

RESOURCE ALLOCATION AND ENTERPRISE COMBINATION
IN A RISKY ENVIRONMENT: CASE STUDY OF THE
GEZIRA SCHEME, SUDAN

By

ABDELHALIM HAMID MOHAMED
"

Bachelor of Science
Khartoum University
Khartoum, Sudan
1973

Master of Science
Leeds University
Leeds, England
1979

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1984

Thesis
1984 D
m697r
cop. 2



RESOURCE ALLOCATION AND ENTERPRISE COMBINATION
IN A RISKY ENVIRONMENT: CASE STUDY OF THE
GEZIRA SCHEME, SUDAN

Thesis Approved:

Dean F. Schreiner
Thesis Adviser
Glenn J. Knowles
Cheryl M. Amos
Daniel D. Badger
Francis M. Epplein
Norman D. Murham
Dean of the Graduate College

ACKNOWLEDGEMENTS

I wish to express my deep gratitude and sincere appreciation to a number of people without whom this study could not have been completed. A special word of appreciation is due to my major advisor, Dr. Dean F. Schreiner, for his patience, encouragement and gentle guidance throughout the course of my doctoral program, especially during preparation of this manuscript. Appreciation is also expressed to the committee members, Dr. Daniel D. Badger, Dr. Glenn J. Knowles, and Dr. Orley M. Amos for their assistance, encouragement and counseling during my graduate program. I am also thankful to Dr. Francis M. Epplin for his kind assistance in developing the programming model.

A lot of thanks are extended to the Department of Agricultural Economics for the opportunity to pursue the graduate study. Also, I wish to express my appreciation to the Arab Planning Institute in Kuwait for granting leave of absence payment to complete this doctoral program, and to the United Nations Development Program for providing financial support during the first two years of my graduate program.

A substantial magnitude of debt is extended to the staff and management of the Gezira Scheme especially friends and colleagues in Economic and Social Research Unit for their sincere efforts in supplying a considerable amount of data related to this research. Thanks are also due to the staff of the Department of Rural Economy,

faculty of Agriculture at Khartown University for suppling a valuable amount of information and data about the Gezira Scheme.

I am very grateful for Mrs. Ann Govek for her typing efforts to many preliminary drafts and the final copy of this dissertation.

On a personal note, I am particularly grateful for the sacrifice and prayers of my dear mother, brothers and sisters, who have been a constant source of encouragement and support throughout my graduate program.

Finally, I wish to express my deepest appreciation to my wife, Somaya, and daughter, Eman, for their understanding, patience, sacrifice, and encouragement during this endeavor.

To Somaya and Eman and the newly arrived Maha, I dedicate this dissertation.

TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION	1—
An Overview	1
Problem Statement	4
Objectives of the Study	6
Plan of Presentation.	7
II. EXISTING CONDITIONS IN THE GEZIRA SCHEME	9—
Background.	9
Resource Use.	13
Land Use	13
Labor Use.	14
Water Resource Use	16
Agricultural Production System.	18
Land Tenure.	18
Cotton Production.	19
Wheat Production	21
Sorghum Production	24
Groundnut Production	25
Vegetable Production	25
Agricultural Services	26
Agricultural Credit.	26
Research and Extension	28
Marketing Services	29
The Rehabilitation Project.	31
III. THEORETICAL FRAMEWORK AND EMPIRICAL TECHNIQUES FOR ENTERPRISE SELECTION IN A RISKY ENVIRONMENT.	34—
Theoretical Framework	34
Direct Elicitation of Utility Functions.	34
Mean-Variance Efficiency Criteria.	38
Probability of Loss Function	42
Empirical Techniques.	45
Quadratic Risk Programming	45
Linear Risk Programming.	47
Selective Applications of Risk Programming Models . .	50
Implications of Risk Analysis to Gezira	54 —

Chapter	Page
IV. SPECIFICATION OF A LINEAR RISK PROGRAMMING MODEL FOR THE GEZIRA SCHEME.	56
The Analytical Framework.	56
Formulation of the Model.	57
Basic Risk Programming Model	58
Assumptions of the Model	59
Limitations of the Model	60
Data Requirements.	61
Sources of Data	62
The Sample Survey.	62
Secondary Data	67
Enterprise Budgets	77
Components of the Model	78
Basic Activities	78
Resource Restrictions.	79
V. ANALYSIS OF RISK EFFICIENT FARM PLANS.	81
Basic Model Results	82
Risk Measurement Statistics.	82
Profit Maximization Plan	82
Risk Efficient Farm Plans.	85
Sensitivity Analysis.	91
Assumptions.	91
Effect of Increasing Hired Labor	92
Effect of Increasing Institutional Credit.	94
Effect of Increasing Both Hired Labor and Institutional Credit	96
Effect of a Change in Producer Prices.	103
VI. SUMMARY, POLICY IMPLICATIONS AND FURTHER RESEARCH.	108
Summary	108
Performance of the Gezira Scheme	109
Theory of Enterprise Selection Under Risk.	110
Results of the Basic Model	111
Results of the Sensitivity Analysis.	113
Policy Implications	116
Increasing Groundnut Production.	117
Increasing Sorghum Production.	117
Reducing Cotton Production	118
Reducing Wheat Cultivation	119
Adjusting Producer Prices to World Market Level.	119
Efficient Utilization of Resources	120
Limitations and Need for Further Research	125
SELECTED BIBLIOGRAPHY	127

Chapter	Page
APPENDIX A - DETAILED ENTERPRISE BUDGETS EXPRESSED IN MONETARY VALUES	132
APPENDIX B - MEAN WATER REQUIREMENTS FOR CROPS IN THE GEZIRA SCHEME IN CUBIC METERS PER FEDDAN PER DAY.	137
APPENDIX C - INITIAL MOTAD TABLEAUX	140
APPENDIX D - CALCULATION OF EXPORT PARITY PRICES.	148

LIST OF TABLES

Table	Page
I. Share of Gezira Scheme in the Sudan's Total Production of Selected Crops for Season 1982-83	12
II. Land Use by Crop and Average Yield in Gezira Scheme for 1982-83 Crop Year.	14
III. Crop Rotation Per Tenancy and Season in Gezira and Managil.	19
IV. Socio-Economic Characteristics of Sample Tenants Interviewed in the Gezira Scheme, 1984	64
V. Monthly Hired Labor Availability From Sample of Tenants Interviewed in the Gezira Scheme, 1982/83.	66
VI. Historical Crop Yields Per Feddan for the Gezira Scheme, 1971-83.	68
VII. Estimated Cost of Production by Crop by Year for the Gezira Scheme, 1971-83	69
VIII. Gross Returns Per Feddan by Crop by Year for the Gezira Scheme, 1971-83.	70
IX. Estimated Gross Margins by Crop by Year for the Gezira Scheme in 1982 Constant Prices, 1971-83.	72
X. Water Balance in the Gezira Scheme by Periods.	73
XI. Estimated Mean Water Requirements Per Feddan Per Day and Availability at Field Canal Level Per Day in the Gezira Scheme for October-November Peak.	74
XII. Monthly Family Labor Use by Crop for the Gezira Scheme . .	75
XIII. Monthly Hired Labor Requirements by Crop for the Gezira Scheme.	76
XIV. Summary Set of Efficient Farm Plans Derived from the Gezira Basic MOTAD Model - Model 1	83

Table	Page
XV. Monthly Hired Labor Use by the Profit Maximization Production Plan for a Representative Farm in the Gezira Scheme.	86
XVI. Irrigation Water Use by the Profit Maximization Production Plan for a Representative Farm in the Gezira Scheme	87
XVII. Summary Set of Efficient Farm Plans Assuming a Potential Increase in Hired Labor - Model 2.	93
XVIII. Summary Set of Efficient Farm Plans Assuming a Potential Increase in Institutional Credit - Model 3.	97
XIX. Summary Set of Efficient Farm Plans Assuming a Parallel Increase in Both Institutional Credit and Hired Labor - Model 4	99
XX. Summary Set of Efficient Farm Plans Derived From the Gezira Basic Model Using Export Parity Prices - Model 5	104
XXI. Detailed Cost of Production Budget for Cotton, Season 1982-83	133
XXII. Detailed Cost of Production Budget for Wheat, Season 1982-83	134
XXIII. Detailed Cost of Production Budget for Groundnut, Season 1982-83	135
XXIV. Detailed Cost of Production Budget for Sorghum, Season 1982-83	136
XXV. Mean Water Requirements for Crops in the Gezira Scheme in Cubic Meters Per Feddan Per Day	138
XXVI. The Initial Tableau of the MOTAD Model.	141
XXVII. Initial MOTAD Tableau for the Gezira Basic Model.	142
XXVIII. Estimation of Export Parity Price Per Ton of Cotton Expressed in 1982 Constant Prices, 1971-83.	149
XXIX. Estimation of Export Parity Price Per Ton of Wheat Expressed in 1982 Constant Prices, 1971-83.	150
XXX. Estimation of Export Parity Price Per Ton of Groundnut Expressed in 1982 Constant Prices, 1971-83.	151

Table	Page
XXXI. Estimation of Export Parity Price Per Ton of Sorghum Expressed in 1982 Constant Prices, 1971-83.	152
XXXII. Estimation of Gross Margins Per Feddan of Cotton Using Export Parity Prices Expressed in 1982 Constant Prices, 1971-83	153
XXXIII. Estimation of Gross Margins Per Feddan of Wheat Using Export Parity Prices Expressed in 1982 Constant Prices, 1971-83	154
XXXIV. Estimation of Gross Margins Per Feddan of Groundnut Using Export Parity Prices Expressed in 1982 Constant Prices, 1971-83.	155
XXXV. Estimation of Gross Margins Per Feddan of Sorghum Using Export Parity Prices Expressed in 1982 Constant Prices, 1971-83	156

LIST OF FIGURES

Figure	Page
1. Map of the Gezira Scheme	10
2. Yield Variability Over Time in the Gezira Scheme	22
3. Gross Margins Variability Over Time in the Gezira Scheme	23
4. Graphical Estimation of Risk Attitude Represented by Three Utility Functions.	36
5. The E-V Efficiency Frontier and the Optimum Farm Plan. . . .	40
6. Probability of Loss Function Associated with Certain Probability Level.	44
7. Risk-Efficiency Frontier for the Basic MOTAD Model - Model 1.	90
8. Risk-Efficiency Frontier for Model 1 and Model 2	95
9. Risk-Efficiency Frontier for Model 1 and Model 3.	98
10. Risk-Efficiency Frontier for Model 1 and Model 4.	101
11. Risk-Efficiency Frontier for Model 1 and Model 5	105

CHAPTER I

INTRODUCTION

An Overview

In general, agricultural producers operate in a risky environment which inevitably affects their expected incomes. Just (1975) identified three sources of risk and uncertainty that deserve attention in agriculture: (1) risk associated with environmental and technological factors such as weather, diseases, pests, and improved crop varieties and livestock breeds; (2) risk associated with market factors such as price and income fluctuations, input supplies and competing demands for inputs, and (3) uncertainty with respect to policy changes such as government programs, level of supports and regulations of pesticides and waste.

Agricultural producers in developing countries are frequently more exposed to risk given the poor economical, technological and institutional conditions which prevail. Therefore, an understanding of the risk factor, as it affects peasant agricultural production and development, is an essential ingredient of rational planning of individual farms and the rural sector as a whole. However, this important ingredient has seldom been considered in studies and plans relating to peasant agriculture in developing countries such as the Sudan.

Agriculture plays a major role in the economy of the Sudan. It contributes nearly 40 percent of the gross domestic product while 80 percent of the population depends for its subsistence on agriculture and related activities. The sector produces food for local population, raw materials for industries and surpluses of food and industrial crops for exports. Indeed, agriculture is the major source of exportable commodities accounting for over 90 percent of the country's foreign exchange earnings. The economic activities in other sectors of the economy, especially transportation and industry are critically linked with those of the agricultural sector. It is natural, therefore, that a vigorous and prosperous agriculture is the cornerstone for any development planning in the Sudan (Ministry of Planning, 1977).

Out of 200 million feddans (1 feddan = 1.038 acres) of productive land suitable for both crop and animal production, less than 10 percent is currently used (World Bank, 1979). The two main subsectors of the agricultural sector are irrigated and rainfed or dryland farming. Government efforts and interests have been directed primarily towards the irrigated subsector. Concentration of the main cash crops such as cotton and groundnut in irrigated areas reinforces this tendency.

The central position of agriculture in the Sudanese economy and the importance of studying the risk factors in irrigated agriculture justified the choice of an irrigation project for this study. The Gezira Scheme is a public sector irrigation enterprise that originated in 1925 when a new dam was constructed across the Blue Nile River to provide irrigation water for the region. The Scheme occupies an area

of 2.2 million feddans which account for 63.7 percent of the total irrigated area in the Sudan (World Bank, 1979). At present the Scheme provides direct employment to about 96,000 tenants (producers) and their families. Tenants in the project area are allocated tenancies described to be homogenous and of equal size. The crops grown in the project area are mainly cotton, groundnut, sorghum, wheat and vegetables.

The government appoints a board of directors to operate and organize the production process in the project area following policy guidelines issued by the Ministry of Agriculture. The project management sets forth rules and guidelines for the tenant that include all aspects of production and marketing, from seed variety selection to the market price of the produce (Zaki, 1980). For the Gezira Scheme, the government provides irrigation water, land, administrative management, research and extension, institutional credit and marketing of cotton and wheat. The tenants, on the other hand, supply the necessary labor to perform crop husbandry practices and provide the credit and marketing for the other crops in the rotation, namely groundnut and sorghum.

The agricultural production relations between the government and the tenant have experienced a variety of changes over time. Currently this relationship is specified by a predetermined land and water charge which the tenant is obliged to pay in return for services provided. The land and water rate is issued by a decree from the Ministry of Agriculture and revised every year based on irrigation costs, management costs and a nominal land fee. It is based on a per feddan basis for each crop.

For the Gezira Scheme the government emphasizes cotton production which is the single cash crop accounting for about 50 percent of total exports. Such heavy dependence on a single export crop is likely to effect on the stability of a country's foreign exchange earnings and consequently the national development process. Indeed, fluctuations in cotton yields and prices have important impacts on both tenant and government income. At the international level, the Food and Agricultural Organization (FAO, 1983) argues that the competitive position of cotton is unlikely to improve in the short term as the downward pressure on prices is expected to continue and prices of competing man-made fibers are expected to remain low. Depressed output levels in the textile industry in some major cotton importing countries, the sharp appreciation of the U.S. dollar and high interest rates for maintaining stocks are among the reasons cited by FAO that have led to reduced import demand, particularly in Europe.

Problem Statement

The six year development plan of the Sudan for the period 1977-1983 emphasized that agriculture must continue to play a major role in the overall development strategy. This emphasis on agriculture was to reverse the recent trend of declining agricultural productivity and diminishing contribution of agriculture to the Sudan's foreign exchange earnings. According to the World Bank Development Report (1982), the percentage contribution of agriculture to the gross domestic product has declined from 61 percent in 1955-56

to 38 percent in 1980-81. Among the agricultural projects which are reported to have declining productivity is the Gezira Scheme. Despite recent efforts to increase production through increased investment funds to the project, productivity and net returns per feddan have declined considerably.

Decisions on crop rotations in the Gezira Scheme are made by the government and dictated by national objectives. Government policy in the Gezira Scheme frequently ignores the tenant's preference including attitudes towards risk. Historically government interest has focused on cotton, which does not necessarily match tenant interest. Since cotton and food crops compete for land, labor, irrigated water and capital resources, the competitive position and risk factors of each activity are essential for selection of the optimum farm plan.

Decisions on institutional credit provided to tenants is the responsibility of the government policymakers and the project management. Again, tenants have not shared in making this decision, even though it directly affects their productivity and reduces their dependence on outside moneylenders. Another problem relates to the scarcity of seasonal labor. A study by Adam (1978) indicates that Gezira tenants find difficulty in meeting labor requirements, especially during peak seasons.

Depending on the amount of water available in the irrigation canals and the amount and frequency of rainfall, the Scheme management determines the frequency and number of irrigations that each crop receives. Once more, tenants have no control on the amount of irrigation water nor the number of irrigations.

Most, if not all, farm planning studies conducted for the Gezira carry the basic assumption that farmers equate marginal cost to marginal revenue, an assumption which only holds true under conditions of risk neutrality. Risk, however, may have a seriously inhibiting effect on production since many farmers cannot afford to suffer a setback which might mean deprivation or even starvation. Hazel et al (1982) state that to neglect consideration of risk behavior in agricultural models can lead to important overstatements of the output levels of risky enterprises, overly specialized cropping pattern, and biased estimates of the supply elasticities of individual commodities. Other consequences may be overestimation of the value of important resources, such as land and irrigation water, and incorrect predictions of technology choices. Given the fact that farmers in developing countries are generally risk averse, farm planning incorporating risk is essential for the Gezira Scheme.

The Objectives of the Study

The main objective of this study is to determine the optimum resource allocation and enterprise combination taking into account the product price and yield variation on irrigated Gezira farms. Data derived from sample information at farm and project level are used in a programming model to determine the optimum plan.

The specific objectives are:

1. To critically analyze the past and present performance of the project taking into account economic, social and institutional constraints.

2. To review literature on risk programming models with special reference to applications in developing countries.

3. To determine the optimum farm resource and enterprise combination under conditions of risk neutrality and under conditions of minimizing risk or income variability for a given level of potential expected income.

4. To analyze the sensitivity of the optimum plan to changes in borrowing limits for institutional credit, availability of seasonal hired labor, irrigation water frequency and quantity constraints, and producer prices.

Plan of Presentation

The remaining text includes five chapters. Chapter II presents detailed information about the study area. A critical review of the project past and present performance is discussed. Economic, social and institutional constraints are presented and analyzed.

Chapter III presents a selective literature review on risk programming models. Special consideration is devoted to applications of the models to developing countries.

Chapter IV specifies the minimization of total absolute deviation (MOTAD) model used in this study and the corresponding assumptions and limitations. Detailed descriptions of the objective function, activities and constraints are presented. Sources of data and the method used to collect and analyze the data are also provided in this chapter.

In Chapter V application of the model is made to determine the optimum farm plan and resource combination. A set of efficient farm plans is identified along the computed efficiency frontier. Sensitivity of the optimum plan to changes in institutional credit limitations, hired labor availability, irrigation water, and producer prices is evaluated and discussed.

Chapter VI provides a summary of the results and findings of the specific model and the sensitivity analysis. The policy implications for future planning and resource allocation in the Gezira Scheme are discussed. Finally, suggestions for further research beyond the scope of this study are given.

CHAPTER II

THE EXISTING CONDITIONS IN THE GEZIRA SCHEME

Background

The Gezira Scheme is unique in Africa and described to be one of the largest gravity irrigation areas in the world. It extends over the central claylands between the Blue and White Niles covering an area of 2.2 million feddans (see Figure 1). The central claylands of the Sudan is described by the Food and Agricultural Organization of the United Nations (FAO, 1974) to be one of the largest agricultural reserves in the world and the potential breadbasket of Africa and the Middle East. The Gezira's great size creates special problems in irrigation control but offers scope for economies of scale in farm operations. Its importance in the national economy and its impact upon the livelihood of over 96,000 farmers, their families and helpers, dictate that changes in agricultural policies and practices should only be made after careful consideration.

Traditionally, prior to the irrigation network, the Gezira area was inhabited by nomadic and semi-nomadic pastoralists growing sorghum (Sorghum vulgare) and dukhn (Pennisetum Typoideum), two staple food crops, during the short rainy season and moving their herds in

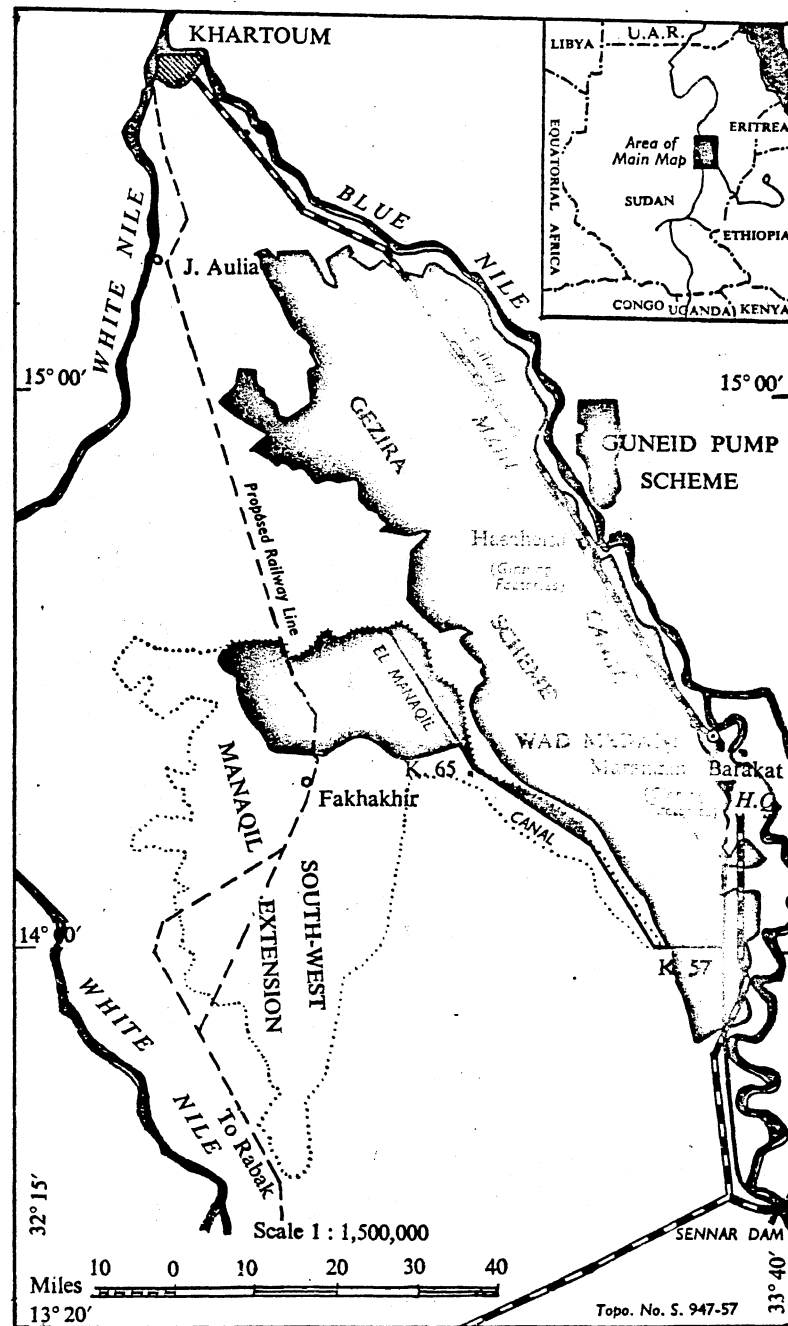


Figure 1. Map of the Gezira Scheme

search of water and grazing during the long, hot, dry season. The beginning of irrigation in Gezira dates back to 1907 when the British authority, which controlled Sudan at that time, realized the suitability of Gezira soil for growing Extra Long Stable (ELS) cotton needed for the Lancashire cotton mills in England (Barnett, 1977). Gaitskell (1959) who witnessed the creation of Gezira Scheme under the management of British commercial companies, represented by the Sudan Plantation Syndicate (SPS), reported that competition from the United States, Germany and even China pushed the British government to seek supplies of raw materials from overseas colonies, namely Egypt and Sudan. By 1925 a dam was constructed at Sennar across the Blue Nile and this put the Scheme into commercial production.

Although cotton was the main crop produced in the Gezira, other crops such as sorghum, groundnut, wheat and vegetables were also grown. The area cultivated in Gezira gradually developed from 250 feddans in 1907-08, to 88,000 feddans in 1925, to 1.14 million feddans in 1950-51 and, currently, to 2.1 million feddans. In 1950 the Scheme was nationalized and the Sudan Plantation Syndicate handed over control to the Sudan Gezira Board (SGB), a government controlled body, which still operates the Scheme. The largest single expansion to the project occurred in 1969-70 when the Managil extension added one million feddans to production. The Managil extension was made possible by the 1959 Nile Water Agreement between Sudan and Egypt under which the Sudan's share of Nile water increased from four milliard cubic meters to 18.5 milliard cubic meters of the annual discharge measured at Aswan Dam.

Organizationally the project is divided into 14 groups and 105 blocks. A group area ranges from 20,000 to 80,000 feddans and a block area varies from 20,000 to 40,000 feddans. The Scheme is administered centrally from Barakat, headquarters of the Gezira Scheme (refer to Figure 1). The organizational aspects of the project will be discussed in more detail latter in this chapter.

Currently the Scheme represents 12 percent of land under cultivation and more than half of the country's irrigated land. The share of Gezira Scheme in the Sudan's total production of cotton, wheat, groundnut and sorghum is presented in Table I.

TABLE I
SHARE OF GEZIRA SCHEME IN THE SUDAN'S TOTAL
PRODUCTION OF SELECTED CROPS FOR
SEASON 1982-83

Crop	Sudan's Total Production (Thousand Tons)	Gezira Production (Thousand Tons)	Percentage Share of Gezira
Cotton	583	319	55
Wheat	141	94	67
Groundnut	497	118	24
Sorghum	1,964	130	7

Source: Ministry of Agriculture and Natural Resources (1983).

Resource Use

Land Use

The central area of the Sudan is characterized by large expanses of clay plains extending over an area of 14,000 square kilometers. Gezira Scheme constitutes the most fertile portion of central claylands that lies between the Blue and the White Niles. Being impervious clay, the soil allows construction of canals which do not require expensive lining with concrete and water loss is minimum. The contour lines slope gently from the upper Blue Nile downwards towards the north and west. This made the siting of the irrigation canals easy and facilitated the development of gravity irrigation. Further, a slight ridge runs from north to south along the eastern edge of the scheme. The main canals from Sennar dam follow the line of this ridge, thus giving good command over the whole area (Barnett, 1977).

Land use in the 1982-83 season was determined largely by the volume of irrigation water available, rotational constraints to maintain soil fertility and crop disease, lack of monetary liquidity at the tenant level, and crop requirements for water. As presented in Table II cotton occupied the major share of area in the rotation accounting for 43 percent, followed by sorghum, the staple food crop, which occupied 28 percent of the cultivated land. Wheat, groundnut and vegetables accounted for 14 percent, 12 percent, and 3 percent, respectively of the cultivated area.

TABLE II
LAND USE BY CROP AND AVERAGE YIELD IN
GEZIRA SCHEME FOR 1982-83 CROP YEAR

Crop	Area		Average Yield Tons/Fed.
	Feddans ^a	% of Total	
Cotton	484,315	43	0.671
Wheat	155,533	14	0.694
Groundnuts	148,182	12	1.200
Sorghum	320,940	28	0.523
Vegetables	28,774	3	N.A. ^b

^a1 Feddan = 1.038 acres = 0.42 hectare.

^bN.A. - not available.

Source: Sudan Gezira Board, the Gezira Current Statistics (1982-83).

Labor Use

The latest statistics available on aggregate labor force in the Gezira Scheme were estimated by Adam (1978) at 666,715 laborers. This figure accounted for 25 percent of the total labor force working in the public agricultural sector in the Sudan. The tenant and his family provide only one third of the total labor used on the farm while the rest is contributed by permanent and seasonal employment. The low farm family contribution to field work is attributed to low farm returns and lack of cash liquidity necessary to meet the urgent,

day to day, family needs. The amount of tenant labor contributed is not uniform among families and varies inversely with tenant assets and off-farm income. The increasingly attractive opportunities in the urban market have in fact led to a substantial rural to urban migration.

Hired labor constitutes nearly half the production expenses for all crops except wheat which is almost fully mechanized by Scheme management for national policy reasons. Cotton picking alone requires about 65 percent of the total labor used.

Following the organizational structure in the Gezira Scheme, the tenant is responsible for the provision of labor on his tenancy. Management assumes that the tenant is able to provide the majority of the labor input to his own tenancy from his own family. The only exception is during peak labor periods such as sowing and harvesting. Since the demand for hired labor is high while the supply is limited, the labor wage is bid up and frequently constitutes a production bottleneck given the tenants weak financial position.

Survey results among 50 Gezira tenants revealed that a critical labor shortage problem existed. Sixty percent of the tenants interviewed reported the loss of up to 25 percent of the crop due to labor shortage. Sudan Gezira Board statistics estimated the shortage in cotton picking labor for season 1981-82 at 43,805 laborers or 11 percent of the total required labor. Other sources (Euroconsultant, 1982), argue that there is no labor shortage in absolute terms, however, there are problems in attracting adequate labor at the right time and at rates the tenants can afford.

Water Resource Use

Water for the Gezira Scheme is diverted from the Blue Nile at Sennar Dam (see Figure 1). Availability is fixed by the Nile Water Agreement of 1959 between Sudan and Egypt. According to the terms of the Agreement, the Sudan's annual share of the Nile water is 18.5 milliard cubic meters or 25 percent of the net discharge measured at Aswan Dam in Egypt (Waterburg, 1979). Allowing for transit losses and evaporation, this corresponds to an annual total of 20.55 milliard cubic meters available at Sennar. At present, the water allocation for the existing irrigation projects in the Sudan is 15.951 milliard cubic meters per annum of which the share of the Gezira is 7.563 milliard. With the existing planning horizon, requirements for further development are estimated at 3.03 and 8.10 milliard cubic meters in 1990 and 2000, respectively (Ministry of Irrigation, 1979). This implies that after 1990 a serious water shortage problem may exist in the Sudan.

In the Gezira Scheme, the water supply at the field level is determined by the existing capacity of the irrigation canals rather than by amount of water available at the dam level. This is because the irrigation canals are heavily infested with weeds and silt. Actually, the canal clearance situation has been deteriorating during the last decade due to shortages in canal clearing equipment. During the period 1972/73 through 1982/83, the percentage of silt removal averaged 50 percent of the amount needed to be removed.

The system which supplies irrigation water to the Gezira Scheme comprises two main canals diverted from the dam at Sennar. At intervals, water is taken from the main canal and conducted to a major canal. Each major canal in turn feeds a set of minor canals, and each minor canal provides water for the fields where cultivation is carried out. A minor canal feeds water to a set of fields of 90 feddans each, known as Numbers. The water is taken out of the minor canal through a channel known as "Abu ishreen", which feeds a complete Number. Each Number is further subdivided into tenancies and each tenancy is fed by small channels called "Abu sitta".

The irrigation water flows to the field from the dam based upon a calculation of the total requirements at any point in time. Calculations are made on a Block by Block basis by the field staff. The water can take as long as four days to travel from the dam to a field in the northern part of the Scheme. The field staff belongs to the Sudan Gezira Board while the irrigation engineers work for the Ministry of Irrigation. Lack of effective communication between the Sudan Gezira Board staff and Ministry of Irrigation staff has contributed significantly to the water shortage problems at the field level. The communication problem has been basically attributed to the absence of proper coordination and deteriorating telephone services. The length of the major tributaries and drains in the Gezira Scheme is 12,674 kilometers (Ministry of Irrigation, 1979). Such a large irrigation network requires highly trained personnel and well-organized and coordinated system.

Agricultural Production System

Land Tenure

The land tenure systems are similar in most public agricultural schemes in Sudan, however, there are slight variations in the size of the holdings. For the Gezira Scheme, the government reserved its right to either purchase or rent the land within the scheme boundaries. Having been purchased or rented, the land was redistributed to the tenants with a priority in allotments given first to the former landowner, then second to the residents in the area. The standard tenancy size in the Gezira was set at 40 feddans. However, over time this size has been reduced. A survey by Ahmed (1977) shows a substantial reduction in tenancy size with 82.5 percent of the tenants in Gezira holding 20 feddans or less. The standard size of the tenancy in the Managil extension is 15 feddans.

Since the land is owned by the government, the government, represented by Sudan Gezira Board, preserves the right to terminate tenancy if the tenant is not capable of fulfilling his obligations. The other common feature is that all tenants follow a particular crop rotation set by the Agricultural Research Corporation and approved by the Gezira management.

The main crops grown in the Gezira Scheme are cotton, wheat, groundnut and sorghum (Table III). Vegetables are grown on a small scale around the villages. The Scheme is divided equally into Main Gezira and the Managil extension (see Figure 1). Each division constitutes nearly half the cultivated area.

TABLE III
CROP ROTATION PER TENANCY AND SEASON
IN GEZIRA AND MANAGIL

Crop	Area (feddan)	Season
Cotton	5	July-March
Wheat	5	October-March
Groundnut/Sorghum	5	June-November
Fallow (Gezira only)	5	December-June

Source: Euroconsultant (1982).

The main crops are cultivated in the Gezira in a crop rotation of cotton, wheat, groundnut, sorghum and fallow. The crop rotation include cotton, wheat, groundnut and sorghum in the Managil Extension. Crop rotation per tenancy and season in Gezira and Mangil is shown in Table III. Rotations are necessary to conserve soil fertility and prevent the carryover of diseases and pests from one year to the next.

Cotton Production

The varieties of cotton grown in the Gezira Scheme were made available through the Agricultural Research Corporation which has been fairly successful in developing new strain of cotton adapted to local environmental conditions. Land preparation, aimed at weed control and the establishment of a good seed bed, is limited by

shortages of machinery and pesticides. Fertilization of cotton is confined to urea which is manually broadcasted at a recommended rate of 80 kg/feddan in main Gezira and 120 kg/feddan in Managil Extension where there is no fallow. Insecticide applications are commonly done by aircraft at intervals from October to February. Number of waterings range from 8 to 12 and the amount of water applied is estimated at 3,552 cubic meters per feddan (Fakki, 1982).

Despite the technology intensification efforts since the early 1970s, statistics reveal a decline in cotton yield from an average of 0.693 tons per feddan in early 1970s to 0.518 in the early 1980s. Variability in cotton yield has been a major problem facing producers, research specialists and the Board administrators. The yield variability problem has a serious impact not only at the producer level but also at the macroeconomic level since cotton is a major foreign currency earner.

Several agronomic and socio-economic factors contribute significantly to the variability problem. Among agronomic factors, sowing date and rotation are important. Cotton sowing dates range from July 25 to mid-August. Early sowing tends to reduce fluctuations in yield while late sowing reduces total yield. In the rotation, cotton preceded by sorghum has the most depressing effect on soil fertility and hence productivity of cotton. This is because both cotton and sorghum are nitrogen depletors. In addition, peasant farmers seldom follow the recommendations of research with respect to seed rate and spacing. This is because sowing is usually performed manually in the Gezira Scheme. Other factors contributing to yield variability are irrigation water timing and frequency and labor

availability, particularly during weeding and picking seasons. Fluctuations in yields of cotton and other field crops over time are presented in figure 2.

The fluctuations in cotton prices has national as well as international dimensions. Cotton is an important international commodity which is influenced by the world supply and demand conditions. Since Sudan is not a major producer of cotton in the world market, it can hardly influence the world market price. In general, the world cotton market has been adversely influenced by the syntheses of man-made fibers since the early 1950s. According to FAO Commodity Review and Outlook, the current and short term prospects in cotton marketing are not very encouraging. FAO (1983) reports that the competitive position of cotton is unlikely to improve in the foreseeable future as the downward pressures on prices are expected to continue and prices of manmade fibers are expected to remain low. At the national level cotton price fluctuations have contributed to not only low, but also destabilizing country and farm incomes. The overall result is the farmer vicious cycle: low and fluctuating cotton yields result in low and unstable incomes so tenants spend less on weeding, irrigation and picking and frequently look for off-farm sources of income. Fluctuations in gross margins for cotton and other crops for the Gezira scheme are represented in Figure 3.

Wheat Production

Because of national objectives aimed at saving foreign exchange and providing food security, the Sudan Gezira Board includes wheat as an integral component of the Scheme's crop rotation. The productivity

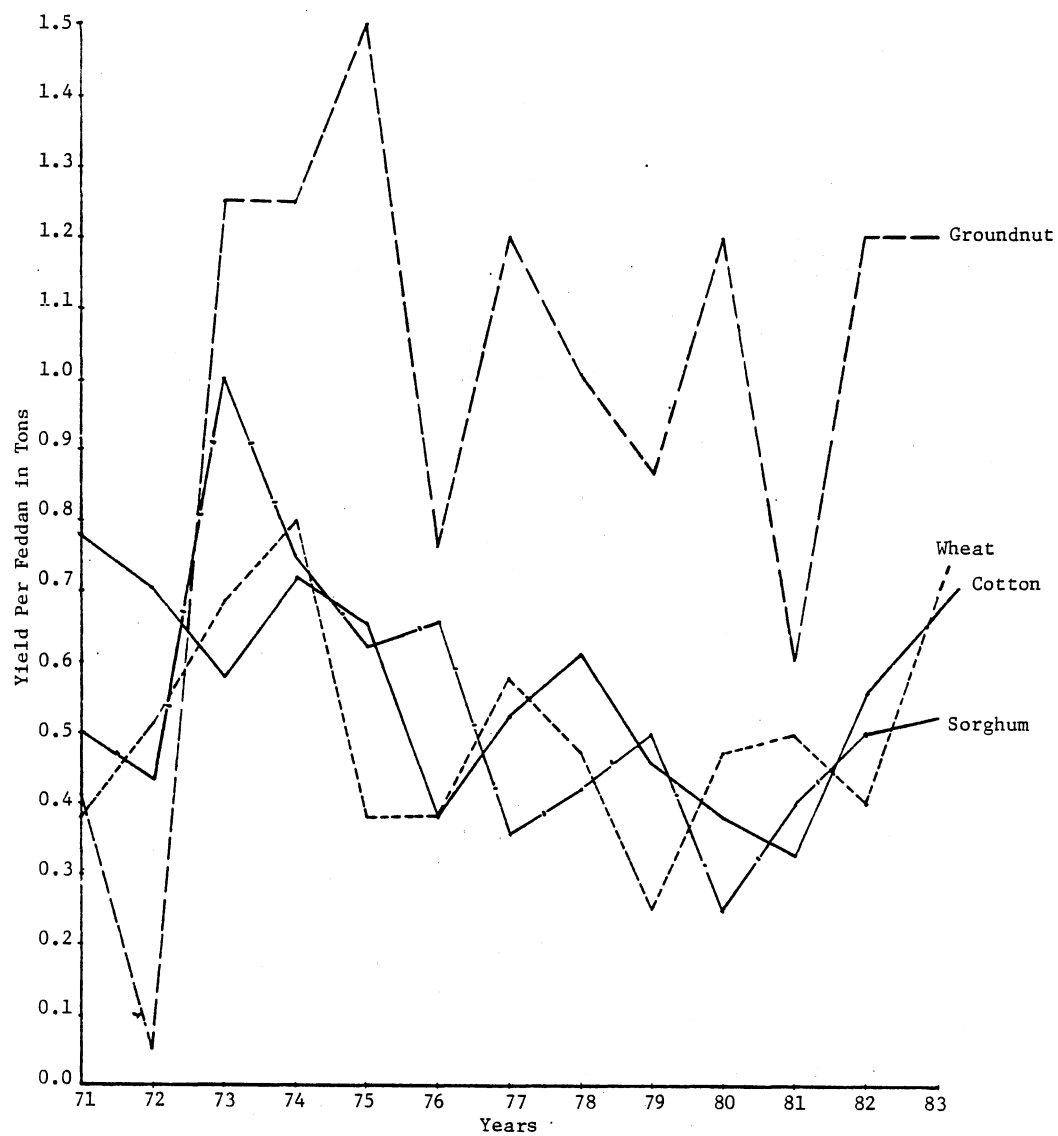


Figure 2. Yield Variability Over Time in the Gezira Scheme

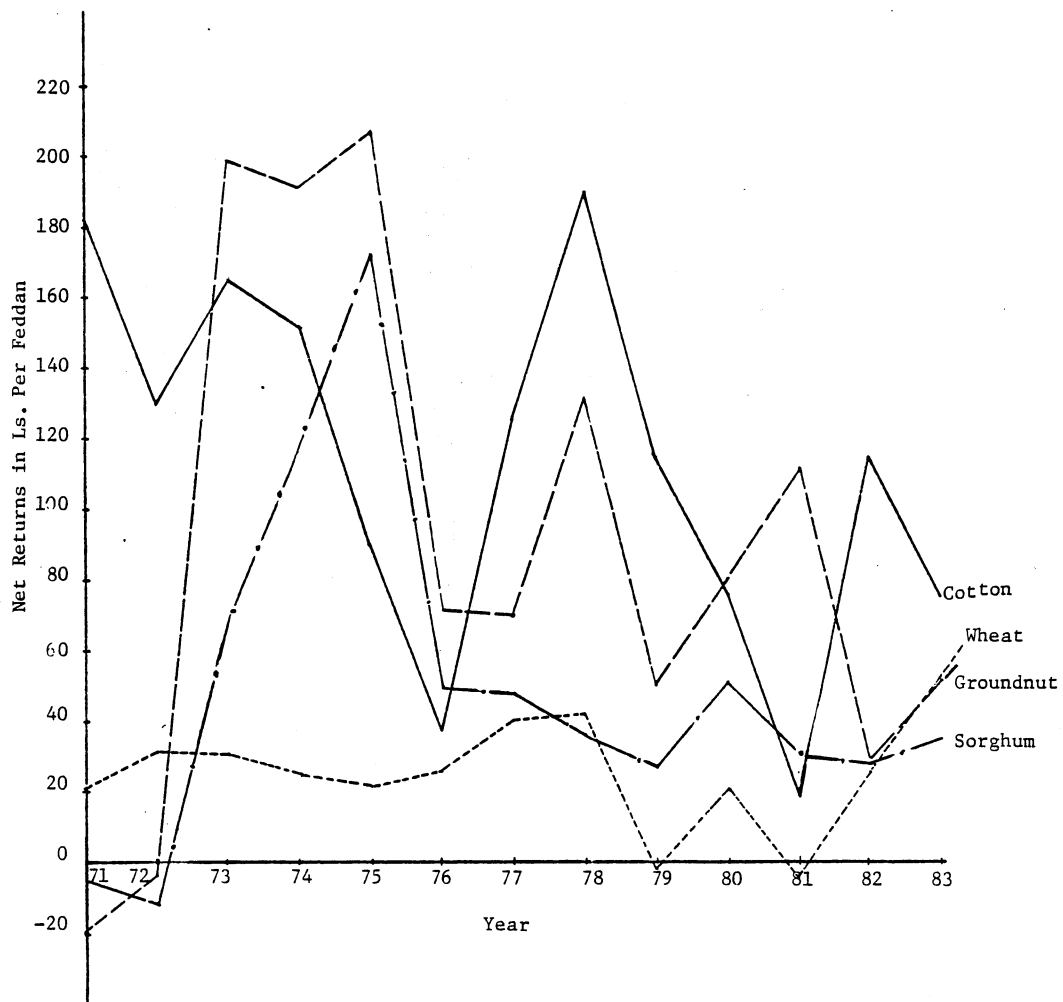


Figure 3. Gross Margins Variability Over Time in the Gezira Scheme.

of wheat under Gezira conditions is low, with an average of 0.4 tons/feddan. Wheat productivity is limited by water competition with other crops, especially cotton, and by inadequate machinery to perform timely land preparation and sowing. Survey results among Gezira tenants show that wheat is a very attractive crop to the tenants despite its low productivity and net revenues for two reasons: (1), wheat is the only crop in the rotation which is completely financed by the Scheme management; and (2) tenants are allowed to keep two sacks, 100 kilograms each, for family consumption and hand over the rest of the crop to the Scheme management. Further, irrigation is the only manual operation performed by the tenant in wheat cultivation.

Sorghum Production

Sorghum is widely regarded as the most important staple food crop in Gezira. However, the tenant has to rely on his own financial resources to raise the crop because the Sudan Gezira Board takes no part in financing the crop. Almost all the materials, machinery and labor inputs are provided by the tenants, either from their own or from outside sources and the produce is privately marketed. Sorghum yields are generally low because the crop is grown with minimal land preparation and without herbicides, insecticides or fertilizers. Unlike wheat, Gezira has a comparative advantage in producing sorghum and the residents have sufficient skill and know-how to raise the crop but lack credit.

Groundnut Production

Like sorghum, groundnut production is completely financed by the tenant. Lack of liquidity and access to improved production inputs result in fluctuating but relatively high yields (Figure 2). Gibbons (1975) reported that the environmental and geographical conditions are favorable for groundnut production in the Gezira Scheme. He further argued that despite the absence of satisfactory marketing institutions and facilities such as for grading and storage, marketing prospects at the national and international levels are believed to be promising.

At present, the government policy aims at drastic reduction in groundnut production in the Gezira Scheme, primarily for the purpose of making room for expanded wheat production. But groundnut does not seem to compete with wheat, neither in terms of land nor in water use, because the two crops are grown in two different seasons (Table III).

Vegetable Production

Vegetable growing is the complete responsibility of the tenant. Despite the fact that it is labor-intensive, many tenants prefer to grow vegetables on a crop-sharing basis. Onion, tomato, okra, cucumber and sweet potato are popular vegetables in Gezira. In general vegetables, especially onion, have relatively high income per feddan compared to field crops.

Agricultural Services

Agricultural Credit

The credit system in the Gezira Scheme is characterized by a marked dualism between institutional credit provided by the Sudan Gezira Board and the Agricultural Bank of Sudan, and the informal credit market consisting of localized transactions of money, goods and services among local merchants and moneylenders. The latter is referred to under Sudan conditions as "Sheil" system which is basically cash loans to be repaid in kind and involve an effective annual interest rate estimated by Ahmed (1977) to range between 115 to 280 percent.

Cotton, and recently wheat, have the highest priority for Sudan Gezira Board credit. Both are regarded as national crops and almost 75 percent of cotton expenses and 90 percent of wheat expenses are directly financed by the Scheme management. The management undertakes the marketing of both cotton and wheat, deducts the loans and pays the balance to the tenant farmers immediately after harvest. Because of the low productivity of wheat under Gezira conditions, the crop may fail to repay the debt. The wheat debt is usually deducted from cotton proceeds, a factor which obviously discourages cotton production and increases tenant debt.

To finance the tenant's advance payments, the Sudan Gezira Board borrows from the Sudan Central Bank at an interest rate ranging from 9 to 15 percent (Ahmed, 1983). In the Gezira Scheme, the role of the

Agricultural Bank of Sudan is to supplement the Sudan Gezira Board credit activities by providing short term loans to the tenant farmers for the production of cash crops other than cotton and wheat, namely groundnuts and vegetables. Because the tenant farmers in the Gezira do not possess the necessary collateral to be eligible for the Agricultural Bank loans, cooperative societies were established for the distribution and collection of the Agricultural Bank loans. However, due to inefficient management, corruption and disloyalty of the members, the cooperative failed to repay more than 39 percent of the loans (Ahmed, 1977) and this eventually led to a complete termination of Agricultural Bank loans.

Inadequacy and deficiencies of the institutional credit system in Gezira has led to the spread of informal agricultural credit systems. Obviously, the Gezira tenant was left with no option but to resort to private traders and village moneylenders to secure credit for crops other than cotton and wheat. Social and ceremonial obligations imposed by custom and religion make a heavy drain on the limited earnings of the tenant (Ahmed, 1983). Frequently the need for children's education, medical care and other domestic obligations requires the provision of cash. Institutional sources of finance are not available to the tenant for such social needs and thus forces him to borrow from the private moneylender.

The practice of share cropping in part stems from the inadequacy of liquidity to meet peak crop resource requirements for groundnut and vegetables. The share-cropping system has become an important tool for the tenants to secure labor on noncash basis. According to the

field survey results, five percent of the tenants interviewed resort to this system because even the moneylenders are very reluctant to finance crops like vegetables since vegetables are labor-intensive and subject to risk arising from fluctuations in yield and prices.

Research and Extension

All agricultural research is entrusted to the Agricultural Research Corporation which is a national research agency financed directly from government funds. Substantial efforts are devoted to development of new varieties and practices. However, most of the technical information is not tested on a Scheme-wide basis, consequently there is little feedback from tenants to the research station.

The Extension Department of the Sudan Gezira Board was established in 1969. Its functions are basically to disseminate agricultural, social, vocational, and health information to the tenants. At present, the department carries out little testing under field conditions and organizes lectures, demonstrations and extension tips through the regional rural television station. Since electricity service is provided to about 10 percent of the villages in the Gezira Scheme and few tenants own TV sets, the effect of such TV extension services is minimal.

At present, coordination between researchers and extension agents, both in defining the research program and in transmitting research results to the farmers, is almost nonexistent. Survey results show that 90 percent of the tenants interviewed did not

benefit from the extension program. In addition, there seems to be a marked communication gap between extension agents and the majority of the farmers. This gap is attributable to the prevalence of illiteracy among farmers and shortage of extension staff and communication facilities.

Marketing Services

Cotton marketing is performed by the Cotton Public Corporation (CPC), which receives cotton lint immediately after ginning. The CPC is an official government body controlling all internal and external sales of cotton lint in the country. The terms under which cotton is offered for sale have varied over time. Currently the CPC announces opening fixed prices, normally at the beginning of each season, on the basis of which competitive bids are received on lots of specified quantities. Bids are in U.S. dollars and the payment has to be made by irrevocable letter of credit at the time of shipment or some other specified date. An important issue which is related to cotton marketing policy is related to the fixing of prices. According to the World Bank report (1979), generally the Sudanese cotton is priced at between 60 to 70 percent of the comparable Egyptian varieties. In periods of low supplies, Sudan would tend to narrow its price differentials with Egypt while in periods of high stock it reduces its relative price. For this reason, Sudanese cotton is subject to variations of price, which in turn, affect the producers and the government revenues.

Since 1970 the marketing of groundnut has been monopolized by the government through the Sudan Oilseeds Company (SOC). But the

activities of this company are oriented towards the external operations, leaving the internal markets for wholesale traders. The traders tend to regard the minimum prices declared by the SOC as maximum prices, making quality a tool of negotiation. The major shortcomings of the policy of the oilseed company is that it is not flexible to match the day to day fluctuations in prices and lacks efficient transportation, storage and processing facilities. In Gezira, the bulk of groundnut production is handled by village merchants and moneylenders as repayment for cash advances to tenants. The tenant is hurt first by an inefficient public marketing policy and second by high interest rates of the moneylender.

The official marketing channels for wheat are the authorized wheat mills scattered at different locations in the Scheme. Each season the Sudan Gezira Board announces a fixed price per ton and tenants are obliged to hand their production of wheat over to the specified mills. Failure to obey this order may result in termination of rights to grow wheat in the future. The free market price is usually higher than the official declared price and a large proportion of the crop is smuggled to the free market. For sorghum, since it is an important staple food crop, many tenants would prefer to keep it. The surplus, if any, is marketed through village merchants and usually consumed locally by landless residents.

Vegetable growers rely on the local market to sell their produce, and to a lesser extent on nearby central markets. Buyers are usually wholesalers or retailers pay cash on the spot. In general, the produce is marketed unsorted and varying considerably in quality. Prices are subject to significant fluctuations due to irregular

produce consignments and related speculations. The lack of timely collection and dissemination of information on prices and supply and demand in local and alternative markets have undoubtedly contributed to the price instability in the study area.

The Rehabilitation Project

Due to a series of adverse developments such as worsening economic conditions, growing backlogs in machinery replacement and maintenance, water management problems and competing employment opportunities outside the Scheme, the performance of the Scheme has been seriously impaired. In June 1979, a joint FAO-IBRD mission visited Sudan for the purpose of identifying the Gezira Scheme's urgent needs for rehabilitation and modernization. The mission identified what is called the Rehabilitation and Modernization Project to satisfy the following objectives:

1. To increase production of all crops, particularly export crops, with the aim of realizing a minimum average increase of seven percent per year during the decade 1980-1990.
2. To improve crop mix in order to maximize the economic returns of the project within the framework of the primary objectives of improving both tenant incomes and government revenues.
3. To upgrade the productive capacity of the project in terms of staff, machinery, and other facilities to a level compatible with the demands of high cropping intensity and high productivity.

4. To evaluate the administrative organization of the Sudan Gezira Board with a view to improving efficiency and performance.

5. To study the present distribution of the individual tenancy income and to suggest ways and means to improve the tenants' net share of income from crop production.

The mission proposed that the rehabilitation and modernization of the Scheme be carried out in two stages, each five years in length. The first stage, Project I, is directed toward strengthening agricultural operations and restoring irrigation water supply to increase the current production levels. The second stage, Project II, would place emphasis on the modernizing the irrigation system, upgrading of technological levels in agricultural operations and improving the social and health services. A detailed feasibility study was conducted in 1981 by a group of international and national consulting firms. Based on the feasibility study results the International Development Association and the European Development Fund provided a credit of U.S. \$76 million under the Agricultural Rehabilitation Project for investment in the public irrigated sector of the Sudan. Of this credit, U.S. \$36.8 million has been allotted to the Gezira Scheme for the procurement of urgently needed equipment and spare parts. As prerequisites for the program two institutional changes took place in the season 1980-81: (1) replacement of crop sharing arrangements by a land and water charge, and (2) announcement of cotton prices early in the season and payment to tenants as soon as picked cotton is received by the Sudan Gezira Board. Other

priorities in the rehabilitation program are not yet specified, however, and it will take at least five years before the results of the program can be evaluated and analyzed properly.

CHAPTER III

THEORETICAL FRAMEWORK AND EMPIRICAL TECHNIQUES
FOR ENTERPRISE SELECTION IN A RISKY
ENVIRONMENT

Theoretical Framework

Direct Elicitation of Utility Functions

The foundation of the expected utility theorem goes back to Daniel Bernoulli who as early as 1738 suggested that the optimal behavior of the decision maker is that which maximizes expected utility. Bernoulli assumed that utility is cardinally measurable and that the decision maker should maximize his expected utility. Typically, the Bernoullian decision theory is defined by Dillon (1971) as follows:

Bernoullian decision theory is a normative approach to risky choice based upon the decision maker's personal strength of belief (or subjective probabilities) about the occurrence of uncertain events and personal valuation (or utility) of potential consequences (p. 4).

Following this definition, the expected utility model provides a single-valued index which orders action choices according to the preferences or attitudes of the decision maker. In 1944, Von Neuman and Morgenstern demonstrated that the utility concept follows logically a set of assumptions or axioms about individual behavior. The set of axioms is summarized as follows:

1. Ordering of choices: For any two action choices, A_1 and A_2 , the decision maker either prefers A_1 to A_2 , prefers A_2 to A_1 , or is indifferent between them.

2. Transitivity among choices: If A_1 is preferred to A_2 , and A_2 is preferred to A_3 , then A_1 must be preferred to A_3 .

3. Substitution among choices: If A_1 is preferred to A_2 , and A_3 is some other choice, then a risky choice $pA_1 + (1-p)A_3$ is preferred to another risky choice $pA_2 + (1-p)A_3$, where p is the probability of occurrence.

4. Certainty equivalent among choices: If A_1 is preferred to A_2 , and A_2 is preferred to A_3 , then some probability p exists that the decision maker is indifferent to having A_2 , for certain or receiving A_1 with probability p and A_3 with probability $(1-p)$. Thus A_2 is the certainty equivalent of $pA_1 + (1-p)A_3$.

According to Bernoulli's principle, if a decision maker obeys these axioms, there exists a utility function $U(A)$ which reflects the decision maker's preference among different alternative outcomes. If the alternative outcomes represent different levels of income Z , then the result is a utility function of income $U(Z)$. When enough utility values are available from repeated gambling questions, a utility index or function can be fitted to these values using graphical or statistical procedures. Graphically, a farmer's attitude toward risk is inferred from the shape of his utility function. As presented in Figure 4, a function concave to the origin implies risk aversion, a linear utility function implies risk neutrality, and a convex function implies a risk preferring attitude. A decision maker may also have a

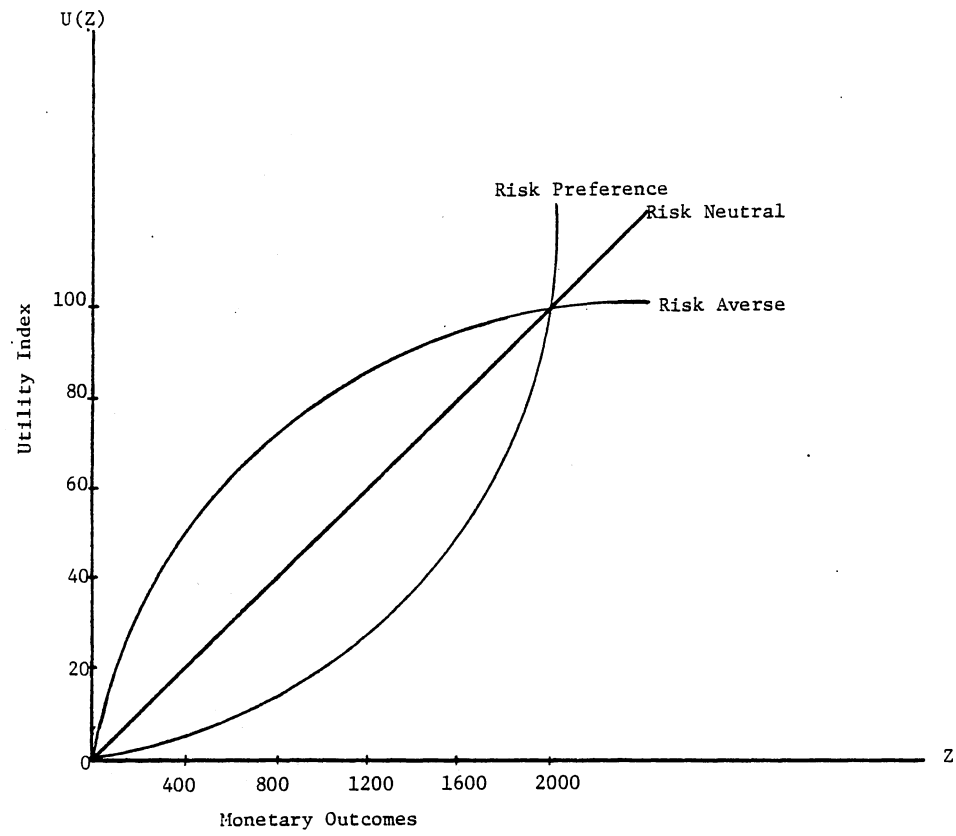


Figure 4. Graphical Estimation of Risk Attitude Represented by Three Utility Functions

utility function with both concave and convex segments indicating changes in risk attitudes for different monetary outcomes.

An important characteristic of the utility function is that they are monotonically increasing, i.e., if $Z_1 > Z_2$ implies $U(Z_1) > U(Z_2)$. The implication of increasing monotonicity is the neoclassical axiom that more income is preferred to less, i.e.,

$\partial U / \partial Z > 0$. Although the first derivative of the utility function is positive, the second derivative may be negative ($\partial^2 U / \partial Z^2 < 0$), zero ($\partial^2 U / \partial Z^2 = 0$), or positive ($\partial^2 U / \partial Z^2 > 0$) which implies that the marginal utility of extra income is decreasing, constant or increasing. As shown in Figure 4, farmers with such utility functions are characterized as risk averse, risk neutral or risk preferring, respectively.

Despite the fact that the Bernoullian Principle implies the existence of $U(Z)$, it tells nothing of its precise form, nor does the decision maker intuitively know the algebraic form of his utility function. Dillon (1971) argued that a variety of different functional forms may suit such as polynomial, logarithmic or exponential utility functions. However, he recommended using the functions that provide simplest manipulation.

Direct elicitation of the utility functions has been emphasized in a series of studies (Officer and Halter, 1968; Lin, Dean and Moore, 1974; Halter and Mason, 1978; Dillon and Scandizzo, 1978; Hildreth and Knowles, 1982). This approach, however, has been criticized as subject to bias from different interviewers, preference for specific probabilities, negative preference towards gambling, absence of

realism in the game setting, lack of time and experience of the participants to become familiar with the hypothetical choices, and compounding of errors in the elicitation process (Roumasset, 1979). Furthermore, studies by Binswanger (1980) and Dillon and Scandanizzo (1978) have indicated that eliciting individual farmer's utility functions are expensive, time consuming, and may not be stable over time because they vary with the socioeconomic status of the household. Hazell (1982) stated:

It seems unlikely that direct elicitation will ever be a widely adopted approach in farm advisory work. A more practical approach has proved to be the derivation of a number of farm plans in the efficient E-V set, and to present these to the farmer for his choice (p. 386).

For the purpose of this study, the E-V approach was assumed to be relevant. The following discussion presents and analyzes the E-V efficiency frontier approach.

Mean-Variance Efficiency Criteria

Both quadratic and linear risk programming provide paths to estimate the E-V efficiency frontier. The approach is widely used in whole farm planning models incorporating risk. It is based on the following assumptions: (a) the farm decision maker views the outcome of any production activity in probabilistic terms meaning that net return or gross margin is considered to have a probability distribution which is normally distributed (Anderson, et al, 1977); (b) in assessing the desirability of alternative combinations of farm activities the decision maker holds preference among farm plans solely

on the basis of their expected income E and variance of expected income V . Therefore his preference can be represented by the following quadratic utility function:

$$U = U(E, V) \quad (3.1)$$

The utility indifference curves derived from Equation 3.1 are assumed to be convex with positive slopes. This means that farmers are risk averters, i.e. increasing levels of expected income are necessary to offset higher levels of risk bearing.

Other assumptions required to insure that the iso-utility curves for the farm firm decision maker exhibit the convexity property are:

(a) higher expected incomes are preferred to lower incomes, ceteris paribus; (b) a low variance is preferred to a high variance for a given level of expected income; and (c) there is a diminishing marginal rate of substitution between the expected level and variance of income. The first two assumptions guarantee the positive slope of the iso-utility curves and the third assumption implies that the iso-utility curves will be convex as depicted in Figure 5. In terms of calculus the relationships in Figure 5 can be stated as follows:

1. $\partial U / \partial V < 0$ i.e., the expected utility will decrease
with an increase in risk.
2. $\partial U / \partial E > 0$ i.e., the expected utility increases
with an increase in expected
income.
3. $\partial E / \partial V > 0$ i.e., the farmer would prefer a farm
plan with higher V if, and only
if, E were also higher.

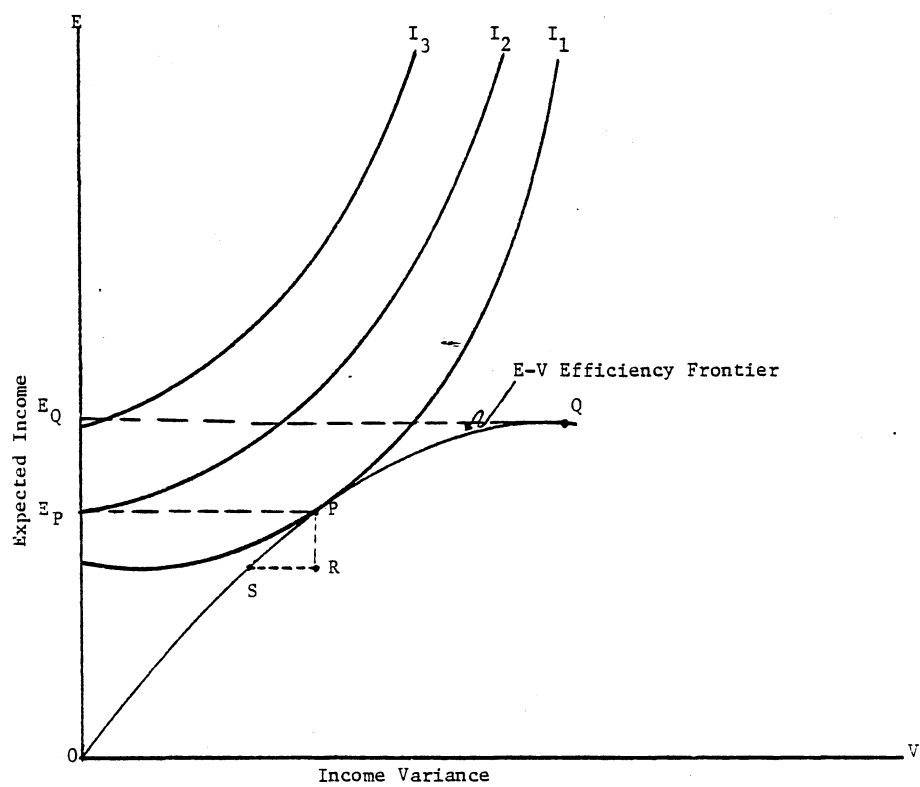


Figure 5. The E-V Efficiency Frontier and the Optimum Farm Plan

4. $\partial^2 E / \partial V^2 > 0$ i.e., the compensation in (3) would have
to increase at an increasing rate
with increases in risk.

Further discussion on the above relationships is presented by Sharp (1963), Johnson (1968) and Hazell (1971).

As shown in Figure 5, the upper bound OQ of the feasible set is the efficiency frontier. The feasible set is bounded above since net revenues from production activities have finite means and variances. Each point lying on the upper bound OQ corresponds to the highest level of expected income attainable for each level of income variance.

From the behavioral assumptions concerning the iso-utility curves, one can conclude that only farm plans having means and variances which lie on the efficiency frontier are expected to be potential choices for the decision maker. Every alternative plan whose expected income and variance is given by a point interior to OQ is dominated by an alternative which has the same variance but a higher expected income or the same expected income and a lower variance. For example, in Figure 5 point R is dominated by point P and point S. Point R has the same variance as point P, however, point P has greater expected income. Similarly, point R has the same expected income as S but S has lower variance than R. It follows that the E-V efficiency frontier can be defined as the locus of all efficient farm plans encountered with the lowest variance for any given income or the highest income for any given variance. Point Q on the efficiency frontier represents the result from the deterministic profit maximizing solution where the decision maker is assumed to be risk neutral. A rational farmer who is averse to risk and his

utility preference corresponds to the utility function, I_1 shown on Figure 5, would select the farm plan represented by point P along the efficiency frontier.

* Despite its wide applicability and acceptability as a planning tool for farmers under risk, the E-V efficiency criteria is associated with some problems. The decision maker is assumed to be everywhere risk averse. When this assumption does not hold, the preferred choice may be excluded from the E-V efficient set. In addition, the assumption of normal distribution of outcomes may not be relevant given the skewness of agricultural yields and incomes (King and Robinson, 1981).

Probability of Loss Function

A definition of risk that is widely applied in the literature, explains risk as a "chance of loss" or the probability (α) that net income (Π) will fall below some critical or disaster level (d). Mathematically the definition can be expressed as:

$$\Pr(\Pi < d) = \alpha \quad (3.2)$$

This definition relates to the "safety-first" models developed by Roy (1952), Telser (1956), Baumol (1963), and Pyle and Turnovsky (1970). It specifies that a decision maker first satisfies a preference for "safety" in organizing a firm's activities, and then follows a profit oriented course of action. The following discussion represents a probability of loss function criterion proposed by Baumol.

Baumol (1963) criticized the E-V approach on the ground that many alternative farm plans along the efficiency frontier may be confusing

to the decision-maker. In addition, plans which do not provide a high probability of meeting minimum level of income are likely to be rejected by farm decision-makers. For example, assume a farmer's minimum acceptable level of income is \$1,000. Therefore only farm plans which generate this income level, at a reasonably high level of probability, are considered in the probability of loss analysis.

Baumol's criticism was based on expected gain confidence limits for portfolio selection. The model can be defined as a set of confidence statements about achieving various levels of income. The income from every efficient plan is assumed to be normally distributed with mean E and variance V . The basic assumption is that the rational decision maker can base his choice for a particular plan on the expected income and the minimum acceptable level of income which could be obtained from that plan, with a given degree of probability. To compute the critical income level d^* , for every level of expected income E , we can use the following equation:

$$\text{Max. } E \quad (3.3)$$

$$\text{Subject to: } E - K_{\alpha} S \geq d^* \quad (3.4)$$

where

d^* is the critical level of income; E is the level of expected income; S is the standard deviation of income; and K is a factor from the standard normal density function taken at the desired probability level α .

The criterion is described in Figure 6. The expected value of income E of various efficient plans is presented on the horizontal axis. The vertical axis represents the values of $E - K S$ corresponding to the same plans. Although all farm plans obtained

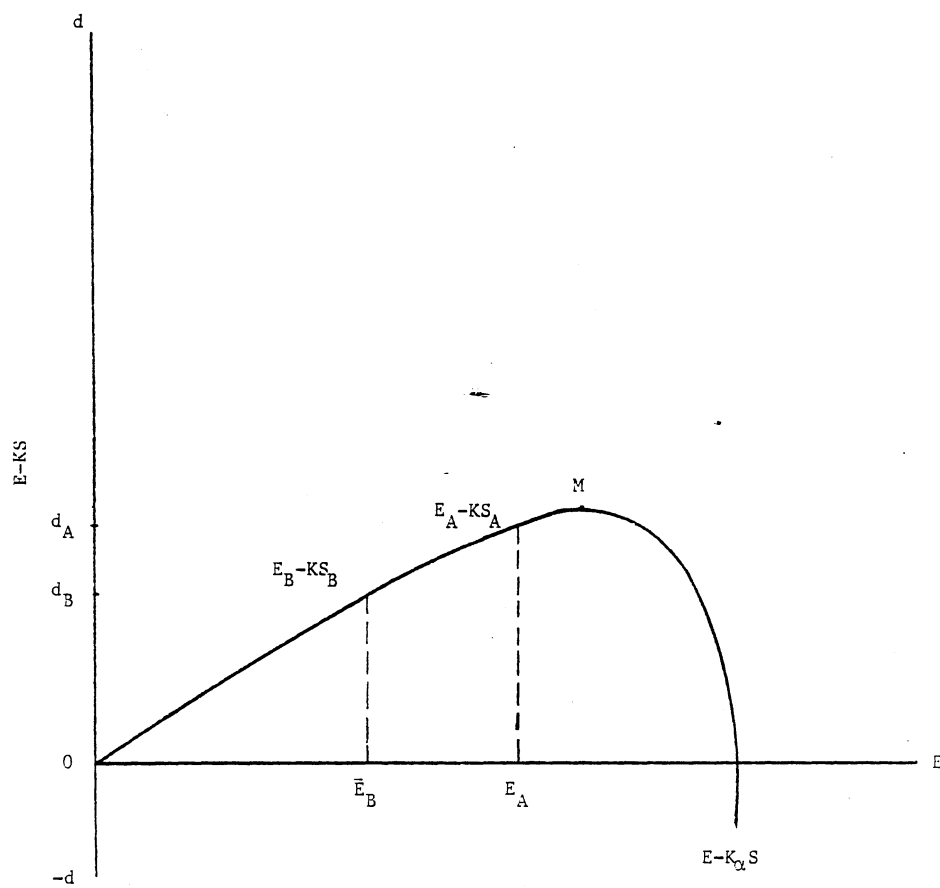


Figure 6. Probability of Loss Function Associated with Certain Probability Level

with the E-V analysis are efficient, it can be demonstrated that the decision maker may readily reject some of them. For example, he will generally prefer farm plan A to farm plan B because $E_A > E_B$ and $(E_A - K_\alpha S_A) > (E_B - K_\alpha S_B)$. That is, farm plan A offers both a higher expected income (E) and a higher floor of income (d^*). However, a rational decision maker would have to choose the farm plan corresponding to point M since at M he can achieve a higher expected income and more safety (higher d^*) at the same probability level. In addition to making this single-valued suggestion, presenting bands for different probability levels would allow the decision maker to have a wide choice and hence a satisfactory level of enterprise combination which maximizes expected income subject to a minimum critical level of income.

Empirical Techniques

Quadratic Risk Programming

Markowitz (1959) provided a valuable decision criterion for selecting efficient portfolios in a quadratic programming framework. He described an efficient portfolio as one with maximum expected return (E) and minimum variance (V), or one with the minimum variance for a given expected return. In matrix notation the quadratic programming model is typically formulated as:

$$\text{Maximize } C'X - \lambda X'\sigma X \quad (3.5)$$

Subject to:

$$AX \leq B \quad (3.6)$$

$$X \geq 0 \quad (3.7)$$

where:

X = a set of activity levels,

C = expected returns associated with each activity,

B = resource restrictions,

σ = the variance covariance matrix of activity returns,

λ = the risk aversion coefficient.

In the model, λ is varied parametrically to derive the efficient E-V frontier. When $\lambda = 0$, or $\sigma = 0$, the problem is reduced to a linear program. The risk aversion parameter represents the decision maker's risk attitude. If the decision maker is risk neutral, $\lambda = 0$ and expected income is maximized. As the risk aversion coefficient parametrically increases, risk becomes increasingly important and more diversified risk efficient farm plans are identified. Any farm plan that is not on the risk efficiency frontier is not a risk efficient farm plan.

The application of quadratic programming to risk analysis in agriculture was introduced by Freund (1956). He demonstrated how a conventional linear programming model could be extended to incorporate income variance and covariances to determine the E-V efficiency frontier. Similar to equation (3.5), Freund's model incorporated a risk aversion parameter in the quadratic portion of the objective

function. Subsequently, examples include studies by How and Hazell (1968); Scott and Baker (1972); Lin, Dean and Moore (1974); and Adams, Menkhus and Woolery (1980).

The quadratic programming model offers considerable potential in farm planning under risk. However, some limitations are often cited which constrain its use. The choice of the risk aversion coefficient is arbitrary, yet critical for determining a risk efficient farm plan. Brink and McCarl (1978) provided an alternative solution by varying the risk aversion parameter until the difference between a farmer's actual plan and a farm plan on the efficient frontier is minimized. Other limitations include lack of accurate data on income variances and covariances and difficulties with quadratic programming algorithms (Anderson, et al, 1977).

To overcome the above difficulties, extensions have been made to the basic linear programming model by incorporating risk in the elements of the objective function. The empirical technique incorporating this development is reviewed below.

Linear Risk Programming

Linear risk programming models have been developed to account for the stochastic nature in agricultural production activity. These approaches include the incorporation of game-theory decision criteria into programming formulations (McInerney, 1969); constraints on maximum admissible loss programming (Boussard and Petit, 1967); multistage linear programming with marginal risk constraints (Chen and Baker, 1974); development of MOTAD (Minimization of Total Absolute

Deviation) by Hazel (1971); and MOTAD with RINOCCO (Risky Input-Output Coefficients) developed by Wicks and Guise (1978).

Hazell (1971) demonstrated that the MOTAD model produces a set of efficient farm plans closely similar to the quadratic solution and may offer cost and computational advantages. The key concept in Hazell's MOTAD model is what he calls mean absolute income deviation defined as:

$$A = \frac{1}{s} \sum_{h=1}^s \left| \sum_{j=1}^n (C_{hj} - g_j) X_j \right| \quad (3.8)$$

where:

A = an unbiased estimator of the population mean absolute income deviation,

s = the number of years of sample observations,

n = the number of activities,

C_{hj} = the gross margin (gross returns per acre minus total variable costs per acre) for the j^{th} activity on the h^{th} year,

g_j = the sample mean gross margin for the j^{th} activity,

X_j = the level of the j^{th} activity.

Hazell argued that since s is constant then sA can be minimized, which is the total absolute income deviation, abbreviated as A. Using A as a measure of risk it is possible to define the set of efficient E-A farm plans as those having minimum mean absolute income deviation for any expected income level E. He further converts A to a linear programming objective function by minimizing only the absolute values

of the negative total gross margin deviations. The final mathematical formulation of the MOTAD model is as follows:

$$\text{Minimize } \sum_{h=1}^s \bar{y}_h \quad (3.9)$$

$$\text{Subject to: } \sum_{j=1}^n (C_{hj} - g_j) X_j + \bar{y}_h \geq 0 \quad (\text{for } h = 1, 2, \dots, s) \quad (3.10)$$

$$\text{and } \sum_{j=1}^n f_j X_j = \lambda \quad (\lambda = 0 \text{ to unbounded}) \quad (3.11)$$

$$\sum_{j=1}^n a_{ij} X_j \leq b_i \quad (\text{for } i = 1, 2, \dots, m) \quad (3.12)$$

$$X_j, \bar{y}_h \geq 0 \quad (\text{for all } h \text{ and } j) \quad (3.13)$$

where:

\bar{y}_h = absolute values of the negative total gross margin deviations,

n = number of activities in the basic linear programming model,

C_{hj} = the gross margin for the j^{th} activity on the h^{th} year,

g_j = the sample mean gross margin for the j^{th} activity,

f_j = the expected gross margin of the j^{th} activity,

λ = the expected total gross margin.

The MOTAD approach has been used in several studies. Brink and McCarl (1978) applied a modified model to draw inferences about

farmers risk aversion based on the difference between a farms' actual plan and what the model predicts. Mapp et al (1979) specified a MOTAD model for a typical farm in Southwestern Oklahoma to evaluate the effects of alternative economic futures. Gebremeskel and Shumway (1979) developed a MOTAD model to evaluate risk-reducing forage and cattle management strategies. Persaud and Mapp (1980) applied a MOTAD model to evaluate risk management strategies for Oklahoma farmers. The strategies included forward contracting of wheat sales and wheat storage, and subsequent periodic sale on a monthly basis throughout the year. Salem and Badger (1983) used a MOTAD model to examine risk and uncertainty in farm planning when using conventional, minimum and no tillage systems.

In this study, a MOTAD model is developed and used to analyze the optimum enterprise combinations on the Gezira farms. The model is presented in the next chapter.

Selective Applications of Risk Programming Models

The Schultzian notion that traditional agriculture farms maximize profits and therefore use resources efficiently within the limits of traditional technology has been subject to criticism. Lipton (1968) argued that farmers may choose less risky crops even if they are less profitable. According to this interpretation, if we assumed that farmers are utility maximizers, allowance must be made for some trade-off between variance (as a measure of risk) and expected profit. Such allowance cannot be made under the assumption that farmers are profit maximizers. Moreover, the variability of production from year

to year implies that economic efficiency is equivalent to maximizing the expected income over some time period. Consequently, a farmer may choose a lower expected income associated with less variability of income to ensure a higher probability of "staying in business". Furthermore, Lipton argued that farmers do not maximize profits as high profit levels are associated with too much risk. A similar conclusion is reached by Dillon and Anderson (1971) which led them to state the following hypothesis:

We would hypothesize that farmers in traditional agriculture (and elsewhere) typically have nonlinear utility functions (implying active consideration of subjective risk) and successfully endeavor to maximize expected utility rather than expected profit...in our view quantitative information on risk attitudes must be an important element in understanding farmer behavior in underdeveloped agricultures, and ipso facto, in the generation of policies for their modernization (p. 31).

Wiens (1976) used a quadratic programming model to examine the impact of yield uncertainty on peasant allocation of land among crops and use of hired factor services such as labor and credit. Using historical data from China, Wiens demonstrated that the peasants decision making behavior exhibited substantial risk aversion. His final conclusion is that neither risk neutrality nor liquidity constraints alone could explain both the cropping patterns and the factor employment observed among Chinese farmers.

In the African continent, the issue of risk is investigated by Wolgin (1975) in Kenya. He demonstrated that the traditional tests of economic efficiency in peasant agriculture, using marginal analysis, are generally misspecified if farmers are making their decisions in the presence of risk. Furthermore, Wolgin concluded that risk plays

an important role in farmer decision making and that farmers under conditions of uncertainty behave as risk averse entrepreneurs.

Consideration of risk and uncertainty in project appraisal studies need more emphasis because it seems that so far no agreed procedure or practice has emerged. Several international organizations such as the World Bank have apparently decided that the informational and analytical costs arising from rather sophisticated methods of risk analysis outweigh the benefits to be gained in terms of better decisions about uncertain projects (Anderson, 1983). The conventional methodology to account for risk and uncertainty in project appraisal is sensitivity analysis adopted by Gittinger (1972) and Little and Mirrlees (1974). However, sensitivity analysis per se is surely inadequate because it is based on subjective judgment about possible increments in project costs or otherwise reduction in project benefits.

Hillier (1963) developed a project appraisal model for estimating the probability distribution of present value (PV) by using expected value $E(PV)$ and variance $V(PV)$. He relied on the Central Limit Theorem for approximately normal distribution of PV. By estimating the mean and variance of PV, the decision maker can evaluate the risk consequences of a particular investment. This model, however, is criticized for statistical dependencies and potential correlations of covariances.

Stochastic simulation has been the most widely used model for evaluating uncertainty in project appraisal (Anderson, 1983). Monte Carlo sampling technique for estimating the distribution of PV and internal rate of return (IRR) was examined by Reutlinger (1970) and

applied by Pouliquen (1970). The approach developed and applied by Pouliquen is based on identifying the most critical components of the project and simulating the probability of IRR under different assumptions underlying the critical components. The World Bank approaches so far are confined to Gittinger's sensitivity analysis and Reutlinger's stochastic simulation approaches.

Finally, there have been attempts to incorporate risk in agricultural sector models. Econometric models are frequently employed in determining the market-clearing prices using supply and demand equations at the sector level. Duloy and Norton (1975) have shown how linear programming models can be adapted to solve production and marketing problems. However, a major difficulty in incorporating risk behavior in sector supply models is the need to aggregate the individual utility functions (Simmons and Pomareda, 1975). The difficulty arises from the fact that the expected utility theorem is based on ordinal preference indices rather than cardinal measures. These preference indices are only defined up to linear transformations, and are not strictly additive over individuals. Moreover, quadratic utility functions for income cannot be added to draw inferences about the whole sector. To overcome aggregation problems economists have developed a weighted average procedure where the weights are the risk shares $\sigma_i / \sum \sigma_i$. Several applications of this weighted average procedure is documented in the literature by the work of Hazell et al (1981), Simmons and Pomareda (1975), and Kutcher and Scandizzo (1981).

Implications of Risk Analysis to Gezira

In Gezira, farmers must decide how much of their limited small holdings should be allocated among various cash and food crops. The E-V analysis provides an opportunity to select the optimum combination of crops that maximizes the tenant satisfaction and leads to improvement in the currently deteriorating economic conditions in the Gezira and the country at large.

Key components of such an analysis include identifying the relevant sources of risk; collecting the appropriate data such as crop yields and prices; and constructing the cost of production series. In addition, one must distinguish between known patterns of variation and random variation. In this study, the basic assumption is that producers base their plans on the long-term mean of net returns and that any deviation from the mean is a random event. The relevant sources of risk are institutional credit, hired labor, and timing and frequency of irrigation water. To account for the rationality of the peasant farmer, subsistence constraints are included in the deterministic model.

In general, the optimum farm plan is determined by many factors such as social and economic status, access to the production factors, family composition, education and years of farming experience. Unfortunately, no detailed socio-economic survey reports at the Scheme level are available about the Gezira, however, a sample survey conducted by the author at the Gezira shows a high degree of economic and social similarities among Gezira tenants. According to the survey results 85 percent of the tenants own equal size tenancies and have

equal access to production factors and services provided by the Gezira management. Eighty percent of the tenants have only pre-school education and almost all tenants have extensive experience in farming. Analytically, the model shows the area to be specified for each crop based on the response of the crop to the availability of scarce resources, particularly capital liquidity, hired labor and irrigation water.

Hazell (1982) asserted that optimal crop mixes could be determined for representative farms using mean-variance models, and these would then have wide-spread applications to other farms of the same type. Following Hazel's assertion and given the fact that Gezira farms are relatively homogenous in nature, this study will utilize a mean-variance criteria to compute a set of efficient farm plans that would minimize the risk for any given expected income. The underlying assumption in this analysis is that the Gezira farmers are risk-averse and that ignorance of risk, as it affects Gezira farmers, has contributed significantly to the deteriorating economic conditions for the Gezira Scheme.

CHAPTER IV

SPECIFICATION OF A LINEAR RISK PROGRAMMING

MODEL FOR THE GEZIRA SCHEME

The Analytical Framework

In this study the framework under which the analysis is conducted is based on the assumption that farmers bear the risk associated with income fluctuations over time. They base their plans on the long term mean of net returns and that any deviation from the mean is a random event. The decision on how much area should be devoted to each crop will be predicted by the model depending on the resource endowment. Other assumptions are that: (a) the tenant will pay a land and water charge to the Scheme management in return for services provided; (b) the tenant will repay all the cash and in-kind credit plus interest advanced by the Scheme; (c) the management will continue to perform and regulate the marketing of cotton and wheat; (d) the tenant may utilize his family labor or hired labor at a given wage rate; (e) the tenant can borrow any amount of informal credit at a given interest rate to supplement his operating capital needs; and (f) the total area cultivated is determined basically by the amount of hired labor, irrigation water and institutional credit available to the decision maker.

Given the above assumptions, the representative tenants may adopt the following alternative decision criteria: (a) to allocate resources so as to maximize net cash returns to fixed farm resources; or (b) to allocate resources to maximize utility by striking some balance between increasing expected income and minimizing income variability to reflect risk behavior.

Deterministic linear programming models can be used to derive the profit maximizing solution. However, the principal criticism leveled against using deterministic models as planning tools relates to the embodied assumption that all coefficients are determined with perfect knowledge. Risk programming models, however, recognize the importance of risk in agricultural planning and have led to the development of a normative decision theory based on inclusion of stochastic elements in whole farm planning models. The analytical framework in this study is based on incorporating such stochastic elements to evaluate the planning process in the Gezira risky environment.

Formulation of the Model

The model adopted for this analysis is a modified MOTAD approach developed to derive a set of efficient farm plans under risky conditions for a typical farm in the Gezira Scheme. The basic concept is to minimize total absolute deviations about expected income subject to linear constraints on level of expected income and other resources.

Basic Risk Programming Model

In matrix notation, the MOTAD model may be formulated as follows:

$$\text{Minimize } Ld, \quad (4.1)$$

$$\text{Subject to: } AX \leq B \quad (4.2)$$

$$DX + Id \geq 0 \quad (4.3)$$

$$C X = \lambda \quad (4.4)$$

and

$$X, d, \lambda \geq 0 \quad (4.5)$$

where

X = a column vector of activity levels;

A = a matrix of technical input-output coefficients;

B = a column vector of available resources;

C = a row vector of expected gross margins;

D = a deviation matrix representing the difference between actual and expected gross margins in a particular year;

d = a vector representing the total negative deviations summed over all risky enterprises;

L = a row vector of ones;

I = an identity matrix of the number of years in the study period;

λ = a scalar used to parametrize the expected total gross margin constraint level. The maximum value of λ is the maximum value of the basic L.P. solution.

There are two steps in the computational procedure of this model. First, a conventional linear programming maximization problem is formulated and solved to determine the maximum value of λ which is the maximum expected total gross margin or highest attainable point on the

risk efficiency frontier. Second, the elements of risk are introduced through minimization of total negative deviations represented by the objective function, Ld . Other points on the risk efficiency frontier are obtained by decreasing the objective function value (λ) parametrically in arbitrary decrements. Along the efficiency frontier, the MOTAD model minimizes total negative deviation (TND) for any given expected total gross margin. This TND value is transformed into an estimate of standard deviation by multiplication of a constant, K . The K value was calculated by Herry (1965), and applied by Hazell (1971), Simmons and Pomareda (1975), Brink and McCarl (1978) and Mapp et al. (1979) as:

$$K = \frac{2}{s} \sqrt{\frac{s \cdot \Pi}{2(s-1)}} \quad (4.6)$$

where

s = number of years in the series; and

Π = a mathematical constant equaling 3.14286.

The standard deviation (S.D.) can therefore be expressed as:

$$S.D. = KLd \quad (4.7)$$

This transformation allows the model to determine a set of efficient farm plans along an $E-\sigma$ or $E-V$ efficiency frontier. Depending on a farmer's attitude toward risk, he can select the farm plan that will maximize his utility.

Assumptions of the Model

Since MOTAD basically is a linear relationship, all the assumptions of the conventional linear programming model hold except

the assumption which states that resource supplies, input-output coefficients, prices of resources and activities are known with certainty. The assumptions for MOTAD are: (a) additivity of resources and activities; (b) linearity of the objective function; (c) non-negativity of the decision variables; (d) divisibility of activities and resource; (e) finiteness of activities and resource restrictions; and (f) proportionality of activity levels and resources.

Other assumptions associated with whole-farm planning models using MOTAD are: (1) net returns or gross margins are considered to have a normal distribution; (2) the decision maker's preference among alternative farm plans is expressed in terms of expected income E and associated variance V , therefore, his preference or utility function may be described as quadratic:

$$U = f(E, V) \quad (4.8)$$

and (3) the indifference curves resulting from the above utility function are convex with positive slopes. This latter characteristic implies that decision makers are risk averse.

Limitations of the Model

Despite MOTAD's wide acceptability as a suitable technique for evaluating whole-farm planning models under risk, the model has limitations. Accurate and reliable time series data on gross margins for the enterprise activities are essential to evaluate risk associated with different plans, yet difficult to secure.

MOTAD measures risk as total negative deviation from expectation. This measure, however, is arbitrary and raises questions about how

farmers perceive risk and what measure of risk is appropriate in such types of farm planning (Brink and McCarl, 1978). In this analysis the mean of the series of gross margins is used as a measure of expectations because of the relatively short series available (13 years). In relatively long series data models, the mean appears to be an unreliable measure of the decision makers expectations. Young (1980) argued that weighted moving average models are theoretically and empirically better for evaluating risk based on long series historical data. However, the choice of appropriate weights for computing moving average is still an empirical limitation.

Data Requirements

Computation of the MOTAD model requires time series data on gross margins (net returns) for each enterprise in the model. The deviation matrix is obtained by subtracting the expected value or average gross margin from the gross margin value for each year in the series. It is this deviation matrix which forms the basic objective function of the model.

Input-output coefficients and resource availability must be specified. The resource constraints specified for the Gezira model include land, family labor, hired labor, irrigation water and institutional credit. The real activities are limited to the main crops grown in the Gezira Scheme and include cotton, wheat, groundnut and sorghum. The initial MOTAD tableau is presented in Appendix C.

Sources of Data

The data for this study were obtained from different sources. Primary data were obtained by conducting a field survey of 50 Gezira tenants during January-February, 1984. Official Gezira managers and field staff were also interviewed, as well as Agricultural Research Corporation specialists. Secondary data were obtained from the Sudan Gezira Board archives and records as well as the Department of Rural Economic studies at the Faculty of Agriculture, Khartoum University. Additional information was available from other sources including the Ministry of Agriculture and Natural Resource, Ministry of Planning, Ministry of Irrigation, the Agricultural Bank of the Sudan, Cotton Public Corporation and the Bank of the Sudan. Furthermore, the data were supplemented by official records of agricultural personnel working at the Gezira Scheme Block level.

The Sample Survey

Organizationally, the Main Gezira Scheme is divided into three divisions: Northern, Central and Southern. Each division is subdivided into groups and blocks. Two blocks were selected randomly from the Central and Northern divisions. Twenty-five tenants were interviewed from each block. The questionnaire included information about various socio-economic characteristics of the tenants, family and hired labor availability, machinery and equipment, credit sources and irrigation water timing and frequency.

The sample of the farmers interviewed was selected randomly with the help of the Block Inspector (B.I.). The B.I. is an administrative officer representing the Sudan Gezira Board. To facilitate communication the purpose of the survey was first explained to the B.I. who in turn introduced the interviewer to the tenants. After the first round, tenant's answers were checked for consistency by comparing responses and revisiting them to obtain explanation for any inconsistency.

The socio-economic characteristics of the tenants interviewed are shown in Table IV. On the average, tenants in the sample survey were 54 years of age, completed pre-school education in Khalwa (religious school), operated the farm most of their lives and cropped an average area of 15 feddans. All tenancies in the survey were owner operated. The average household size was six members. Four out of the six members were adults while two were dependent children. The household composition is important both as a source of labor and as a consumption unit. Field observation indicates that women, especially wives, were active participants in the agricultural production. In the Gezira Scheme widows were allowed to operate a tenancy even if there were no adult sons.

Adequate supply of household labor is very critical especially during peak periods such as weeding and harvesting. The age at which family members are considered economically active in this study is 15 to 65 years. Family labor supplied on a regular basis was estimated from the survey at 240 manhours per month. Hired labor availability was estimated by respondents during the survey in terms of man days per month. The man days available were converted to equivalent

TABLE IV
SOCIO-ECONOMIC CHARACTERISTICS OF SAMPLE TENANTS
INTERVIEWED IN THE GEZIRA SCHEME, 1984.

Characteristics	Mean	Standard Deviation
Age (yrs).	54	13.4
Educational achievement (yrs).	2.4	1.39
Years associated with operating the farm	34	14.2
Area cropped (feddans)	15	4.1
Average household size (persons)	6	3.8
Hours of family labor available per month	240	46.2

manhours by assuming a working day of seven hours. The monthly available hired labor derived from the survey results is presented in Table V. More hired labor is usually recruited from outside the project region during peak harvesting periods (December-April).

Eighty-three percent of the tenants interviewed considered themselves as full-time farmers while the remaining 17 percent were part-time farmers. This implies that the majority of the farmers in the Gezira derived their incomes from the farm. Almost all the respondents adopted the rotation set by the Gezira management which included five feddans of cotton, five feddans of wheat, and five feddans of groundnut, sorghum and vegetables. Only five percent of the respondents incorporated vegetables in the rotation.

Eighty percent of the respondents expressed preference to devote more feddans to sorghum. Among the reasons cited by the tenants for sorghum preference are: (a) to satisfy family consumption needs; (b) simple cultural operations; (c) tenants are familiar with growing sorghum since it is a traditional crop of the Gezira area even before the irrigation system; (d) easy marketing to local merchants; and (e) it represents a risk management strategy against unforeseen future hazards.

Most of the respondents reported the possession of an average of four goats or sheep to provide daily milk consumption. None, however, reported the possession of any mechanical equipment. Almost all tenants interviewed expressed a willingness to utilize higher mechanical power especially during land preparation and weeding seasons. They all raised the issue that the tractor fleet owned by the Gezira management is not adequate to perform timely land

TABLE V
MONTHLY HIRED LABOR AVAILABILITY FROM SAMPLE OF TENANTS
INTERVIEWED IN THE GEZIRA SCHEME, 1982/83.

Month	Man-hours Equivalent
June	140.0
July	140.0
August	140.0
September	140.0
October	210.0
November	210.0
December	210.0
January	420.0
February	420.0
March	420.0
April	420.0
May	140.0

preparation operations. Private machinery contractors are available but demand very high prices. Fifty-eight percent of the respondents reported problems due to timing and frequency of irrigation.

Information concerning the institutional credit was obtained from the records of the Block Inspector since all institutional credit is provided to the tenants on equal basis and is channeled through that office of the Block Inspector. The institutional credit is provided both in-kind (materials, mechanical services and marketing services) and in cash. In season 1982-83, each tenant received in-kind and cash advances for cotton and wheat equalling Ls. 197.484 and Ls. 116.029 per feddan, respectively.

Secondary Data

The basic source of secondary data is the annual economic reports submitted by the Economic and Social Research Unit (ESRU) of the Sudan Gezira Board. The ESRU conducts an annual economic survey based on observations and continuous follow-up of cultivation practices from land preparation to harvesting at different locations throughout the Scheme. Historical crop yields per feddan presented in Table VI were derived from ERSU data. These yields were multiplied by season prices to obtain the gross returns.

The net returns or gross margins are the annual gross returns minus the total variable cost of production for any particular enterprise in any particular year. Time series data on total variable costs and gross returns were derived from ERSU survey data and are presented in Tables VII and VIII, respectively. The high variability in costs and gross returns is attributed to yield fluctuations,

TABLE VI
HISTORICAL CROP YIELDS PER FEDDAN FOR THE
GEZIRA SCHEME, 1971-83

Year	Cotton	Wheat	Groundnut	Sorghum
-----tons ^a /feds.-----				
1971	0.782	0.387	0.413	0.507
1972	0.713	0.512	0.501	0.436
1973	0.583	0.668	1.250	1.000
1974	0.723	0.800	1.250	0.750
1975	0.657	0.386	1.500	0.623
1976	0.388	0.388	0.767	0.655
1977	0.523	0.580	1.200	0.354
1978	0.613	0.471	1.075	0.427
1979	0.467	0.251	0.872	0.500
1980	0.380	0.476	1.200	0.250
1981	0.329	0.500	0.605	0.400
1982	0.555	0.400	1.200	0.500
1983	0.671	0.694	1.200	0.523

Source: Various issues of the Gezira Current Statistics, Economic and Social Research Unit, the Sudan Gezira Board, Barakat.

^a Metric ton = 2,204.6 Lbs.

TABLE VII
ESTIMATED COST OF PRODUCTION BY CROP BY YEAR
FOR THE GEZIRA SCHEME, 1971-83

Year	Cotton	Wheat	Groundnut	Sorghum
-----Ls. ^a /fed-----				
1971	32.553	10.872	14.239	11.721
1972	33.913	12.641	15.221	12.560
1973	37.758	12.970	13.860	11.331
1974	39.820	14.441	14.210	9.420
1975	51.572	18.682	18.341	13.421
1976	72.141	15.431	20.540	12.222
1977	74.964	27.520	22.711	12.431
1978	82.264	29.371	24.322	13.810
1979	95.735	44.842	26.010	15.241
1980	111.715	51.010	38.451	19.801
1981	147.991	84.255	46.910	24.400
1982	212.665	67.160	41.480	41.480
1983	300.755	124.288	90.415	60.575

^a Ls. = Sudanese pound

Source: Various issues of the Gezira Current Statistics, Economic and Social Research Unit, the Sudan Gezira Board, Barakat.

TABLE VIII
GROSS RETURNS PER FEDDAN BY CROP BY YEAR
FOR THE GEZIRA SCHEME, 1971-83

Year	Cotton	Wheat	Groundnut	Sorghum
-----Ls. ^a /fed.-----				
1971	74.458	14.110	10.651	13.761
1972	66.265	19.210	14.321	9.800
1973	82.313	20.100	66.211	29.321
1974	84.124	37.900	69.512	43.412
1975	82.081	25.431	88.610	71.516
1976	86.692	25.213	48.710	31.700
1977	128.340	44.723	52.610	32.601
1978	173.294	49.152	87.430	30.211
1979	155.670	41.260	52.511	29.312
1980	161.214	65.380	90.233	52.516
1981	164.362	81.659	139.561	50.899
1982	329.970	93.141	71.211	71.500
1983	401.760	194.100	159.440	109.540

^aLs. = Sudanese pound.

Source: Various issues of the Gezira Current Statistics, Economic and Social Research Unit, the Sudan Gezira Board, Barakat.

increases in input prices and the two major devaluations of the Sudanese pound which took place in 1979 and 1981. The gross margin series were deflated using GDP deflator to reflect 1982 constant prices. The deflated time series gross margins are shown in Table IX.

Secondary data on irrigation water supplied to the Gezira Scheme on daily basis were obtained from Agricultural Research Corporation studies. The current water supply and deficit were estimated by Faki (1982) and are shown in Table X. According to Fakki study, the June/September deficit could have been met by rainfall which was estimated by the Gezira Meteorological Station records at an average of 6.755 mil. m³ per day. Therefore, the major water constraint occurs during the October/November period when most crops compete for irrigation water. For this reason a water constraint was specified in the model for the October/November period only. In general, the field irrigation canals layout in the Gezira specified an area of 15 feddans to be irrigated by each field canal. Water requirements per feddan for each crop and availability at field canal level is presented in Appendix B and summarized for October-November peak in Table XI. The water availability at field canal level per day is assumed by the irrigation specialists in the Gezira Scheme to represent the current supply conditions for a field of an average size of 15 feddans.

The final set of data derived from ERSU are the monthly labor requirements by crop for both family and hired labor. The estimated labor requirements by crop activity per feddan for family and hired labor are presented in Tables XII and XIII, respectively. A general feature in the Gezira Scheme is low contribution of family labor to

TABLE IX
ESTIMATED GROSS MARGINS BY CROP BY YEAR
FOR THE GEZIRA SCHEME IN 1982
CONSTANT PRICES, 1971-83^b

Year	Cotton	Wheat	Groundnut	Sorghum
-----Ls. ^a /fed.-----				
1971	182.196	21.578	-19.191	- 6.609
1972	129.404	31.380	- 4.856	-13.640
1973	165.019	31.664	198.685	70.037
1974	152.772	26.693	191.641	116.552
1975	89.732	22.768	206.265	172.679
1976	37.310	26.974	72.874	49.356
1977	124.130	40.279	70.302	47.295
1978	189.646	42.604	131.500	36.817
1979	115.260	-2.367	50.869	27.790
1980	76.152	21.538	80.355	51.125
1981	19.724	-4.163	111.216	31.927
1982	117.305	25.981	29.731	30.020
1983	77.696	53.954	52.697	37.664
Mean	104.680	26.081	90.183	50.078
Standard Deviation	74.358	36.044	51.188	48.896

^aLs. = Sudanese pound.

^bThe capital and labor cost are not included.

TABLE X
WATER BALANCE IN THE GEZIRA SCHEME
BY PERIODS

Particulars	June/Sept	Oct/Nov	Dec/March
	-----mil.m ³ /day-----		
Canal capacity	31.000	31.000	31.000
Max. Transit losses	3.200	2.100	2.000
Requirements for other uses	3.868	1.873	1.170
Max. requirements for main crops	30.668	35.09	27.750
Balance	-6.736	-8.063	0.080

Source: Fakki (1982).

TABLE XI
ESTIMATED MEAN WATER REQUIREMENTS PER FEDDAN PER DAY AND
AVAILABILITY AT FIELD CANAL LEVEL PER DAY IN THE
GEZIRA SCHEME FOR OCTOBER-NOVEMBER PEAK

Time ^a	Mean Requirements Per Feddan Per Day				Availability at Field Canal Level Per Day
	Cotton	Wheat	Groundnut	Sorghum	
	-----m ³ /day-----				
Oct. 1-10	28.50	-	29.00	25.00	605.09
11-20	30.30	25.00	24.50	17.80	605.09
21-31	30.30	25.00	21.50	-	605.09
Nov. 1-10	30.30	16.90	18.00	-	481.95
11-20	30.00	21.80	15.00	-	481.95
21-30	28.50	26.90	-	-	481.95

Source: Appendix B.

^aWater requirements per feddan was assumed to change every ten days.

TABLE XII
MONTHLY FAMILY LABOR USE BY CROP
FOR THE GEZIRA SCHEME

Month	Cotton	Wheat	Groundnut	Sorghum
-----Manhours/fed.-----				
June	0.67	-	6.64	3.54
July	0.52	-	4.92	6.51
Aug	5.82	-	-	5.87
Sept	9.90	-	2.46	3.50
Oct	11.52	0.48	0.30	0.30
Nov	5.46	7.54	0.20	15.43
Dec	2.94	7.50	4.18	5.61
Jan	8.35	0.48	2.12	0.80
Feb	15.28	1.92	-	-
March	22.17	1.88	-	-
April	6.69	-	-	-
May	0.12	-	-	-

Source: ESRU survey, 1982/83.

TABLE XIII
MONTHLY HIRED LABOR REQUIREMENTS BY CROP
FOR THE GEZIRA SCHEME

Month	Cotton	Wheat	Groundnut	Sorghum
-----Manhours/fed.-----				
June	-	-	33.51	4.71
July	1.01	-	32.10	21.65
Aug	13.21	-	13.14	17.42
Sept	16.32	-	6.90	1.38
Oct	18.42	0.44	1.08	0.68
Nov	1.53	2.13	10.72	22.05
Dec	1.15	2.93	36.58	40.96
Jan	11.95	2.28	13.48	2.00
Feb	75.10	1.76	-	-
March	79.46	0.68	-	-
April	30.13	1.94	-	-
May	-	-	-	-

Source: ESRU survey, 1982/83.

agricultural production. Adult sons of tenants usually preferred off-farm work in urban areas. Ahmed (1977) cited two reasons for the low family labor contribution to agricultural production in the Gezira: (1) low returns to farm labor, and (2) spread of diseases such as Malaria and Beharzia in the Scheme area.

Enterprise Budgets

An enterprise budget is a statement of the physical inputs and costs necessary to produce a particular crop. Enterprise budgets are presented in Appendix A and were derived from a detailed economic survey conducted by the Economic and Social Research Unit of the Sudan Gezira Board in 1982-83 season. The survey results are based on field observations and with continuous follow-up throughout the season for a random sample of 140 tenants at different locations in the Scheme. A major drawback of the survey results, however, is that the information provided is presented as stock rather than flow estimates, i.e. the production items are expressed in total value without a breakdown of physical quantity and price per unit. Hence the author's sample survey was used to supplement the Gezira survey results in deriving model parameters, particularly labor and credit coefficients. The enterprise budgets were used to derive operating capital financed by both institutional and informal credit sources.

Components of the Model

Basic Activities

In the Gezira Scheme the traditional crops included in the current rotation are cotton, sorghum, wheat, groundnut and vegetables and account for 43 percent, 28 percent, 14 percent, 12 percent and 3 percent of the crop area, respectively. The rotation system in the Scheme permits production of only one crop from the same land every season. Due to the lack of time series data about vegetables they have been excluded in the analysis. However, this exclusion is assumed to have a minimum effect on a tenant's decision criteria because vegetables are grown by only five percent of the tenants. In addition, vegetables are labor-intensive crops and tenants usually rely on sharecroppers to raise vegetables. According to sharecropping terms the tenant provides the land and irrigation water while the partner provides the labor and credit. Livestock activities were excluded also because they are not an integrated part of the Scheme rotation and no time series data about their costs and returns are available.

The time series data available from the Gezira records extends over 13 years (1971-83). In this analysis aggregate time series data were used because individual farm data were not available. This aggregation, however, may give a downward bias to variance estimation because the aggregation process "averages out" part of the variability (Eisgruber and Schuman, 1963).

Resource Restrictions

In mathematical programming models production coefficients are normally stated in terms of the amounts of inputs required per unit of activity. In this study the information obtained from the survey results and secondary data sources discussed earlier were used to estimate the amount of each of the scarce resources needed per unit of crop activity defined as one feddan (1 feddan = 1.038 acres). The representative farms had an area of 15 feddans each. The land is nearly homogenous and reported yields in Table VI are appropriate for different soil types throughout the study area. Technology constraints are not considered because there were no reliable and accurate data about the input-output coefficients. Generally, all cultivation operations are manual except land preparation. A tractor fleet owned by the Sudan Gezira Board performs part of the land preparation. However, private contractors contribute the largest share in mechanical operations of the Scheme. None of the tenants interviewed reported possession of mechanical equipment, however, most of the tenants stated that they usually contracted for land plowing. The cost of plowing was considered as an operating cost.

For the Gezira Scheme, the major binding resource constraints are institutional credit, hired labor and irrigation water. Hired labor and irrigation water are critical during peak periods such as planting and harvesting. The year was divided into 12 months during which crops may be planted or harvested and the amounts of family labor, hired labor, water and credit available to the program in each month were specified. The average wage rate for hired labor was Ls.

0.5/hour. For both groundnut and sorghum no institutional credit was available and the tenant must depend on the informal credit sources. The informal credit from local money-lenders and merchants is assumed available and can be borrowed at 50 percent interest rate. The institutional credit available was estimated by Gezira management at Ls. 1500 per average tenancy size of 15 feddans. This credit can be borrowed at ten percent interest rate.

CHAPTER V

ANALYSIS OF RISK EFFICIENT FARM PLANS

This chapter presents and discusses a set of risk efficient farm plans derived from the analysis of the representative farms in the Gezira Scheme. The farm plan that maximizes expected income was determined by a linear programming model. The results of this basic linear programming model are given first. The model is then extended to incorporate risk parameters measured as deviations from an expected gross margin for each enterprise. The linear program maximum income solution is the highest attainable point on the risk efficiency frontier. Other points on the risk efficiency frontier are determined by decreasing the objective function parametrically in arbitrary decrements of Ls. 50 expected income. The sensitivity of the optimum plan to changes in the hired labor constraint, the institutional credit constraint, and a parallel increase in both hired labor and institutional credit is analyzed assuming a given potential increase in the availability of the two resources. The results of the sensitivity of the optimum plan to any increase in irrigation water quantity will not be presented because the model results have shown that water quantity is not a limiting constraint in all the computed solutions. Finally, the sensitivity of the optimum plan to a change

in crop gross margins is examined assuming the government paid producers prices equivalent to world prices rather than the government market price.

Basic Model Results

Risk Measurement Statistics

The risk measurement statistics used in the analysis of this chapter are total negative deviation (TND), standard deviation (SD), and coefficient of variation (CV). For every expected income specified along the efficiency frontier, the MOTAD model solves for the minimum TND that satisfies all the model constraints. This TND is then transformed into an estimate of standard deviation by multiplying by the constant K as discussed in Chapter III. Standard deviation measures the dispersion in expected income. Higher incomes are usually associated with higher dispersion or variability as measured by standard deviation or variance. The coefficient of variation statistic provides a measure of relative variability expressed as a percentage and calculated by dividing standard deviation by expected income. The farm decision maker may select any plan along the risk efficiency frontier depending on his relative perception of risk and his resource endowment.

Profit Maximization Plan

Farm plan 1 presented in Table XIV represents the profit maximization solution derived from the basic linear programming model.

TABLE XIV

SUMMARY SET OF EFFICIENT FARM PLANS DERIVED FROM
THE GEZIRA BASIC MOTAD MODEL - MODEL 1

Farm Plans	Unit	Plan 1 ^a	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
Expected Income	Ls.	848.298	798.000	748.000	698.000	648.000	598.000	548.000	498.000	448.000	398.000
Total Negative Deviation	Ls.	2841.000	2327.000	2091.000	1804.000	1727.000	1566.000	1387.000	1087.000	927.000	828.000
Standard Deviation	Ls.	570.076	498.271	437.288	382.191	346.562	314.344	278.413	228.134	195.059	166.205
Coefficient of Variation	%	67.23	62.44	58.45	54.75	53.49	52.56	50.80	45.81	43.54	41.45
Total Area Cultivated	Fed	13.4	12.1	11.2	10.8	9.4	8.2	6.6	5.7	4.5	3.5
Cotton	Fed	5.3	4.6	4.2	4.0	3.3	2.9	2.4	2.1	1.6	1.4
Wheat	Fed	4.6	2.5	2.2	2.0	1.2	0.5	-	-	-	-
Groundnut	Fed	3.5	3.6	3.6	3.7	4.0	4.2	3.7	3.1	2.5	1.9
Sorghum	Fed	-	1.4	1.2	1.1	0.9	0.6	0.5	0.4	0.3	0.2
Hired Labor Use	M.H.	1959.4	1786.5	1684.5	1615.9	1443.2	1298.6	1118.7	931.2	743.5	555.8
Institutional Credit Use	Ls.	1500.00	1189.926	1084.406	1003.038	800.277	627.800	526.896	438.579	350.262	261.945
Informal (Sheil) Credit Use	Ls.	853.094	766.992	685.664	601.187	528.045	422.174	309.506	196.838	168.338	130.500
Irrigation Water (Oct-Nov Peak only)	M ³	1848.7	1516.8	1429.5	1361.1	1189.3	1023.2	877.5	727.3	581.0	434.3

^aThis Plan represents the linear programming profit maximization solution.

This plan is likely to be selected by risk-neutral decision makers. The maximum expected income attainable, given the existing resource situation in the Gezira, is Ls. 848.298. The profit maximization is also associated with the maximum variability measured by TND at Ls. 2841.000, standard deviation of Ls. 570.076 and coefficient of variation equalling 67.23 percent. This plan utilizes 13.4 feddans of land consisting of 5.3 feddans of cotton, 4.6 feddans of wheat and 3.5 feddans of groundnut. Sorghum does not enter this profit maximization plan.

On the resource side, the profit maximization plan utilizes 1959.4 manhours of hired labor per year, the maximum amount of institutional credit specified in the model of Ls. 1500, and 1848.7 m³ of irrigation water during the October-November peak. The only limiting constraints in this solution are labor and institutional credit. When labor is specified on a monthly basis, the model predicts labor scarcity during June, July and March. This implies a seasonal labor-shortage problem in the Gezira Scheme. Irrigation water is not a limiting constraint even during the October-November peak.

The profit maximization plan is similar to the current rotation in the Gezira Scheme which is enforced by the project management--more feddans of cotton and wheat are specified relative to groundnut and sorghum. However, while this rotation provides the highest expected income, it is also associated with a corresponding higher risk and income variability as measured by the standard deviation and coefficient of variation. The dominating position of cotton in the model solution is a direct consequence of its high expected gross

margin but it is limited at the margin by labor and institutional credit constraints. Wheat comes into the solution basically because of its low labor requirements but it is also restricted at the margin by institutional credit. Sorghum does not enter the plan because of relatively low gross margin and labor scarcity during the planting season.

Hired labor utilization for the profit maximization plan during the 12 month period is outlined in Table XV. All available hired labor is used by the plan during June, July and March, while varying amounts of hired labor are left unused during the other seven months. The shadow price column denotes the marginal value product or reduction in expected income associated with reducing the amount of hired labor available to the plan by one manhour. When hired labor is not fully utilized it has a zero shadow price.

The irrigation water utilization during the October-November peak is presented in Table XVI. The total amount of water utilized by the plan in any single period falls below the irrigation water limitation imposed on the model. Thus the constraint placed on the amount of irrigation water available to the plan does not seem to be limiting under the assumed supply condition presented in Chapter IV. Hence, additional cropping area could be brought into cultivation at the Scheme level to utilize the surplus water.

Risk Efficient Farm Plans

As expected income is parameterized from Ls. 848.298 to Ls. 398.000 in arbitrary decrements of Ls. 50, a set of efficient

TABLE XV
MONTHLY HIRED LABOR USE BY THE PROFIT MAXIMIZATION
PLAN FOR A REPRESENTATIVE FARM
IN THE GEZIRA SCHEME

Month	Plan Requirements (Manhours)	Surplus (Manhours)	Shadow Price (Ls./Hr)
June	140.0	-	2.870
July	140.0	-	1.493
August	124.3	15.7	-
September	114.5	25.5	-
October	103.0	107.0	-
November	61.3	148.7	-
December	170.6	39.4	-
January	120.0	300.0	-
February	401.4	18.6	-
March	420.0	-	3.874
April	165.9	254.1	-
May	-	140.0	-

TABLE XVI
IRRIGATION WATER USE BY THE PROFIT MAXIMIZATION
PRODUCTION PLAN FOR A REPRESENTATIVE FARM
IN THE GEZIRA SCHEME

Time Period	Plan Requirements (m ³ /day)	Surplus (m ³ /day)
Oct. 1-10	270.828	334.262
11-20	361.311	243.779
21-31	348.775	256.315
Nov. 1-10	301.808	180.142
11-20	308.841	173.109
21-30	257.086	224.864

farms plans is generated with results presented as plans 2 to 10 in Table XIV. The plans are furnished to provide the decision maker with a wide choice for enterprise combination and resource allocation. The decision maker has to judge the suitability of any plan as determined by the trade-off between expected income and the standard deviation or variance of income.

When the expected income is decreased from Ls 848.298 to Ls. 798.000, the total area cultivated is reduced to 12.1 feddans. Cotton and wheat area reduces to 4.6 feddans and 2.5 feddans, respectively, while groundnut increases slightly to 3.6 feddans. Sorghum comes into the solution at a level of 1.4 feddans. By reducing the area of cotton and wheat the standard deviation is reduced by Ls. 71.805 and the coefficient of variation by 4.79 percent. This implies that high variability is associated with cotton and wheat production and, as risk in terms of variability is reduced, cotton and wheat enterprises are reduced. The less risky enterprises of groundnut and sorghum are increased. A decision maker who selects plan 2 must purchase 1786.5 manhours of hired labor, Ls. 1189.926 of institutional credit and have 1848.7 m³ of irrigation water at his disposal during October-November peak.

For Plan 3, expected income is further reduced from Ls. 798.000 to Ls. 748.000. The standard deviation and coefficient of variation are reduced by Ls. 60.983 and 3.99 percent, respectively. The cropping pattern consists of 4.2 feddans of cotton, 2.2 feddans of wheat, 3.6 feddans of groundnut and 1.2 feddans of sorghum. Hired labor requirements are further reduced to 1684.5 manhours, institutional capital to Ls. 1084.406 and irrigation water needs to

1429.5 m³ during October-November peak. Through the rest of the plans between Ls. 798.000 and Ls. 398.000, the production pattern shows a steady relative decline in the areas of cotton and sorghum. Wheat production is discontinued at income levels below Ls. 598.000, while groundnut shows a steady increase up to Plan 6 then reduces steadily. Subsequent declines in standard deviation, coefficient of variation and resource use is associated with lower expected incomes.

The risk efficiency frontier shown in Figure 7 represents the alternative risk efficient farm plans outlined in Table XIV. The frontier may also be denoted as the E-V curve where E represents the expected income and V the variance of income. Moving to the right along the efficiency frontier, greater risk has to be assumed by the decision maker to obtain a given increase in expected income. Moving to the left of the E-V frontier is associated with less risk and lower expected incomes. The trade-off between income and risk is best represented by the coefficient of variation. Plans associated with income levels below Ls. 398.000 are excluded from the analysis because the coefficient of variation shows an upward increase implying that a rational decision maker may consider the elimination of these farm plans if he is really concerned with his income relative to income variability measure.

As indicated by the above analysis, production and sale of cotton and wheat in the Gezira Scheme is associated with high income but also more risk. If risk has to be reduced both cotton and wheat area should be reduced and substituted by the less risky crops which are groundnut and sorghum.

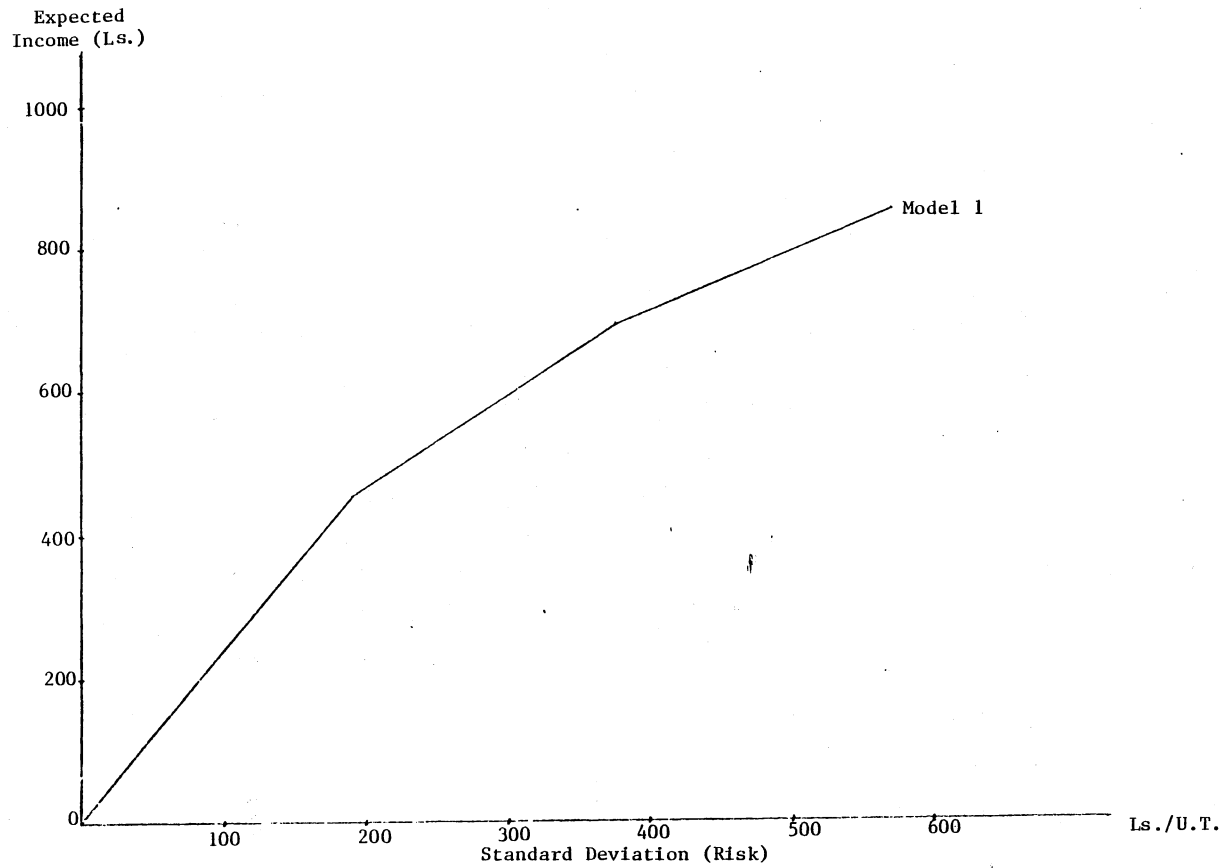


Figure 7. Risk-Efficiency Frontier for the Basic MOTAD Model-Model 1.

Sensitivity Analysis

Assumptions

The sensitivity of the basic model discussed in the previous section was tested to estimate the effect of increasing the hired labor constraint, the institutional credit constraint, a parallel increase in both hired labor and institutional credit, and a change in crop prices caused by paying producers a price equivalent to the world market price rather than the government market price. This was done by increasing hired labor supplied during June to September by 35 manhours, January to April labor by 105 manhours, and institutional credit by Ls. 150. The underlying assumptions for the potential increase in hired labor and institutional credit availability is discussed below.

According to Gezira economic reports, the hired labor availability at the project and farm levels has been declining during the last 13 years and prospects for future increases are not promising because of other newly established irrigation projects. During the survey period, most of the tenants interviewed mentioned that hired labor is available on regular basis for only 20 days each month. However, if we assumed the hired labor will work 25 days a month instead of 20 days then the available labor manhours will increase by the figures stated above. On the other hand, the potential increase in the institutional credit from Ls. 1500 to Ls. 1650 per tenancy may be possible through the Rehabilitation Project of the Gezira Scheme which is assumed to start in the 1984-85 season. An amount of U.S.

\$36.8 million has been allotted to the Gezira Scheme for the procurement of equipment, spare parts and credit as discussed in Chapter II.

Comparison of the basic plan with the new solutions provided by the sensitivity analysis are presented and discussed. To facilitate the comparison procedure, the basic MOTAD model with results presented in Table XIV will be referred to as 'Model 1', the effect of an increase in hired labor as 'Model 2', the effect of an increase in institutional credit as 'Model 3', the effect of an increase in both hired labor and institutional credit as 'Model 4', and the effect of a change in crop prices as 'Model 5'.

Effect of Increasing Hired Labor

The response to a potential increase in hired labor is traced in Table XVII. As shown in the table, expected income in the profit maximization plan (plan 1) has increased to a higher level of Ls. 956.343 compared to an expected income of Ls. 848.298 in the corresponding plan of Model 1. The cropping mix shows the area of cotton is increasing from 5.3 feddans to 6.5 feddans while wheat area reduces to 3.9 feddans. One possible explanation is that since cotton is more labor-intensive than the other crops, by increasing the labor constraint more cotton area comes into production and consequently more risk. On the resource side, the hired labor use increased by 22 percent implying that any attempt to increase cotton area in the Gezira Scheme should be associated with a corresponding increase in

TABLE XVII

SUMMARY SET OF EFFICIENT FARM PLANS ASSUMING A POTENTIAL
INCREASE IN HIRED LABOR - MODEL 2

Farm Plans	Unit	Plan 1 ^a	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
Expected Income	Ls.	956.343	906.000	856.000	806.000	756.000	706.000	656.000	606.000	556.000	506.000
Total Negative Deviation	Ls.	3239.000	2715.000	2480.000	2301.000	2045.000	1716.000	1586.000	1485.000	1306.000	1125.000
Standard Deviation	Ls.	650.166	576.759	515.825	461.881	410.494	368.461	332.477	298.085	256.594	225.822
Coefficient of Variation	%	67.98	63.66	60.26	57.30	54.29	52.19	50.53	48.18	46.15	44.63
Total Area Cultivated	Fed	13.9	13.4	13.4	12.8	11.7	10.1	9.1	7.9	6.7	5.5
Cotton	Fed	6.5	5.4	5.1	4.9	4.3	3.8	3.4	3.02	2.5	2.1
Wheat	Fed	3.9	2.9	2.6	2.3	1.6	0.9	0.5	0.4	0.3	0.2
Groundnut	Fed	3.5	3.6	4.5	4.7	5.2	5.1	5.0	4.3	3.8	3.1
Sorghum	Fed	-	1.5	1.2	0.9	0.6	0.3	0.2	0.2	0.1	0.1
Hired Labor Use	M.H.	2385.5	2176.9	2073.7	2005.8	1833.1	1677.8	1523.4	1336.1	1148.5	961.1
Institutional Credit Use	Ls.	1500.000	1429.267	1319.613	1237.239	1031.142	858.820	717.741	629.424	541.107	452.789
Irrigation Water (Oct-Nov Peak only)	M ³	1996.6	1847.7	1654.9	1687.4	1514.9	1349.2	1190.4	1043.8	897.59	750.9

^aThis Plan represents the linear programming profit maximization solution.

hired labor availability. The irrigation water consumption, however, shows only a slight increase of eight percent.

The remaining set of efficient farm plans in Table XVII traces out the effects of parameterizing expected income from Ls. 956.343 to Ls. 506.000 in decrements of Ls. 50. In plan 2 the area of cotton and wheat reduces, while sorghum comes into the solution at a level of 1.5 feddans. The standard deviation is reduced by Ls. 105.183 and the coefficient of variation is reduced from 67.98 percent to 63.66 percent. This again implies that as cotton area is reduced, income variability or risk is also reduced. Between expected incomes of Ls. 906.000 and Ls. 506.000, the area of production, the standard deviation, and the coefficient of variation are reduced steadily. However, groundnut shows an increasing trend up to plan 5 then decreases steadily.

The risk efficiency frontier obtained from Model 2 is traced in Figure 8. This frontier is higher than the one derived from Model 1. Thus we may conclude that the provision of additional hired labor in the Gezira Scheme, especially during peak periods, will both increase expected income and reduce risk for given levels of income. For example, at expected income level of Ls. 800, Model 2 is associated with less risk as compared to Model 1 at the same income level.

Effect of Increasing Institutional Credit

As the institutional credit constraint is increased from Ls. 1500 to Ls. 1650, the maximum expected income increases slightly from Ls. 848.298 in the basic model (Model 1) to Ls. 868.444 as shown in Table

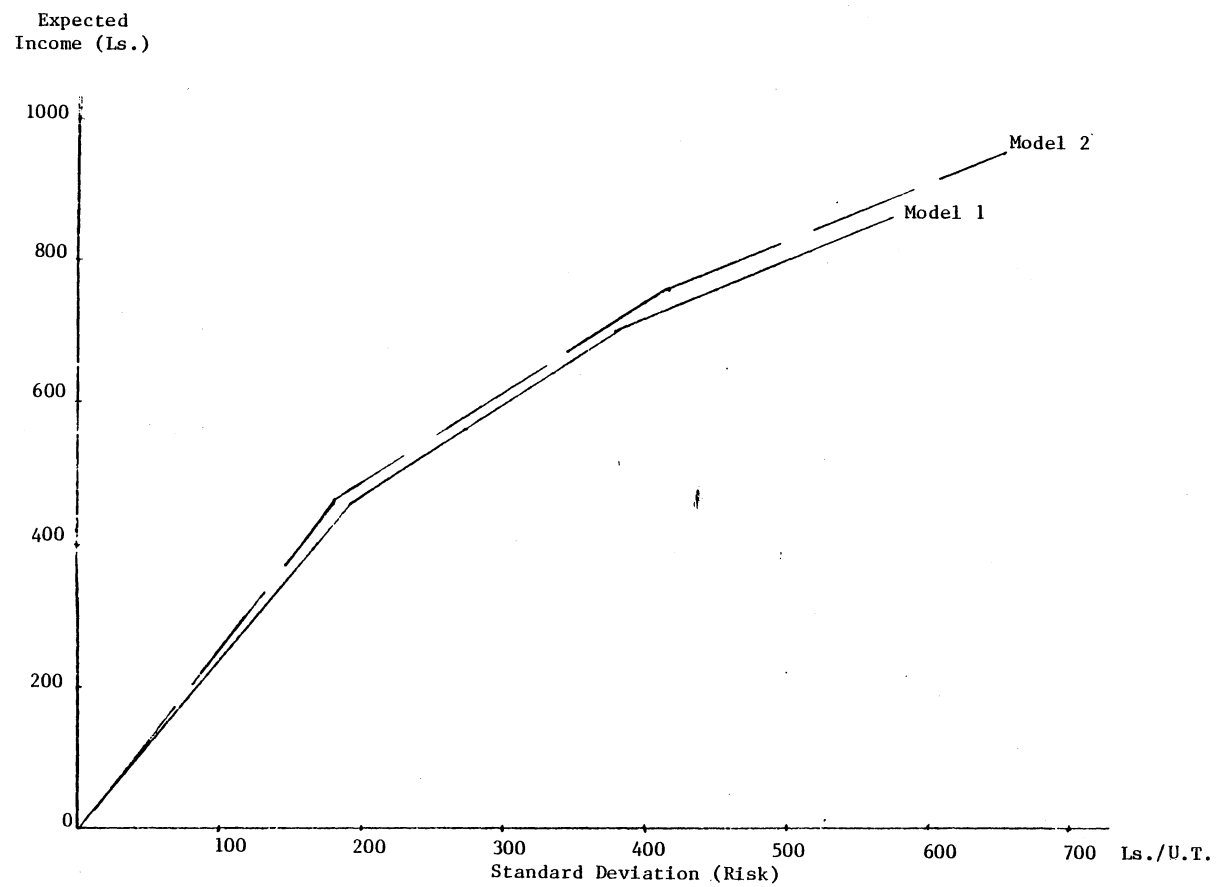


Figure 8. Risk-Efficiency Frontier for Model 1 and Model 2

XVIII. The increase in expected income is two percent. The standard deviation also increases by an equivalent amount, thus the relative variability measure remains the same. Cotton area remains the same while wheat area increases from 4.6 feddans to 5.3 feddans. This may be explained by the fact that cotton is restricted at the margin by the March picking labor constraint.

When the expected income in Table XVIII is parameterized from Ls. 868.444 to Ls. 818.000, the area of both cotton and wheat is reduced from 5.3 feddans to 4.8 feddans and 2.7 feddans, respectively. Groundnut area remains at 3.2 feddans while sorghum comes into the solution at 1.5 feddans. Standard deviation and coefficient of variation decrease by Ls. 72.388 and 4.69 percent, respectively. This again implies that as cotton area decreases, risk and income variability also decrease. Between expected incomes of Ls. 768.000 and Ls. 418.000 all crops, except groundnut, show steady reduction. Standard deviation and coefficient of variation also show a corresponding reduction.

The set of efficient farm plans derived from Model 3 is traced along the efficiency frontier in Figure 9. This frontier is slightly higher than the frontier derived for the basic model (Model 1). The trade-off between expected income as measured by the coefficient of variation is shown by the shape of the efficiency frontier.

Effect of Increasing Both Hired Labor and Institutional Credit

Results of a parallel increase in institutional credit and hired labor availability are shown in Table XIX. The maximum expected

TABLE XVIII
SUMMARY SET OF EFFICIENT FARM PLANS ASSUMING A POTENTIAL INCREASE
IN INSTITUTIONAL CREDIT - MODEL 3

Farm Plans	Unit	Plan 1 ^a	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
Expected Income	Ls.	868.444	818.000	768.000	718.000	668.000	568.000	518.000	468.000	418.000	448.850
Total Negative Deviation	Ls.	2928.882	2516.000	2290.000	2103.000	1946.000	1946.000	1765.000	1486.000	1137.000	926.000
Standard Deviation	Ls.	585.765	513.377	462.950	422.184	377.220	335.759	298.286	258.140	222.209	185.877
Coefficient of Variation	%	67.45	62.76	60.28	58.80	56.47	54.33	52.51	49.83	47.48	44.46
Total Area Cultivated	Fed	13.8	12.2	11.5	10.9	9.8	8.7	7.3	6.1	5.0	3.9
Cotton	Fed	5.3	4.8	4.4	4.2	3.6	3.2	2.6	2.2	1.8	1.4
Wheat	Fed	5.3	2.7	2.4	2.2	1.4	0.8	0.4	0.3	0.2	0.2
Groundnut	Fed	3.2	3.2	3.4	3.5	4.0	4.2	3.9	3.3	2.7	2.1
Sorghum	Fed	-	1.5	1.3	1.0	0.8	0.6	0.4	0.3	0.3	0.2
Hired Labor Use	M.H.	1988.2	1854.4	1753.1	1685.5	1416.4	1351.3	1193.7	1006.6	819.1	631.4
Institutional Credit Use	Ls.	1650.0	1261.000	1155.266	1084.920	880.010	698.958	562.481	474.164	385.8	197.530
Irrigation Water (Oct-Nov Peak only)	M ³	2029.3	1575.3	1487.9	1429.6	1258.1	1090.3	932.9	786.4	639.6	493.4

^a This Plan represents the linear programming profit maximization solution.

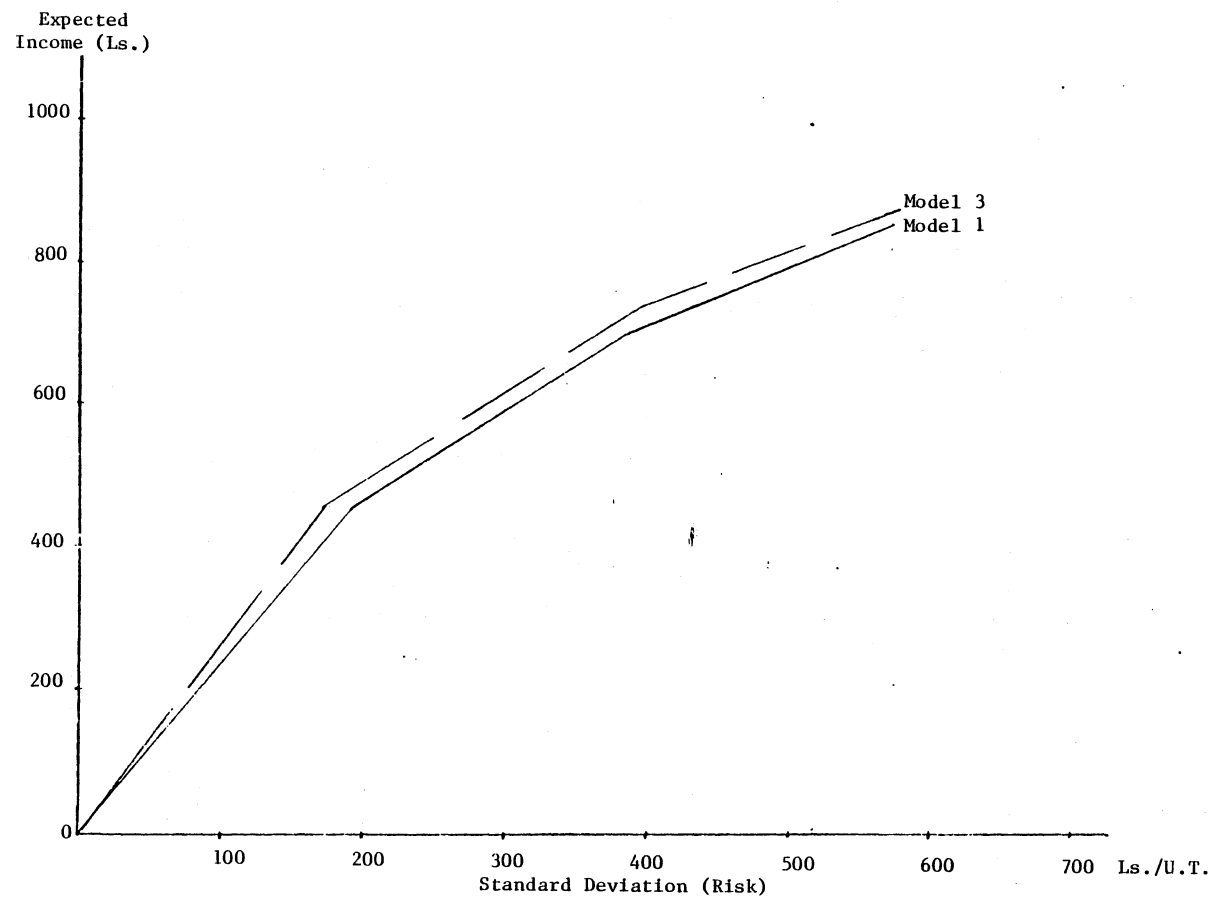


Figure 9. Risk-Efficiency Frontier for Model 1 and Model 3.

TABLE XIX

SUMMARY SET OF EFFICIENT FARM PLANS ASSUMING A PARALLEL INCREASE IN
BOTH INSTITUTIONAL CREDIT AND HIRED LABOR - MODEL 4

Farm Plans	Unit	Plan 1 ^a	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
Expected Income	Ls.	975.161	925.000	875.000	825.000	775.000	725.000	675.000	625.000	575.000	525.000
Total Negative Deviation	Ls.	3428.000	2941.000	2681.000	2500.000	2246.000	2061.000	1785.000	1584.000	1505.000	1225.000
Standard Deviation	Ls.	688.104	618.270	557.220	501.765	450.341	413.706	358.304	317.957	279.048	245.895
Coefficient of Variation	%	70.56	66.84	63.68	60.82	58.17	57.06	53.08	50.87	48.53	46.87
Total Area Cultivated	Fed	15.0	14.7	14.0	13.4	12.1	11.0	9.5	8.4	7.3	6.1
Cotton	Fed	6.6	5.7	5.3	5.1	4.5	4.0	3.5	3.1	2.7	2.3
Wheat	Fed	5.2	4.1	2.9	2.6	1.8	1.2	0.5	0.4	0.4	0.3
Groundnut	Fed	3.2	3.2	4.4	4.5	4.9	5.2	5.1	4.6	4.0	3.4
Sorghum	Fed	-	1.7	1.4	1.2	0.9	0.6	0.4	0.3	0.2	0.1
Hired Labor Use	M.H.	2413.9	2240.7	2139.2	2070.8	1898.2	1727.6	1594.2	1406.5	1218.9	1031.6
Institutional Credit Use	Ls.	1650.000	1495.457	1389.937	1314.742	1108.691	925.287	750.980	662.663	574.346	486.028
Irrigation Water (Oct-Nov Peak only)	M ³	2106.1	1902.5	1814.9	1752.4	1579.8	1412.2	1245.4	1098.8	952.54	805.9

^aThis Plan represents the linear programming profit maximization solution.

income derived from this solution is Ls. 975.161 compared to Ls. 848.298 maximum expected income derived from the basic model (Model 1). As expected, the increase in income is associated with more risk and more income variability. This is because the cropping pattern associated with maximum income devotes more area to cotton than any other crop. Consequently the resource use increases to its maximum level compared to all three previous models.

The other efficient farm plans shown in Table XIX are traced out by parameterizing the expected income from Ls. 975.161 to Ls. 525.000 in constant decrements of Ls. 50 each. Cotton and wheat area declines steadily as expected income decreases, while groundnut area shows a gradual increase from 3.2 feddans to 5.2 feddans in plan 6 and then decreases steadily. Sorghum comes into the solution in plan 2 at a level of 1.7 feddans, then declines steadily as income is parametrically reduced. Plans below expected income level of Ls. 525.000 are excluded from the analysis because the income variability as measured by the coefficient of variation begins to increase. This implies that decision makers have to sacrifice a greater percentage of change in income for any given percentage reduction in risk as measured by the standard deviation. A rational producer is unlikely to choose plans with higher variability unless there are other exogenous reasons important to the producer but not represented in the model, such as a preference for off-farm work. As shown in Figure 10, the producer attains a higher risk efficiency frontier from Model 4 than from Model 1. The reason is that an increase in both

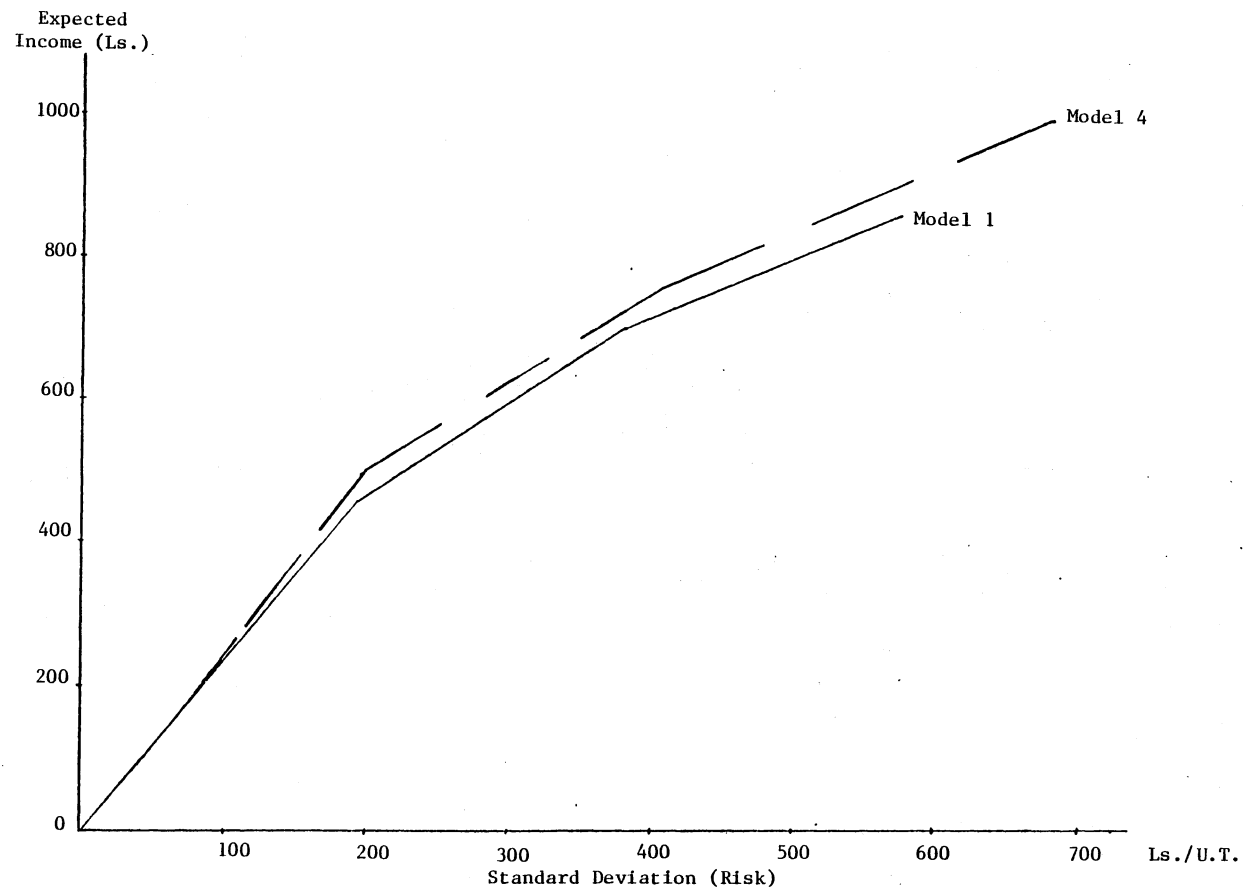


Figure 10. Risk-Efficiency Frontier for Model 1 and Model 4.

institutional credit and hired labor provides an opportunity for reorganization of the production pattern to attain less risk at any given level of income.

To summarize the effect of an increase in resource base, the trade-off between any level of expected income and the corresponding risk levels is determined from the shape of the efficiency frontier. Each farm plan along the E-V frontier is an efficient plan in the sense that it specifies the minimum amount of risk associated with any given level of expected income. In considering alternative farm plans, the resource base is an important economic criteria to be kept in sight. From the sensitivity results of hired labor and institutional credit it can be concluded that the basic efficiency frontier (Model 1) derived for the Gezira Scheme and the associated set of efficient farm plans are more sensitive to increases in hired labor than institutional credit given the underlying assumptions for the potential increase in both resources. By increasing both credit and hired labor availability, the Gezira tenant can attain a higher risk efficiency frontier. This implies that increasing the tenant resource base of credit and hired labor is necessary to offset the risk associated with production organization and cropping pattern at the Farm and Scheme level. In all the models, irrigation water is unlikely to be a limiting resource. However, timing and frequency of irrigation may be a problem to those tenants located a long distance from the dam or main canal. Lack of detailed data and information about the frequency and timing of irrigation water available at the field level limited a further investigation of this problem.

Effect of a Change in Producer Prices

In this analysis the sensitivity of the optimum plan in the basic model (Model 1) is tested assuming that the producers are paid a price equivalent to the export parity price rather than the government market price. The concept of export parity price is introduced because the government market price is substantially lower than the corresponding world price. Disparities between export parity price and government market price may result in misallocation of resources caused by inefficiency in marketing channels and high export taxes and duties. For the purpose of economic analysis, export taxes and duties are considered as internal transfers from one sector of the economy to another and hence excluded from the analysis. The data for calculating export parity prices were obtained from different sources. The CIF prices for all commodities were obtained from FAO Commodity Review Publications. Shipping, handling and transportation costs were based on estimations of the World Bank for 1979 expressed in 1982 constant prices. The FOB price is converted to domestic currency (border prices) using the official exchange rate as the market equilibrium price. The calculation of gross margins using export parity price is presented in Appendix D. On the average, gross margins are 50 percent higher than the ones estimated using the government market prices. The summary set of efficient farm plans derived using export parity prices is presented in Table XX while the corresponding E-V frontier is traced in Figure 11. The resource base is kept at the same levels as in the basic model and only the gross margins and deviation matrix are changed.

TABLE XX

SUMMARY SET OF EFFICIENT FARM PLANS DERIVED FROM THE GEZIRA BASIC MODEL
USING EXPORT PARITY PRICES - MODEL 5

Farm Plans	Unit	Plan 1 ^a	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
Expected Income	Ls.	1420.915	1320.000	1290.000	1270.000	1220.000	1170.000	1120.000	1070.000	1020.000	970.000
Total Negative Deviation	Ls.	2811.000	2297.000	2062.000	1884.000	1707.000	1545.000	1354.000	1058.000	904.000	805.000
Standard Deviation	Ls.	564.056	460.917	413.762	378.044	342.527	310.020	271.694	212.298	181.397	161.532
Coefficient of Variation	%	39.70	34.92	32.07	29.77	28.07	26.49	24.26	19.84	17.78	16.65
Total Area Cultivated	Fed	13.4	12.4	11.5	11.2	9.8	8.7	7.4	6.8	6.1	5.7
Cotton	Fed	5.3	4.6	4.2	4.0	3.4	2.9	2.4	2.1	1.6	1.5
Wheat	Fed	4.2	2.5	2.2	2.0	1.2	0.8	0.6	0.5	0.4	0.3
Groundnut	Fed	3.9	3.5	3.5	3.7	4.0	4.2	3.9	3.8	3.7	3.7
Sorghum	Fed	-	1.8	1.6	1.5	1.2	0.8	0.5	0.4	0.4	0.2
Hired Labor Use	M.H.	1960.4	1795.5	1164.5	1103.8	905.3	718.9	630.6	541.6	466.9	390.6
Institutional Credit Use	Ls.	1500.000	1280.134	1162.501	1105.830	910.311	780.900	640.698	584.631	482.905	365.615
Irrigation Water (Oct-Nov Peak only)	M ³	1848.7	1526.7	1480.5	1350.1	1280.3	1059.6	982.5	850.9	660.7	540.8

^aThis Plan represents the linear programming profit maximization solution.

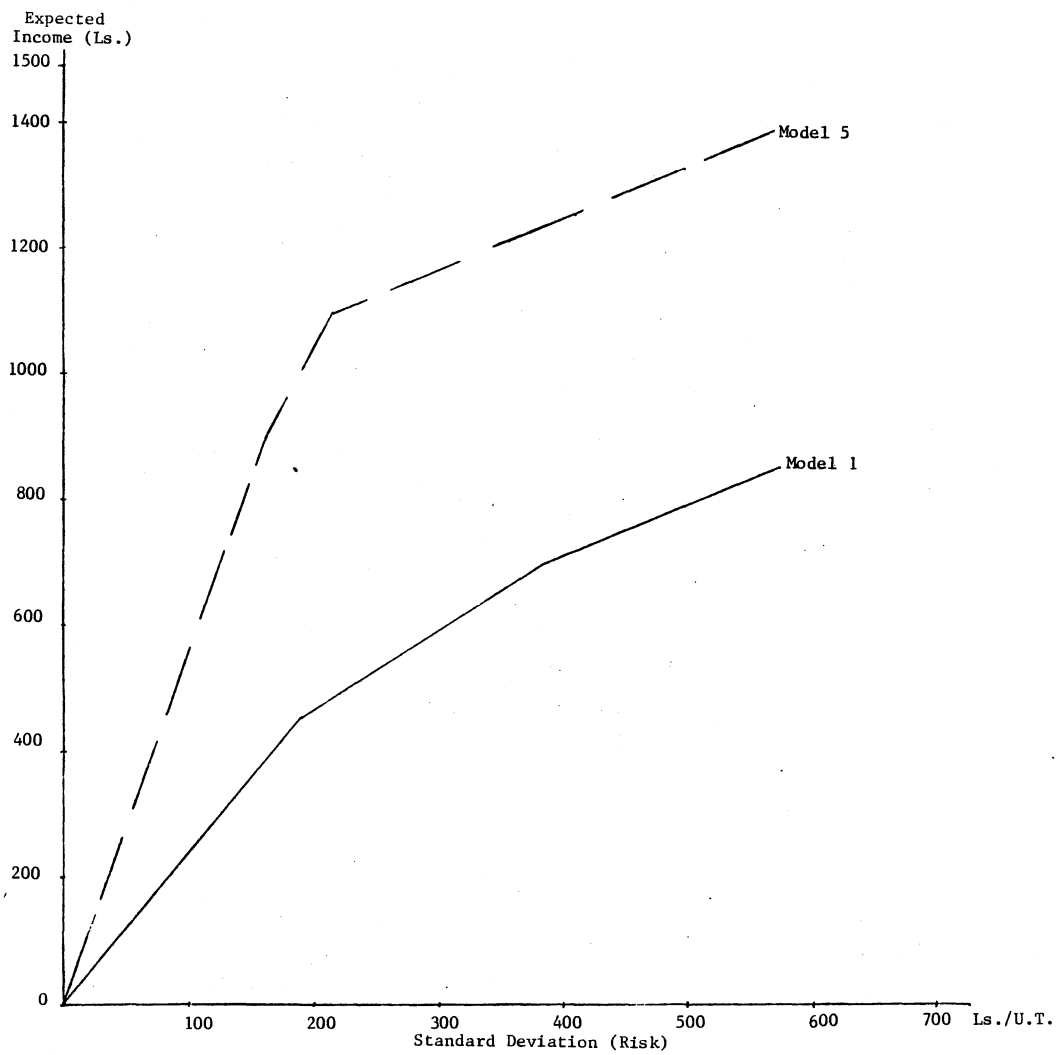


Figure 11. Risk-Efficiency Frontier for Model 1 and Model 5.

As expected, the increase in crop gross margins have resulted in a higher expected income and less risk as compared to the basic model (Model 1). However, the cropping pattern and total area cultivated remains almost the same since the resource base of hired labor and institutional credit remained unchanged.

Similar to the basic model, labor is in shortage during peak periods. The shadow wage rates during June, July and March are Ls. 3.765, Ls. 2.239 and Ls. 5.042, respectively. These values are higher than the corresponding shadow prices of the basic model depicted in table XV. It is clear that price policies have resulted in discrimination against agriculture through paying resources committed to agricultural production, especially labor and capital, lower returns. Indeed, labor wages in the Gezira Scheme are substantially lower than the comparative wage rates in other sectors such as industry and transportation sectors. The low returns to labor have resulted in rural-urban migration even among the family labor. The low returns to capital in agricultural investment in the Gezira Scheme may provide explanation why the private sectors' contribution to agricultural investment is minimal. The relatively stagnant performance of agriculture during the past decade is attributed in part to such price policy decisions. Based on this analysis, agricultural prices set at world levels and adjusted flexibly over time should increase returns to resources used in agriculture substantially. Results of this border price policy further stabilizes domestic prices with proportionally smaller variations. By permitting

the private sector to take on a greater role in performing agricultural marketing activities, the government may reduce distortions in domestic prices.

CHAPTER VI

SUMMARY, POLICY IMPLICATIONS AND FURTHER RESEARCH

Summary

The primary objective of this study was to determine the optimum resource allocation and enterprise combination taking into account the product price and yield variation on irrigated Gezira farms. This was accomplished using an LP-MOTAD model and data derived from sample information at the farm and Scheme level. A field survey of 50 Gezira tenants was conducted in January-February, 1984, to determine the socio-economic characteristics of the tenants and their resource base. Secondary data obtained from Gezira statistical records and research institutions were also utilized to determine the input-output coefficients of the basic model.

Specific objectives of the study included: (1) critical analysis of the past and present performance of the Gezira Scheme taking into account economic, social and institutional constraints; (2) review of the theory of farm planning under risk; (3) estimation of the optimum farm resource and enterprise combinations assuming profit maximization and risk minimization decision criteria; and (4) evaluation of the

sensitivity of the different decision criteria to potential increases in hired labor, irrigation water, institutional credit and producer prices.

Performance of the Gezira Scheme

The Gezira Scheme is unique in Africa and described to be one of the largest gravity irrigation areas in the world. It occupies more than half of the Sudan's irrigated land and provides direct employment for 96,000 tenants and their families. The Scheme extends over the central clay lands of the Sudan covering an area of 2.2 million feddans (1 feddan = 1.038 acres). The total area of the Scheme is divided into tenancies said to be homogenous and of an average size of 15 feddans. The Gezira management sets forth rules and guidelines for the tenant that encompass all aspects of production and marketing, from seed variety selection to the market price of the produce. Under the existing cropping pattern, cotton and wheat occupy two thirds of the tenancy while the other third is devoted to groundnut, sorghum, and vegetable production.

A review of the Gezira Scheme performance since the early 1970s to present reveals a declining trend in yields and net returns. Several economic, social, and institutional constraints contribute to the decreasing productivity trend. Government policy in the Gezira frequently ignores the tenants preference including attitudes towards risk. Historically, government interest has focused on cotton production which is the single cash crop accounting for about 50 percent of Sudan's total exports. Cotton, however, is associated with

high yield and price variability and thus contributes to income variability at the farm, scheme and country level.

Despite low and fluctuating productivity of wheat, tenants are forced to devote one third of their area to wheat production. The cultivation of wheat in the Gezira Scheme is a direct consequence of government policy which is directed to the achievement of self-sufficiency in some basic food commodities.

Theory of Enterprise Selection Under Risk

The theoretical framework adopted in the analysis was the mean-variance efficiency criteria using Minimization of Total Absolute Deviation (MOTAD) approach. This approach usually assumes the decision maker maximizes expected utility. Thus his preference among alternative farm plans is expressed in terms of expected income and associated variance. Other assumptions are that the net returns or gross margins are considered to have a normal distribution, and the decision maker has a convex utility function which implies a risk aversion behavior.

Historical time series data for yields, prices and cost of production provided the basis for calculating the net returns associated with each production activity. The time series data extends over the period 1971-83. Producers were assumed to base their plans on the long-term mean of net returns and that any deviation from the mean is a random event. The series of net returns was deflated using the GDP deflator to reflect 1982 constant prices.

Results of the Basic Model

There are two steps in the computational procedure of the MOTAD model. First, a conventional linear programming maximization problem is formulated and solved to determine the maximum expected income or the highest attainable point on the risk efficiency frontier. Second, the elements of risk are introduced through minimization of total negative deviation represented by the objective function of the MOTAD model. Other points on the risk efficiency frontier are obtained by decreasing the maximum expected income parametrically in arbitrary decrements. Along the efficiency frontier, the MOTAD model minimizes total negative deviation (TND) for any given expected income. This TND value is transformed into an estimate of standard deviation by multiplication of a constant, K . This transformation allows the model to determine a set of efficient farm plans along an E-V efficiency frontier where E is the expected income and V is the variance of income. Depending on a farmer's attitude toward risk, he can select the farm plan that will maximize his utility.

Following the above discussion, the results of the Gezira basic model have two components which are the profit maximization results derived from the linear programming model and the risk minimization results obtained after elements of risk are incorporated in the model. The profit maximization solution predicts that the cropping pattern should include 5.3 feddans of cotton, 4.6 feddans of wheat and 3.5 feddans of groundnut. The sorghum activity did not enter the profit maximization solution. The existing cropping pattern enforced by the management in the Gezira Scheme specifies five feddans of cotton, five

feddans of wheat, and five feddans to be shared between groundnut, sorghum and vegetables. The results of the profit maximization solution suggest that if risk is ignored, the existing cropping pattern which emphasizes cotton and wheat should be continued given the underlying assumptions concerning the resource base.

On the resource side, the profit maximization plan is limited at the margin by institutional credit. Hired labor was found critical during peak planting, weeding and harvesting periods. Irrigation water was found nonlimiting under the assumed supply conditions in the Gezira Scheme. The value of the objective function associated with the profit maximization plan was Ls. 848.298.

The basic LP model is then extended to a MOTAD model by changing the objective function to minimization of total negative deviation and adding a deviation matrix. Ten different expected income levels were specified and for every income level a corresponding plan was derived and presented. Risk measurement statistics such as total negative deviation, standard deviation and coefficient of variation were used to describe the variability associated with each plan.

When expected income was reduced from Ls. 848.298 to Ls. 798.298, cotton area reduced from 5.3 feddans to 4.6 feddans, wheat area reduced to 2.5 feddans, while groundnut increased slightly to 3.6 feddans. By reducing the area of cotton, the standard deviation and coefficient of variation were reduced by 12.46 and 4.79 percent, respectively. This implies that high variability is associated with cotton and wheat production and as cotton and wheat becomes less important in the cropping pattern, risk in terms of variability is reduced. The subsequent farm plans associated with lower expected

incomes showed a steady decline in cropping area which is also associated with less resource use and less income variability.

Sorghum production entered the solution in the second production plan. This implies that sorghum is associated with less risk but limited at the margin by the availability of labor during planting season.

Results of the Sensitivity Analysis

The set of efficient farm plans derived in the basic model show a relative reduction in risk, for any given level of expected income, associated with an increase in hired labor, institutional credit and producer prices. With increased hired labor, expected income of the profit maximization plan increased from Ls. 848.298 to Ls. 956.343. The area of cotton increased from 5.3 feddans to 6.5 feddans while wheat area reduced to 3.9 feddans. One possible explanation is that since cotton is more labor intensive than the other crops, by increasing the labor constraint more cotton area comes into production and consequently greater risk. On the resource side, hired labor increased by 22 percent implying that any attempt to increase cotton area on the representative farm should be associated with a corresponding increase in hired labor availability. The irrigation water consumption showed a relatively small increase of eight percent.

As the expected income was reduced parametrically from Ls. 956.343 to Ls. 906.000, cotton and wheat area reduced while sorghum came into the solution at a level of 1.5 feddans. This change in cropping pattern was associated with a 16.67 percent and 4.32 percent

reduction in standard deviation and coefficient of variation, respectively. This implies that as cotton area is reduced, risk is also reduced. Between expected incomes of Ls. 906.000 and Ls. 506.000 the standard deviation and coefficient of variation reduced steadily.

When the institutional credit constraint was increased from Ls. 1500 to Ls. 1650, the maximum expected income showed a corresponding increase from Ls. 848.298 to Ls. 868.444. Cotton area remained the same while wheat area increased from 4.6 feddans to 5.3 feddans. This may be explained by the fact that cotton is limited at the margin by labor constraint during March picking season as predicted earlier by the basic model. Wheat, on the other hand, was not limited in the basic model by hired labor but rather by institutional credit.

Between expected incomes of Ls. 816.000 and Ls. 418.000 the cropping area showed a steady decline. The standard deviation and coefficient of variation also showed a reduction. Sorghum entered in the second plan at a level of 1.5 feddans. Comparison of the efficiency frontier derived from Model 3 with the basic model revealed that at any given level of expected income Model 3 is associated with less risk. This implies that increasing institutional credit to the Gezira farmers reduces risk for any given level of expected income.

As expected, results of a parallel increase in both institutional credit and hired labor availability showed an increase in both the maximum expected income and cropping area. The maximum expected income increased from Ls. 848.298 to Ls. 975.161. The cropping pattern associated with the maximum income devoted more area to cotton and consequently more risk. Resource use of institutional credit and hired labor increased to the maximum level. This is because cotton is

a more labor and capital intensive crop compared to wheat and groundnut. As the expected income was parameterized from Ls. 975.161 to Ls. 525.000 in constant decrements of Ls. 50, cotton and wheat area decreased steadily while groundnut showed a gradual increase up to plan 6 and then decreased steadily. Sorghum entered the solution in plan 2 at a level of 1.7 feddans. This implies that Gezira farmers tend to substitute sorghum for cotton as risk becomes important.

The trade-off between any level of expected income and the corresponding risk level is determined from the shape of the efficiency frontier. Each farm plan along the E-V frontier is an efficient plan in the sense that it specifies the minimum amount of risk associated with any given level of income. In considering the alternative farm plans, credit seems to be the most important limiting factor followed by availability of hired labor during peak periods. In all models, irrigation water was not a limiting resource. However, timing and frequency of irrigation may be a problem to those tenants located far from the dam or main canal.

Finally, the sensitivity of the basic model to an increase in producer prices was tested assuming that the producers are paid a price equivalent to the export parity price rather than the government market price. The gross margins derived from export parity price are higher and less variable than those derived using the government market price. Consequently, the analysis resulted in higher expected incomes and less risk through all the efficient plans including the profit maximization plan. However, the cropping pattern and total

area cultivated remained almost the same as in the basic model since the resource base of hired labor and institutional credit remained unchanged.

This analysis provides evidence that price policies in the Gezira Scheme have resulted in discrimination against agriculture through paying resources committed to agricultural production, especially labor and capital, lower returns. The low returns to labor have resulted in rural-urban migration and severe labor shortage problems in the Gezira Scheme. The low returns to capital provide an explanation of why the private sector, so far, is very reluctant to invest in agricultural production in the Gezira Scheme.

Policy Implications

As shown by the results of the MOTAD model, efficient resource allocation and enterprise combination in the Gezira risky environment requires making several adjustments to the existing agricultural production pattern. Such adjustments should include but not necessarily be limited to: (1) increasing groundnut and sorghum production; (2) reducing total area under cotton and wheat; (3) adjusting producers prices to world market level; and (4) improving efficiency in utilization of resources to raise tenant income and reduce risk. Since the tenants under the Gezira conditions cannot change the existing cropping pattern and pricing policy except with management participation and approval, government initiative is needed to bring about the more efficient resource use and stabilized income. Such initiative may be pursued along the following policy guidelines.

Increasing Groundnut Production

Policies proposed for groundnut production are based on the Gezira's considerable potential for growing this crop at less risk and on the availability of profitable world markets. Under irrigated conditions the potential exists to increase yield and consequently make groundnut even more competitive with cotton. The realization of this potential is not in line with current government policy which aims at drastic reduction in groundnut production on irrigated schemes, primarily for the purpose of making room for expanded wheat production. For this reason, institutional credit has been shifted from groundnut to wheat production.

Increasing groundnut production in the Gezira Scheme is a result of farmer's risk attitude as shown by the MOTAD model. However, to achieve this target certain difficulties should be overcome. These relate to labor shortages for planting and harvesting operations, adequate research and extension to develop new high yielding varieties, increasing credit services, and more efficient marketing services and facilities.

Increasing Sorghum Production

Sorghum is the most important staple food crop in the Gezira area. Tenants were familiar with growing sorghum even before the establishment of the irrigation network. It is regarded as a risk management strategy against unforeseen future hazards since the major supply of sorghum in the Sudan is from the rainfed agricultural zones. However, the major bottlenecks for increasing sorghum production in

the Gezira Scheme is the scarcity of labor during planting season and low yields. Provision of labor-saving technologies, institutional credit services, marketing facilities and improved seeds is necessary to achieve higher productivity and incomes.

Reducing Cotton Production

Major constraints to further development of cotton production relate to high income variability and thus risk, labor shortages at the time of planting and picking, and institutional credit. Cotton is both a labor-intensive and a capital-intensive crop. It requires considerable production inputs such as fertilizers and insecticides which can be obtained only as imports and at considerable cost. At the same time research findings and experience indicate that cotton productivity is very sensitive to shortages in both inputs. Given the limited ability of the Sudan government to increase institutional credit, a reduction in cotton area would seem to be consistent with reducing risk associated with income variability. Other irrigated schemes surrounding the Gezira Scheme compete with Gezira for the same hired labor force. Mechanized harvesting would alleviate part of the problem.

A detailed feasibility study for mechanical harvesting of cotton under the Gezira conditions is recommended if the existing efforts to increase cotton production is to be a risk-efficient alternative. Cotton mechanization would not displace labor in the aggregate but rather free labor to cultivate other labor-intensive crops such as vegetables.

Reducing Wheat Cultivation

A major constraint on limiting wheat production under Gezira conditions is the relatively low gross margins associated with low and fluctuating yields. The crop seems to be suffering from the shortness of the cool season and may need to be extended to new ecological zones, such as the northern part of the Sudan, where the relatively longer cold season is more favorable.

The cultivation of wheat in the Gezira Scheme is a direct consequence of government policy which seeks self-sufficiency in some food commodities. However, choices among production possibilities should be based not only on political objectives but also on economic objectives and comparative advantage. It should be pointed out that attempts to increase wheat production in the Gezira Scheme at a lower risk must be associated with the development of new varieties suited to hot climates and relatively short growing periods. Wheat prices paid to Gezira tenants are relatively low in comparison with prices prevailing at the international level. Low government set prices reduces further the profitability of wheat cultivation.

Adjusting Producer Prices to World Market Level

By paying agricultural producers prices well below international levels, the government price policy in the Gezira Scheme discriminates against agriculture relative to enterprises in other sectors. Some of the implications of this discrimination is that both labor and capital are encouraged to move out of the agricultural sector. Both public

and private sector investments in agriculture are reduced relative to what would be without the discrimination. Furthermore, reduced investment in agriculture is likely to be associated with low growth and productivity of all agricultural resources and sectors linked to agriculture.

To reduce the discriminatory effects of domestic agricultural price policies, agricultural prices must be set at international levels and adjusted flexibly over time. By implementing a rational price policy, farmers will receive the right signal to mobilize resources in a manner compatible with the country's comparative advantage.

Efficient Utilization of Resources

Efficient utilization of resources and the improvement of agricultural services in the Gezira Scheme requires the development and adoption of suitable economic and institutional measures which may include: (1) efficient utilization of irrigation water; (2) improved credit services; (3) test of a suitable technology to alleviate the seasonal labor shortage problem; (4) a reconciliation of private and public efforts in the utilization of unused resources such as land and irrigation water; (5) development of crop marketing activities; (6) strengthening of the research and extension units; (7) effective price policy; (8) development of plant breeding and selection units; and (9) better weed control methods. These measures are discussed in more detail below.

According to government sources in the Sudan, irrigation costs absorb a large part of public sector investment. Frequently low water charges and inadequate taxes on agricultural incomes have made the burden on the government's budget heavier than it needs to be. To insure a reasonable return on irrigation investment in the Gezira Scheme, the system has to be carefully organized and fully utilized. Efficiency in water use is becoming increasingly critical, partly because of actual or threatened water shortages. More important, most of the high-yielding seeds require reliable supplies of water at specified times if they are to fulfill their promise. As indicated in the study, at present no water quantity problem exists, however, the timing and frequency problems reported by the Gezira farmers should be emphasized and solved. Coordination between different ministries involved in supplying water to the Gezira Scheme, especially Ministry of Irrigation and Ministry of Agriculture, is crucial to improving water use efficiency. Furthermore, farmers themselves should share in the decision making process regarding the timing and frequency of waterings.

As indicated in the study, institutional credit does offset the variability problem in farmer's expected incomes. Thus institutional credit should be further evaluated for expansion. The major limitation to such expansion relates to the lack of sufficient finances at the Scheme level. Loans granted by national credit institutions, such as the Agricultural Bank, are inaccessible to small farmers since they do not have the necessary collateral. Peasant tenants in the Gezira Scheme are forced to rely heavily on informal credit sources, and primarily the "shail" system under which they

receive advances in cash and kind from private merchants against promises to deliver crops after harvest, thus paying very high rates of interest. As most of the "shail" credit is usually not invested on the farm, it does not contribute to agricultural production and in reality may impede it. To promote credit, both commercial and agricultural banks should extend their services to the villages and rural communities and should also develop closer links with cooperatives and collective farm organizations. Furthermore, if more farmers are to be served, interest rates and other charges should reflect the opportunity cost of lending and credit recovery.

Given the seasonal labor shortage problem, research is needed to develop and test technologies most suited to Sudan's ecological, social and economical conditions. Mechanization has to play the crucial role in the effective utilization of the Gezira's scarce resource such as land and irrigation water and to alleviate the problems of seasonal labor shortages.

Plans which leave land idle may be considered as basis for redistribution of land among landless residents in the Scheme area. Integration of livestock in the Gezira rotation may also provide an alternative for the utilization of unused or underutilized land and water resources. It also provides scope for spreading the risk associated with raising only field crops. In this respect, the reconciliation of private and public efforts is recommended to establish specialized dairy and poultry production units to utilize unused resources and improve the diet of the Gezira farmers.

Crop marketing activities are often the key to the development of subsistence agriculture. Marketing institutions are needed to

finance, sell, buy, transport, process and store products and to distribute inputs at the time and place needed. Once marketing channels are established, farmers are expected to respond eagerly to market opportunities. Gezira management can help in organizing the tenants into associations linked to a central distribution agency to build local storage facilities, to develop rural markets, and to conduct a consumer information program through the Scheme extension service.

At present, fertilizer consumption in the Gezira Scheme is limited to only cotton and wheat. The development of research programs to determine the optimum fertilizer rates, optimum seeding rates, sowing dates and seed bed preparation is urgently required. The present crop protection services concentrate on cotton with relatively little attention given to other crops that suffer considerable losses. It is necessary, therefore, to provide crop protection measures if pests and diseases are to be removed as serious obstacles to further improvement in productivity.

Producer prices in the Gezira Scheme are low and there is a lack of clear price policies to obtain development objectives of the Scheme and of the country. Higher producer prices combined with more rational taxation policies could provide effective stimulus for increased production and exports. Government fiscal policies which assign high priority to export taxes as major sources of revenues and consequently impose relatively high taxes on agricultural exports, should be reviewed with the purpose of making agriculture competitive on the world market. Import duties on agricultural inputs, especially

machinery, fertilizers and insecticides, should be evaluated relative to their impact on agricultural productivity.

Except for cotton, little has been done in the Gezira in plant breeding and selection. Future efforts should be oriented toward solution of the low resource productivity problem. Quality improvements in groundnut production is an important prerequisite for successful competition in international markets. Again, except for cotton, no official seed organization exists in the country and the private seed agencies generally sell uncertified seed of low germination and with high percentage of foreign matter and weed seeds. Major emphasis needs to be placed on strengthening and expanding the capacity for seed propagation, seed importation and establishment of rural seed distribution companies.

Weed infestation is frequently cited as the single major factor responsible for low and fluctuating yields in the Gezira Scheme. In view of labor shortages, better weed control can be obtained from better land preparation, mechanical cultivation and chemical weed control. In the short-run, Gezira farmers may have to continue to rely on the use of hand labor to the extent it is available. Meanwhile, government efforts are needed to develop new combinations of mechanical and hand labor systems for improving cultivation and weed control methods.

Finally, current foreign aid policy in the Sudan depends heavily on multilateral agencies, especially the World Bank and its affiliates such as the International Development Association and the International Monetary Fund. So far, the largest share of international loans has been devoted to establishing new irrigation

projects with the main objective of producing cotton as the principal cash crop. Little or no attention has been given to improving the technical and institutional framework of existing agricultural projects such as the Gezira Scheme. However, the development of transportation, mechanization, storage, improved irrigation facilities, credit institutions and agricultural processing facilities need to be further emphasized and call for more bilateral assistance.

Limitations and Need for Further Research

A number of important limitations of this analysis deserve mentioning. Primary among these is the scarcity of detailed and reliable information at the farm and Scheme level. Data about vegetables which provide scope for diversification and further reduction in risk are not available. This limitation has restricted the analysis to the main crops under the existing rotation which are cotton, wheat, groundnut and sorghum. Data have also limited the analysis of mechanization effects to alleviate labor shortage problems. This is because mechanization in the Gezira Scheme is very limited and data about input-output coefficients are not available. Further research is needed to incorporate the effects of mechanization in the analysis once detailed and reliable information is obtained.

A second limitation relates to whether an expectation model which measures risk as the deviation from the mean of net returns for a series of years is a reliable measure. Weighted moving average models may be theoretically better for evaluating risk based on a long series

of historical data. However, the choice of appropriate weights for computing moving average is still an empirical limitation. More research is needed to resolve the questions of how farmers perceive risk and what measure of risk is appropriate in farm planning models.

Another limitation relates to the use of aggregate data at the Scheme level on yields, prices and costs in deriving net returns. This aggregation may have a downward bias on the estimated standard deviation since aggregation itself averages out part of the variability. Therefore, efforts should be made to collect and record farm-level time series data for future use in risk analysis.

The use of official exchange rates to convert FOB prices to domestic border prices may over- or under-value the returns to some resources and production activities. That is because in countries like Sudan, the official exchange rate frequently overvalues the real exchange rate of the Sudanese pound. Research is needed to estimate the real exchange rate of the Sudanese currency taking into account market distortions and the scarcity of foreign currency in the Sudan.

A SELECTED BIBLIOGRAPHY

- Adam, F. H. "Evolution of the Gezira Pattern of Development Within the Context of the History of Sudanese Agrarian Relations." Sudan Journal of Development Research, 2(1978): 31-44.
- Adams, R. M., D. J. Menhkaas and B. A. Woolery. "Alternative Parameter Specifications in E-V Analysis: Implications for Farm Level Decision Making." Western Journal of Agricultural Economics, 5(1980): 13-20.
- Ahmed, A. H. Agriculture Finance and Credit in the Sudan. Department of Rural Economy, Faculty of Agriculture, University of Khartoum, Sudan, Research Bulletin 33, 1983.
- Ahmed, S. E. "The Integration of Agricultural Credit and Marketing in the Gezira Scheme of the Sudan with Special Reference to the 'Shail' System." Unpublished Ph.D. Thesis, University of London, 1977.
- Anderson, J. R. "An Overview of Modeling in Agricultural Management." Review of Marketing and Agricultural Economics, 40(1972): 111-122.
- _____. "Forecasting, Uncertainty and Public Project Appraisal." World Bank Working Paper No. 1983-4, July 1983.
- Anderson, J. R., J. L. Dillon, and B. Hardaker. Agricultural Decision Analysis. Ames: Iowa State University Press, 1977.
- Barnett, T. The Gezira Scheme: An Illusion of Development. London Cass, 1977.
- Baumol, W. J. "An Expected Gain-Confidence Limit Criterion for Portfolio Selection." Management Science, 10(1963): 174-182.
- Binswanger, H. "Attitudes Toward Risk: Experimental Measurement in Rural India." American Journal of Agricultural Economics, 62(1980): 395-407.
- Boussard, J. M. and M. Petit. "Representation of Farmers Behavior Under Uncertainty with a Focus Loss Constraint." Journal of Farm Economics, 49(1967): 869-881.

- Brink, Lars and B. McCarl. "The Tradeoff Between Expected Return and Risk Among Cornbelt Farmers." American Journal of Agricultural Economics, 60(1978): 259-263.
- Chen, T. T. and C. B. Baker. "Marginal Risk Constraint Linear Program for Activity Analysis." American Journal of Agricultural Economics, 56(1974): 622-627.
- Dillon, John L. "An Expository Review of Bernoullian Decision Theory in Agriculture: Is Utility Futility?" Review of Marketing and Agricultural Economics, 39(1971): 3-80.
- Dillon, John L. and J. R. Anderson. "Allocative Efficiency, Traditional Agriculture, and Risk." American Journal of Agricultural Economics, 53(1971): 26-32.
- Dillon, John L. and P. L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." American Journal of Agricultural Economics, 60(1978): 425-435.
- Duloy, J. H. and R. D. Norton. "Prices and Incomes in Linear Programming Models." American Journal of Agricultural Economics, 57(1975): 591-600.
- Euroconsultant, Sir Alexander Gibb and T. C. S. Gezira Rehabilitation and Modernization Project 1. June, 1982.
- Fakki, H. "Economics and Management of Irrigation in the Sudan Gezira Scheme." Unpublished PH.D. Thesis, Hohenheim University, W. Germany, 1982.
- Food and Agricultural Organization (FAO) of the United Nations. Commodity Review and Outlook, No. 25 (1983), Rome.
- Freund, R. J. "The Introduction of Risk in a Programming Model." Econometrica, 24(1956): 253-263.
- Gaitskell, A. Gezira, A Story of Development in the Sudan. Faber and Faber, 1959.
- Gebremsked T. and C. R. Shumway. "Farm Planning and Calf Marketing Strategies for Risk Management: An Application of Linear Programming and Statistical Decision Theory." American Journal of Agricultural Economics, 61(1979): 591-602.
- Gibbons, E. T. Memorandum on the Sudan Gezira Board's Groundnut and General Policy for 1975-1985. Unpublished Draft Report, 1975.
- Gittinger, J. P. Economic Analysis of Agricultural Projects. John Hopkins University Press, 1972.

- Halter, A. N. and Robert Mason. "Utility Measurement for Those Who Need to Know." Western Journal of Agricultural Economics, 3(1978): 99-109.
- Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty." American Journal of Agricultural Economics, 53(1971): 53-62.
- _____. "Application of Risk Preference Estimates in Firm Household and Agricultural Sector Models." American Journal of Agricultural Economics, 64(1982): 384-90.
- Hazell, A. N., R. D. Norton, M. Parthasarathy, and C. Pomareda. "The Importance of Risk in Agricultural Planning Models." The Book of CHAC, Baltimore, MD: Johns Hopkins University Press, 1981.
- Heady, E. O. and W. Chandler. Linear Programming Methods. Ames: Iowa State University Press, 1958.
- Herrey, E. M. J. "Confidence Intervals Based on the Mean Absolute Deviation of a Normal Sample." Journal of American Statistical Association, 60(1965): 2257-69.
- Hildreth, C. and Glenn J. Knowles. Some Estimation of Farmer's Utility Functions. University of Minnesota Agricultural Experiment Station Technical Bulletin 335, 1982.
- Hillier, F. S. "The Derivation of Probabilistic Information for Evaluation of Risky Investments." Management Science, 9(1963): 443-57.
- How, R. B. and P. B. R. Hazell. Use of Quadratic Programming in Farm Planning Under Uncertainty. Cornell University Agricultural Experiment Station Agricultural Economics Research 250, 1968.
- Humaidan, S. H. "Policies and Management Guidelines for Optimum Resource Utilization at AL-Hasa Irrigation and Drainage Project, Saudi Arabia." Unpublished Ph.D. Thesis, Oklahoma State University, 1980.
- ILO/UNDP Employment Mission. Growth, Employment and Equity: A Comprehensive Strategy for the Sudan. Geneva, International Labor Office, 1976.
- Johnson, S. R. "A Re-examination of the Farm Diversification Problem." Journal of Farm Economics, 49(1967): 610-21.
- Just, R. E. "An Investigation of the Importance of Risk in Farmer's Decisions." American Journal of Agricultural Economics, 56(1974): 14-25.

- Kutcher, G. P. and P. L. Scandizzo. The Agricultural Economy of Northeast Brazil. Baltimore, MD: Johns Hopkins University Press, 1981.
- Lin, William, G. W. Dean and C. V. Moore. "An Empirical Test of Utility vs. Profit Maximization in Agricultural Production." American Journal of Agricultural Economics, 56(1974): 497-508.
- Lipton, M. "The Theory of the Optimizing Peasant." Journal of Development Studies, 4(1968): 327-51.
- Little, I. M. D. and J. A. Mirrlees. Project Appraisal and Development Planning for the Developing Countries. London: Heinemann, 1974.
- Low, A. R. C. "Decision Taking Under Uncertainty: A Linear Programming Model of Peasant Farmer Behavior." Journal of Agricultural Economics, 25(1974): 311-20.
- Mapp, H. P., M. L. Hardin, O. L. Walker, and T. Persaud. "Analysis of Risk Management Strategies for Agricultural Producers." American Journal of Agricultural Economics, 61(1979): 1071-77.
- Markowitz, H. Portfolio Selection: Efficient Diversification of Investments. New York: John Wiley and Sons, Inc., 1959.
- Ministry of Agriculture and National Resource. Current Agricultural Statistics, December, 1983.
- Ministry of Irrigation. Irrigation in the Gezira Scheme. December, 1979.
- Ministry of National Planning. The Six-Year Plan for Social and Economic Development 1977/78 - 1982/83, Khartoum, Sudan, 1977.
- Officer, R. R. and A. N. Halter. "Utility Analysis in a Practical Setting." American Journal of Agricultural Economics, 50(1968): 257-77.
- Poliquene, L. Y. Risk Analysis in Project Appraisal. Baltimore, MD: Johns Hopkins University Press, 1970.
- Pyle, D. H. and S. J. Turnovsky. "Safety-First and Expected Utility Maximization in Mean-Standard Deviation Portfolio Analysis." Review of Economic Studies, 52(1970): 75-81.
- Reutlinger, S. Techniques for Project Appraisal Under Uncertainty. Baltimore, MD: The Johns Hopkins University Press, 1970.
- Roumasset, J. A., J. Boussard, and I. Singh. Risk, Uncertainty and Agricultural Development. New York: Agricultural Development Council, 1979.

- Roy, A. D. "Safety First and the Holding of Assets." Econometrica, 20(1952): 431-49.
- Salem, M. A. and D. D. Badger. "Economics of Reduced Tillage Technology on Soil Conservation and Risk Analysis for Eastern Oklahoma Farmers." Oklahoma State University, AE 8380, 1983.
- Scott, J. T. and C. B. Baker. "A Practical Way to Select an Optimum Farm Plan Under Risk." American Journal of Agricultural Economics, 57(1972): 657-60.
- Sharp, W. F. "A Simplified Model for Portfolio Analysis." Management Science, 9(1963): 277-93.
- Simmons, R. L. and C. Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." American Journal of Agricultural Economics, 57(1975): 472-479.
- Sudan Gezira Board. The Gezira Current Statistics, Annual Repoort on Economic Surveys of Crop Production: Seasons 1969/70 - 1982/83. The Economic and Social Research Unit, Barakat.
- Telser, L. "Safety-First and Hedging." Review of Economic Studies, 23 (1956): 1-56.
- Von Neuman, J. and O. Morgenstern. Theory of Games and Economic Behavior. Princeton: Princeton University Press, 1947.
- Wicks, J. A. and J. W. B. Guise. "An Alternative Solution to Linear Programming Problems with Stochastic Input-Output Coefficients." Australian Journal of Agricultural Economics, 22(1978): 22-40.
- Wiens, T. B. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." American Journal of Agricultural Economics, 58 (1976): 629-35.
- Wolgin, J. "Resource Allocation and Risk: A Case Study on Smallholder Agriculture in Kenya." American Journal of Agricultural Economics, 57(1975): 622-30.
- World Bank. Sudan Agricultural Survey. World Bank Report No. 1836-SU., Washington, D. C., 1979.
- _____. World Development Report, 1982.
- Young D. "Evaluating Procedures for Computing Objective Risk from Historical Time Series." In Risk Analysis in Agriculture: Research and Educational Development, 1980, pp. 1-21.
- Zaki, E. A. "An Ongoing Evaluation of the Planning, Implementation and Tenancy Size of the Rahad Irrigation Project of the Sudan." Unpublished Ph.D. Thesis, Michigan State University, 1980.

APPENDIX A

**DETAILED ENTERPRISE BUDGETS EXPRESSED
IN MONETARY VALUES**

TABLE XXI
DETAILED COST OF PRODUCTION BUDGET
FOR COTTON, SEASON 1982-83

	-----Ls./Fed.-----	
I. Land Preparation Operations:		
Deep plowing	9.732	
Ridging	6.901	
Opening irrigation canals	1.165	
Raising of field channels	3.200	
Irrigation labor	0.122	
Mixing and spraying of fertilizer	<u>0.800</u>	
Subtotal		22.955
II. Cultural Operations:		
Sowing	3.500	
Resowing	0.500	
Mechanical weeding	1.137	
Manual weeding	8.250	
Thinning	1.699	
Irrigation labor	4.588	
Cleaning field canals	<u>2.079</u>	
Subtotal		27.521
III. Harvest Operations:		
Transport of picking labor	6.903	
Picking labor	31.585	
Sacking	2.670	
Pulling and collection of stalks	<u>9.912</u>	
Subtotal		51.070
IV. Materials:		
Seeds	3.666	
Sacks	7.574	
Fertilizer	42.695	
Insecticides	60.510	
Herbicides	13.004	
Transport of materials	<u>7.234</u>	
Subtotal		143.684
V. Interest on operating capital		27.025
VI. Land and water rates		<u>28.500</u>
GRAND TOTAL		<u>300.755</u>

TABLE XXII
DETAILED COST OF PRODUCTION BUDGET
FOR WHEAT, SEASON 1982-83

		-----Ls./Fed.-----
I. Land Preparation Operations:		
Plowing	4.923	
Opening field channels	2.724	
Irrigation labor	0.038	
Cleaning irrigation canals	<u>1.463</u>	
Subtotal		9.158
II. Cultural Operations:		
Sowing	3.201	
Resowing	0.110	
Irrigation labor	4.577	
Fertilizer application	<u>0.768</u>	
Subtotal		8.656
III. Harvest Operations:		
Breaking field canals	2.071	
Mechanical harvesting	<u>12.537</u>	
Subtotal		14.608
IV. Materials:		
Seeds	19.989	
Sacks	5.716	
Fertilizer	28.868	
Insecticides	6.375	
Seed dressing	<u>0.199</u>	
Subtotal		61.147
V. Transport		7.809
VI. Services		4.330
VII. Land and water rates		<u>18.000</u>
GRAND TOTAL		<u>124.288</u>

TABLE XXIII

DETAILED COST OF PRODUCTION BUDGET
FOR GROUNDNUT, SEASON 1982-83

		-----Ls./Fed.-----
I. Land Preparation Operations:		
Plowing	3.798	
Opening of field channels	1.854	
Irrigation labor	0.192	
Cleaning irrigation canals	<u>0.226</u>	
Subtotal		6.065
II. Cultural Operations:		
Sowing	3.659	
Resowing	0.319	
Weeding	19.165	
Irrigation labor	<u>3.667</u>	
Subtotal		26.704
III. Harvest Operations:		
Pulling and collection	14.142	
Threshing and packing	13.202	
Picking fallen nuts	<u>4.278</u>	
Subtotal		31.638
IV. Materials:		
Seeds	7.423	
Sacks	2.929	
Transport	<u>1.659</u>	
Subtotal		12.011
V. Land and water rates		<u>14.000</u>
GRAND TOTAL		<u>90.418</u>

TABLE XXIV
 DETAILED COST OF PRODUCTION BUDGET
 FOR SORGHUM, SEASON 1982-83

	-----Ls./Fed.-----	
I. Land Preparation Operations:		
Plowing	3.813	
Cleaning field channels	1.568	
Irrigation labor	0.129	
Opening field canals	<u>0.798</u>	
Subtotal		6.379
II. Cultural Operations:		
Sowing	3.513	
Resowing	0.336	
Weeding	9.855	
Thinning	0.014	
Irrigation labor	<u>2.050</u>	
Subtotal		15.769
III. Materials:		
Seeds	1.469	
Sacks	2.806	
Transport	<u>2.159</u>	
Subtotal		6.434
IV. Land and water rates		<u>7.000</u>
GRAND TOTAL		<u>60.575</u>

APPENDIX B

MEAN WATER REQUIREMENTS FOR CROPS IN THE GEZIRA
SCHEME IN CUBIC METERS PER FEDDAN PER DAY

TABLE XXV

MEAN WATER REQUIREMENTS FOR CROPS IN THE
GEZIRA SCHEME IN CUBIC METERS PER
FEDDAN PER DAY

Time	Cotton	Sorghum	Ground- nuts	Wheat	Lubia	Phill- ipesara	Avail-(3) ability
-----m ³ /day-----							
June 1-10	-	-	27.25	-	-	-	481.95
11-20	-	-	27.25	-	-	-	481.95
21-30	-	-	18.50	-	-	-	481.95
July 1-10	-	60.00	19.00	-	-	-	481.95
11-20	-	18.20	19.50	-	-	-	481.95
21-31	20.00	21.50	21.00	-	-	-	481.95
Aug 1-10	-	27.00	22.50	-	-	-	481.95
11-20	13.80	30.30	25.00	-	-	-	481.95
21-31	15.00	31.50	28.50	-	-	-	481.95
Sept 1-10	16.80	32.00	31.50	-	-	-	481.95
11-20	18.90	32.00	32.00	-	-	-	481.95
21-30	23.50	30.00	31.00	-	10.00	10.00	481.95
Oct 1-10	28.50	25.00	29.00	-	15.00	15.00	605.09
11-20	30.30	17.80	24.50	25.00	15.00	15.00	605.09
21-31	30.30	-	21.50	25.00	15.00	15.00	605.09
Nov 1-10	30.30	-	18.00	16.90	-	-	481.95
11-20	30.00	-	15.00	21.80	-	-	481.95
21-30	28.50	-	-	26.90	-	-	481.95

TABLE XXV (continued)

Time		Cotton	Sorghum	Ground-nuts	Wheat	Lubia	Phillipesara	Avail-(3) ability
		-----m ³ /day-----						
Dec	1-10	27.00	-	-	28.80	-	-	481.95
	11-20	26.00	-	-	29.20	-	-	481.95
	21-31	24.50	-	-	28.60	-	-	481.95
Jan	1-10	22.30	-	-	24.70	-	-	494.69
	11-20	22.30	-	-	24.70	-	-	494.69
	21-31	21.50	-	-	21.30	-	-	494.69
Feb	1-10	20.50	-	-	16.20	-	-	494.69
	11-20	20.00	-	-	14.20	-	-	494.69
	21-28	20.00	-	-	-	-	-	494.69
Mar	1-10	21.00	-	-	-	-	-	494.69
	11-20	22.40	-	-	-	-	-	494.69
	21-31	-	-	-	-	-	-	494.69

Source: H.G. Farbrother; water requirements of crops in the Gezira, in cotton research reports, Republic of the Sudan 1972/73.

APPENDIX C

INITIAL MOTAD TABLEAUX

TABLE XXVI

THE INITIAL TABLEAU OF THE MOTAD MODEL

Resources	Row Type	R.H.S.	X_1	X_2	X_3	.	.	.	X_m	d_1	d_2	d_3	.	.	.	d_t
Minimize:																
Objective (TND)										1	1	1	.	.	.	1
Resource 1	L or G	B_1	a_{11}	a_{12}	a_{13}	.	.	.	a_{1n}							
Resource 2	L or G	B_2	a_{21}	a_{22}	a_{23}	.	.	.	a_{2n}							
Resource 3	L or G	B_3	a_{31}	a_{32}	a_{33}	.	.	.	a_{3n}							
"	"							
"	"							
"	"							
Resource m	"	B_m	a_{m1}	a_{m2}	a_{m3}	.	.	.	a_{mn}							
Year 1	G	0	D_{11}	D_{12}	D_{13}	.	.	.	D_{1n}	1						
Year 2	G	0	D_{21}	D_{22}	D_{23}	.	.	.	D_{2n}		1			.		
Year 3	G	0	D_{31}	D_{32}	D_{33}	.	.	.	D_{3n}			1				
"	"	"			
"	"	"		
"	"	"	
Year t	G	0	D_{t1}	D_{t2}	D_{t3}	.	.	.	D_{tn}							1
Gross Margins	E	λ	C_1	C_2	C_3	.	.	.	C_n							

TABLE XXVII (Continued)

[illegible]

TABLE XXVII (Continued)

MPSX/370 R1.6 PTF9 GEZIRA

PAGE 9 84/199

ACTIVITY	CO	WH	GN	SO	6FLB	7FLB	8FLB	9FLB	1.....1 ACTIVITY
LAND	1.00000	1.00000	1.00000	1.00000					LAND
6FL	.67000		6.42000	3.54000	1.00000-				6FL
7FL	.52000		4.92000	6.51000		1.00000-			7FL
8FL	5.82000			5.87000			1.00000-		8FL
9FL	9.90000		2.46000	3.50000				1.00000-	9FL
10FL	11.52000	.48000	.30000	.30000					10FL
11FL	5.46000	7.54000	.20000	15.43000					11FL
12FL	2.94000	7.50000	4.18000	5.61000					12FL
1FL	8.35000	.48000	2.12000	.80000					1FL
2FL	15.28000	1.92000							2FL
3FL	22.17000	1.88000							3FL
4FL	6.69000								4FL
5FL	.12000								5FL
6HL			33.51000	4.71000					6HL
7HL	1.01000		32.10000	21.65000					7HL
8HL	13.21000		13.14000	17.42000					8HL
9HL	16.32000		6.90000	1.38000					9HL
10HL	18.42000	.44000	1.08000	.68000					10HL
11HL	1.53000	2.13000	10.72000	22.05000					11HL
12HL	1.15000	2.93000	36.58000	40.96000					12HL
1HL	11.95000	11.95000	2.28000	2.00000					1HL
2HL	75.10000	1.76000							2HL
3HL	79.46000	.68000							3HL
4HL	30.13000	1.94000							4HL
OCCDWH	330.26100	140.59000							OCCDWH
OCCNSO			107.00000	87.71600					OCCNSO
ICTR	197.40400-	116.02900-							ICTR
IW1	28.50000		29.00000	25.00000					IW1
IW2	30.30000	25.00000	24.50000	17.80000					IW2
IW3	30.30000	25.00000	21.50000						IW3
IW4	30.30000	16.90000	18.00000						IW4
IW5	30.30000	21.80000	15.00000						IW5
IW6	28.50000	26.90000							IW6
SSC				1.00000					SSC
YR83	126.98400-	127.87300	37.48500-	21.95000-					YR83
YR82	112.62500	100.04100-	60.16300-	35.45500-					YR82
YR81	184.95600-	130.24400-	21.03300	32.08500					YR81
YR80	128.52800-	114.54300-	9.82800-	1.83800					YR80
YR79	110.58000	128.44800-	39.31400-	39.39500-					YR79
YR78	184.96600	116.52300	41.31700	23.44400-					YR78
YR77	119.45000	114.19800	19.88100-	4.93000-					YR77
YR76	167.37000-	100.89000	17.30900-	1.28800-					YR76
YR75	114.94800-	113.31300-	116.08200	316.62400					YR75
YR74	148.09200	100.61200	101.45800	117.44700					YR74
YR73	160.33900	115.69300	108.50200	35.25500					YR73
YR72	124.72700	115.29900	95.03900-	112.60200-					YR72
YR71	177.51600	114.50300-	109.37400-	100.17800-					YR71
AVGM	342.70000	52.72800	196.60500	135.79100					AVGM

TABLE XXVII (Continued)

MPSX/370 R1.6 PTF9 GEZIRA

ACTIVITY	PAGE 10 84/199								2....1 ACTIVITY
	10FLB	11FLB	12FLB	1FLB	2FLB	3FLB	4FLB	5FLB	
10FL	1.00000-	.	.	.	.	.	.	.	10FL
11FL	.	1.00000-	.	.	.	.	.	.	11FL
12FL	.	.	1.00000-	.	.	.	.	.	12FL
1FL	.	.	.	1.00000-	.	.	.	.	1FL
2FL	1.00000-	.	.	.	2FL
3FL	1.00000-	.	.	3FL
4FL	1.00000-	.	4FL
5FL	1.00000-	5FL

MPSX/370 R1.6 PTF9 GEZIRA

ACTIVITY	PAGE 11 84/199								3....1 ACTIVITY
	FACAPTR1	FACAPTR2	6HLB	7HLB	8HLB	9HLB	10HLB	11HLB	
6HL	.	.	1.00000-	.	.	.	.	.	6HL
7HL	.	.	.	1.00000-	.	.	.	.	7HL
8HL	1.00000-	.	.	.	8HL
9HL	1.00000-	.	.	9HL
10HL	1.00000-	.	10HL
11HL	1.00000-	11HL
OCCDWH	1.00000-	.	.50000	.45800	.41700	.37500	.33300	.29200	OCCDWH
OCGNSO	.	1.00000-	.50000	.45800	.41700	.37500	.33300	.29200	OCGNSO
FLOCTR	1.00000	1.00000	.	.	.	.	.	.	FLOCTR
6HLMAX	.	.	1.00000	.	.	.	.	.	6HLMAX
7HLMAX	.	.	.	1.00000	.	.	.	.	7HLMAX
8HLMAX	1.00000	.	.	.	8HLMAX
9HLMAX	1.00000	.	.	9HLMAX
10HLMAX	1.00000	.	10HLMAX
11HLMAX	1.00000	11HLMAX
AVGM	.	.	.50000-	.50000-	.50000-	.50000-	.50000-	.50000-	AVGM

TABLE XXVII (Continued)

MPSX/370 R1.6 PTF9 GEZIRA

PAGE 12 84/199

ACTIVITY	12HLB	1HLB	2HLB	3HLB	4HLB	5HLB	ICB	SCB1	4.....1 ACTIVITY
12HL	1.00000-	.	.	.	.	.	.	.	12HL
1HL	.	1.00000-	.	.	.	.	.	.	1HL
2HL	.	.	1.00000-	.	.	.	.	.	2HL
3HL	.	.	.	1.00000-	.	.	.	.	3HL
4HL	.	.	.	.	1.00000-	.	.	.	4HL
5HL	.	.	.	.	.	1.00000-	.	.	5HL
OCCOWH	.25200	.20800	.16600	.12500	.08300	.04200	1.00000-	1.00000-	OCCOWH
OCGNSO	.25200	.20800	.16600	.12500	.08300	.04200	.	.	OCGNSO
ICTR	.	.	.	.	.	.	1.00000	.	ICTR
ICMAX	.	.	.	.	.	.	1.00000	.	ICMAX
12HLMAX	1.00000	.	.	.	.	.	.	.	12HLMAX
1HLMAX	.	1.00000	.	.	.	.	.	.	1HLMAX
2HLMAX	.	.	1.00000	.	.	.	.	.	2HLMAX
3HLMAX	.	.	.	1.00000	.	.	.	.	3HLMAX
4HLMAX	.	.	.	.	1.00000	.	.	.	4HLMAX
5HLMAX	.	.	.	.	.	1.00000	.	.	5HLMAX
SC	.	.	.	.	.	.	.	1.00000	SC
AVGM	.50000-	.50000-	.50000-	.50000-	.50000-	.50000-	.10000-	.50000-	AVGM

MPSX/370 R1.6 PTF9 GEZIRA

PAGE 13 84/199

ACTIVITY	SCB2	DYR83	DYR82	DYR81	DYR80	DYR79	DYR78	DYR77	5.....1 ACTIVITY
C	.	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	C
OCGNSO	1.00000-	.	.	.	.	.	.	.	OCGNSO
SC	1.00000	.	.	.	.	.	.	.	SC
YR83	.	1.00000	.	.	.	.	.	.	YR83
YR82	.	.	1.00000	.	.	.	.	.	YR82
YR81	.	.	.	1.00000	.	.	.	.	YR81
YR80	.	.	.	.	1.00000	.	.	.	YR80
YR79	.	.	.	.	.	1.00000	.	.	YR79
YR78	.	.	.	.	.	.	1.00000	.	YR78
YR77	.	.	.	.	.	.	.	1.00000	YR77
AVGM	.50000-	.	.	.	.	.	.	1.00000	AVGM

TABLE XXVII (Continued)

MPSX/370 R1.6 PTF9 GEZIRA

PAGE 14 84/199

ACTIVITY	DYR76	DYR75	DYR74	DYR73	DYR72	DYR71	B	CHCOL	6....1 ACTIVITY
C	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	15.00000	.	C
LAND	250.00000	.	LAND
6FL	250.00000	.	6FL
7FL	250.00000	.	7FL
8FL	250.00000	.	8FL
9FL	250.00000	.	9FL
10FL	250.00000	.	10FL
11FL	250.00000	.	11FL
12FL	250.00000	.	12FL
1FL	250.00000	.	1FL
2FL	250.00000	.	2FL
3FL	250.00000	.	3FL
4FL	250.00000	.	4FL
5FL	250.00000	.	5FL
FLOCTR	500.00000	.	FLOCTR
ICMAX	1500.0000	.	ICMAX
6HLMAX	140.00000	.	6HLMAX
7HLMAX	140.00000	.	7HLMAX
8HLMAX	140.00000	.	8HLMAX
9HLMAX	140.00000	.	9HLMAX
10HLMAX	210.00000	.	10HLMAX
11HLMAX	210.00000	.	11HLMAX
12HLMAX	210.00000	.	12HLMAX
1HLMAX	420.00000	.	1HLMAX
2HLMAX	420.00000	.	2HLMAX
3HLMAX	420.00000	.	3HLMAX
4HLMAX	420.00000	.	4HLMAX
5HLMAX	140.00000	.	5HLMAX
IW1	605.09000	.	IW1
IW2	605.09000	.	IW2
IW3	605.09000	.	IW3
IW4	481.95000	.	IW4
IW5	481.95000	.	IW5
IW6	481.95000	.	IW6
YR76	1.00000	.	.	.	.	.	.	.	YR76
YR75	.	1.00000	.	.	.	.	.	.	YR75
YR74	.	.	1.00000	.	.	.	.	.	YR74
YR73	.	.	.	1.00000	.	.	.	.	YR73
YR72	1.00000	.	.	.	YR72
YR71	1.00000	.	.	YR71
AVGM	848.29800	50.00000-	AVGM

APPENDIX D

CALCULATION OF EXPORT PARITY PRICES

TABLE XXVIII
ESTIMATION OF EXPORT PARITY PRICE PER TON OF COTTON EXPRESSED IN
1982 CONSTANT PRICES, 1971-83

Particulars		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
CIF price ^a (European Ports)	(\$)	860.00	786.69	1068.73	988.11	965.51	998.72	813.94	962.34	727.19	719.89	434.97	462.87	397.95
Shipping cost ^b	(\$)	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42
FOB price (Port Sudan)	(\$)	821.58	748.27	1030.31	949.69	927.09	960.09	775.52	923.92	688.77	681.47	396.55	424.45	359.53
FOB price in domestic currency ^c	(Ls.)	410.790	374.135	515.155	474.845	463.545	640.060	517.013	615.947	688.770	681.470	708.125	757.946	642.018
Port handling cost ^b	(Ls.)	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430
Transportation ^b from Scheme to Port	(Ls.)	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220
Export parity price per ton	(Ls.)	394.14	357.485	498.505	458.195	446.895	623.410	500.363	599.297	672.12	664.820	691.475	741.296	625.368

^aSource: FAO Commodity Review.

^bShipping, handling and transportation costs are based on World Bank (1979) estimations.

^cFOB price is converted to domestic currency using official exchange rate for foreign currency as the market equilibrium rate.

TABLE XXIX
ESTIMATION OF EXPORT PARITY PRICE PER TON OF WHEAT EXPRESSED IN
1982 CONSTANT PRICES, 1971-83

Particulars		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
CIF price ^a (European Ports)	(\$)	420.24	363.78	317.61	493.68	675.43	481.03	305.63	359.40	419.85	339.11	352.41	325.50	336.15
Shipping cost ^b	(\$)	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42
FOB price (Port Sudan)	(\$)	381.82	325.36	279.19	455.26	637.01	442.61	267.21	320.98	381.43	300.68	313.99	287.08	297.73
FOB price in domestic currency ^c	(Ls.)	190.910	162.680	139.595	227.630	318.505	295.073	178.140	213.987	381.430	300.680	560.696	512.643	531.661
Port handling cost ^b	(Ls.)	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420
Transportation ^b from Scheme to Port	(Ls.)	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220
Export parity price per ton	(Ls.)	174.260	146.030	122.945	210.980	301.855	278.423	161.490	197.337	364.780	284.030	544.046	495.993	515.011

^aSource: FAO Commodity Review.

^bShipping, handling and transportation costs are based on World Bank (1979) estimations.

^cFOB price is converted to domestic currency using official exchange rate for foreign currency as the market equilibrium rate.

TABLE XXX

ESTIMATION OF EXPORT PARITY PRICE PER TON OF GROUNDNUT EXPRESSED IN
1982 CONSTANT PRICES, 1971-83

Particulars		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
CIF price ^a (European Ports)	(\$)	534.77	412.43	484.07	550.89	399.34	342.44	344.12	318.74	265.20	177.10	178.52	144.26	187.91
Shipping cost ^b	(\$)	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42
FOB price (Port Sudan)	(\$)	496.35	374.01	445.659	512.47	360.92	304.02	305.75	310.32	226.78	138.68	140.10	105.84	149.49
FOB price in domestic currency ^c	(Ls.)	248.175	187.005	222.825	256.235	180.460	202.680	203.333	206.880	226.780	138.680	250.179	189.000	266.946
Port handling cost ^b	(Ls.)	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430
Transportation ^b from Scheme to Port	(Ls.)	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220
Export parity price per ton	(Ls.)	231.525	170.355	206.175	239.585	163.810	186.030	187.333	190.230	210.130	122.030	233.529	172.350	250.296

^aSource: FAO Commodity Review.^bShipping, handling and transportation costs are based on World Bank (1979) estimations.^cFOB price is converted to domestic currency using official exchange rate for foreign currency as the market equilibrium rate.

TABLE XXXI

ESTIMATION OF EXPORT PARITY PRICE PER TON OF SORGHUM EXPRESSED IN
1982 CONSTANT PRICES, 1971-83

Particulars		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
CIF price ^a (European Ports)	(\$)	369.33	440.54	258.48	451.37	739.59	249.27	511.24	336.36	224.88	609.09	209.73	280.04	319.39
Shipping cost ^b	(\$)	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42	38.42
FOB price (Port Sudan)	(\$)	330.91	402.12	220.06	412.95	701.17	210.85	472.82	297.94	186.46	570.67	171.31	241.62	280.97
FOB price in domestic currency ^c	(Ls.)	165.455	201.060	110.030	206.475	350.585	140.567	315.213	198.627	186.460	570.670	305.911	431.464	501.732
Port handling cost ^b	(Ls.)	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430	3.430
Transportation from Scheme to Port ^b	(Ls.)	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220	13.220
Export parity price per ton	(Ls.)	148.805	184.410	93.380	189.825	333.935	123.917	298.563	181.977	169.810	554.020	289.201	414.814	485.082

^aSource: FAO Commodity Review.^bShipping, handling and transportation costs are based on World Bank (1979) estimations.^cFOB price is converted to domestic currency using official exchange rate for foreign currency as the market equilibrium rate.

TABLE XXXII

ESTIMATION OF GROSS MARGINS PER FEDDAN OF COTTON USING
EXPORT PARITY PRICES EXPRESSED IN 1982
CONSTRAINT PRICES, 1971-83

Year	Export Parity Price (Ls./ton)	Yield (Tons/fed.)	Gross Returns (Ls./fed.)	Cost of Production (Ls./fed.)	Gross Margins (Ls./fed.)
1971	394.140	0.782	308.217	117.535	190.683
1972	357.485	0.713	254.887	119.235	135.651
1973	498.505	0.583	290.628	120.508	170.120
1974	458.195	0.723	331.275	171.078	160.179
1975	446.895	0.657	293.610	151.682	141.928
1976	623.410	0.388	241.883	184.977	56.906
1977	500.363	0.523	261.690	154.335	107.355
1978	599.297	0.613	367.369	171.383	195.986
1979	672.120	0.467	313.880	184.106	129.774
1980	664.820	0.380	252.632	171.923	80.707
1981	691.475	0.329	227.495	158.302	69.193
1982	741.296	0.555	411.419	222.665	188.754
1983	625.368	0.671	419.622	251.350	<u>168.272</u>
Mean					138.116

TABLE XXXIII

ESTIMATION OF GROSS MARGINS PER FEDDAN OF WHEAT USING
EXPORT PARITY PRICES EXPRESSED IN 1982
CONSTANT PRICES, 1971-83

Year	Export Parity Price (Ls./ton)	Yield (Tons/fed.)	Gross Returns (Ls./fed.)	Cost of Production (Ls./fed.)	Gross Margins (Ls./fed.)
1971	174.260	0.367	63.953	40.300	23.653
1972	146.030	0.512	74.767	50.564	24.203
1973	122.945	0.668	82.127	53.485	28.642
1974	210.980	0.800	168.784	64.421	104.363
1975	301.855	0.386	116.516	54.365	62.151
1976	278.423	0.388	108.028	45.385	62.643
1977	161.490	0.580	93.664	64.000	29.664
1978	197.337	0.471	92.946	61.190	31.756
1979	364.780	0.251	91.560	86.346	5.214
1980	284.030	0.476	135.198	78.477	56.721
1981	544.046	0.500	272.023	120.840	151.183
1982	495.993	0.400	198.397	112.665	85.732
1983	515.011	0.694	357.418	177.961	<u>179.456</u>
Mean					51.225

TABLE XXXIV

ESTIMATION OF GROSS MARGINS PER FEDDAN OF GROUNDNUT USING
EXPORT PARITY PRICES EXPRESSED IN 1982
CONSTRAINT PRICES, 1971-83

Year	Export Parity Price (Ls./ton)	Yield (Tons/fed.)	Gross Returns (Ls./fed.)	Cost of Production (Ls./fed.)	Gross Margins (Ls./fed.)
1971	231.525	0.413	95.620	61.869	33.751
1972	170.355	0.501	85.348	60.884	24.469
1973	206.175	1.250	257.719	51.333	206.386
1974	239.585	1.250	299.481	49.000	250.481
1975	163.810	1.500	245.715	53.944	191.771
1976	186.030	0.767	142.685	52.667	90.018
1977	187.333	1.200	224.800	52.816	171.984
1978	190.230	1.070	203.546	50.671	152.875
1979	210.130	0.872	183.233	50.000	133.233
1980	122.030	1.200	146.436	59.135	87.301
1981	233.529	0.605	141.285	56.516	84.769
1982	172.350	1.200	206.820	49.486	157.334
1983	250.296	1.200		69.550	<u>200.805</u>
Mean					134.725

TABLE XXXV

ESTIMATION OF GROSS MARGINS PER FEDDAN OF SORGHUUM USING
EXPORT PARITY PRICES EXPRESSED IN 1982
CONSTRAINT PRICES, 1971-83

Year	Export Parity Price (Ls./ton)	Yield (Tons/fed.)	Gross Returns (Ls./fed.)	Cost of Production (Ls./fed.)	Gross Margins (Ls./fed.)
1971	148.805	0.507	75.444	57.743	17.701
1972	184.410	0.436	80.403	50.240	30.163
1973	93.380	1.000	93.380	39.072	54.308
1974	189.825	0.750	142.369	32.483	109.885
1975	333.935	0.623	208.042	39.474	168.568
1976	123.917	0.655	81.166	31.338	49.827
1977	298.563	0.354	105.691	28.909	76.782
1978	181.977	0.427	77.704	28.771	48.933
1979	169.810	0.500	84.905	29.307	55.598
1980	554.020	0.250	138.505	30.463	108.042
1981	289.201	0.400	115.680	29.397	86.283
1982	414.814	0.500	207.407	41.480	165.927
1983	485.082	0.523	253.698	46.596	<u>207.102</u>
Mean					90.717

VITA 2

Abdelhalim Hamid Mohamed

Candidate for the Degree of

Doctor of Philosophy

Thesis: RESOURCE ALLOCATION AND ENTERPRISE COMBINATION IN A RISKY
ENVIRONMENT: CASE STUDY OF THE GEZIRA SCHEME, SUDAN

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Elsagai, Sudan, January 1, 1952, the son
of Mr. and Mrs. Hamid Mohamed Khalifa.

Education: Graduated from Merowie High School, March 1968,
received a Bachelor of Science degree in Agricultural
Economics from Khartum University in March, 1973; received a
Master of Science degree in Agricultural Economics from Leeds
University, England, in June 1979; completed requirements for
the Doctor of Philosophy degree at Oklahoma State University
in December, 1984.

Professional Experience: Assistant Agricultural Economist,
Agricultural Economics Department, Ministry of Agriculture,
Sudan 1973-75, Agricultural Economist, Rahad Agricultural
Corporation, Sudan 1975-1977; Researcher, Arab Planning
Institute, Kuwait, 1980-present.

Professional Organizations: Member of American Agricultural
Economics Association, Western Agricultural Economics
Association, Southern Agricultural Economics Association,
Oklahoma Agricultural Economics Association, and fellowship,
Economic Development Institute of the World Bank.