is indicated by the magnitude of the coefficient above or below 1.00. A coefficient of less than 1.00 indicates that it is not profitable for the producer to produce the crop for the market at the prevailing yields and producer prices. Because of low yields, wheat and

sorghum were the only profitable crops in the 1980/81 cropping season. The coefficient of private profitability is of primary interest to the individual producers.

6.3.2 Youngblood and Leonard (1983) analyzed the sensitivity of foreign exchange dependence, value added, domestic resource cost, and private profitability indicators on changes in yields, input costs, border and producer prices and exchange rates.

Table 6.2 presents the values of the four indicators. Wheat has comparative disadvantage, lowest value added, and highest foreign exchange dependence, but it is the least unprofitable to the producers. Groundnuts shows the best comparative advantage, third highest value added and least foreign exchange dependence. Long-staple cotton shows the highest value added and low foreign exchange dependence but it is not profitable to the producers.

6.3.3 Jansen (1989) built a model for analyzing crop profitability in the Sudan. She estimated domestic resource cost ratios for all the major crops.

TABLE 6.1 COEFFICIENTS OF DEPENDENCE, COMPETITIVENESS AND PROFITABILITY, 1980/1981.

CROP \ COEFFICIENT	1. CFED	2. CIC	3. CPP
Cotton MS	42	1.19	0.75
Cotton LS	43	1.26	0.77
Wheat	126	-0.46	1.08
Groundnuts	32	1.35	0.62
Sorghum	37	1.20	1.26

1. CFED = Coefficient of foreign exchange dependence.

2. CIC = Coefficient of international competitiveness.

3. CPP = Coefficient of private profitability.

Source: Sattar, 1982.

TABLE 6.2 DOMESTIC RESOURCE COST, VALUE ADDED, DEPENDENCE, PROFITABILITY COEFFICIENTS, 1983.

CROP \ INDICATOR	1. DRC	2. VA	3. CFED	4. CPP
Cotton MS	0.88	156.8	0.40	0.71
Cotton LS	0.91	173.5	0.38	0.72
Wheat	1.05	26.3	0.59	0.97
Groundnuts	0.86	102.4	0.29	0.76
Sorghum	0.94	49.0	0.33	0.76

1. DRC = Domestic resource cost ratio.

2. VA = Value added.

3. CFED = Coefficient of foreign exchange dependence.

4. CPP = Coefficient of private profitability.

Source: Youngblood and Leonard, 1983.

Table 6.3 summarizes her economic analysis for the 1988/89 cropping season for medium-staple cotton, long-staple cotton, wheat, groundnuts and sorghum grown in the Gezira using economic prices for crop inputs and outputs. The first line shows world prices, fob Port Sudan in US cents per pound. The second line indicates the yield assumption used in the analysis in Kg per feddan (Kantars per feddan for cotton). Lines 3-5 present net revenue per feddan, production costs per feddan and profits per feddan. Border-equivalent prices are used to calculate crop revenues. Lines 6-8 present government floor price, the border-equivalent price and production costs on a per metric ton or per kantar basis. Lines 9-11 provide a comparison of these variables: floor price as a percent of border-equivalent price, floor price as a percentage of production costs, and finally border-equivalent price as a percentage of production costs, respectively. Line 12 presents the domestic resource cost ratios which are the ratios of domestic resource costs to international value added.

Jansen (1989) presented her domestic resource cost ratios for the 1989/90

TABLE 6.3 SUMMARY OF ECONOMIC VALUE CALCULATIONS, 1988/89.

VARIABLE \ CROP	COTTON MS	COTTON LS	WHEAT	PEANUTS	SORGHUM
Exchange rate (LS/$)	9.00	9.00	9.00	9.00	9.00
1 World price fob Port Sudan 1/	0.50	0.80	194	550	115
2 Yield, (Kg/Fed) 2/	6.00	4.50	500	600	500
3 Border-Equiv Revenue/Fed LS 3/	2,142	2,877	1,014	1,169	320
4 Production Costs per Fed, (LS)	2,300	2,337	750	913	591
5 Profit/Fed (LS)	(-158)	540	264	256	(-271)
6 Government floor (F) Price 4/	337	535	NA	NA	NA
7 Border Equivalent Price 4/	357	639	2,027	2,784	639
8 Prod Costs (LS/Mt) 4/	383	519	1,501	1,521	1,182
9 F Price % Border Equiv Price	94%	84%	NA	NA	NA
10 F Price % Production Costs	88%	103%	NA	NA	NA
11 Border Equiv P % Prod Costs	93%	123%	135%	183%	54%
12 DRC Ratios 5/	1.09	0.77	0.52	0.76	2.18

1/ All are fob Port Sudan, US $/Mt Except Cotton which is US cents/lb and wheat which is cif Port Sudan.

2/ Cotton yield in Kantars (143 Kg) per Feddan.

3/ Border-Equivalent net revenue assumes both lint and cottonseed oil and cake are exported.

4/ Unit varies by crop, but is same for floor price, border-equivalent price and production costs.

5/ DRC is the ratio of domestic resource costs to international value added in Sudanese pounds calculated using economic prices.

Source: Jansen, 1989.

cropping season calculated at a shadow exchange rate of LS 9/$. If the domestic resource cost ratio is less than one at the shadow exchange rate, we can conclude that Sudan has a comparative advantage in the production of a particular crop. On the other

hand, if the domestic resource cost ratio is greater than one at the shadow exchange rate, we can conclude that Sudan does not have a comparative advantage in the production of the particular crop. The profitability calculations indicate what the profitability to the farmer would be if he/she were able to export the crop at the estimated world price, less the estimated marketing costs from Port Sudan to the farmer's region. In the case of wheat, it indicates the revenue the farmer would get if he/she were to receive the same amount from a local buyer as the buyer would pay for imported wheat. Table 6.3 shows that profitability is negative for medium-staple cotton and sorghum production based on calculations at the shadow exchange rate of LS 9.0/$. Line 12 shows that Sudan has a comparative advantage in the production of long-staple cotton, wheat and groundnuts. It does not have a comparative advantage in the production of medium-staple cotton and sorghum. These results are sensitive to world prices, yield and exchange rate assumptions.

Medium-staple cotton profitability analysis shows that the crop was profitable in 1986/87 LS 28, unprofitable in 1987/88 (LS -212) and 1988/89 (LS -341) at the shadow exchange rate. In 1987/88, the procurement price was 42 percent above production costs and exceeded the border-equivalent price by 75 percent, and revenue-equivalent price by 48 percent. The analysis indicates that at the shadow exchange rate of LS 9/$ the border-equivalent price will increase to LS 357 per Kantar in 1988/89. This represents 93 percent of production costs. The domestic resource cost ratio (0.63) indicates that Sudan was close to having a comparative advantage in the production of medium-staple cotton.

The profitability of **long-staple cotton** valuing revenue at border-equivalent prices at shadow exchange rates, varied from positive LS 639 in 1984/85 to negative LS (-426) the next year, a recovery to LS 69 in 1986/87 and a sizable increase to LS 176 in 1988/89.

The variations in profitability can be attributed to 1) fluctuations in world lint prices; 2) yield; and 3) exchange rate.

In 1988/9 crop yields and world prices increased while exchange rates fell. The procurement price which is the price the tenant receives set by the government, has been higher than production costs and has exceeded the border-equivalent price. In 1988/89 the procurement price was 45 percent above production costs, even though these costs include a 10 percent return to management and a 10 percent return on capital. It was also 31 percent greater than border-equivalent price which is all the revenue the government receives on the lint sales and the domestic sales of cottonseed. Table 6.4 shows that the domestic resource cost ratio for long-staple cotton has been less than one since 1984/85 except for the drought season 1985/86 when it climbed to 4.98. The domestic resource cost ratio of 0.77 for the year 1988/89 has been calculated using a shadow exchange rate of LS 9.0/$. At this shadow exchange rate the supply and demand for foreign exchange is less imbalanced than at the official exchange rate of LS 4.5/$. The border-equivalent price declined to 23 percent of production costs.

Wheat production has been profitable in the Gezira since the 1986/87 season with production valued at the import parity price for wheat using shadow exchange rates. The domestic resource cost ratio were 0.60 in 1986/87, 0.73 in 1987/88 and 0.52 in 1988/89. The procurement price increased by 30 percent from LS 770 in 1986/87 to LS 1,001 per metric ton in 1987/88. This represents 145 percent of production costs and exceeds the border-equivalent price by 17 percent. If tenants had received the border-equivalent price of LS 858 per metric ton, this would have exceeded production costs by 25 percent and represented an 11 percent increase over the 1986/87 procurement price. Profit per feddan has increased from LS 82 in 1986/87 to LS 263 in 1988/89. The domestic resource cost

ratio at LS 9.0/$ declined to 0.52 in 1988/89 indicating that Sudan has a comparative advantage in wheat production as an import substitute at the shadow exchange rate. The border-equivalent price is 35 percent greater than production costs [LS 2,027/Mt versus LS 1,501/Mt], (Jansen, 1989).

Under irrigation conditions at the Gezira in 1988/89 **groundnuts** had a domestic resource cost ratio of 0.76 indicating that it is economically profitable, showing a significant improvement from the 1987/88 cropping season that had a domestic resource cost ratio of 1.26 which indicates comparative disadvantage. The improvement can be attributed to the higher world price and a favorable exchange rate. Production costs rose from LS 431 per feddan in the 1987/88 cropping season to LS 913 per feddan in 1988/89 and profitability improved from LS -148 per feddan in 1987/88 to LS 257 per feddan in 1988/89. The border-equivalent price was 83 percent greater than the production costs [LS 2,784/Mt versus LS 1,521/Mt].

Sorghum prices have increased only slightly from $105 in 1986/87 to $115 in 1988/89. Production costs rose from LS 184 per feddan to LS 591 per feddan. Profitability

TABLE 6.4 DOMESTIC RESOURCE COST RATIOS FOR GEZIRA CROPS.

CROP \ PERIOD	1984/85	1985/86	1986/87	1987/88	1988/89
Exchange rate (LS/$)	2.50	2.50	3.25	4.5	9.00
Cotton MS	---	---	0.98	1.17	1.09
Cotton LS	0.32	4.98	0.93	0.89	0.77
Wheat	---	1.82	0.60	0.73	0.52
Groundnuts	0.17	0.21	0.42	1.26	0.76
Sorghum	0.52	0.64	1.10	3.33	2.18

Source: Jansen, 1989.

fell from LS 25 per feddan to negative LS (271) per feddan. Domestic resource cost ratios for sorghum produced in the Gezira are 0.52 in 1984/85, 0.64 in 1985/86, 1.10 in 1986/87, 3.33 in 1987/88 and 2.18 in 1988/89. Sudan does not have the comparative advantage in the production of sorghum for export even at the shadow exchange rate of LS 9/$. The domestic resource ratios are extremely high especially for the 1987/89 season. The import parity price at $155 per metric ton, cif, Port Sudan, is higher than the fob export parity price of $115. Yields and world prices reveal that sorghum is not an efficient crop to be grown under irrigated conditions but could be a viable crop under the mechanized conditions at Gedarif.

6.4 DOMESTIC RESOURCE COST RATIOS.

Financial analysis of Sudan's major crops utilizes the criterion of financial profitability and attempts to determine the relative and absolute financial profitability of crops. The assumption is that farmers are interested in profit maximization and would therefore allocate their resources to the crops with the highest positive financial profitability. The government can encourage the production of a crop by increasing its producer price or subsidizing its costs of production.

Economic analysis utilizes the criterion of economic profitability. The government objectives of economic efficiency, regional balance and self-sufficiency can be analyzed by calculating the losses in economic efficiency that would be incurred in reaching the various levels of improvements. This approach allows the assessment of tradeoffs of the promotion of conflicting goals such as economic growth, food production and equity.

Economic valuations measure inputs and outputs by assigning them prices that reflect underlying scarcity values or opportunity costs. These prices will result in

optimum allocation of scarce resources and thereby maximize efficiency and generate highest attainable level of national income. The primary task is to find reasonably accurate approximation of the economic prices of inputs and outputs in the system. The logic is that Sudan government officials always have the option of setting policy that will permit more imports or exports at world price levels. World prices provide relevant standard of comparison and establish economic valuation for tradable inputs and outputs.

Domestic factors of production--land, labor and capital--are evaluated with respect to opportunity costs for each factor which is the amount of national income foregone by removing a unit of that factor from working in its best alternative activity. The opportunity cost of each factor is a measure of scarcity because it shows the cost to society of utilizing the factor in one activity rather than another. Nontradable inputs such as government services or road transport cannot be evaluated by making comparisons to the cost of traded goods, since by definition they do not enter into international commerce. Their costs have to be disaggregated into their tradable inputs and domestic factor costs (Jansen, 1986).

A modified version of the domestic resource cost ratio equation developed in section 6.1 was employed in the calculation of domestic resource cost ratios for all crops grown in the Gezira for the 1989/90 cropping season. The modification is to account for domestic and traded portions of transport costs from the Gezira to Port Sudan. The necessary information includes border prices, and other data obtained from the survey: production costs, yields and transport costs for cotton, wheat, groundnuts and sorghum.

There are three important steps in the calculation of domestic resource cost ratios: 1) the development of enterprise budgets for each alternative production enterprise that competes for the same resources; 2) classification of inputs into traded

goods that are traded or potentially traded internationally and non-tradable goods that are not traded; and 3) determination of import or export parity prices intended to reflect true economic value of goods and services in the absence of government distortions (Morris, 1988).

Table 6.5 shows the border prices in dollars per unit, efficient marketing margins and producer parity prices in Sudanese pounds per unit. We calculate export parity prices for medium-staple cotton, long-staple cotton, groundnuts and sorghum, and an import parity price for wheat. The border prices quoted in dollars are converted into Sudanese pounds using the shadow exchange rate of LS 12/$. Except for wheat, the percentages for the efficient marketing margins were adopted from Youngblood (1983) based on Sattar (1982) who determined these margins using the differences between the border and producer prices.

For wheat, the marketing margin was estimated from information on transport and marketing costs and prices contained in Jansen (1987). The fixed percentage efficient marketing margins are: medium-staple cotton 40 percent, long-staple cotton 35 percent, wheat 30 percent, groundnuts 35 percent and sorghum 43 percent. Youngblood (1983) also calculated the percentages of the tradable components for each of the crop inputs used in production at the Gezira Scheme.

The value of domestic resources, value of traded inputs and yields are taken from the crop enterprise budgets developed from the 1989/90 farm survey. The calculation of domestic resource cost ratios requires that input costs be decomposed into their traded and nontraded components. Any input that can be exported or imported is considered tradable. Table 6.6 presents the values of total, domestic and tradable components of the input costs for the different crops grown in the Gezira.

TABLE 6.5 BORDER AND PRODUCER PARITY PRICES, 1989/90.					
CROP PRICE	BORDER PRICES		MARKET MARGIN		PROD PRICES
UNIT 1/	($)	(LS)	(%) 2/	(LS)	(LS)
Cotton MS	62.10	745.20	40	298.08	447.12
Cotton LS	92.22	1,046.64	35	366.32	680.32
Wheat	190.00	2,280	30 3/	684.00	1,596.00
Groundnuts	220.00	2,640	35	924.00	1,716.00
Sorghum	113.00	1,356	43	583.30	772.92
1/ LS/Mt = wheat, groundnuts and sorghum. Cotton = LS/Kantar.					
2/ Efficient marketing margin in Youngblood, 1983.					
3/ Marketing and transport costs in Jansen, 1987.					
Source: Compiled from survey data.					

TABLE 6.6 DOMESTIC AND TRADED COST COMPONENTS, 1989/90.				
CROP\COST	TOTAL COST	DOMESTIC COST	TRADED COST	
UNIT	(LS/Fed)	(LS/Fed)	(LS/Fed)	($/Fed)
Cotton MS	2,345	1,639	706	58
Cotton LS	2,404	1,620	784	65
Wheat	857	503	354	30
Groundnuts	832	702	130	11
Sorghum	689	581	108	9
Source: Compiled from survey data.				

The DRC ratio is the ratio of domestic factor costs to the net foreign exchange earnings or savings. The numerator is the domestic factor costs and the denominator is the international value added (traded outputs minus traded inputs) in Sudanese pounds.

The DRC ratio is calculated as follows: domestic production costs plus domestic transport costs incurred minus domestic transport costs saved divided by revenue per feddan minus tradable production cost minus tradable transport cost incurred plus tradable transport costs saved.

Table 6.7 presents the domestic resource cost ratios for medium and long-staple the cotton grown in the Gezira in 1989/90 survey season using a shadow exchange rate of LS 12/$. The domestic resource cost ratios for medium and long-staple cotton are 0.49 and 0.48, respectively. Sudan therefore has comparative advantage in the production of medium and long-staple cotton for export.

TABLE 6.7 DOMESTIC RESOURCE COST RATIOS FOR COTTON, 1989/90.

		Unit	COTTON MS	COTTON LS
	Exchange rate	LS/$	12.00	12.00
1	Fob World price	$/Kan	62.1	92.22
2	Yield	Kan/Fed	6.80	4.50
3	Total Production cost	LS/Fed	2,345	2,404
4	Production cost (1/Domestic)	LS/Fed	1,639	1,620
5	Production cost (1/Traded)	LS/Fed	706	784
6	Ginning Cost (Domestic)	LS/Fed	261.12	213.12
7	Ginning Cost (Traded)	LS/Fed	391.68	319.68
8	Transport cost (Domestic) 3/	LS/Fed	23.08	15.27
9	Transport cost (Traded)	LS/Fed	53.86	35.64
10	DRC Ratio		0.49	0.48

1/ = Domestic cost component in Sudanese pounds per feddan.

2/ = Traded cost component in Sudanese pounds per feddan.

3/ = Transport cost, Gezira to Port Sudan

Source: Computed from survey data.

Table 6.8 presents the DRC ratios for wheat, groundnuts and sorghum grown in the Gezira in the 1989/90 survey season using a shadow exchange rate of LS 12/$. Wheat is valued as an import substitute, and groundnuts and sorghum as exports. The DRC for wheat is 0.32 indicating a clear comparative advantage for wheat grown in the Gezira. The DRC for groundnuts is 0.53. Sudan has comparative advantage in groundnuts production, but its export potential remains underutilized because tenants

TABLE 6.8 DOMESTIC RESOURCE COST RATIOS, 1989/90.

		Unit	WHEAT	GROUNDNUTS	SORGHUM
	Exchange rate	LS/$	12.00	12.00	12.00
1	Fob Price Port Sudan	$/Mt	190 1/	220	113
2	Yield	Mt/Fed	0.65	0.75	0.50
3	Total Production cost	LS/Fed	857	832	689
4	Production cost (2/ domestic)	LS/Fed	503	702	581
5	Production cost (3/ traded)	LS/Fed	354	130	108
6	Handling (Domestic) 4/	LS/Fed	56.37	65.04	43.36
7	Handling (Traded)	LS/Fed	76.51	88.29	58.86
8	Transport cost (Domestic) 5/	LS/Fed	46.79	53.99	36.00
9	Transport cost (Traded)	LS/Fed	126.51	145.98	97.32
10	Transport cost (Domestic) 6/	LS/Fed	10.30	11.88	7.92
11	Transport cost (Traded)	LS/Fed	27.85	32.13	21.42
12	DRC ratio		0.32	0.53	1.70

1/ = Wheat price cif Port Sudan.

2/ = Domestic cost components in Sudanese pounds per Feddan.

3/ = Traded cost components in Sudanese pounds per Feddan.

4/ = Handling, packaging and storage cost components.

5/ = Transport cost, Khartoum to Port Sudan.

6/ = Transport cost, Gezira to Khartoum.

Source: Computed from survey data

lack funds, production inputs, research and extension, infrastructure and marketing services.

The domestic resource cost ratio for sorghum is 1.70 indicating that Sudan has a comparative disadvantage in the production of sorghum in the Gezira for export under current yields and world prices. Thus, the cost of the resources used in the production of sorghum are more than the foreign exchange saved and hence it is not an efficient use of the resources to produce the crop for export. Nonetheless, Gezira tenants will continue growing sorghum to ensure their food security.

The 1989/90 domestic resource cost findings are comparable to Jansen's 1988/89 findings presented in table 6.4 where long-staple cotton, wheat and groundnuts have comparative advantage and medium-staple cotton and sorghum have comparative disadvantage, except for medium-staple cotton that now shows a strong comparative advantage.

Domestic resource cost ratios are sensitive to changes in exchange rates, world prices, production costs and yields. Exchange rates determine the prices of imported imputs and agriculture products. The effects of changes in the exchange rate are important when the uses of the tradable inputs vary significantly across enterprises and when the production technology includes nontradable versus tradables commodities. A change in the world reference prices of an output will have a great effect on the economic profitability of an enterprise. Because economic prices are based on long term trends in world reference prices that may not provide accurate projections of future prices, the expected long term world prices can be distorted due to subsidies by exporting countries and it is important therefore to know whether the subsidies will continue into the future. Production techniques will change with the introduction of improved

technologies that lower costs of production and increase enterprise profitability to the farmer and to the nation. The production of a crop may not be efficient under current technology but may be efficient with the introduction or development of new tecnology. Agricultural research is a long term process and decisions on research resource allocation must take a long-term perspective on the policy environment. Comparative advantage rankings tend to be sensitive to the level of yields assumed for any given quantity of inputs to the extent that any success in raising mean yields above current levels can make enterprises that appear economically unprofitable at present to become profitable in the future.

Changes in exchange rates, world prices, production costs and crop yields are important policy variables. Some of these factors are under the control of the policy makers while others are not. Real exchange rates and world prices are exogenous and cannot be considered as policy instruments because Sudan is a price taker except for long-staple cotton. Maintenance of an overvalued domestic currency imposes an implicit tax on producers. The effects of the exchange rate would have implications for resource allocation in the Gezira. Producer prices are policy instruments available to policy makers. Policies that cause the producers to diverge from the import or export parity equivalent could have significant impact on the tenants. Policy makers can formulate reasonable expectations about the potential effects of their actions. The total effect of these policies discriminates against or favors some commodities or farmers in some ways such that the profitability of a particular crop or technology to the farmer bears little relationship to the profitability to the country. This may be the case with groundnut production in the Gezira Scheme.

CHAPTER VII

LINEAR PROGRAMMING MODEL FOR THE GEZIRA

This chapter introduces and discusses the structure of the linear programming models used to analyze the economic activities of the survey tenants. The issues to be discussed include an overview of the linear programming model, mathematical representation, limitations of the model, the objective function, the production activities, model restrictions, and the derivation of the righthand side (RHS) values.

7.1 OVERVIEW

The last two decades have seen an improvement in the incorporation of economic theory and observed institutional and economic reality into the programming models of consumer demand, market equilibrium in both factor and product markets, risk and risk aversion, and the role of economic instruments. The ability of agricultural economists to model decisions of the farm households has undergone much improvement. The cumulative effect of these advances has been to provide analytical tools more adaptable to different situations and realistic portrayal of the agricultural situations. Planning models have to link economic theory to data as well as provide practical appreciation of problems and policy orientations. Their logical consistence frameworks do provide analysts and policy makers with valuable economic representation in order to test ideas and proposals. Thus, model construction requires a grasp of the relevant economic theory, an understanding of the issues and a familiarity with sound techniques of model building and their applications (Hazell and Norton, 1986).

The appropriateness of the use of linear programming for the analysis of smallholder agriculture has been questioned. The linear programming model operates under the assumption that the producer wants to maximize a particular objective function, but social and economic variables can be inseparable in smallholder agriculture in the less developed countries. The usefulness of the model will be limited when the objectives are non-economic.

Palmer-Jones (1977) questions the legitimacy of using average input-output coefficients in linear programming models for several reasons: 1) farmers may alter their strategies or technical inputs under different environmental conditions; and 2) the assumption of average inputs may not give rise to average outputs. He questions the application of linear programming to smallholder farmers in general, particularly with regard to data problems since records are rarely kept. Even when recorded, their degree of reliability is normally low.

Lipton (1968) argues that for peasant farmers, the most important consideration is food security. Low (1974) supports the use of linear programming in smallholder agriculture. He argues that linear programming models when carefully formulated are able to generate useful information that could not have been obtained by the usual budgeting techniques. Linear programming permits a more rapid analysis in determining the relative profitability of enterprises when the number of enterprises under consideration is large.

A model is a functional account of relationship between relevant variables which will be given cardinal values in the empirical phase of the study. It is an abstraction describing and duplicating the situation under investigation. Many linear programming models assume a profit maximizing behavior, single period planning and a certain

environment. Linear programming is preferred because of its widespread availability, familiarity and cost effectiveness. It has the ability to choose the best set of a very large number of alternatives, and the marginal evaluation of constraining resources makes it ideal for an agricultural setting.

In agriculture, decisions on what to produce, how to produce it, and what to do with the produce are made by many farmers. By using indirect instruments that involve changes in prices and subsidies or incentives, we can make changes in the farmer's objective functions to get them to adopt cropping patterns and resource use patterns more to the public good. Agriculture models need thorough specification of the production possibilities, full understanding of what motivates farmers and the constraints of their motivation. Farmers need to have the flexibility in choosing the crops they grow, timing of the growing and the type of land use.

The use of a linear programming model for the Gezira is appropriate since the tenants grow for the market, their main goals appear to be profit maximization and food security, and the data are fairly reliable. This study uses a linear programming model to determine the optimal mix of production activities. The model seeks to maximize the farmer's net income subject to food security constraints.

Sensitivity analysis of the Gezira model will be employed to investigate the following issues of importance.

1. The impact of government mandated cropping pattern on the tenant's income.
2. The impact of improved technology on resource mix, product mix and farm income.
3. The impact of irrigation water on productivity.
4. The effect of increasing producer prices.

5. The effect on farm income of making formal credit available.

7.2 MATHEMATICAL REPRESENTATION

Linear programming uses a mathematical model to describe the resource allocation problem in agriculture. All the mathematical functions in the model are required to be linear. Non linear problems can be handled by separable or quadratic programming. The word programming is essentially a synonym for planning. Thus, linear programming involves the selection of activities to obtain optimal plans. A typical linear programming problem contains more variables X_j than will appear in the optimal solution.

The mathematical formulation of an linear programming model has three main features: l) an objective function to be maximized or minimized; 2) resource constraints; and 3) the activity set.

The linear programming problem is stated as follows:

Maximize: $Z = C_1X_1 + C_2X_2 + \text{-----} + C_nX_n$

Subject to the restrictions:-

$$a_{11}X_1 + a_{12}X_2 + \text{-------} + a_{in}X_n \leq b_1$$
$$a_{21}X_1 + a_{22}X_2 + \text{-------} + a_{2n}X_n \leq b_2$$
$$\vdots \qquad \vdots \qquad\qquad \vdots$$
$$a_{m1}X_1 + a_{m2}X_2 + \text{-------} + a_{mn}X_n \leq b_n$$
$$X_1 \geq 0 \quad i = 1, 2, \text{----}, n .$$

Alternatively:

Maximize: $\sum_{j=1}^{n} Z = C_jX_j$

Such that: $\sum_{j=1}^{n} a_{ij}X_j \leq b_i \; i = 1, \text{----}, m$

$$X_j \geq 0 \qquad j = 1, \text{----}, n$$

where:

Z = objective function to be maximized or minimized
C = n x 1 vector of prices
X = n x 1 vector of activity levels
a = m x n matrix of input-output coefficients
b = m x 1 vector of resource constraints

Each column of the tableau defines an activity with its respective input-output coefficients. Each row represents a restriction. A negative coefficient signifies an addition to the resource while a positive coefficient indicates a demand on the resource.

7.3 ASSUMPTIONS OF LINEAR PROGRAMMING

Linear programming has a rigid set of assumptions that can constrain the applicability of the model results. A review of the main linear programming assumptions are given below:

1. Proportionality: This means that if X units of inputs are necessary to produce one unit of output, then 2X units of input will be needed to produce two units of output and that the fixed input-output ratio holds for the entire production range. A constant gross margin for a unit of activity assumes a perfectly elastic demand curve for the product, and a perfectly elastic supply of any variable input that may be used.

2. Additivity: It is assumed that there are no interactions between activities. Its requirement is that given the activity levels (X_1, X_2, X_3, ---, X_n), the total usage of each resource and the resulting total output equal the sum of the corresponding input and output quantities generated by each activity conducted separately.

3. Divisibility: It is assumed that resources can be used and activities produced in quantities that are fractional units. This may not be limiting as the non-integer values that appear in the solution can be rounded off to the nearest integer.

4. Deterministic: This assumes that all the parameters in the model such as the input-output coefficients (A_{ij}), the resource levels (B_i), the righthand side (RHS), yields, and input and output prices are known with certainty. But linear programming models are formulated to predict some future course of action which inevitably involves uncertainty.

5. Homogeneity: It is assumed that all units of the same resource or activity are identical but this may not be true in practice.

6. Non-negativity: It is assumed that the level of activities and the resource levels is greater than or equal to zero.

7.4 OBJECTIVE FUNCTION

The objective function maximizes net income from the farm activities subject to securing the minimum requirement of sorghum for food security, and subject to other physical and institutional constraints. The numbers in the objective function represent returns to all variable inputs except for the cost of hired labor represented by negative numbers in the tableau. Net income is defined as gross income from farm enterprises less operating expenses. Gross farm income is derived from the sale of cotton, wheat, groundnuts and sorghum. The cash expenditures were on 1) material inputs -- seeds, fertilizers, insecticides, herbicides and sacks; 2) mechanical operations -- plowing, ridging, levelling and opening irrigation canals; and 3) transport services and water rates. Family

labor and local food consumption have not been assigned values in the objective function.

The combination of enterprises to be selected will depend on the objective function. If we maximize this function we can find the combination of activity levels which gets the maximum profit given the resources available to the farm. In the face of risk, a minimum level of subsistence consumption can be assured by the consumption of lower bounds on the level of foodstuff production function; this applies to local sorghum in the Gezira.

7.5 ACTIVITIES IN THE MODEL

Activities in the model fall under the following categories:

1. Crop production activities
2. Labor hiring activities
3. Irrigation water activities
4. Capital flow activities
5. Crop selling activities
6. Sorghum buying activities
7. Capital transfer activities

7.5.1 CROP PRODUCTION ACTIVITIES

The cropping activities in the Gezira model include medium-staple cotton (shambat), long staple-cotton (Barakat), wheat, groundnuts, local sorghum and hybrid sorghum variety (Hageen dura 1). Good cotton farmers are allowed to grow some vegetables (tomatoes, cucumbers, eggplants, pepper) on a small amount of the land under fallow.

TABLE 7.1 CROP PRODUCTION ACTIVITIES.

			A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
ACTIVITY a)			FALL	MSC1	MSC2	LSC1	LSC2	WHT1	WHT2	GNT1	GNT2	LSO1	LSO2	HSO1	HSO2
ROW	RES	UNIT	0	-1162	-1389	-1241	-1474	-647	-867	-285	-574	-253	-484	-511	-779
1	LANT	Fd	1	1	1	1	1	1	1	1	1	1	1	1	1
2	LANF	Fd	1												
3	LANC	Fd		1	1	1	1								
4	LANW	Fd						1	1						
5	LAGS	Fd								1	1	1	1	1	1
6	JUNL	Md		1.6	1.9	1.6	1.9			2.5	3.5	0.6	0.6	0.6	0.6
7	JULL	Md		2.7	2.7	2.7	2.7			7.6	7.6	3.3	5.1	3.3	4.2
8	AUGL	Md		4.4	4.4	4.4	4.4			6.1	6.1	4.1	4.1	4.1	4.1
9	SEPL	Md		5.4	5.4	5.4	5.4			2.5	2.5	1.7	1.7	1.7	1.7
10	OCTL	Md		1.3	1.3	1.3	1.3	0.4	1.4	1.8	1.8	0.8	0.8	0.8	0.8
11	NOVL	Md		1.1	1.1	1.1	1.1	1.6	1.6	4.5	6.2	6.4	9.9	6.4	6.4
12	DECL	Md		3.7	3.7	3.7	3.7	1.1	1.1	8.8	8.8	3.1	3.1	3.1	3.1
13	JANL	Md		7.4	8.9	7.4	8.9	0.8	0.8	5.7	5.7	0.5	0.5	0.5	0.5
14	FEBL	Md		7.3	8.8	7.3	9.1	0.6	0.6	0.9	0.9				
15	MARL	Md		5.5	6.2	5.1	6.3	1.1	1.1						
16	APRL	Md		2.9	3.5	2.9	3.6	0.5	0.5						
17	MAYL	Md		2.2	2.2	2.2	2.2								
18	JUNW	Cbm		420	420	420	420			420	420				
19	JULW	Cbm		420	420	420	420			420	420	420	420	420	420
20	AUGW	Cbm		840	840	840	840			420	420	420	420	420	420
21	SEPW	Cbm		840	840	840	840			840	840	840	840	840	840
22	OCTW	Cbm		840	840	840	840	420	420	840	840	420	420	420	420
23	NOVW	Cbm		840	840	840	840	840	840	420	420				
24	DECW	Cbm		840	840	840	840	840	840						
25	JANW	Cbm		840	840	840	840	840	840						
26	FEBW	Cbm		840	840	840	840	840	840						
27	PMSC	Kg		-6.8	-8.8										
28	PLSC	Kg				-4.5	-6.2								
29	PWHT	Kg						-550	-750						
30	PGNT	Kg								-750	-1200				
31	PLSO	Kg										-500	-750		
32	PHSO	Kg												-1200	-1600
33	MSBR	Kg													
34	JUNC	LS		281	281	281	281			129	129	66	66	66	66
35	JULC	LS		16	16	20	20				194	9	9	9	9
36	AUGC	LS									75		194	110	304
37	SEPC	LS		125	320	127	420	177	177						
38	OCTC	LS		383	383	483	483	76	76						
39	NOVC	LS						128	299	28	39	34	51	102	136
40	DECC	LS						20	20	24	33	144	164	224	264
41	JANC	LS		35	45	45	36			104	104				
42	FEBC	LS		75	97	60	87								
43	MARC	LS		90	90	90	90	115	164						
44	APRC	LS		157	157	157	157	131	131						
45	MAYC	LS													
46	ENDC	LS													
47	RPBM	LS													

a) See appendix C for explanation of abbreviations

Source: Computed from survey data.

A cropping activity is a single variable in a linear program representing the level at which a given crop is cultivated. We define the cropping activity on a per feddan basis which is the way farmers make their production decisions and is a unit of data collection. Table 7.1 shows the crop production activities, each of which has two intensity levels. Yield assumptions for the intensity levels 1 are averages for five years 1984/85-1988/89 (Socioeconomic Unit, 1989) and yield assumptions for intensity levels 2 are based on Gezira Research Station field trial results where 20 percent was deducted from trial yield in order to arrive at potential yield increase following improvements in technology embodied in better management of land preparation, irrigation and fertilizer application (Brandt et al., 1987). The costs related to yield (transport, sacks and threshing), will rise proportionately.The Board supplies fertilizer for the production of cotton, wheat and hybrid sorghum variety.

The input-output coefficients represent the resource requirements per units of activities that correspond to production activities. The level of activity times the input coefficient gives the derived demand by the activity and the sum of derived demands for all crops must not exceed the righthand side.

The input-output coefficients show the magnitude a resource level would decrease with an increase of one unit of each activity in the model. The coefficients representing a decrease in the magnitude of a constraint carry positive signs, while those coefficients indicating an increase in the magnitude of the constraint have negative signs. The input-output coefficients of crop production activities are derived from the survey data of 96 farmers in the main Gezira. These coefficients were estimated for the typical 20-feddan main Gezira tenancy for inclusion in the production enterprise model. Crop yields were estimated for each enterprise per feddan.

7.5.2 LABOR HIRING ACTIVITIES

Tenants in the Gezira are dependent on hired labor for most farm operations. Labor hiring takes place throughout the season with the highest level of labor hiring during the peak periods. The activity units are man-days (Md); each man-day is equivalent to eight hours of fieldwork per day in a 6-day work week. When a laborer performs a farm operation that takes him/her less than the standard eight hours, we count it as a man-day equivalent. The survey reveals that the majority of the laborers are adult males and females that participate in weeding and harvesting. Although women were slower than men in farm operations like irrigation and land clearing; the opposite is true for harvesting and cotton picking. We will therefore assume that a man-day is equivalent to a woman-day.

The monthly labor requirement corresponds with the monthly pattern of land use. The extent to which critical operations are performed in a given time span needs to be taken into consideration. We do this by mapping the different tasks into months in which they occur given the time dimension. Labor has to be disaggregated over the year because its opportunity cost changes so drastically over the course of the production season. Monthly disaggregation of Gezira labor requirements will suffice as the schedule is not tight and timing flexible under the irrigation conditions. The labor input-output coefficients are positive in units of man-days per feddan per month.

No labor selling activity was established for the farm since each tenancy is a net buyer of labor especially at the peak periods. The model defines 12 labor buying activities to allow for the purchase of labor that will augment family labor. Each cycle covers four weeks for one production season; June 1989 to May 1990.

Labor is hired per feddan and remunerated both in cash and in-kind in the form of sorghum. An average monthly wage rate was estimated by combining the value of the cash and in-kind payments.

Table 7.2 shows that labor hiring activities have negative values on the objective function row equal to the average wage rate in the particular month. Thus, a hired unit of labor reduces the objective function by the amount of the monthly wage. Wage rates

TABLE 7.2 LABOR HIRING ACTIVITIES.

ACTIVITY			A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25
(C1)	a)		JNNL	JULL	AUGL	SEPL	OCTL	NOVL	DECL	JANL	FEBL	MARL	APRL	MAYL
ROW	RES	UNIT	-21.5	-22.8	-24.6	-17.2	-16.3	-22.4	-27.3	-13.8	-14.2	-13.4	-20.3	-14.5
6	JUNL	Md	-1											
7	JULL	Md		-1										
8	AUGL	Md			-1									
9	SEPL	Md				-1								
10	OCTL	Md					-1							
11	NOVL	Md						-1						
12	DECL	Md							-1					
13	JANL	Md								-1				
14	FEBL	Md									-1			
15	MARL	Md										-1		
16	APRL	Md											-1	
17	MAYL	Md												-1
34	JUNC	LS	21.5											
35	JULC	LS		22.8										
36	AUGC	LS			24.6									
37	SEPC	LS				17.2								
38	OCTC	LS					16.3							
39	NOVC	LS						22.4						
40	DECC	LS							27.3					
41	JANC	LS								13.8				
42	FEBC	LS									14.2			
43	MARC	LS										13.4		
44	APRL	LS											20.3	
45	MAYC	LS												14.5
46	ENDC	LS												
47	RPBM	LS												

a) See appendix C for explanation of abbreviations

Source: Computed from survey data

vary with the type of activity, month and timing of the different operations. Family and hired labor activities are specified for the 12 labor periods covering the entire 1989/90 cropping season.

7.5.3 IRRIGATION WATER ACTIVITIES

The economics of irrigation focuses on the water demanded at the farm level and the price charged for water deliveries. However, water may not be available to the farmer on demand and the charge may be a flat rate independent of water use. Water deliveries are constrained by canal capacity and loss characteristics; and water available from nature and from storage in reservoirs.

Irrigation water is the single most important resource in the Gezira scheme. Table 7.3 shows crop water (Cbm) requirements specified by crop and month. Water is brought to the crops at a fourteen day interval at a rate of 420 cubic meters per feddan per irrigation. The Agricultural Research Corporation recommends that cotton receive 16 irrigations, wheat 10 irrigations, groundnuts 8 irrigations and sorghum 4 irrigations. Rainfall in August to October supplements the irrigation water for groundnuts and sorghum. Gezira tenants have to pay flat land and water rates to the government which in the 1989/90 cropping season stood at cotton (LS 157), wheat (LS 131), groundnuts (LS 104), sorghum (LS 104) and vegetables (LS 175). Water shortages occur in October and November. The total water use on the farm is constrained by an accounting equation with an upper bound on total water use.

7.5.4 CAPITAL BORROWING ACTIVITIES

Farmers require operating capital from various sources such as savings, relatives, banks and government to hire labor, purchase seed and meet consumption requirements. Table 7.4 shows capital borrowing activities specified on monthly basis at a 20 percent

TABLE 7.3 IRRIGATION WATER ACTIVITIES.

ACTIVITY			A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Cj	a)		MSC1	MSC2	LSC1	LSC2	WHT1	WHT2	GNT1	GNT2	LSO1	LSO1	HSO1	HSO2
ROW	RES	UNIT	0	0	0	0	0	0	0	0	0	0	0	0
18	JUNW	Cbm	420	420	420	420			420	420				
19	JULW	Cbm	420	420	420	420			420	420	420	420	420	420
20	AUGW	Cbm	840	840	840	840			420	420	420	420	420	420
21	SEPW	Cbm	840	840	840	840			840	840	840	840	840	840
22	OCTW	Cbm	840	840	840	840	420	420	840	840	420	420	420	420
23	NOVW	Cbm	840	840	840	840	840	840	420	420				
24	DECW	Cbm	840	840	840	840	840	840						
25	JANW	Cbm	840	840	840	840	840	840						
26	FEBW	Cbm	840	840	840	840	840	840						

a) See appendix C for explanation of abbreviation.

Source: Ministry of Irrigation.

TABLE 7.4 CAPITAL BORROWING ACTIVITIES

OBJ. FUNC			CAPITAL BORROWING ACTIVITIES												
ACTIVITY			A47	A48	A49	A50	A51	A52	A53	A54	A55	A56	A57	A58	A59
(Cj)	a)		BMJN	BMJL	BMAG	BMSP	BMOT	BMNV	BMDC	BMJN	BMFB	BMMR	BMAP	BMMY	RPBM
ROW	RES	UNIT	-.20	-.18	-.17	-.15	-.13	-.12	-.10	-.08	-.07	-.05	-.03	-.02	0
34	JUNC	LS	-1												
35	JULC	LS		-1											
36	AUGC	LS			-1										
37	SEPC	LS				-1									
38	OCTC	LS					-1								
39	NOVC	LS						-1							
40	DECC	LS							-1						
41	JANC	LS								-1					
42	FEBC	LS									-1				
43	MARC	LS										-1			
44	APRC	LS											-1		
45	MAYC	LS												-1	
46	ENDC	LS													
47	RPBM	LS	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1

a) See appendix C for explanation of abbreviations

Source: Compiled from survey data.

interest rate which is the rate the Agricultural Bank of the Sudan charges its customers. The activity unit is a Sudanese pound. The farmers borrow from money lenders and friends to supplement their personal cash to finance farming. Borrowed capital activities carry negative coefficients in the operating row to indicate the use of borrowed capital.

The objective function coefficient (C_j's) for borrowed capital are negative, indicating a decrease in the objective function by the interest rate paid on capital.

The model employs the actual amounts spent on crop production estimated from the survey data. The expenses involved typical inputs in the tenancy such as planting material, mechanical operations, transport, services and land and water rates. The operating capital constraint for the cropping activities was entered on monthly basis. The demand for operating capital by the various enterprises was assumed to vary with variable costs per unit of production. The total annual operating capital was cotton (LS 2,345), wheat (LS 889), groundnuts (LS 832) and sorghum (LS 689) Sudanese pounds per feddan.

7.5.5 CROP SELLING ACTIVITIES

Table 7.5 shows crop selling activities in the model that include medium staple-cotton, long-staple cotton, wheat, groundnuts, local sorghum and hybrid sorghum varieties. Local sorghum is included such that any surplus beyond subsistence requirements can be sold. The Gezira model assumes that all the selling is done at harvest and that there is no storage. Prices are those observed during the 1989/90 survey season. Cotton and wheat prices are set by the government and sold through official channels immediately after harvest. The selling units are "Kantar" for cotton and Kg for wheat, groundnuts and sorghum. Sack weights of different crops are cotton = Kantar (45 kg), wheat = 90 kg, groundnuts = 45 kg and sorghum = 90 kg.

TABLE 7.5 SELLING, BUYING AND CONSUMPTION ACTIVITIES.

OB FUNC			SELLING ACTIVITIES						BUY	CON
ACTIVITY			A26	A27	A28	A29	A30	A31	A32	A33
(CJ) a)			SMSC	SLSC	SWHT	SGNT	SLSO	SHSO	BLSO	CLSO
ROW	RES	UNIT	530	740	3	2.8	2.9	2.3	-3.5	0
27	PMSC	Kg	1							
28	PLSC	Kg		1						
29	PWHT	Kg			1					
30	PGNT	Kg				1				
31	PLSO	Kg					1		-1	1
32	PHSO	Kg						1		
33	MSBR	Kg								1

a) See appendix C for explanation of abbreviation.

Source: Computed from survey data.

The objective coefficients are positive because selling adds to the value of the objective function. The selling price coefficient appear negative in the operating capital rows because crop selling adds to the operating capital.

7.5.6 SORGHUM BUYING ACTIVITIES

A sorghum buying activity is added into the model in case sorghum production cannot meet the minimum household subsistence requirements. This introduces the possibility that it may be more economic to buy sorghum from outside than to produce it in the Gezira. Sorghum purchase is valued at market prices. The sorghum buying activity has a coefficient of -1 at the local sorghum production row indicating an increase of inventory by a unit. The objective function is -3.5 which implies a purchase price of sorghum which is 20 percent above the sales price. The reason being that farmers purchase sorghum well after harvest when prices are much higher.

7.5.7 CAPITAL TRANSFER

Table 7.6 represents capital transfer activities which are used to pass surplus capital from one month to another during the year. The transfer activities have a zero value in the objective function, and negative and positive values in the operating capital rows to transfer any capital surplus to the next month. Capital estimated from sales receipts is introduced into the model in June and is allowed to be transferred from one month to the next with the condition that at the end of the year the same or greater amount of capital can be transfered to the next year.

TABLE 7.6 TRANSFER ACTIVITIES

(Cj)			TRANSFER ACTIVITIES												
			A34	A35	A36	A37	A38	A39	A40	A41	A42	A43	A44	A45	A46
ACTIVITY		a)	JNKT	JLKT	AGKT	SPKT	OTKT	NVKT	DGKT	JAKT	FBKT	MRKT	APKT	MYKT	KT
ROW	RES	UNIT	0	0	0	0	0	0	0	0	0	0	0	0	0
34	JUNC	LS	1												
35	JULC	LS	-1	1											
36	AUGC	LS		-1	1										
37	SEPC	LS			-1	1									
38	OCTC	LS				-1	1								
39	NOVC	LS					-1	1							
40	DECC	LS						-1	1						
41	JANC	LS							-1	1					
42	FEBC	LS								-1	1				
43	MARC	LS									-1	1			
44	APRC	LS										-1	1		
45	MAYC	LS											-1	1	
46	ENDC	LS												-1	1
47	RPBM	LS													

a) See appendix C for explanation of abbreviation

Source: Compiled from survey data

7.6 MODEL RESTRICTIONS

This section discusses the structure of the model restrictions. The Gezira tenant operates under the constraints of land, hired labor, water, operating capital and minimum sorghum consumption.

7.6.1 LAND CONSTRAINTS

The total available land for cultivation is limited by the size of the tenancy and the mandated cropping pattern. The typical farm size is 20 feddans. The tenants are not allowed to buy, rent or sell land. The tenancy is assumed to be homogeneous with no distinction in physical characteristics allowed in the model. The land rows represent all the available land allocated to production of cotton, wheat, groundnuts and sorghum.

7.6.2 LABOR CONSTRAINTS

Both family and hired labor supply the labor demands of the production activities. Hired labor is valued at market prices. Family labor is not mobile and is not valued in monetary terms. The row unit for hired labor is one man-day. The amount of hired labor is constrained by the amount of operating capital available for the activities. The monthly pattern of labor requirements corresponds to monthly pattern of land use. The cropping activities need not account, and seldom do account for all of the labor requirements on the tenancy because of off-farm activities.

7.6.3 WATER CONSTRAINTS

The total water allocation to the Gezira tenant is fixed on an annual basis. The fixed monthly water deliveries to the individual farmer are constrained by canal capacity, and the water is available to the farmer at a flat annual charge. The water constraint indicates the water requirements per crop per period and the total demand will not exceed the available water per month.

7.6.4 OPERATING CAPITAL CONSTRAINTS

All the farm operations need cash especially weeding and harvesting. The Board bears the cost of production for cotton and wheat. The tenant bears the total cost of production for groundnuts and sorghum from his own sources.

A set of capital constraints insure that capital needs for crop production is limited by the availability of capital. The amount of funds available for cash expenses on the Gezira model farm was the total amount spent on crop production activities for the 1989/90 cropping season. All the unused operating capital made available is transferred from one month to the next.

7.6.5 MINIMUM SORGHUM CONSUMPTION CONSTRAINT

The tenant has to secure the minimum sorghum subsistence requirement from his own production. The food security constraint was represented by a coefficient that corresponds with a minimum yield per unit of local sorghum activity and a righthand side of 1,180 kg representing the minimum subsistence requirement. This is a lower bound constraint in the production of sorghum. This constraint was incorporated into the model to force the production of minimum amounts of sorghum for family consumption that will be met in the feasible solution; the selling activity can only dispose of surplus production of sorghum.

7.7 DERIVATION OF THE RIGHTHAND SIDE VALUES

This section discusses the derivation of the righthand side values in the Gezira model.

7.7.1 AVAILABLE LAND

The standard tenancy size in the Gezira is 20 feddans in a single field. The survey reveals that 80 percent of the tenants possess the standard tenancy size. The Board's policy limits the available land for each crop to the area specified by the rotation pattern.

7.7.2 AVAILABLE LABOR

Collinson (1983) asserts that both labor availability and use need to be treated as flows which are only meaningful at a point in time. The usual techniques tend to assume a theoretical level of availability as a constant constraint on the observed usage at peak periods can be accepted as a limit throughout the season. This study employs the

TABLE 7.7 FAMILY AND HIRED LABOR IN MAN-DAYS PER FEDDAN.

PERIOD \ DEMAND	FAMILY	HIRED
June	15	35
July	15	35
August	15	35
September	15	35
October	15	35
November	15	35
December	15	35
January	25	90
February	25	90
March	25	90
April	15	35
May	15	35
TOTAL	210	585

Source: Compiled from survey data.

technique of observed labor usage at peak periods as a limit for the seasonal available labor.

Factors affecting labor availability include age, number of hours on a working day and the time spent on off-farm work. Family labor participation in the Gezira is low because children go to school and "Arab" culture secludes family women from fieldwork. Much of the work is done by adult males. Table 7.7 shows that 15 man-days of family labor are available for farm work per month. The family labor is augmented by about 35 man-days of hired labor that rises to 90 man-days per month during cotton picking in January, February and March following the arrival of cotton picking labor from western Sudan.

TABLE 7.8 MONTHLY WATER TO A 20-FEDDAN TENANCY.

PERIOD	CUBIC METERS
June	3,700
July	6,600
August	7,300
September	7,300
October	7,800
November	7,300
December	6,900
Janaury	5,200
February	4,100
March	2,100
April	800
May	1,700
TOTAL	60,800

Source: Computed from Ministry of Irrigation records.

7.7.3 AVAILABLE WATER

The amount of water available to a Gezira model farm is 60,800 cubic meters per annum. The available water was computed from the actual amount of water flowing from the Roseires Dam through the two main canals to the tenants field's less 8 percent to account for losses to evapotranspiration on transit. Table 7.8 shows the monthly specification of available water by month for the 1989/90 cropping season.

7.7.4 AVAILABLE OPERATING CAPITAL

The available operating capital for a Gezira model farm was estimated from the monthly cash expenditures on inputs and hired labor for the 1989/90 cropping season. The total cash expenses by the standard tenancy amounted to about LS 7,150 which is rather a conservative estimate of capital availability.

7.7.5 FAMILY SUBSISTENCE NEEDS

The 1,180 Kg of family local sorghum requirement per season was estimated from the survey data with an average household of 7.3 persons and each member consumes 145 Kg per year. Thus, a minimum of 1.6 feddans has to be allocated to local sorghum production in order to cater for the family food security needs.

CHAPTER VIII

RESULTS OF THE LINEAR PROGRAMMING ANALYSIS

The structure of the linear programming model used in this study was described in Chapter VII. This Chapter presents the results of the linear programming analysis. The discussion focuses on changes in cropping pattern, resource use, resource productivity and farm income. It also includes a discussion of the important economic efficiency measures that are associated with the improvements in cultural practices and resource use in the main Gezira farming system.

The base run was obtained with two enterprise intensity levels. Intensity level 1 was the existing resource levels and intensity level 2 assumes improvements in the resource use, cultural practices and farm management with some increase in the level of production inputs. The optimum base plan also deals with the possibility of buying the subsistence local sorghum from the market rather than growing it on the farm.

Several adjustments were made to the base run to determine the impact of the changes on the optimum base plan. The four scenarios include: 1) omitting all elements of the mandated cropping pattern; 2) 15 percent increase in crop yields; 3) 25 percent increase in the prices of: i) all crops; ii) cotton; iii) non cotton crops; and iv) sorghum; and 4) 25 percent increase in the amount of available water and family labor.

The linear programming output in each of the four scenarios provided information on the value of the objective function, the optimum enterprise combination, the level of resource use with the shadow prices or marginal value products (MVP) of each resource, the non optimal activities with the costs associated with forcing each of

them into the solution; and the stability limits of the base run. The constraint patterns and the shadow prices tell us the input utilization on the farm and how much the tenant would value an additional unit of each input. The validity of the optimal solution depends on the realism of the assumptions made about prices, technical coefficients and resource constraints.

8.1 BASE RUN ANALYSIS

8.1.1 LEVEL OF ENTERPRISES IN THE BASE RUN

Table 8.1 shows the optimum base run under the existing resource intensity levels. The value of the objective function is equal to LS 19,997.75 Sudanese pounds. Gezira tenants have no buildings on the farm, have limited storage space and use hand tools. Since their fixed costs are minimal, the total gross margin is equivalent to net farm income.

The optimum combination of enterprises includes cash crops and food crops, and does not utilize all the available land. Medium-staple cotton 2 was cultivated on 3.69 feddans, wheat 2 on 1.19 feddans, local sorghum 2 on 1.57 feddans, hybrid sorghum 2 on 3.43 feddans and 5.12 feddans remain not cultivated. The base run includes all the crops grown under the mandated cropping pattern in the main Gezira except for long-staple cotton and groundnuts whose exclusion from the optimal plan means that under present conditions they are not competitive enough to enter the optimum plans. The 1.57 feddans for the cultivation of local sorghum varieties satisfies the 1,180 Kg consumption requirement for food security.

TABLE 8.1 LEVEL OF ENTERPRISES IN THE GEZIRA MODEL.		
ACTIVITY	UNIT	BASE RUN
MSC1	Fed	-
MSC2	Fed	3.69
WHT1	Fed	-
WHT2	Fed	1.19
LSO1	Fed	-
LSO2	Fed	1.57
HSO1	Fed	-
HSO2	Fed	3.43
Gross margin	LS	19,997.75
Land	Fed	9.88
Cropping Intensity	%	49
Family labor	Md	60
Hired labor	Md	247.23
Total labor	Md	307.23
Operating capital	LS	16,519.34
Returns to land	LS	2,024.06
Returns to labor	LS	65.09
Returns to operating capital	LS	1.21
Source: LP88 printout.		

The average return to a unit of land is LS 2,024. The average return to a unit of labor is LS 65. The total labor use in the optimum farm plan was 307 man-days comprising of 60 man-days of family labor and 247 man-days of hired labor.

The optimum base plan bears some similarity to the existing farming practices in the main Gezira in that very few tenants prefer to cultivate groundnuts because of: 1) high production costs; 2) lack of marketing facilities; and 3) lack of formal credit. Medium-staple cotton is preferred to long-staple cotton because it gives high yields and has better marketing prospects.

A comparison of the actual farm and the base run reveals that improvements in the efficiency of factor use through the reallocation of resources on the farm has a high potential for the achievement of increases in farm incomes. The optimum base run is much better than the actual cropping pattern. The objective function increases by 36 percent, family labor by 33 percent, total labor by 11 percent, returns to a unit of land by 57 percent and returns to a unit of labor by 41 percent. This implies that the existing resources could be utilized more efficiently than under the actual plan.

The inclusion of a local sorghum buying activity at a price of LS 3.50 per Kg into the base run resulted in the model picking the purchase alternative to meet the subsistence needs. The 1.57 feddans under local sorghum were reallocated to hybrid sorghum 2 and returns increases by 7 percent to LS 21,315.24. However, Gezira tenants have always grown their own sorghum rather than depend on the inefficient local market. The farm would be better off by LS 1,317.49 per year if it could rely on the market to supply food at the same prices the farm receives when it sells.

8.1.2 SHADOW PRICES IN THE BASE RUN

The shadow price measures the rate of change of the objective function with respect to a small change in one of the resources. The shadow price is sometimes called marginal value product which is akin to the partial derivative in calculus. The marginal value products shown in table 8.2 are the shadow prices of the disposal activities of the linear programming model. The marginal value product of a resource is defined as the increase in the value of the total output that is obtained from the use of an additional unit of the resource with all other inputs held constant. Shadow prices of disposal activities are operationally useful since they provide information about the resources whose expansion will increase net farm income. Linear programming solutions will hold for specific ranges of shadow prices until some resources become limiting at which point another farm organization becomes optimal and the shadow prices of the resources change.

The shadow prices indicate the productivity of resources on the farm. The shadow prices are zero for excess (slack) resources and are positive for limiting resources. They represent the gains in income that are possible through the acquisition of a scarce resource. A high shadow price indicates a scarcity of the resource. The more limiting the resource, the higher the shadow price. The shadow prices have to be considered relative to the marginal factor cost for them to have some meaning. It is profitable to acquire a resource if its shadow price is greater than its marginal factor cost.

The optimum solution provides an indication of the opportunity cost or value for each of the resources used by the Gezira tenant in the production process. Land has a shadow price of zero because it has slack. The shadow price of labor indicate that labor

TABLE 8.2 SHADOW PRICES FOR THE RESOURCES IN THE BASE RUN.

RESOURCE	UNIT	SHADOW PRICES
LAND	Md	0.00
JUNL	Md	0.00
JULL	Md	25.54
AUGL	Md	27.55
SEPL	Md	19.26
OCTL	Md	0.00
NOVL	Md	25.09
DECL	Md	30.03
JANL	Md	14.90
FEBL	Md	15.19
MARL	Md	0.00
APRL	Md	0.00
MAYL	Md	0.00
AUGW	Cbm	1.46
FEBW	Cbm	1.44
MSBR	Kg	4.62
JUNC	LS	0.12
JULC	LS	0.12
AUGC	LS	0.12
SEPC	LS	0.12
OCTC	LS	0.12
NOVC	LS	0.12
DECC	LS	0.10
JANC	LS	0.08
FEBC	LS	0.07
MARC	LS	0.05
APRC	LS	0.03

Source: Computed from survey data.

is scarce in July, August, September, November, December, January and February. The high shadow price of labor in July can be attributed to land preparation and planting of cotton, groundnuts and sorghum. The shadow price of labor implies that unless a farmer can hire below or equal to the shadow wage rate, he should not hire labor because the cost will be greater than what is worth. The months where labor becomes limiting corresponds closely to the peak periods in the farming activities when farm operations like land preparation, planting, weeding and harvesting have to be done. Additional units of labor during these months can increase the value of the objective function by their marginal value products. An additional unit of labor increases the gross margin by LS 25.54 in July, LS 27.55 in August, LS 19.26 in September, LS 25.09 in November, LS 30.03 in December, LS 14.90 in January and LS 15.19 in February.

Water is scarce in August with a shadow price of LS 1.46 when cotton, groundnuts and sorghum are being established and a shadow price of LS 1.43 in February when cotton and wheat are at a late maturing stage and the level of water at the Roseires dam is low.

The results also indicate that meeting the minimum sorghum subsistence requirements reduces the net cash income by LS 4.62 for each kg produced and consumed on the farm, since it takes scarce resources away from the production of cash crops.

8.1.3 COST OF FORCING EXCLUDED ACTIVITIES INTO THE BASE RUN

The linear programming output provides information on the activities excluded from the base run. The excluded enterprises are the least profitable. The cost of forcing an excluded enterprise into the solution indicates how the value of the objective function would be reduced if a unit of the enterprise were forced into the base run. The value

TABLE 8.3 COST OF FORCING EXCLUDED ACTIVITIES INTO BASE RUN.

ACTIVITY	UNIT	COST (LS)
MSC1	Fed	762.11
LSC1	Fed	1,125.74
LSC2	Fed	176.62
WHT1	Fed	357.03
GNT1	Fed	1,399.38
GNT2	Fed	505.53
LSO1	Fed	992.86
HSO1	Fed	597.66
JUNL	Md	24.08
OCTL	Md	18.26
MARL	Md	14.07
APRL	Md	20.91
MAYL	Md	14.50
SLSC	Kan	28.49
SLSO	Kg	1.72

Source: Computed from survey data.

indicates the competitive position of the enterprise. The higher the value of the enterprise, the lower its competitive position.

The enterprises excluded from the optimum plan include medium-staple cotton 1, long-staple cotton 1 and 2, wheat 1, local sorghum 1, and hybrid sorghum 1. These enterprises are shown in table 8.3. Forcing units of these enterprise into the optimum solution will reduce the total gross margins as follows: medium-staple cotton 1 by LS 762.11, long-staple cotton 1 by LS 1,125.74, long-staple cotton 2 by LS 176.62, wheat 1 by LS 357.03, groundnuts 1 by LS 1,399.38, groundnuts 2 by LS 505.53, local sorghum 1 by LS 992.86 and hybrid sorghum 1 by LS 597.66. We could rank the crops not active in the

optimum plan to see which enterprises will come in when we relax the most important constraint. Suppose increasing domestic groundnut production is a national priority and the government is proposing a subsidy. The subsidy would have to be massive as groundnuts is the last crop a tenant would want to produce since the high shadow price indicates that it is the least profitable.

Hiring additional units of labor reduces gross margin by LS 24.08 in June, LS 18.26 in October, LS 14.07 in March, LS 20.91 in April and LS 14.50 in May. Selling long-staple cotton reduces the objective function by LS 28.49 per Kantar and local sorghum by LS 1.72 per Kg, respectively.

The shadow prices of operating capital is also a constraint in most months. Farm income could increase if operating capital is available. There is a need for formal credit to relax the capital constraint.

8.1.4 RESOURCE RANGE COEFFICIENTS IN THE BASE RUN

Table 8.4 shows the righthand side stability limits of the base solution. The optimum solution will hold as long as any of the resource levels do not fall below the minimum or above the maximum limits. When any of the resources become limiting then a different enterprise combination will become optimal and the shadow prices will change. The tenancy size can vary from 14.9 to infinity feddans without affecting the enterprise mix. August labor varies from 3.8 to 36.8 man-days, August water from 6,461 to 7,400 cubic meters of water, the subsistence requirement of local sorghum from 0 to 3,750 kilograms, starting capital from LS 6,875.5 to LS 8,415.6; and the tenant could secure any amount of capital for his farm operations. The repayment of borrowed capital is not binding on this plan.

8.2 SENSITIVITY ANALYSIS OF THE GEZIRA MODEL FARM

Sensitivity analysis is the study of how changes in the coefficients of the linear program affect the optimal solution. Sensitivity analysis helps determine the most effective agricultural development policy instruments that will increase tenancy profitability in the Gezira Scheme. The policy variables are both economic such as input and output prices; and technical such as improvements in crop variety, cultural practices and farm management. The efficiency of the policy instruments will depend on how sensitive the base solution is to changes in the coefficients.

This section presents the results of changes in the base Gezira farm model. The four scenarios involve; 1) relaxation of the mandated cropping pattern, 2) changes in crop yields; 3) changes in crop prices; and 4) changes in water and labor availability in the Gezira tenancy.

8.2.1 THE EFFECT OF RELAXING THE MANDATED CROPPING PATTERN

8.2.1.1 LEVEL OF ENTERPRISES IN THE SOLUTION

This scenario attempts to evaluate the effect of the removal of the mandated cropping pattern (MCP) on the enterprise mix of the optimum base run. The four-course rotation in the main Gezira has been mandated by the government whose sole interest is the production of cotton for export and wheat as an import substitute whereas groundnuts and sorghum are the tenant's crops.

The results indicate that the relaxation of all aspects of the existing rotation and crop mix is profitable for the Gezira tenant since he would have the freedom to choose the crops to grow.

Table 8.5 shows the total area cultivated is 13.7 feddans. The enterprise mix is different from that of the base plan because tenants have complete freedom to choose

TABLE 8.4 RESOURCE RANGE VARIATIONS IN THE GEZIRA MODEL.

CONSTRAINT	UNIT	RIGHTHAND SIDE	MINIMUM	MAXIMUM
LANT	Fed	20	14.9	(***)
LANF	Fed	5	0.0	10.1
LANC	Fed	5	3.7	(***)
LANW	Fed	5	1.2	(***)
LANGS	Fed	5	4.8	6.0
JUNL	Md	15	10.0	(***)
JULL	Md	15	3.0	32.4
AUGL	Md	15	3.8	36.8
SEPL	Md	15	-1.0	28.4
OCTL	Md	15	10.5	(***)
NOVL	Md	15	(***)	43.5
DECL	Md	15	(***)	30.5
JANL	Md	25	(***)	36.3
FEBL	Md	25	(***)	33.2
MARL	Md	25	24.2	(***)
APRL	Md	15	13.5	(***)
MAYL	Md	15	8.1	(***)
JUNW	Cbm	3,700	3,650.0	(***)
JULW	Cbm	6,600	3,650.0	(***)
AUGW	Cbm	7,300	6,461.0	7,400.0
SEPW	Cbm	7,300	5,200.0	(***)
OCTW	Cbm	7,800	3,600.0	(***)
NOVW	Cbm	7,300	4,100.0	(***)
DECW	Cbm	6,900	4,100.0	(***)
JANW	Cbm	5,200	4,100.0	(***)
FEBW	Cbm	4,100	3,100.0	4,718.2
MSBR	Kg	1,180	0.0	3,750.0
JUNC	LS	7,150	6,875.6	8,415.6
ENDC	LS	7,180	0.0	(***)

(***) Means no lower or upper bound limits respectively.

Source: Computed from survey data.

the crops they wish to grow on financial grounds. The new optimum plan has eliminated medium-staple cotton 2, the area of wheat 2 increases by 310 percent and hybrid sorghum 2 increases by 108 percent. Cotton drops out of the new plan because it occupies land for a longer period of time and requires more labor and water whereas wheat is a winter crop that requires less labor. The changes in the optimum plan can be attributed to the shortage of capital for hiring more labor in the critical periods. The 1.57 feddans are maintained under local sorghum 2 for meeting food security. Land under cultivation increases by 37 percent, cropping intensity by 39 percent, hired labor decreases by 30 percent and total labor by 24 percent. Return to capital decreases by 8 percent which is an indication of diminishing returns to resources.

TABLE 8.5 ENTERPRISE LEVELS WITHOUT MANDATED CROPPING PATTERN.

ACTIVITY	UNIT	BASE MCP	WITHOUT MCP	% CHANGE
MSC2	Fed	3.69	0.0	-100
WHT2	Fed	1.19	4.88	+310
LSO2	Fed	1.57	1.57	
HSO2	Fed	3.43	7.12	+108
Gross margin	LS	19,997.75	23,360.92	+17
Land	Fed	9.88	13.57	+37
Cropping intensity	%	49	68	+39
Family labor	Md	60	60	
Hired labor	Md	247.23	172.24	-30
Total labor	Md	307.23	232.24	-24
operating capital	LS	16,519.34	19,451.46	+18
Returns to Land	LS	2,036.06	1,721.51	-15
Returns to Labor	LS	65.09	100.59	+55
Returns to capital	LS	1.21	1.20	-8

Source: Computed from survey data.

8.2.1.2 SHADOW PRICES IN THE OPTIMUM SOLUTION

Table 8.6 shows the shadow prices of the resources used in the optimum plan without the mandated cropping pattern. The shadow price of labor drops to zero in September and rises by 100 percent in January and February during cotton and wheat harvesting. The shadow price of water increases by 90 percent in August but that of subsistence sorghum and operating capital remains the same.

TABLE 8.6 SHADOW PRICES WITHOUT MANDATED CROPPING PATTERN.

ACTIVITY	UNIT	BASE MCP	WITHOUT MCP	% CHANGE
LAND	Fed	0.00	0.00	
JUNL	Md	0.00	0.00	
JULL	Md	25.54	25.54	
AUGL	Md	27.55	27.55	
SEPL	Md	19.26	0.00	-100
OCTL	Md	0.00	0.00	
NOVL	Md	25.09	25.09	
DECL	Md	30.03	30.03	
JANL	Md	14.90	0.00	-100
FEBL	Md	15.19	0.00	-100
MARL	Md	0.00	0.00	
APRL	Md	0.00	0.00	
MAYL	Md	0.00	0.00	
AUGL	Md	1.46	2.78	+90
FEBL	Md	1.44	1.46	+1
MSBR	Kg	4.62	4.61	

Source: Computed from survey data.

8.2.1.3 COST OF FORCING EXCLUDED ACTIVITIES INTO THE SOLUTION

Table 8.7 shows the cost of forcing into the optimal solution the enterprises that have been excluded from the plan. The cost of bringing enterprises into the plan or hiring additional units of labor increased tremendously such that the losses in the objective function following their inclusion will be significant. These costs reveal the

TABLE 8.7 COST OF FORCING EXCLUDED ACTIVITIES INTO THE PLAN.

ACTIVITY	UNIT	BASE MCP	WITHOUT MCP
MSC1	Fed	762.11	1,566.58
MSC2	Fed	0.00	758.58
LSC1	Fed	1,125.74	1,930.81
LSC2	Fed	1,125.74	931.11
WHT1	Fed	357.03	357.03
GNT1	Fed	1,399.38	1,289.67
GNT2	Fed	505.53	395.82
LSO1	Fed	992.86	992.86
HSO1	Fed	597.66	597.66
JUNL	Md	24.08	24.08
SEPL	Md	0.00	19.26
OCTL	Md	18.26	18.26
JANL	Md	0.00	14.49
FEBL	Md	0.00	14.91
MARL	Md	14.07	14.07
APRL	Md	20.91	20.91
MAYL	Md	14.50	14.50
SLSO	Kg	1.72	1.72

Source: Computed from survey data.

competitive position of the enterprise. The lower costs indicate potential competitive position. Forcing a unit of medium-staple cotton 2 into the optimum solution would reduce the total gross margin by LS 758.58, local sorghum 2 by LS 931.11 and groundnuts by LS 395.82. Hiring an additional unit of June labor reduces the objective function by LS 24.08 and the sale of one more kilogram of local sorghum produced on the farm will reduce the objective function by LS 1.72.

8.2.2 CHANGES IN CROP YIELDS

8.2.2.1 LEVEL OF ENTERPRISES IN THE SOLUTION

Gezira research station field trial results have shown that increases in yield higher than intensity level 2 are feasible with fertilizer application, improvements in the delivery of research packages; and incentive structure to encourage tenants to adopt new technology. This scenario examines the effect of a 15 percent increase in yields of all crops following technological improvements. The area under local sorghum decreases by 12 percent since the high yields imply that the subsistence needs can be met with less land, and the area of hybrid sorghum increases by 6 percent.

The new plan is much better due to improvements in the efficiency of resource utilization. The objective function increases by 28 percent. Returns to land increases by 28 percent, returns to labor increases by 29 percent and returns to capital increases by 54 percent. These returns are much higher than in the optimum base plan.

8.2.2.2 SHADOW PRICES WITH 15 PERCENT INCREASE IN YIELDS

When crop yields increase by 15 percent, land has a shadow price of zero. Bringing more land into production would add no return to the value of the objective function. The new plan gives more output and the shadow prices of labor remain the same. The shadow prices of water increases by 29 percent in August and 28 percent in

TABLE 8.8 LEVEL OF ENTERPRISES WITH 15 % INCREASE IN YIELD.			
ACTIVITY	UNIT	BASE RUN	15 % YIELD
MSC2	Fed	3.69	3.69
WHT2	Fed	1.19	1.19
LSO2	Fed	1.57	1.37
HSO2	Fed	3.43	3.63
Gross margin	Md	19,997.75	25,662.58
Land	Md	9.88	9.88
Crop intensity	%	49	49
Family labor	Md	60	60
Hired labor	Md	247.23	246.35
Total labor	Md	307.23	306.35
Operating capital	LS	16,519.06	16,468.24
Returns to land	LS	2,036.06	2,597.43
Returns to labor	LS	65.09	83.77
Returns to capital	LS	1.01	1.56
Source: Computed from survey data.			

February. Water is a limiting factor. Labor is limiting in July, August and September during the period of planting and weeding of cotton, groundnuts and sorghum; and in November, December, January and February during the period of crop harvesting. Availability of funds could break the labor bottleneck leading to production increases.

8.2.2.3 COST OF FORCING EXCLUDED ACTIVITIES INTO THE SOLUTION

Table 8.10 shows the cost of forcing in activities excluded from the optimum plan. The production of one feddan with long-staple cotton 1 will decreases the value of the objective function by LS 1,296.74, groundnuts 1 by 1,634.98 and local sorghum 1 by LS 1,212.73. The high cost of forcing in groundnuts into the optimum plan reflects its low value on the local market reduced by the opportunity value of the resources it requires.

TABLE 8.9 SHADOW PRICES WITH 15 PERCENT INCREASE IN YIELD.			
RESOURCE	UNIT	BASE RUN	15 % YIELD
LAND	Md	0.00	0.00
JUNL	Md	0.00	0.00
JULL	Md	25.54	25.54
AUGL	Md	27.55	27.55
SEPL	Md	19.26	19.26
OCTL	Md	0.00	0.00
NOVL	Md	25.09	25.09
DECL	Md	30.03	30.03
JANL	Md	14.90	14.90
FEBL	Md	15.19	15.19
MARL	Md	0.00	0.00
APRL	Md	0.00	0.00
MAYL	Md	0.00	0.00
AUGW	Cbm	1.46	1.88
FEBW	Cbm	1.44	1.84
MSBR	Kg	4.62	4.65
Source: Computed from survey data.			

The cost is so high because groundnuts requires a lot of labor in November and December. The low cost of long-staple cotton 2 suggests that a slight change in the model structure could bring it into the basis. The cost of hiring additional units of labor is LS 24.08 in June, LS 18.26 in October, LS 14.07 in March, LS 20.91 in April and LS 14.50 in May. Selling a kilogram of locally produced sorghum would result in the loss of LS 1.76.

TABLE 8.10 COST OF FORCING EXCLUDED ACTIVITIES INTO SOLUTION.		
ACTIVITY	UNIT	COST (LS)
MSC1	Fed	921.11
LSC1	Fed	1,296.74
LSC2	Fed	199.62
WHT1	Fed	447.03
GNT1	Fed	1,634.98
GNT2	Fed	553.53
LSO1	Fed	1,212.73
HSOI	Fed	735.66
JUNL	Md	24.08
OCTL	Md	18.26
MARL	Md	14.07
APRL	Md	20.91
MAYL	Md	14.50
SLSO	Kg	1.76
Source: Computed from survey data.		

8.2.3 CHANGES IN CROP PRICES

8.2.3.1 LEVEL OF ENTERPRISES IN THE SOLUTION

There is no change in the crop areas for medium-staple cotton 2, wheat 2, local sorghum 2 and hybrid sorghum 2 when the prices of: (i) all crops, (ii) cotton, (iii) non cotton crops; (iv) sorghum increases by 25 percent. Higher producer prices would be needed if the tenants are to produce more of these crops.

Table 8.11 shows increases in prices of: (i) all crops, (ii) cotton, (iii) non cotton (iv) and sorghum by 25 percent respectively. In alternative ii: the cropping pattern changes. The area under medium-staple cotton 2 increases by 14 percent, that under wheat decreases by 42 percent and that under hybrid sorghum decreases by 15 percent.

TABLE 8.11 LEVEL OF ENTERPRISES WITH 25 PERCENT PRICE INCREASES.

		i	ii	iii	iv
ACTIVITY	UNIT	ALL CROPS	COTTON	NON COTTON	SORGHUM
MSC2	Fed	3.69	4.19	3.69	3.69
WHT2	Fed	1.19	0.69	1.19	1.19
LSO2	Fed	1.57	1.57	1.57	1.57
HSO2	Fed	3.43	2.93	3.43	3.43
Gross margin	LS	28,320.97	24,342.18	24,001.63	23,287.35
Land	Fed	9.88	9.38	9.88	9.88
Crop intensity	%	49	47	49	49
Family labor	Md	60	75	60	60
Hired labor	Md	247.23	243.0	247.23	247.23
Total labor	Md	307.23	318.0	307.23	307
Operating capital	LS	16,519.34	16,124.19	16,519.33	16,519.33
Returns to Land	LS	2,866.49	2,595.11	2,429.31	2,357.02
Returns to Labor	LS	92.19	76.55	78.12	75.80
Return to Capital	LS	1.71	1.51	1.45	1.41

Source: Computed from survey data.

The cropping intensity decreases by 2 %. The family contributes 25 percent more labor than in the other alternatives. Hired labor decreases by 2 percent and total labor increases by 4 percent. Operating capital decreases by 2 percent.

Returns to the scarce resources are much higher than in the optimum base plan. The objective function, returns to land and returns to operating capital increases range from 16 to 42 percent compared with the base run.

8.2.3.2 SHADOW PRICES WITH 25 PERCENT PRICE INCREASES

Table 8.12 shows the shadow prices after 25 percent price increase in all crops, cotton, non cotton and sorghum, respectively. The shadow price of land remains zero since there is slack land. The shadow prices of labor are the same in all the alternatives

TABLE 8.12 SHADOW PRICES WITH 25 PERCENT PRICE INCREASES.

		i	ii	iii	iv
ACTIVITY	UNIT	ALL CROPS	COTTON	NON COTTON	SORGHUM
LAND	Fed	0.00	0.00	0.0	0.00
JUNL	Md	0.00	0.00	0.0	0.00
JULL	Md	25.54	25.54	25.54	25.54
AUGL	Md	27.55	27.55	27.55	27.55
SEPL	Md	19.26	19.26	19.26	19.26
OCTL	Md	0.00	0.00	0.0	0.00
NOVL	Md	25.09	25.09	25.09	25.09
DECL	Md	30.03	30.03	30.03	30.03
JANL	Md	14.91	14.90	14.90	14.90
FEBL	Md	15.19	15.19	15.19	15.19
MARL	Md	0.00	14.07	0.00	0.00
APRL	Md	0.00	9.21	0.00	0.00
AUGW	Cbm	2.14	2.74	0.75	1.46
FEBW	Cbm	2.15	1.41	2.15	1.44
MSBR	Kg	5.90	4.60	5.90	5.90

Source: Computed from survey data.

except for April labor under alternative 2 where the shadow price rises by 100 percent.

Under alternative i, the shadow price of water increases by 47 percent in August, 49 percent in February and subsistence requirements increases by 28 percent.

Under alternative ii, the shadow price of water increases by 88 percent in August and decreases by 2 percent in February. Under alternative iii, the shadow price of August water decreases by 49 percent and increases by 49 percent in February and that of minimum subsistence sorghum increases by 28 percent under alternative iii.

8.2.3.3 COST OF FORCING EXCLUDED ACTIVITIES INTO THE SOLUTION

Table 8.13 shows the cost of forcing excluded activities into the optimal plan.

Alternative i: The costs of bringing in enterprises not in the optimal solution increases by 34 percent for medium-staple cotton, 30 percent for long-staple cotton 1, 13 percent for long-staple cotton 2, 49 percent for wheat 1, 31 percent for groundnuts, 24 percent for groundnuts 2, 38 percent for local sorghum 1, 40 percent for hybrid sorghum and 34 percent for the sale of local sorghum 2.

Alternative ii: The cost of forcing excluded enterprises into the optimal plan increases by 32 for medium-staple cotton 1, 28 percent for long-staple cotton 1 and by 15 percent for long-staple cotton 2. The cost of hiring additional labor declines by 100 in March and 44 percent in April.

TABLE 8.13 COST OF FORCING EXCLUDED ACTIVITIES INTO SOLUTION.

		i	ii	iii	iv
ACTIVITY	UNIT	ALL COTTON	COTTON	NON COTTON	SORGHUM
MSC1	Fed	1,028.11	1,007.11	762.11	762.11
LSC1	Fed	1,463.64	1,442.64	1,125.74	1,125.74
LSC2	Fed	200.02	202.35	176.62	176.62
WHT1	Fed	517.03	357.03	517.03	357.03
GNT1	Fed	1,834.38	1,399.38	2,359.38	2,359.38
GNT2	Fed	625.53	505.53	1,465.53	1,465.53
LSO1	Fed	1,374.86	992.86	1,376.86	1376.86
HSO1	Fed	837.66	597.66	837.66	837.66
JUNL	Md	24.08	24.08	24.08	24.08
OCTL	Md	18.26	18.26	18.26	18.26
MARL	Md	14.07	0.00	14.07	14.07
APRL	Md	20.91	11.70	20.91	20.91
MAYL	Md	14.50	14.50	14.50	14.50
SLSO	LS	2.30	1.72	2.30	2.30

Source: Computed from survey data.

Alternative iii: The cost of forcing excluded enterprises into the optimum plan increases. Wheat 1 increases by 49 percent, groundnuts 1 by 69 percent, groundnuts 2 by 190 percent, local sorghum 1 by 39 percent and hybrid sorghum 1 by 40 percent from the optimum base plan.

8.2.4 CHANGES IN THE LEVELS OF WATER AND LABOR

8.2.4.1 LEVEL OF ENTERPRISES IN THE SOLUTION

Alternative i: the amount of available water increases by 25 percent for all months. The area under medium-staple cotton 2 increases by 36 percent and that under wheat 2 decreases by 15 percent. The amount of the objective function increases by 14

TABLE 8.14 INCREASES IN AVAILABLE WATER AND LABOR BY 25 %.

ACTIVITY	UNIT	25 % WATER	25 % LABOR
MSC2	Fed	5.00	3.69
WHT2	Fed	1.01	1.19
LSO2	Fed	1.57	1.57
HSO2	Fed	3.43	3.43
Gross margin	LS	22,795.87	20,663.87
Land	Fed	11.01	9.88
Cropping Intensity	%	55	49
Family labor	Md	75.0	75
Hired labor	Md	296.91	232.73
Total labor	Md	371.91	307.73
Operating capital	LS	13,675.77	17,267.09
Returns to land	LS	2,070.47	2,091.48
Returns to labor	LS	61.29	67.25
Returns to capital	LS	1.67	1.20

Source: Computed from survey data.

percent, cropping intensity by 12 percent, family labor use by 25 percent, hired labor by 20 percent, total operating capital decreases by 17 percent, returns per feddan decreases by 3 percent, return per man-day by 6 percent and return per operating capital by 38 percent which indicates diminishing returns to capital.

Alternative ii: The amount of available labor increases by 25 percent for all the months. The cropping intensity is similar to that of the optimum base run. The value of the objective function increases by 3 percent, hired labor by 6 percent, total operating capital by 5 percent, return to land by 3 percent, return to labor by 3 percent and return per operating capital is similar to that of the base plan.

8.2.4.2 SHADOW PRICES WITH 25 % MORE AVAILABLE WATER AND LABOR

The high prices attached to water, labor and operating capital in some months of the year indicate that increases in these resources would be profitable.

Alternative i: The availability of more water brought more land under medium-staple cotton 2. Shadow prices of March and April labor increases by 100 percent because more labor will be required for picking and pulling of cotton. Shadow price of August water increases by 100 percent and that of February water decreases by 3 percent.

Alternative ii: The availability of family labor led to no significant changes in the values of the shadow prices that remain similar to that of the base plan and the reason being that the tenant could always substitute it with hired labor if funds are available.

8.2.4.3 COST OF FORCING EXCLUDED ACTIVITIES INTO THE SOLUTION

Table 8.16 shows the cost of forcing excluded activities into the solution. The cost value indicates the competitive position of the enterprise. The higher the value of the excluded enterprise, the lower its competitive position.

TABLE 8.15 SHADOW PRICES WITH 25 % WATER AND LABOR INCREASE.			
RESOURCE	UNIT	25 % WATER	25 % LABOR
LAND	Fed	0.00	0.00
JUNL	Md	0.00	0.00
JULL	Md	25.76	25.54
AUGL	Md	27.80	27.55
SEPL	Md	19.44	19.26
NOV	Md	25.09	25.09
DECL	Md	30.03	30.03
JANL	Md	14.90	14.90
FEBL	Md	15.19	15.19
MARL	Md	14.07	0.00
APRL	Md	20.91	0.00
MAYL	Md	0.00	0.00
AUGW	Cbm	0.00	1.46
FEBW	Cbm	1.40	1.44
MSBR	Kg	4.62	4.62
Source: Computed from survey data.			

Alternative i: The cost of forcing excluded activities into the optimum plan decreases by 4 percent for medium-staple cotton, 4 percent for long-staple cotton and increases by 3 percent for wheat 1. The cost of hiring more labor in March and April decreases by 100 percent. Hiring more units of labor in June, October, March, April and May will reduce the value of the objective function by their respective costs.

8.2.5 LEVEL OF ACTIVITIES WITHOUT BORROWING

This scenario evaluates the effect of the removal of borrowing on the enterprise

TABLE 8.16 COST OF FORCING EXCLUDED ACTIVITIES INTO SOLUTION.			
ACTIVITY	UNIT	25 % WATER	25 % LABOR
MSC1	Fed	732.14	762.11
LSC1	Fed	1,096.81	1,125.74
LSC2	Fed	181.16	176.62
WHT1	Fed	357.03	357.03
GNT1	Fed	1,398.28	1,399.38
GNT2	Fed	507.12	505.53
LSO1	Fed	990.16	992.86
HSO1	Fed	595.51	597.66
JUNL	Md	24.30	24.08
OCTL	Md	18.42	18.26
MARL	Md	0.00	14.07
APRL	Md	0.00	20.91
MAYL	Md	14.50	14.50
SLSO	Kg	1.72	1.72
Source: Computed from survey data.			

mix of the base run. The objective function decreases by 33 percent. The area under cultivation decreases to 6.59 feddans. The activities in the solution include medium-staple cotton 2, local sorghum 2 and hybrid sorghum 2. Wheat 2 drops out of the solution. The area under medium staple cotton 2 decreases by 54 percent, hybrid sorghum 2 decreases by 3 percent. Returns to land, labor and capital decrease by significant amounts. The changes in the optimum base plan can be attributed to capital shortage such that most aspects of the rotation will not be profitable.

Shadow prices of labor in July, August, September, November, and December increase by more than 100 percent. Shadow prices of labor decreases by 100 percent in January and February.

8.3 SUMMARY

This chapter presents the optimum enterprise combinations of the base run and the postoptimality analysis solutions of the Gezira model farm. The empirical findings indicate that the enterprises produced under improved technology would be in a more competitive position than those produced under the existing technology. Improvements in the efficiency of factor use and farm income could result from resource reallocation under the new technology.

The results indicate that the omission of the mandated cropping pattern, 15 percent yield increase, 25 percent price increases and the 25 percent more water being made available will lead to farm profitability. The high potential can be realized by increased resource use, resource productivity and farm income through improvements in cultural practices, crop variety and farm management leading to the attainment of the new technology production levels. Capital, water and labor are limiting. Provision of institutional credit could enable tenants to pay for the maintenance of water channels and hire more labor during peak labor demand periods.

There is a 7 percent reduction in net farm income when the tenants are constrained to produce their own subsistence sorghum. Improvements in crop marketing could make this unnecessary since they could purchase it from the market and would still be better off financially. The important production constraints are lack of improved

technical packages, remunerative producer prices, production inputs and research knowledge.

CHAPTER IX

SUMMARY, POLICY IMPLICATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

This chapter will give a summary of the study, draw policy implications, indicate the major limitations of the study, and give suggestions for future research.

9.1 SUMMARY

Agriculture is the most important sector of the Sudanese economy. It represents a vital development problem and offers the most attractive development opportunity. Sudan is blessed with a vast agricultural potential and three different subsectors: traditional, mechanized and irrigated offering a range of opportunities and challenges. Agriculture employs 75 percent of the population and contributes 95 percent to export earnings. The irrigated subsector contributes a disproportionately large share to export earnings. Despite the vast agricultural potential, Sudan cannot satisfy its internal food needs. This is reflected in low agriculture productivity, uncertain weather, civil war, poor use of irrigable land and weak infrastructure with limited storage and inadequate transport to move food supplies. All the three subsectors suffer from low productivity due to inadequate technology, lack of access to productive inputs and credit; and soil fertility decline.

The major constraints to growth in the agriculture sector are: the uncertainty of rainfed agriculture; the fragile sahelian environment; weak transportation; an unstable

economic and political environment and an agricultural commodity marketing system that provides little return to farmers.

The irrigated subsector has been characterized by low output, producer income and resource productivity. The major problems that plague the irrigated subsector include poor maintenance, bad management, shortage of equipment, price controls and lack of proven technology. These problems limit the capacity of the irrigated subsector to contribute to economic development.

Lack of proven technology is an important cause of the poor performance of the Gezira Scheme. The Gezira rehabilitation project has been established in order to improve the scheme by enhancing its capacity to perform efficiently. The strategy of this project is to improve technology by providing chemical fertilizers, improved seed varieties, land preparation and cultural practices. The proper use of these inputs could alter the relative resource requirements of the cropping enterprises as well as their relative revenues. Improved technology and the resulting changes in resource allocation could have significant impact on cropping pattern, resource productivity, employment and farm income. The relevant information on changes in cropping patterns, resource productivity and farm income can form the basis for the formulation of sound agricultural policies that can meet the major government goals. The major problems facing Gezira tenants are: 1) lack of tenant participation in decision making, 2) lack of flexibility in choosing enterprise combinations; and 3) inability of the tenants to adjust farm size to fit their family lifecycles.

9.1.1 THE DESIGN OF THE STUDY

The purpose of the study was to analyze changes in resource use, enterprise combination and farm income. The study focused on five objectives: 1) Describe the

farming system of the Gezira irrigation Scheme; 2) identify the main constraints facing tenants in increasing food production and farm income; 3) evaluate alternative policy scenarios which can lead to more efficient resource use; 4) evaluate the economic viability and Sudan's comparative advantage of the crops grown in the Gezira; and 5) draw policy implications for raising crop productivity. The theoretical framework approach include: 1) domestic resource cost ratios to evaluate Sudan's comparative advantage in the production of crops in the Gezira, and 2) linear programming models of the Gezira to obtain optimum farm plans under existing resource constraints

1) The domestic resource cost ratios provided the theoretical model for the determination of comparative advantage for the 1989/90 cropping season. A domestic resource cost ratio of less than one means Sudan has a comparative advantage in the production of the particular crop because it can exchange domestic resources for foreign resources at a rate below which the economy as a whole converts the domestic resources into foreign exchange. The necessary information for computing domestic resource cost ratios includes: the value of domestic resources used in the production of the commodity, value of joint product, border price of the commodity, value of traded inputs and shadow exchange rate.

2) Static linear programming model provided the framework for analyzing the economics of resource use under existing conditions and improvements in technology. The structure of the linear programming model described in chapter VII was formulated to maximize net income subject to meeting minimum sorghum consumption requirements of the household. The activities in the model included crop production, labor hiring, irrigation water, capital flow, crop selling, sorghum buying and capital

borrowing. The model generated optimum farm plans that gave the direction of change in cropping pattern, resource use and farm income.

Data from this study were obtained from both primary and secondary sources. A survey of 96 farm households was conducted by the researcher in four administrative blocks (Wad Numan, Tayba, Turis, Loata). Twenty four tenants chosen from each of the four blocks were interviewed once a month by eleven enumerators who resided in these blocks during the 1989/90 cropping season. The information collected was on labor use, crop yields, cost of production, available water and socioeconomic characteristics of the household. The socioeconomic characteristics of the tenant households, their resource use and crop enterprise budgets were analyzed in chapter IV. Lotus 1-2-3 and SPSS software packages were employed to produce the descriptive statistics presented in Chapter V and the technical coefficients necessary for building the linear programming model in Chapter VII. The choice of the linear programming model was based on its ability to give an optimal solution over a range of alternative activities and an identification of resource scarcities at particular periods. The linear programming base run provided information on the value of the objective function, enterprise combination, level of resource use, shadow prices, cost of forcing excluded activities into the optimal solution; and the range of stability limits. Sensitivity analyses were conducted to evaluate the effects of changes on the gross margin. The four postoptimality scenarios involve: 1) relaxing the mandated cropping pattern, 2) changes in crop yields; 3) changes in crop prices; and 4) changes in the available water. The sensitivity analyzes were aimed at determining the most effective agricultural development policy instruments. The policy instruments are both technical and economic. The efficiency of these instruments depend on how sensitive the coefficients are in the optimal base run.

The unit of analysis was a typical 20 feddan main Gezira tenancy that uses 60 man-days of hired labor, 247 man-days of family labor and LS 7,150 (Sudanese pounds) of operating capital per annum.

9.1.2 THE RESULTS OF THE STUDY

The results of the study indicate the potential increase in farm income under improved technology that serves to improve efficient use of the production factors. The shadow price of labor was positive for most months and well above the estimated average wage. Since labor adds more to gross income than it costs, it is economic to hire more labor. Capital requirements for all the crops are limiting because all the necessary inputs have to be purchased and there is an unavailability of formal credit. Trials on the use of chemical fertilizers in the production of groundnuts and local sorghum varieties have shown high potential improvements in productivity.

The cropping pattern was less diversified in the base plan than the actual plan. The optimal enterprise mix includes medium-staple cotton 2, wheat 2, local sorghum 2, and hybrid sorghum 2 but excludes long-staple cotton and groundnuts because of a high cost of production and low sale prices. The crops in the base solution are those produced under intensity level 2 which reflects improvements in technology. The high shadow prices of labor for most months indicate that labor is limiting during the peak demand periods and additional units of labor will increase the value of the objective function by the value of the shadow price. Irrigation water is limiting in August and February, additional cubic meters of water will increase the value of the objective function in these periods. The high shadow prices for capital shows that capital is limiting in the Gezira. Provision of credit will ease the capital constraint. It puts the tenant in a position to finance most of the expenses such as hiring of more labor during the peak periods.

The objective function value increases by 17 percent when all the restrictions on the mandated cropping pattern were removed. Cotton dropped out of the optimum plan, the area of wheat 2 increases by 310 percent and that of sorghum by 108 percent. Both wheat and sorghum require less labor and are for local consumption. More crops will enter the plan if more water and funds are made available for hiring more labor.

The objective function value increases by 28 percent when yields increases by 15 percent. The enterprise mix is the same with 28 percent increase in return to land, 29 percent increase in return to labor and 54 percent increase in returns to capital. Labor remains limiting in the peak periods; and water in August and February.

The objective functions, returns to land, returns to labor, and returns to capital all increases under various scenarios of 25 percent increases in prices of all crops, cotton, non cotton crops and sorghum.

The objective function value increases by 14 percent with some decreases in returns to land, returns to labor and returns to capital increases by 38 percent when the available irrigation water increases by 25 percent. The increase in the amount of family labor by 25 percent increases the value of the objective function by 3 percent but has little effect on returns to the resources.

The domestic resource cost ratios for the 1989/90 cropping season indicate that Sudan has comparative advantage in the production of medium-staple cotton (0.49), long-staple cotton (0.48), wheat (0.32), and groundnuts (0.53) and comparative disadvantage in the production of sorghum (1.70) in the Gezira. The ranking of the crops is as follows: wheat, long-staple cotton, medium-staple cotton, groundnuts and sorghum. The greatest comparative advantage exist in groundnuts and the smallest in sorghum.

The domestic resource cost ratios are sensitive to changes in border prices, exchange rates and yields.

9.2 POLICY IMPLICATIONS

The study results indicate that there is potential for improvement in resource use, productivity and farm income through better land preparation, cultural practices, input use, improved seed and farm management. The strategy for the development of the Gezira Scheme has to focus on the design and improvement of programs that include efficient input supply and utilization, reduction in costs, better water distribution network, credit provision, agriculture research and marketing system. These programs should aim to make inputs available to the tenants in order to facilitate the adoption of new technology in timely manner. Improvements in market infrastructure, research and extension services are prerequisites that could encourage the Gezira tenants to adopt new technology.

Family labor is inadequate leading to the development of labor bottlenecks in peak labor demand months. Hired labor is available but tenants lack funds for labor hire for groundnuts and sorghum production. The government needs to provide formal credit to the tenants to enable them hire the additional labor required for the peak demand periods. One way to handle credit could be through producer cooperatives that mobilize savings and charge real interest rates. Improvements in the process of financial intermediation can reduce the cost of borrowing to society. Agricultural researchers will have to focus on the need for improvements in input and credit delivery and the complementarities between credit and adoption of new technology. This is important given the administrative problems that have frustrated credit programs in the Sudan such

as low repayment rates, low interest rate and diversion of farm credit to non farm uses. The provision of credit has to be approached with utmost care.

This study indicates that the amount of family labor available for farm work is low, this might be due to low farm incomes, prospects of off-farm jobs, out-migration of the young to the towns, lack of participation by female tenants, number of working sons, the degree of mechanization and the pattern of cultivation. Improvements in productivity and farm income could attract more family labor to the farm. There is need to improve the health and nutrition of the tenants since the bad effects of irrigation are being felt in the prevalence of malaria, bilharzia and abdominal diseases that could limit the physical ability of the tenants to work long hours.

The government needs to develop factor markets since biological and mechanical inputs are needed to raise the productivity per feddan per person. Improved seeds, fertilizers and pesticides are necessary to raise the productivity. The Board needs to make inputs available for groundnuts and sorghum production. Research on demand and supply of production inputs can determine the best input distribution system that will meet tenant needs.

Silt deposits and weed growth in the Gezira canal system have become serious problems. Research on irrigation should focus on improvements in water measurements, estimates of crop water requirements, water control and removal of sediments and weeds.

The Board is interested in the production of cotton for export and the tenants have to grow cotton in order to safeguard the production of groundnuts and sorghum. Sudan has a comparative advantage in the production of long and medium-staple cotton. The government through Sudan Cotton Company makes huge losses and does not repay

Bank of Sudan cash advances for the production and purchase of cotton. Sudan lost market for long-staple cotton to competition from synthetics, honeydew problems, and to the emergence of India and China from being net importers to net exporters. The market has shifted from long-staple to medium-staple cotton. The government has to promote the production of medium-staple cotton on the available 500,000 feddans in the Gezira since market opportunities appear to be good. Medium-staple cotton gives high yield and high ginning out-turn, and commands more than 80 percent of the world cotton trade. Improvements in ginning efficiency and early picking could lead to increases in prices up to 15 percent.

Gezira tenants like to produce wheat because it is a food staple, requires less labor and receives a prefinance from the Board. Sudan has a comparative advantage in the production of wheat. Wheat production in the Gezira is economic when valued at import parity prices with better input application. Since Sudan cannot afford to import wheat due to budget constraints, wheat price support program at import parity would be an efficient food strategy that saves foreign exchange spend on wheat imports. The success of the policy will depend on improvements in seed, fertilizer application, water management, land levelling and timely harvesting. These measures can lead to increases in area and productivity. But increases in wheat area will mean reductions in the area of other crops because of competition for land and water. Thus sustained increases in wheat production will require radical improvements in irrigation systems and water management.

Groundnuts suffers from inadequacy in transport, storage, grading and finance. Information on the market situation on a timely basis is lacking as well as information on prices and the infrastructure for moving the produce from a low to high price markets.

The overvalued exchange rate and high transport costs hurt groundnut exports. The private sector should be encouraged to provide the necessary market coordination. Market research needs to address market linkages through exchange and the efficiency of the market in the transmission of information to producers. The economic analysis shows that prospects for the continuation of the exportation of groundnuts are good if only the internal constraints could be attended to. Groundnuts policy should focus on the resolution of the following constraints: high demand for labor, shortage of credit and lack of efficient markets.

Sorghum is a food staple that the tenants like to grow. Sudan has comparative disadvantage in sorghum production in the Gezira. Sorghum production is not economic due to the high cost of the factor inputs of land, water, labor and capital. An increase in sorghum production beyond subsistence is uneconomic since it would take land away from other more profitable crops. Government policies on prices and exports have been deleterious to sorghum trade. The overvalued exchange rate, restrictions on trade and uncertain producer prices leads to huge losses on sorghum exports.

Exchange rate reform, increase in producer prices, and the removal of government monopoly in groundnuts marketing will increase farm income in the Gezira, foreign exchange earnings and government revenues. Changes in cropping pattern, decision making and provision of farm inputs are important for the Gezira tenants.

Changes in cropping patterns have implications on water use, food security and foreign exchange earnings. Reducing the area under cotton makes more water available for sorghum and wheat production,and increases in cereal production but potential export earnings will decrease. Changes in production technology will increase wheat yields.

Scheme management decides on crop mix, timing of operations, kind of technology and input use. Flexibility in tenant decision making will lead to efficient resource allocation with price incentives serving as the basis with important implications for production, income, foreign exchange and employment.

Making inputs available will increase productivity. Fertilizers should be made available for groundnuts and sorghum. Improvements in weeding and harvesting technology will help.

The following are the three important broader policy issues:-

1. There needs to be a greater role for the private sector participation in the irrigated subsector with the government providing a conducive environment that fosters free entry and competition. This policy will encourage the private sector to make rational decisions in response to market forces. The modernization of the irrigated subsector will provide food, employment and income. Direct government investment is appropriate for the provision of public goods such as agricultural research and market information because the private sector has no capacity or the economic incentive to provide these goods.

2. Formulation of economic stabilization package that includes monetary policy that supply adequate credit; fiscal and budget policy that balances revenue and expenditure and provide funds for operation. A competitive exchange rate is good for the Gezira that produces the bulk of the cotton for export, wheat for import substitute and groundnuts for domestic consumption and export.

3. Increases in the farmer's share of farm income can be achieved through increases in productivity from improved technology that lowers unit costs of production and from economies of scale and improvements in factor and product markets.

Important policy issues that relate to the irrigated subsector that need to be tackled are: 1) pricing policy of agriculture commodities and unifying the dual exchange rate; 2) foreign exchange potential of the different crops; 3) improvements in the efficiency of irrigation through more rational pricing; 4) removal of silt and weeds from the canal system; 5) relaxation of excessive government control on the cropping pattern; 6) viability of public corporations; 7) policies to increase marketing efficiency through privatization; 8) agricultural research policies that are effective in promoting development; 9) policies to increase farmer incentives by reducing controls over the cropping pattern; and 10) policies that reduce the cost of production of all crop.

9.3 LIMITATIONS OF THE STUDY

The static linear programming model used in the analysis can be useful for comparative analysis of equilibrium situations but farmers operate in a dynamic world where their environment undergoes continuous changes. The static model may not provide all the information about the adjustment path of supply response as one set of policy variables is replaced with another. This information could be of a greater use for policy evaluation than simple knowledge of the supplies obtained from equilibrium situations.

The study approach provides only partial equilibrium solutions. It assumes that when a product price changes, the prices of other products will remain constant which means complete independence between products. However, in agriculture the majority of the products have competitive, supplementary and complementary relationships in the processes of crop production. Competitive product prices tend to be positively correlated

where a rise or fall in the price of one product tends to pull competing product prices in the same direction.

The study relies mainly on the 1989/90 cropping season data and does not handle the analysis of the consequences of the variation in the input-output coefficients. However, the information on crop yields and available water was a five year average and the data collection covers 1989/90 that was a normal cropping season. The computed domestic resource cost ratios are sensitive to exchange rates, border prices and costs of production.

The activities not included in the model are vegetables, livestock and off-farm employment. These enterprises were excluded from the model because they are not important enough to influence the decision process.

Most of these limitations are associated with many techniques used in farm planning and supply estimation. Thus the results of this study provide some useful insights on resource allocation and the impact of public policy on the allocation of the scarce resources in the Gezira .

9.4 FURTHER RESEARCH

Further research should focus on: 1) the production of vegetables for domestic consumption and export market; 2) the contribution of off-farm employment to tenant income; 3) the integration of livestock production into the Gezira farming system; 4) the distribution effect of current government policies; 5) the marketing of groundnuts; and 6) production constraints and development opportunities. Researchers need to assess the prospects of the tenants managing their tenancies through their own producer associations rather than being administered by the Board.

APPENDICES

APPENDIX A

GEZIRA TENANCY AGREEMENT, 1927

APPENDIX A

GEZIRA TENANCY ORDINANCE, 1927.

(a) TENANCY AGREEMENT FORM

Name of block .....

Name of rightholder .....

Name of cultivating tenant .....

Status of tenant (rightholder nominee, etc.) .....

Date of agreement .....

Season .....

An agreement made between the Sudan Plantations Syndicate, LTD. (hereafter called the syndicate) of the first part and -- (hereafter called the tenant) of the second part: whereas the tenant is desirous of taking from the syndicate a cultivating tenancy under the provisions of the Gezira land ordinance, 1927, of -- feddans of land at -- for the cultivation of cotton and other crops and the said tenant has seen the land specified and has a thorough knowledge of its boundaries. And whereas the parties have agreed that the said cotton crop shall be grown and marketed and the proceeds of the sale thereof divided as set out in the 1936 standard conditions of tenancy published by the syndicate and posted at the syndicates block office at .....

Now it is hereby agreed between the parties:

l. The syndicate agrees to let and the tenant agrees to take until the first day of June next the plot of land -- feddans in area above described.

2. The provisions of the 1936 standard conditions of tenancy published by the syndicate and posted in the syndicate's said block office at -- shall apply to and govern the tenancy

hereby created and the growth and marketing of the said cotton crop and the division of the proceeds of sale thereof in the same manner as if the same were incorporated and set out herein verbatim, and the tenant hereby acknowledges that he has had the opportunity of reading and having read to him the said standard conditions.

----------Signed by The tenant---------- for
---------- The Syndicate----------

Seal on signature of Sheikh (or responsible as)
as a certificate of tenants identity.

I hereby certify that before signing the agreement -- has had an opportunity of reading and having read to him the 1936 standard conditions of tenancy posted at the Syndicates Block office at ----------

---

Signed: Omida or Sheikh

MEMORANDUM OF RENEWAL

This tenancy has been renewed for the period stated below, namely:

Period ending	Signature on behalf of company	Signature or seal of tenant

(b) STANDARD CONDITIONS OF TENANCY (1936)

1. Tenancies are created under and subject to the provisions of Gezira land ordinance, 1927, certain of which, without prejudice to the application of the ordinance as a whole are, for the information of the tenancy, set out in the schedule hereto.

2. The tenant shall cultivate the land in a proper manner and according to the scheme of crop rotation laid down by and to the satisfaction of the syndicate and shall in all things obey the reasonable orders of the syndicate's officials in all matters relating to the cultivation, irrigation and harvesting of the said crops. The said scheme of crop rotation

shall allow the growth by rain cultivation and subject to the prior requirements of the cotton crop by irrigation water on a portion of the said land of a crop of dura sufficient for and restricted the tenant's own requirements. Provided that the tenant shall not sell any part of the said crop and shall in no way neglect the cultivation of the cotton crop for the sake of dura crop. Provided further that the tenant shall not remove nor permit the removal of any stalks of such dura from the said land but shall ensure that they shall be entirely consumed on the land by animals, and if the tenant shall remove any part of such stalks or shall not introduce on to the said land animals in the opinions of the Syndicates to consume such stalks within a reasonable period the syndicate may bring on to the said land such animals for such period or periods as it thinks fit to ensure the consumption of such stalks as aforesaid without prejudice to the provisions of condition 13 hereof.

3. The tenant shall at his own cost make the field channels (abu sittas) on his land and shall bear the cost of the work done by the syndicate in excavating the part of the feeder channels (abu ishreen) which abuts on his land to an extent not exceeding PT.25 per chain (twenty meters) and shall during the tenancy keep the same in sound repair and free from seepage or leaks.

4. The syndicate shall supply the plowing and other machinery necessary for the cultivation of and shall carry out the plowing of the said land and the cost of such plowing and the supply of such plowing and the supply of such machinery shall be apportioned between the tenant and all the other cultivation tenants under the said ordinance on a feddanage basis.

5. The Syndicate shall supply water necessary for irrigation of the said scheme of crop rotation but if at any time by reason of breakdown of machinery, canals or other

irrigation work or any other compulsory circumstances the supply of water to the said land is interrupted, the tenant shall have no claim against the Syndicate for any compensation on account of the water not reaching the land under cultivation.

6. The tenant during his tenancy shall comply with the sanitary regulations for the time being in force and shall deliver back to the Syndicate the said land free of all cultivation together with all gadwals clean and in proper working order on the first day of June next.

7. Immediately upon harvesting the said cotton crop the tenant shall deliver it to the Syndicate at the Syndicate's collection station at ----------

8. If at any time the tenant is reasonably in need of an advance in money or kind in order to enable him to carry out his agricultural obligations hereunder the Syndicate shall, provided that it considers such a course businesslike and proper, make such advances on such reasonable terms and to such an extent as the Syndicate shall in its absolute discretion think fit.

9. The Syndicate shall sell and dispose of the cotton crop harvested and delivered by the tenant as aforesaid together with that of all the other cultivating tenants under the said ordinance for such prices and in such manner as it may think fit. The gross profits of the said cotton crops shall be the sale price thereof realized as aforesaid after deduction of the cost of transport, ginning and other expenses of sale or incurred for the benefit of the said crop. Of the said gross profits the cultivating tenant shall be entitled collectively to 40 percent while the Syndicate shall retain the remaining 60 percent as the share of the Syndicate and the Sudan government in satisfaction of rent, land tax, and expenses of irrigation and management.

10 (1) There shall be opened for the said crop a tenants' collective account to which shall be credited the tenants collective 40 percent of the gross profits and any other sums

which from time to time may be transferred from the tenant's reserve fund or which fall to be credited to the tenants as a whole through the tenants collective account covering the said crop.

(2) There shall be debited to the said collective tenants account:

(l) The total of the sums from time to time credited in the individual tenants' accounts kept by the Syndicate in respect of their share of the net divisible profits whether such payment be in anticipation of or subsequent to the realization of the gross profits;

(2) The usual and proper tenants' collective charges and expenses;

(3) The total of the debt balances appearing in individual tenants' account kept by the Syndicate as at the 30th June in the year covered by the tenants' collective account in question. Individual debit balances so dealt with shall thereafter be deemed to be debt due by the individual tenant's collective account.

(4) Any sum which may be transferred to the tenants reserve fund in accordance with the provisions of condition l2 hereof.

ll. There shall be debited to the tenants' collective account such sums as the government and the Syndicate may agree should be so debited and paid into a tenants' Reserve Fund to be used for the benefit of the cultivation scheme under the said ordinance for which fund moneys have already been temporarily provided in advance by the government and syndicate.

l2. If the tenant neglects or is careless in the cultivation of his crops the Syndicates shall have the right without the consent of the tenant to take such steps as the Syndicate may consider proper for the safeguarding of the crops, and any expenses incurred thereby shall be a debt from the tenant to the Syndicate and may without his consent be deducted by the Syndicate from his share of the proceeds of the crops. Further, if the

tenant neglects or is careless in the cultivation of his crops or neglects to carry the reasonable orders of the syndicate's officials in any of the aforesaid matters or fails to comply with any of the other provisions of the government on the Syndicate, the Syndicate shall have the right to terminate the tenancy forthwith without any compensation to the tenant (except as hereinafter provided) and to hand over the land and cultivation to a new tenant who shall take over the land and cultivation subject to the debts to the Syndicate secured thereon but free from any claims by the old tenant (except as hereinafter provided).

13. If the Syndicate terminate the tenancy under condition 13 hereof the Syndicate shall as soon as the proceeds of the cotton crop become payable to the new tenant pay over the old tenant out of such proceeds the value of the labor and capital put into the cultivation of the said crop by the old tenant. Such value shall be assessed as soon as possible, after the termination of tenancy by the Board composed of a nominee of the outgoing tenant, a nominee of the incoming tenant and a nominee of the Syndicate.

14. If in the opinion of the Syndicate the tenant shall have committed a breach of these conditions warranting the cancellation of the annual renewal of his agreement, then the Syndicate will give the tenant notice of the breach complained of and such notice shall be delivered to the tenant not later than the first day of June in the current year of the tenancy.

16. The English copy of the tenancy agreement and these conditions shall together form the official contract. The Arabic translation thereof is merely for the information of the tenant.

THE GEZIRA LAND ORDINANCE 1927

Section 11(1) Except as hereinafter provided in sub-section (2) and (3) the owners of every plot of land which is acquired by the government under this ordinance and which is irrigated under the irrigation scheme shall have the right to take up within a reasonable period after the date when water is first available for the said land under the said irrigation scheme yearly cultivating tenancies of such areas as they themselves are in the opinion of the government competent to cultivate subject to the conditions hereafter set out and in other respects upon the usual terms and conditions upon which from time to time all cultivating tenancies within the area of the irrigation scheme shall be granted and they shall also be entitled to a renewal of the tenancies every season so long as they shall have duly performed and observed these conditions.

Section 13(1) Every sale, transfer, assignment or other disposition of crops growing or intended to be grown on land comprised within a cultivating tenancy or of the proceeds thereof every mortgage or a charge by a cultivating tenant purporting to be secured by such crops on the proceeds thereof shall, if made or created without the consent in writing of the government be absolutely void and of no effect.

(2) Every transaction to which a cultivating tenant is a party whereby such a tenant is or may become liable for the payment of any sum of money to the calculated by reference either expressed or implied to the value of any crops growing or intended to be grown on the land comprised within a cultivating tenancy shall, if entered into without the consent in writing of the government, be absolutely void and of no effect.

Section 13(3) no action shall lie for the recovery of any moneys claimed to be payable under any transaction made void under the provisions of sub-sections (1) and (2) whether the sale, transfer or assignment or other disposition relates solely on the proceeds

thereof mortgaged or charged are alleged to be the sole security or only part of the security for such moneys or whether the value of the crops is the sole basis or is only partly the basis for calculating the amount of such moneys.

4. No execution under the provisions of order XV of schedule I to the civil Justices ordinance shall be granted by seizure and sale of the crops of any cultivating tenancy; and save with the consent of the governor or commissioner appointed under this ordinance no such execution shall be granted by attachment of any sum due to a cultivating tenant in respect of the proceeds of or any part of the proceeds of the crops of his cultivating tenancy except in the cases following; that is to say (a) an execution of an order to pay maintenance alimony or other family allowances made by a court of a competent authority against such cultivating tenant; (b) an execution of a decree for the payment of a sum of money due by such cultivating tenant to a laborer for wages in respect of labor performed by such a laborer on a cultivating tenancy; and (c) an execution of a decree for the payment of a sum of money due by such cultivating tenant in respect of any transaction mentioned in sub-sections (l) and (2) to which the consent in writing of the government has been obtained.

APPENDIX B

STANDARD PRACTICES ON THE GEZIRA RESEARCH FARM

APPENDIX B
STANDARD PRACTICES ON THE GEZIRA RESEARCH FARM

A. **COTTON**

VARIETIES: Shambat (MS), Barakat (LS).

1. LAND PREPARATION June

The fallow preceding cotton is plowed after the rains. This prevents weeds from seeding. Clod-crushing, levelling, ridges, gadwals, tagnats and re-ridging are necessary.

2. PREWATERING

Pre-watering follows ridging to prevent weed infestation that could seed from one watering.

3. FERTILIZER DISTRIBUTION

2N per feddan of urea is broadcasted evenly a week after sowing. Machine distributors can be used.

4. SEED DRESSING

Abavit B plus 30 percent dieldrin at the rate of 3 grams per pound of seed for protection against bacterial blight and flea beetles.

5. SOWING July 15, - August 15.

Sowing is done by seluka on top of the ridge. It starts at the beginning of August. Light watering may be necessary to facilitate germination.

6. SPACING AND SEED RATE

Spacing is 80 cm x 50 cm. Spacing for a late sowing is 80 cm X 30 cm. 6-10 seeds per hole and a seed rate of 20 pounds that include resowing reserve.

7. RESOWING August

Commences immediately after germination not later than 14 days after the original sowing.

8. RE-RIDGING (GREEN RIDGING)

Carried out during the 4 weeks after sowing. Bait is applied for termite control.

9. THINNING

Diseased and weak plants are thinned leaving 3 plants per hole. Thinned out plants have to be removed from the farm.

10. WEEDING September - November

Essential during the early stages of growth. Presowing weeding is necessary.

11. WATERING

Light waterings are given during the rainy season. Flooded plots have to be drained as soon as soon as possible. After the rains, normal irrigations should be about 400 cubic meters per feddan at a regular 14 day interval. Heavy watering is necessary at the time of fruit formation. Watering should stop by the end of March.

12. PICKING January - March

Picking begins in January and continues every 14 days till complete. Seed cotton is packed in sacks to the collection station for transportation to the ginneries.

13. DISPOSAL OF COTTON PLANTS April

The cotton stalks are uprooted, heaped and burnt. Cotton ratoon and volunteer crops have to be eliminated by May.

14. YIELD
Highest yields are 12 Kantars/feddan for shambat and 7.9 Kantars/feddan for Barakat.

B. **WHEAT**
VARIETIES: Condor, Debeira

1. LAND PREPARATION September
Plowing, clod-crushing and levelling wheat is very susceptible to water-logging. Proper levelling reduces the risk and improves the efficiency of irrigation.
Prewatering two weeks before sowing to control weeds, provide good seed bed and more efficient future irrigation.

2. SEED TREATMENT
Before planting treat with Dieldrex B at the rate of 1 gram for each pound of seed for protection from termites and fungal diseases.

3. SOWING October 15, - November 15.
Sowing is carried out on the flat by seed drilling. The gadwals, tagnats and sub-plots are made after seed drilling. Mechanical planting is recommended for superior wheat stands.

4. SPACING AND SEED RATE
Planted in rows 20 cm apart. Seed rate is 50 Kg/feddan.

5. FERTILIZATION At Sowing
2N of urea per feddan broadcasted at the time of sowing.

6. IRRIGATION October 16, - February 30.
10 irrigations are required. Commences immediately after sowing and then at a 14 day interval. Care has to be taken to avoid wash out of seeds by the earlier irrigations.

7. WEEDING
Well prepared seed bed minimizes weed infestation. High plant population and presowing weeding. Hand weeding is required during the early stages of growth.

8. HARVESTING March 1-30
Delay in harvesting results in losses through shattering and lodging. Harvesting is by combines.

9. YIELD
Maximum yield under research conditions is one ton per feddan.

C. **GROUNDNUTS.**
VARIETIES: Ashford, baberton

1. LAND PREPARATION May
Groundnuts follows cotton in the rotation. The usual operations are plowing, clod-crushing, levelling and ridging 60 cm apart.

2. SEED TREATMENT Before Planting.
Dieldrex B at the rate of one gram for each pound of kernel for protection against fungi and termites.

3. SOWING June 1-20
Highest yields are obtained from the earliest sowing dates.

4. SPACING AND SEED RATE
Grown on ridges spaced 60 cm apart. Planted in holes 15 cm apart, 2-3 kernels per hole using a sowing stick. The seed rate is 50 kgs of shelled seed per feddan.

5. IRRIGATION June 16 - October 15
8 irrigations are recommended starting with sowing at a 14 day interval. Avoid water logging in the rainy season. A light irrigation before harvest will facilitate hand lifting.

6. RE-RIDGING June 20-30
Done three weeks after sowing and before flowering.

7. WEEDING July 20, - August 30
Weeding should be done three weeks after planting.

8. LIFTING November 10-30
Lifting is done by hand following a light irrigation. Delayed lifting can cause shedding of mature nuts during the operation whereas early harvesting results in small unfilled nuts.

9. DRYING AND STRIPPING
Groundnuts are stacked and the dry pods are stripped off, cleaned from adhering soil by rubbing against each other and bagged.

10. YIELD
The highest yield obtained under research conditions is 1.22 tons per feddan.

D. **SORGHUM**
VARIETIES: Hegari, white milo, Feterita and Hageen Dura 1.

1. LAND PREPARATION June
Plowing clod-crushing and levelling gadwals and tagnats are made after planting when the seed is drilled.

2. SEED TREATMENT Before Sowing
Seed treated with fernasan D at the rate of one gram for every pound of seed for protection against soil pests, smut and other fungi.

3. SOWING July 1-15
Sowing in early July results in high yields and freedom from midge and aphids. Sowing is on a flat bed using a seed drill or broadcasting.

4. SPACING AND SEED RATE
Grown on ridges spaced 80 cm apart with a spacing of 50 cm between plant holes made by the Seluka. The seed rate is 12 pounds per feddan giving 6-8 plants per hole.

5. RESOWING July 10-15
Resowing is carried out not later than 14 days after the original sowing.

6. THINNING
Thinning can be done to reduce the plant population.

7. FERTILIZER August 1-10
IN as urea is broadcasted one month after sowing followed by an irrigation. Need to eradicate early weeds before fertilizer application.

8. IRRIGATION July 16, - October 15
During the rains water is given according to the crop weeds. 4 irrigations are necessary at 14 day interval following the end of the rains. Avoid over irrigation because sorghum is susceptible to water lodging. Stop irrigation 14 days before harvest.

9. WEEDING August 15, - September
Weeding is thorough by a hand hoe. Striga is removed and fed to animals or burnt. Close spacing and nitrogen application help reduce the number of weeding as the crop canopy can smother weeds.

10. HARVESTING October 16, - November 15
The heads are cut two inches below the lowest grain and are fed into a stationary combine for threshing. The sorghum straw is cut and used as animal feed or building shelters for workers. Stubble is grazed over by cattle and sheep.

11. YIELD Maximum research conditions yield is 0.92 tons/feddan.

APPENDIX C

EXPLANATIONS OF ABBREVIATIONS USED IN THE LP MATRIX

APPENDIX C EXPLANATION OF ABBREVIATIONS USED IN LP MATRIX

RESOURCES (ROWS)

ROW NUMBER	ABREVIATION USED	COMPLETE HEADING
1	LANT	Total land
2	LANF	Fallow land
3	LANC	Cotton land
4	LANW	Wheat land
5	LAGS	Groundnuts/Sorghum land
6	JUN	June hire labor
7	JUL	July hire labor
8	AUG	August hire labor
9	SEP	September hire labor
10	OCT	October hire labor
11	NOV	November hire labor
12	DEC	December hire labor
13	JAN	January hire labor
14	FEB	February hire labor
15	MAR	March hire labor
16	APR	April hire labor
17	MAY	May hire labor
18	JUNW	June water
19	JULW	July water
20	AUGW	August water
21	SEPW	September water
22	OCTW	October water
23	NOVW	November water
24	DECW	December water
25	JANW	January water
26	FEBW	February water
27	PMSC	Produce cotton MS
28	PLSC	Produce cotton LS
29	PWHT	Produce wheat
30	PGNT	Produce groundnuts
31	PLSO	Produce local sorghum
32	PHSO	Produce hybred sorghum
33	MSBR	Minimum subsistence requirement
34	JUNC	June operating capital
35	JULC	July operating capital
36	AUGC	August operating capital
37	SEPC	September operating capital
38	OCTC	October operating capital
39	NOVC	November operating capital
40	DECC	December operating capital
41	JANC	January operating capital
42	FEBC	February operating capital
43	MARC	March operating capital
44	APRC	April operating capital
45	MAYC	May operating capital
46	ENDC	End of operating capital
47	RPBM	Repay borrowed money

EXPLANATIONS OF ABBREVIATIONS USED IN LP MATRIX

ACTIVITIES (COLUMNS)

COLUMN NUMBER	ABREVIATION USED	COMPLETE HEADING
1	FALL	Fallow land
2	MSC1	Grow medium staple cotton 1
3	MSC2	Grow medium staple cotton 2
4	LSC1	Grow long staple cotton 1
5	LSC2	Grow long staple cotton 2
6	WHT1	Grow wheat 1
7	WHT2	Grow wheat 2
8	GNT1	Grow groundnuts 1
9	GNT2	Grow groundnuts 2
10	LS01	Grow local sorghum 1
11	LS02	Grow local sorghum 2
12	HS01	Grow hybrid sorghum 1
13	HS02	Grow Hybrid sorghum 2
14	JUNL	June hired labor
15	JULL	July hired labor
16	AUGL	August hired labor
17	SEPL	September hired labor
18	OCTL	October hired labor
19	NOVL	November hired labor
20	DECL	December hired labor
21	JANL	January hired labor
22	FEBL	February hired labor
23	MARL	March hired labor
24	APRL	April hired labor
25	MAYL	May hired labor
26	SMSC	Sell medium staple cotton
27	SLSC	Sell long staple cotton
28	SWHT	Sell wheat
29	SGNT	Sell groundnuts
30	SLSO	Sell local sorghum
31	SHSO	Sell hybrid sorghum
32	BLSO	Buy local sorghum
33	CLSO	Consume local sorghum
34	JNKT	June capital transfer
35	JLKT	July capital transfer
36	AGKT	August capital transfer
37	SPKT	September capital transfer
38	OTKT	October capital transfer
39	NVKT	November capital transfer
40	DCKT	December capital transfer
41	JAKT	January capital transfer
42	FBKT	February capital transfer
43	MRKT	March capital transfer
44	APKT	April capital transfer
45	MYKT	May capital transfer
46	KT	Capital transfer
47	BMJN	Borrow money in June
48	BMJL	Borrow money in July
49	BMAG	Borrow money in August

50	BMSP	Borrow money in September
51	BMOT	Borrow money in October
52	BMNV	Borrow money in November
53	BMDC	Borrow money in December
54	BMJA	Borrow money in January
55	BMFB	Borrow money in February
56	BMMR	Borrow money in March
57	BMAP	Borrow money in April
58	BMMY	Borrow money in May
59	RPBM	Repay borrowed money

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7.7.1 AVAILABLE LAND

The standard tenancy size in the Gezira is 20 feddans in a single field. The survey reveals that 80 percent of the tenants possess the standard tenancy size. The Board's policy limits the available land for each crop to the area specified by the rotation pattern.

7.7.2 AVAILABLE LABOR

Collinson (1983) asserts that both labor availability and use need to be treated as flows which are only meaningful at a point in time. The usual techniques tend to assume a theoretical level of availability as a constant constraint on the observed usage at peak periods can be accepted as a limit throughout the season. This study employs the

TABLE 7.7 FAMILY AND HIRED LABOR IN MAN-DAYS PER FEDDAN.

PERIOD \ DEMAND	FAMILY	HIRED
June	15	35
July	15	35
August	15	35
September	15	35
October	15	35
November	15	35
December	15	35
January	25	90
February	25	90
March	25	90
April	15	35
May	15	35
TOTAL	210	585

Source: Compiled from survey data.