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Institutional Change, Incentive Effects, and Choice of Technology in Sudan's Irrigated Subsector

A Model of the Rahad Scheme

Brian C. D'Silva
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INSTITUTIONAL CHANGE, INCENTIVE EFFECTS, AND CHOICE OF TECHNOLOGY IN SUDAN'S IRRIGATED SUBSECTOR: A MODEL OF THE RAHAD SCHEME. By Brian C. D'Silva and Kamil I. Hassan. Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture. ERS Staff Report No. AGES870922.

ABSTRACT

Sudan's irrigated subsector is the largest and among the most modern in Sub-Saharan Africa. A linear programming model of an average farm in the Rahad scheme is used to analyze the implications of technological and institutional change for cropping patterns, farm income, and demand for imported inputs. A base run and several alternative scenarios test how tenant farmers would react to a number of incentives and constraints.

Keywords: Irrigation, resource use, decisionmaking, technology, institutions, Sudan.

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FOREWORD

This report is the third in a series of research reports on the agricultural sector of Sudan. Much of the data and information used in these reports were collected when Brian D'Silva was resident at the University of Khartoum, Sudan, under a Ford Foundation grant.

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A NOTE ON CURRENCY

The currency of Sudan is the Sudanese pound (LS). Sudan has had a variety of exchange rate regimes. Several devaluations have taken place over the last 6 years. In 1980, LS1.0 was valued at $2.80, while in 1986 LS2.5 = $1 at the official rate, and the street rate was LS5.0 = $1. All cotton and gum Arabic exports and inputs (such as fertilizer and jute sacks) are valued at LS2.5 = $1, while other agricultural exports are valued at an effective rate of LS3.0 = $1.

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INTRODUCTION

Sudan's irrigated subsector, the largest and among the most modern in Sub-Saharan Africa, has historically been a major source of the country's foreign exchange earnings, primarily through production and export of cotton. However, a decline in export earnings, combined with an accumulated external debt of over US$9 billion and debt servicing reaching US$1 billion in 1985, has focused attention on the underlying productive capacity of the subsector and its ability to generate increased foreign exchange earnings. Recent macroeconomic policy changes such as exchange rate changes, together with producer price incentives and institutional change initiated in the subsector, have had less than complete success, primarily due to the structure of the economy, the irrigated subsector, and the effects of a 3-year drought.

An earlier report delineated issues for policy analysis in the irrigated subsector, such as changing cropping patterns, technological change, and institutional change (2). 1/ As changing cropping patterns could be related to institutional change, this report analyzes technological and institutional change in the irrigated subsector, and their implications for crop production, tenant (farmer) income, and demand for imported inputs. Construction and use of a linear programming (LP) model of an average farm in the Rahad scheme helps us analyze these effects.

The Rahad scheme is among the newest in Sudan and has been in operation since 1976/77. The majority of tenants are the original inhabitants of the area. These were originally nomads prior to the start of the scheme, which was an attempt to settle the people in the area. Tenancy (farm) sizes and cropping patterns are fixed for over 90 percent of the scheme tenants. Most (over 80 percent) of tenants have 22-feddan tenancies, with 11 feddan planted to medium staple (MS) cotton and 5.5 feddan each to dura (sorghum) and groundnuts (1 feddan = 1.03 acres). Due to the role of the scheme in provision and use of inputs, tenants operate in a restrictive institutional environment. Hence, tenant choice focuses primarily on use of inputs under their control, such as labor and capital.

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1/ Underscored numbers in parentheses refer to items in the References section.

The scheme began under the institutional arrangement the individual account, which has been viewed as a means of both transmitting incentives from the scheme to the farm level and recovering costs of scheme-provided services from the tenants. 2/ The scheme was also the first to introduce mechanical harvesting technologies for cotton and groundnuts.

Implications of changes in institutional arrangements for estimating productive capacity can be analyzed in an LP framework by relaxing constraints on cropping patterns and choice of technology and input use for weeding, fertilizing, and harvesting operations. Incentive effects can be analyzed by transmitting world prices for export crops, traded inputs, and full costs for irrigation through the individual account system under both the present restrictions on tenant decisionmaking and a less restrictive environment.

This report is organized into six sections. The second section presents an overview of the Rahad farming system. Specific issues to be addressed by the Rahad model are discussed in the third section. An overview of the model is presented in the fourth section. Results from the base model and alternative policy runs are presented in the fifth section. Conclusions are in the last section. A computer listing of the base run in the GAMS (General Algebraic Modeling System) language is provided in the Appendix.

THE RAHAD FARMING SYSTEM

The Rahad scheme began in 1976/77 and is now in the 10th year of production. 3/ Its first phase of 300,000 feddan was completed in 1981/82. The first phase covers an area 25 kilometers wide and 140 kilometers long.

The Project Area

The Rahad scheme lies east of the Rahad River in the central clay plains of Sudan. The scheme is an irrigated agricultural production project, presently covering approximately 300,000 feddan, with a target area of 800,000 feddan.

Description of the Irrigation System

The Rahad's irrigation system is patterned after the Gezira scheme's design and use. Land is irrigated by gravity-flow water from the Blue Nile and the Rahad rivers, assisted by large electric pumps during off-peak times. A system of canals delivers water into minor canals, which are called Abu XX. Each Abu XX serves an individual number (or land area) that consists of 88 feddan, or 8 tenancies. Tenants have 11 feddan in each of 2 adjacent numbers, thereby having a tenancy size of 22 feddan.

Distribution of Tenants and Organization of the Scheme

The first phase of the project was completed in stages running from south to

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2/ A discussion of institutional arrangements in the irrigated subsector, such as the individual account and the joint account, can be found in (2).
3/ In this report, scheme is synonymous with project.

north. The scheme is divided into three divisions--the southern, central, and northern--with each division containing three blocks. Five villages exist in each block. Table 1 shows the distribution of tenants by division.

Cropping Patterns

As the scheme was planned to increase Sudan's export crop production, initially the scheme allowed farmers to grow only cotton and groundnuts. But, after protests, the farmers were allowed to include dura in their cropping pattern in 1981/82 to meet their subsistence needs. Each tenant is now supposed to allocate the 22-feddan tenancy by planting 11 feddan to cotton, 5.5 to groundnuts, and 5.5 to dura. (There is no fallow practiced in this rotation, so the cropping intensity is 100 percent.) (The above standard size tenancies constitute over 80 percent of the scheme.) In the ninth block (in the Northern Division), tenancies are 11 feddan, with farmers growing equal areas of only cotton and dura. There are also some vegetable tenancies, 5 feddan in area, distributed throughout the scheme. A majority of the vegetable tenancies are in the ninth block of the scheme.

Scheme Activities

The scheme operates under an institutional arrangement known as the individual account. Under this arrangement, each tenant maintains an account to pay costs for activities that the scheme provides. These accounts are maintained by crop. As the scheme also purchases cotton from the farmers, all costs assessed to the farmer are charged against the tenant's individual account, with the net returns given to the tenant. The range of activities provided to the tenant varies by crop, although some activities are common to all crops. Table 2 shows these activities by crop. Table 3 summarizes costs charged against the tenant's individual account by crop.

Because the scheme is the only purchaser of cotton in the area, it announces the price for cotton at the beginning of the picking season. The scheme also contracts hired labor, particularly for picking cotton, on behalf of tenants.

Table 1--Distribution of tenants

Division	Tenants
	Number
Southern	8,048
Central	2,739
Northern	1/ 1,760

1/ And vegetable tenancies.
Source: (4).

Tenants' Activities

Crop Activities

The tenant is involved in agricultural, nonagricultural, and off-farm activities. Tenants undertake all crop operations not done on their behalf by the scheme. Tenants usually sell groundnuts to merchants who come to the area at harvest time, while dura is retained for home consumption. Labor, for weeding and harvesting crops, is augmented by hired tenants. Hired labor for weeding is usually labor from the area, while labor to pick cotton is recruited predominantly from western Sudan.

Livestock Activities

The tenants were formerly nomads, and they still own livestock although it is illegal to keep livestock on the scheme. The livestock herds are usually kept away from the scheme and are looked after by members of the family or an individual hired from the village. Livestock are brought on to the scheme after harvest for grazing on crop residues.

Table 2--Scheme-provided activities, by crop

Activity	Cotton	Groundnuts	Dura
Land preparation	Yes	Yes	Yes
Ploughing/ridging	Yes	No	No
Planting	Yes	No	No
Fertilizer availability	Yes	No	No
Fertilizer application	No	No	No
Insecticide application	Yes	No	No
Insecticide availability	Yes	No	No
Herbicide availability	Yes	No	No
Herbicide application	Yes	No	No
Water availability	Yes	Yes	Yes
Mechanical weeding	No	No	No
Seed	Yes	Yes	No
Cotton picking (mechanical)	Yes	--	--
Cotton-stalk pulling	Yes	--	--
Cash advances for hiring labor	Yes	--	--
Groundnut digging and threshing	--	Yes	--
Cotton baling, sacking, and transporting to ginneries	Yes	--	--

-- = Not applicable.

Off-Farm Activities

Tenants may also engage in off-farm activities during the cropping season and in the off-season. The types of off-farm activities are numerous and trading is also common. Tenants work as hired laborers, merchants, and money lenders. This affects the availability of family labor for farm activities.

Credit Activities

Tenants borrow formally or informally, with formal credit being provided at a nominal interest rate of 11.5 percent in the form of cash advances the scheme gives to tenants for hiring labor (table 3). Merchants, shopkeepers, or relatives provide informal credit known as shail. Under the shail system, tenants have access to seasonal credit by pledging crops in the field as collateral. Shail credit consists of repayment of crops at a shail, or harvest price for the crop (usually lower than the market price at harvest time).

Table 3--Costs charged against tenant's individual account, by crop, Rahad scheme, 1983/84 season

Item	Cost for--		
	Cotton	Groundnuts	Dura
		LS	
Land and water charges (per feddan)	48.00	33.00	32.00
Material inputs (per feddan)	204.68	15.50	7.40
Mechanical operations (per feddan)	27.36	18.20	18.20
Formal credit (by operation): 1/			
Sowing	42.91	--	--
Fertilizer application	12.67	--	--
Thinning	33.00	--	--
1st weeding	120.05	--	--
2nd weeding	80.22	--	--
3rd weeding	46.57	--	--
Harvesting and stalk pulling 2/	84.80	--	--
Total	420.22	66.70	57.60

-- = Not applicable.
1/ Formal credit is provided by the scheme primarily for cotton and the amounts shown are for a cotton tenancy of 11 feddan.
2/ Depends on yield level.
Source: (3).

Calendar of Cropping

The combination of activities undertaken on behalf of the tenant and by the tenant constitutes a calendar of tasks for each crop. This can help us understand the decisionmaking processes of the tenant. In our discussion of the decisionmaking process of the tenant, we assume that the tenant has a standard size tenancy (22 feddan) and grows cotton, groundnuts, and dura.

The cropping intensity of the scheme is 100 percent (there is no fallow), so land preparation for cotton could begin as soon as dura and groundnuts are harvested. However, availability of machinery and fuel determines the actual timing of this operation. Land preparation for dura and groundnuts is done later in the season, after cotton stalks have been removed. Planting is done by the scheme (by machine) and by the tenants (by hand). The first crop planted is groundnuts, with seed either provided by the scheme or from the tenant's stock. The variety of groundnuts used is Ashford. Groundnuts are usually planted by the tenant by hand between mid-May and mid-June. The tenant usually plants dura between mid-June and late July.

Cotton is planted in early to mid-July. The scheme is supposed to mechanically plant the cotton for most tenants. However, area planted mechanically for cotton has decreased from 100 percent in 1977/78 to 44 percent in 1981/82 due to lack of machinery. Groundnut area sown mechanically also decreased from 45 percent in 1978/79 to zero in 1981/82. Cotton sowing is supposed to be completed by August 15, as delays in sowing can reduce yields between 10-20 percent (2).

Weeding of dura and cotton begins in July, while weeding of groundnuts begins in June. Tenants usually hire labor for weeding on all three crops; the scheme provides cash advances for tenants for cotton weeding. Hired labor usually comes from within the scheme. This labor is referred to as resident hired labor, to distinguish it from the hired labor that migrates seasonally to the scheme from other regions to pick cotton.

Irrigation usually begins after planting, except for groundnuts, which need a preplanting irrigation. Water is released at a rate of up to 400 cubic meters per feddan, regardless of crop, at regular 14-day intervals until December 1, after which water availability determines irrigation. Irrigation varies by crop in amount and timing.

The scheme applies insecticides to cotton through contracts with companies who aerially spray the fields. Hence, the farmer has no control over the timing or duration of spraying, but the scheme charges the farmer a fixed cost.

Cotton is the only crop that the scheme requires to be fertilized. The scheme provides enough fertilizer for the cotton area planted. However, it is possible (although illegal) for tenants to divert some of this fertilizer to other crops, such as dura.

Dura harvesting begins in October, primarily with family labor. Most dura is usually retained for home consumption, but some is used to repay debts or as payment-in-kind for hired laborers who harvest cotton.

Harvesting of groundnuts can be done mechanically or manually. 4/ Area harvested (dug) mechanically for groundnuts was 56 percent in 1978/79, 21 percent in 1981/82, and 55 percent in 1983/84 when more mechanical groundnut diggers were procured. If labor is hired for harvesting groundnuts, it is usually under a share-cropping basis, with about half of the total output paid to the laborer for pulling, heaping, and threshing. Groundnuts are usually sold soon after harvest for cash or for debt repayment.

Cotton harvesting begins in December and continues until March. Two to three pickings of cotton are usually undertaken. Labor is hired to assist in cotton picking in a variety of ways. The scheme provides tenants with a cash advance to harvest cotton. The scheme can contract labor on behalf of the tenant, but costs are charged against the tenant's account. Labor can be contracted either directly by the farmer or by the village as a whole. Most of the labor contracted for picking comes from the western part of Sudan. Payment for labor is both in cash and in kind. Tenants usually transport the family, provide housing and food, and pay a cash incentive. Wages are paid on a piece-work basis, such as based on kantars picked. 5/ Once the cotton is picked, the tenant is responsible for transporting it from the fields to a collection point. The scheme provides the sacks and transportation to the ginnery, but charges these services to the tenant's account.

Tenants are responsible for cutting and removing cotton stalks. Removal is sometimes done mechanically on behalf of the tenants by the scheme. At this time, livestock are allowed to graze on the tenancies. After all costs are calculated and deducted, the scheme pays farmers their net returns.

ISSUES TO BE ADDRESSED BY THE RAHAD MODEL

Sudan has the largest irrigated subsector in Sub-Saharan Africa and an economy undergoing structural adjustment through policy changes. An analysis of factors affecting institutional and technological change helps determine the productive capacity of the subsector and its ability to generate foreign exchange. Some of the broader issues that need to be addressed are:

- Efficiency of resource use under alternative institutional arrangements within the subsector;
- Structure of incentives facing the subsector, their transmission from the macroeconomy to the farm level, and their effects on productivity;
- Implications of conflicting objectives between scheme management and tenants for resource use; and
- The extent of mechanization, choice of technologies, and relative dependence (compared with the rainfed subsectors) on imported inputs.

This report analyzes these issues at the farm and scheme level, using a model of the Rahad scheme.

4/ Mechanical harvesting of groundnuts could involve a combination of activities, depending on the type of machinery used. Groundnuts could be dug mechanically but threshed by hand, or vice versa. In some instances, a combination of digger-thresher is used.

5/ One kantar = 315 pounds of seed cotton.

Incentive Effects

The Rahad scheme uses the individual account system rather than the joint account system. Under the individual account, the scheme charges each tenant's account for costs the scheme incurs on behalf of the tenant (see table 3). These accounts are kept according to crop, and the charges are deducted from the gross value of the tenant's cotton production. 6/

The individual account has been viewed as a means to transmit incentives to individual tenants, because the system is supposed to reward the more productive tenants. But the individual account is affected by the relative prices that tenants receive for their crops and by land and water charges.

Relative Prices Received by Tenants for Crops Produced

The price of cotton is announced just before the cotton harvest season begins. Tenants receive net returns immediately after harvest. The cotton price is important because it is an incentive and it affects yield through picking intensity (as the scheme predetermines area planted). As the scheme also determines the costs of inputs charged to tenants, the scheme affects the profit margin on cotton and the relative profitability of cotton through that of groundnuts and dura. Prices for groundnuts are usually extremely low after harvest, as tenants are forced to sell to the few buyers (who are traders) for lack of storage facilities and to repay informal credit. In recent years, world medium staple cotton prices have been declining, and exchange rate adjustments have been taking place in Sudan. Prices of imported inputs should increase, but farmgate prices of cotton should also increase if the full effects of these changes (devaluations) are passed on to the farmer. As the scheme sets these prices and uses the individual account to transmit price effects, the extent and impact of these price transmissions need to be determined, especially on cotton production.

System of Land and Water Charges (LWC)

Each tenant is charged a fixed cost per feddan for land and water services under the individual account system. This cost varies by crop, primarily due to differences in area allocated to each crop and the number of irrigations required for each crop. The present system of determining the LWC is based on a fixed consumption schedule and not on actual water use. And, while in theory tenants cannot allocate water released for cotton to dura or groundnuts, tenants practice a system of night-watering (albeit illegal) that diverts water from cotton to dura or groundnuts.

6/ Prior to the 1981/82 season, the Gezira scheme operated under the "joint account" system, under which expenditures incurred by the scheme were deducted from the total revenues received from cotton sales. The net revenue was then divided among the government, scheme, and tenant by a predetermined ratio. The tenants' share was then divided by total scheme production of seed cotton to determine individual tenant shares. Hence, input costs were recovered per kantar of cotton produced, rather than per feddan of area planted. This system penalized the more productive cotton producers, whose actual per kantar costs were lower, but also guaranteed income for all producers.

The LWC is an important source of scheme income: it allocates costs by crop and recovers irrigation and land costs from the tenants. Analyzing the effects of changing LWC is important because recent estimates by the World Bank suggest that the present level of LWC does not constitute full cost recovery for the schemes and, therefore, represents a subsidy to the tenants (6). Furthermore, changes in cropping patterns in the irrigated subsector, either through a reduction in MS cotton area or through expansion of irrigated groundnuts area, affect the demand for water and its opportunity cost in alternative cropping patterns. As the individual account transmits LWC, the effects of these changes need to be determined, both under the present system of fixed cropping patterns and under a system of free tenant decisionmaking. These need to be evaluated in terms of tradeoffs between tenants' objective of maximizing income and scheme objectives of increasing cotton production and full cost recovery.

Institutional Change

Institutional change is related to the organization and use of resources in the scheme and at the farm level.

Choices of Crops and Crop Rotation

The present crop area allocations mandated by the scheme reflect the scheme's objective of maximizing production of crops (such as cotton and groundnuts) that earn foreign exchange. This selection also presupposes a set of farm operations to be done by the scheme, their timing, and resource requirements. An analysis of existing cropping patterns under the present system would indicate the extent to which resources are being used efficiently. An analysis of alternative cropping patterns through relaxing scheme-imposed constraints on crop area allocations would indicate the extent to which tenants' objectives of maximizing income conflict with scheme objectives. These analyses will enable us to determine tradeoffs between tenant and scheme objectives as well as implications for aggregate crop production and input use.

Conflicts Between Tenants' and Scheme Objectives

In addition to the area of crop and cropping patterns, there are other areas of conflict between tenant and scheme objectives. To achieve scheme objectives, tenants are required to follow a fixed rotation and to plant a fixed area to specific crops. Tenants are also restricted in their use of scheme-provided inputs. As the scheme controls the timing of major operations such as land preparation, irrigation, and insecticide spraying, the tenant can only affect the timing and intensity of those operations under his/her control--primarily weeding and harvesting. The tenant may, however, be undertaking forbidden activities, such as night-watering or allocating fertilizer to dura, to maximize income (from farm and nonfarm occupations) subject to meeting subsistence needs, which is contrary to the scheme's objective of maximizing cotton production.

The effect on output and resource use needs to be determined if the scheme frees tenant decisionmaking concerning area planted to various crops and the level of input use. The impact of imposing the schemes' objectives on the tenant can also be analyzed. The tradeoffs between the two objectives on output, input use, and tenant and scheme incomes can also be evaluated.

The example of fertilizer use could help illustrate this issue. Tenants are given a fixed amount of fertilizer for use on cotton. Tenants want, however, to use fertilizer on other crops, such as dura, for home consumption and payment-in-kind for hired labor. Because the scheme restricts the area on which tenants plant dura, production can only be increased through higher yields. Fertilizer increases yields of dura and, therefore, total output. The scheme forbids diverting fertilizer from cotton to other crops because that could depress cotton yields. In some instances, the scheme mixed herbicide with fertilizer to damage crops other than cotton. Fertilizer is also a scarce imported commodity requiring foreign exchange for its purchase. Reallocating fertilizer to nonexport crops could decrease export crop production levels and, hence, reduce potential export earnings.

Choice of Technology

The irrigated subsector is more capital intensive and depends more on imported inputs than do the rainfed subsectors (2). This, together with the perceived shortage of labor for key operations (especially for picking cotton), led scheme management to design the Rahad scheme at a higher level of mechanization than the Gezira scheme. This higher level produced larger tenancies and introduced mechanical cotton pickers and groundnut diggers and threshers into the scheme.

While key operations (such as land preparation) are done mechanically in Rahad, other operations (such as planting or applying fertilizer) could be done either mechanically or manually. The possibility exists for spraying herbicide or hand weeding, as well as for hand or machine harvesting for cotton and groundnuts. Adopting improved technologies, while increasing yields, could require additional monetary and nonmonetary resources. Chemical fertilizer requires increased labor for application, weeding, and harvesting. Therefore, the implications of technology choice for increased productivity needs to be analyzed along with the relative profitability and resource use of alternative technologies. Choice of technology is also related to tenant freedom of choice for chemical fertilizers used on crops other than cotton.

Some technologies used by the scheme require foreign exchange for their purchase: chemical fertilizers, herbicides, insecticides, and mechanical harvesters. Adopting these technologies should also be analyzed in relation to foreign exchange constraints. Use of these imported inputs is also related to the extent that changes in exchange rates are transmitted to the farm level, thereby affecting the relative profitability and use of these resources.

Labor Availability and Use

In addition to affecting the use of chemical and mechanical technologies, choice of technology is related to labor availability and use. The Rahad scheme's orientation toward mechanization favors the use of tenant, rather than hired labor; but labor shortages, especially for cotton harvesting, exist. However, hired labor primarily works on harvesting cotton. 7/ Hiring labor requires an available pool of labor and an adequate wage incentive, both cash and food in kind. Tenants may also find off-farm occupations more lucrative than working on farms, which could affect the intensity of family labor participation. Another factor affecting family labor participation in cotton activities is that scheme tenants have comparatively less experience in cotton production because they were nomads before the scheme started.

The Rahad model is used to examine: (a) the implications of the present and alternative cropping patterns for labor use, at the farm and scheme level; (b) how changes in the wage structure for hired labor and the tenant's off-farm opportunity cost affect the mix and availability of labor; (c) how choices of technology (both chemical and mechanical) in cropping activities affect the demand for labor (both hired and tenant).

OVERVIEW OF THE RAHAD MODEL

As over 80 percent of the Rahad scheme consists of 22-feddan tenancies with fixed area allocations (under present institutional arrangements), we constructed a linear programming model of an average farm in the Rahad scheme to analyze effects of institutional change, incentive effects, and technology choices. This section shows how we modeled the characteristics of the Rahad farming system and the tenants' choice of activities. Data used for the model came from a field survey conducted by the authors in the Rahad scheme during the 1983/84 cropping season. The survey focused on input use, production levels, and tenants' choice of technology (3). In addition, supplementary data collected by the Rahad socioeconomic unit are also used (5). Hence, input/output coefficients used in the model are actual rather than recommended.

The model maximizes net farm income, subject to meeting the subsistence needs of the tenant, the scheme-imposed constraints on cropping patterns, and use of scheme-provided inputs. Modifications to the model help analyze alternative policy issues. These modifications are the basis of generating alternative solutions under different scenarios, which are then compared with results from the base solution. Results are shown in the next section of the report. The appendix presents the computer output from the base solution of the GAMS package.

Land

A 22-feddan tenancy is modeled. Tenants are required to plant cotton, groundnuts, and dura. The actual area required to be planted depends on the assumptions being modeled. Relative profitability and availability of resources determine area planted to cotton and groundnuts, while tenant subsistence needs and availability of dura to pay cottonpickers determines area planted to dura. Hence, area planted to cotton (as in-kind wage, cotton-picking is related to area planted) and tenant family size determine area planted to dura.

7/ Elseed reports that only 15 percent of potential family labor works on cropping activities in the Rahad scheme (4).

Labor

The crop labor requirements require that all preplanting operations for all crops are done mechanically by the scheme. All planting is done manually while choice of technology exists for weeding and harvesting activities. Spraying of insecticides is done aerially for cotton and, hence, requires no tenant labor.

There are three sources of labor: family labor, hired resident labor, and hired migrant labor who are only involved in picking cotton. Family labor availability is determined by family size, adjusted for age and sex. Up to 15 percent of total family labor is available at zero opportunity cost. Hired resident labor is paid a wage rate of LS2.5 per day, and is paid working capital at the time of hiring. Family labor is also available at LS2.5 per day, but there is an upper bound in the model of 35 percent of family labor being used in this manner. This bound has been derived from family labor participation data.

Labor for picking cotton comes from migrant laborers from western Sudan. They are paid a lower cash wage rate than resident workers, but are also paid a wage in kind in the form of dura. The tenant must also pay relocation costs for the migrant workers and provide them with temporary shelter. Hence, labor costs can be allocated among family labor, hired resident labor, and hired migrant labor. Hiring of labor is constrained by availability of working capital, which comes from tenant sources, formal scheme-provided credit, and informal shail credit.

Capital

Tenants require working capital to hire labor, to purchase seed, and for consumption requirements to meet subsistence needs. There are several sources of tenant capital. Tenants are given a cash level, which can be carried forward to the next month if unused. Scheme-provided formal credit is available for crop operations at an interest rate of 11.5 percent. In shail, a ton of either groundnuts or dura is sold at a discount before the harvest. The shail price will be lower than the market price because the shail price depends on the expected market price, the implicit interest rate being charged, and the duration of the loan. A ton of crop that is being shailed is not available for sale and is deducted from the overall production level of the crop. All formal and informal credit is accounted for separately, with formal credit deducted with other scheme charges from the tenant's cotton revenues.

Water

Crop water requirements are specified by crop and month. The model determines the number of irrigations by crop and the timing of these irrigations. The scheme releases 400 cubic meters per feddan for each irrigation, regardless of crop to be fertilized. Cotton receives the most irrigations, followed by groundnuts, then sorghum. At the farm level, water constraints are not binding due to fixed water allocation.

Technologies

Choice of technology is specified for three levels of fertilization for all three crops. Technology choice also is specified for using herbicide or for weeding cotton by hand. Cotton and groundnuts are harvested manually or by machine. The choices available to the tenants are analyzed under various assumptions, ranging from the existing situation of minimal choice to a situation where the tenants face all of the specified choices. Labor requirements for fertilizing, weeding, and harvesting are adjusted for each level of technology as are yields and material input costs. We also model different levels of fertilizer availability.

Assumptions Used in Different Policy Scenarios

The model is used to analyze effects of institutional change, incentive effects, and technology choice. The base solution of the model is determined with assumptions reflecting the present situation. Alternative scenario runs of the model are then made by modifying the tenant choice of activities and constraint levels. Table 4 shows the different assumptions and choices used.

Table 4--Model specification under different policy simulations and policy options

Policy simulation	Policy option: Institutional change	Policy option: Incentive effects	Policy option: Technology choice
Base run (present situation)	Cotton = 11 feddan Groundnuts=5.5 feddan Dura = 5.5 feddan	Individual account system with scheme-determined costs and prices	Fertilizer use is only on cotton at fixed level No herbicide use No mechanical harvester use
Scenario 1	Cotton = 11 feddan Tenant choice for area allocated to groundnuts and dura	LWC increased to reflect full cost recovery Formal credit for cotton increased by 25 percent	Tenant has choice in fertilizer levels and use among different crops Tenant has choice of herbicide for use on cotton
Scenario 2	Tenant has complete choice in crop area allocation	LWC as in base run World prices transmitted for inputs and outputs at official exchange rate	Tenant has complete choice in fertilizer use, herbicide use, and cotton harvesting technology
Scenario 3	Tenant has complete choice in crop area allocation	LWC reflects full cost recovery Formal credit increased by 25 percent World prices transmitted for inputs and outputs at shadow exchange rate	Tenant has complete choice in use of fertilizer, herbicide (for cotton), and technology for groundnuts and harvesting cotton

RESULTS OF THE BASE RUN AND DIFFERENT ALTERNATIVES

The results of the base run will be analyzed with specific reference to: area allocated to different crops, labor use by type of labor, water use by month and crop, individual account costs, production levels by crop, gross farm income, and net farm income. In addition, when necessary, shadow prices and reduced costs are presented and discussed.

The Base Model

In the base run, all of the cotton, dura, and groundnut area is used. Therefore, sufficient dura is planted to meet tenant subsistence and needs of cottonpickers. The shadow price of all land is LS76.9, while the reduced cost for cotton land is LS149.4 and LS34.4 for dura land (table 5). Notice the relative profitability of cotton at base level yields and prices.

In analyzing labor use, hired resident labor (temporary labor) is used for all the months between June and December and in March. The highest level of hired resident labor occurs in August. The highest level of migrant cottonpickers occurs in January. Labor costs vary by month, with August and January having the highest levels at LS227 and LS210, respectively. Total labor costs are LS1,563.

Cotton used 10 irrigations, compared with 6 for groundnuts and 5 for dura, reflecting their respective water needs. An analysis of gross income and individual account costs by crop shows the relatively higher costs associated with cotton production, compared with those of groundnuts and dura. Cotton production accounted for over half the labor costs and over half of the formal credit. This relatively high cost of production kept net farm income at LS2,364 for the 22-feddan tenancy.

In interpreting these results, the following assumptions should be emphasized: (a) the tenant is following a scheme-determined cropping pattern; (b) the higher relative net profitability of cotton is due to scheme-guaranteed prices; (c) as much of individual account costs are related to cotton, changes in the cost structure are primarily due to devaluations, and changes in relative prices could affect resource allocation at the farm level; (d) the use of water transfer activities may not reflect actual farm-level constraints due to scheme- or environmentally-determined constraints on water availability.

Alternatives to the Base Model

The Rahad model helps analyze effects of specific alternative policy options at the farm level. Alternative policies must address: incentive effects such as relative price changes, and full cost recovery of land and water charges; conflicts between tenant and scheme objectives; choices of crops and crop rotations; labor availability and use; and choice of technology.

Because alternative model scenarios have implications for more than one policy option, a limited number of alternative scenarios are run and analyzed. The modifications to the base model in each of these scenarios are discussed below.

Table 5--Results from the base run

Item	Area planted and shadow prices: Area planted	Shadow price	Reduced cost
	Feddan	------LS/feddan------	
Cotton (MS)	11.00	--	149.4
Groundnuts	5.50	--	--
Dura	4.75	--	34.4
Total	21.25	All land 76.9	--

Item	Labor use and cost: Labor use: Family 1/	Temporary	Family 2/	Cotton-picking	Labor costs
	---------------Labor days---------------				LS
January	12.6	0	0	84.20	210.50
February	12.6	0	0	26.40	66.10
March	12.6	44.70	29.40	2.50	184.00
April	12.6	0	0	47.90	119.70
May	12.6	0	0	0	0
June	12.6	18.20	0	0	36.40
July	12.6	84.50	0	0	169.15
August	12.6	113.75	0	0	227.51
September	9.1	79.50	0	0	159.00
October	12.6	46.50	0	0	93.00
November	12.6	55.40	0	0	110.90
December	12.6	93.20	0	0	186.50
Total	147.7	535.75	29.40	161.00	1,562.76

Item	Water use by crop: Cotton	Groundnuts	Dura
	Number of irrigations 3/		
January	1	1	0
February	1	0	0
March	1	0	0
April	0	0	0
May	0	0	0
June	0	1	1
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	1	0	0
December	1	0	0

See footnotes at end of table.

Continued--

Table 5--Results from the base run--Continued

Item	Production, gross income, and net income
Production:	
Cotton	78.1 kantars
Groundnuts	77 sacks
Dura	38 sacks
	LS
Gross income from:	
Cotton	6,560.00
Groundnuts	1,231.00
Dura	1,064.00
Total	8,855.00
Individual account costs: 4/	
Cotton	3,080.00
Groundnuts	366.00
Dura	382.00
Total	3,828.00
Total labor costs	1,562.76
Formal credit costs	833.00
Net farm income	2,364.00

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

Scenario 1

This scenario makes several changes to the base model. In scenario 1.1, the tenant is forced to grow exactly 11 feddan of cotton, 5.5 feddan of groundnuts, and 5.5 feddan of dura. In scenario 1.2, the tenant is required to grow only 11 feddan of cotton and can reallocate the rest of the area in any manner between the other two crops. Scenario 1.3 gives tenants free choice: the tenant is not required to follow any prescribed cropping pattern.

Scenario 2

In this scenario, the three runs under scenario 1 are repeated, but with 3 alternative price scenarios for inputs and outputs. In scenario 2.1, groundnut and dura prices are increased, while cotton prices remain unchanged. In scenario 2.2, cotton prices are reduced to reflect world prices; groundnut and dura prices remain as in scenario 2.1. Scenario 2.3 increases the costs of traded inputs by the rate of devaluation, and charges full costs for land and water.

Results of Alternative Model Specifications

The results of alternative model specifications focusing on different policy changes will be discussed in terms of conflicts between scheme and tenant objectives and incentive effects.

Conflicts between Scheme and Tenant Objectives

The base model specified an upper bound on the area that could be planted to cotton (11 feddan), dura (5.5 feddan), and groundnuts (5.5 feddan). A longstanding conflict between tenant and scheme objectives concerns fixed area allocations to specific crops (the scheme's objective is to produce cotton, tenant's objectives are to the maximize income and provide for their own food needs). In the base run, subsistence needs are incorporated as a constraint. While tenants were required to follow the prescribed cropping pattern, relative profitability of crops and resource availability determined area planted to each crop (up to the maximum level specified).

The scheme's strictly prescribed cropping pattern would require tenants to plant exactly 11 feddan of cotton, 5.5 feddan of groundnuts, and 5.5 feddan of dura (scenario 1.1). If the scheme was interested only in producing a fixed level of cotton, the scheme would require tenants to grow 11 feddan of cotton and allow them freedom in deciding how the other 11 feddan should be allocated between groundnuts and dura (scenario 1.2). But if the tenant has complete freedom in allocating area planted according to maximizing income subject to available resources, relative prices would help determine areas allocated to each of the three crops (scenario 1.3). But since the scheme determines cotton prices and the costs of scheme-provided services, it could also determine the relative profitabilities of the three crops. Hence, an analysis of results from scenarios 1.1 to 1.3 indicates the extent to which scheme and tenant objectives can conflict or coincide under existing pricing arrangements. Tables 6-8 present the results of runs under scenarios 1.1-1.3.

Cotton is clearly the most profitable crop under the base level of yields and input and output prices. When tenants are given the choice, they plant over 60 percent of their land to cotton and the rest to dura (scenario 1.3). Dura is grown to meet household subsistence needs and the needs of cottonpickers. The net income under scenario 1.3 is the highest, nearly 30 percent greater than the base level. Only those with access to sources of credit other than scheme-provided credit could achieve the high level of production due to the high level of labor costs (LS1,791).

While the tenant's level of net income is closer to the base case, the cropping pattern differs in scenarios 1.1 and 1.2. When restricted to grow 11 feddan of cotton, tenants plant the remaining area to dura, suggesting the higher profitability of dura to groundnuts and the need of dura to meet household needs (scenario 1.2). The shadow price for land is highest under scenario 1.3, reflecting the profitability of cotton land. Changes in labor requirements reflect cropping patterns, reflecting the intensity of labor required by cotton. There are no restrictions on availability of labor hired to pick cotton.

Incentive Effects

Pricing decisions by the scheme affect the relative profitabilities of crops, and hence incentives, because the scheme determines output prices for cotton and prices for scheme-provided inputs. Scenarios 2.1-2.3 in tables 9-11 show how changes in relative prices affect tenant decisions.

Increasing dura prices (to reflect prices existing before the drought) and allowing tenants the freedom to decide how area should be allocated leads tenants to allocate all land to dura. The shadow price of land is LS367 per feddan. Labor costs for picking are reduced as cotton is not in the cropping pattern. Family labor is used during July-October and in December. In scenario 2.2, a decrease in the price of cotton leads to the same results as in scenario 2.1. World prices of MS cotton have declined over the past 2 years, but prices at the farm level in Rahad have increased. Hence, resources are allocated inefficiently when world prices are not passed on to the tenancies. In scenario 2.3, output prices change; input prices change to reflect full cost recovery; and exchange rates change (table 10). But because the tenant is forced to grow 11 feddan of cotton, this results in the negative reduced cost for cotton of LS284. Hence, reducing cotton area by 1 feddan could increase farm income LS284. Cropping patterns under this condition reduce net farm income from LS4,446 under scenarios 2.1 and 2.2 to LS644 in scenario 2.3 (the individual account costs for cotton are greater than the income received from cotton in this scenario).

The base run and the alternative scenarios show how price changes and free decisionmaking affect the farm's allocation of resources. Restricting tenants' flexibility in allocating area to crops may initially achieve scheme objectives. But the scheme will cause disincentives through increased costs (charged for cotton) if the scheme attempts to achieve cost recovery. But if the scheme does not attempt to recover costs, then the credit needs of the scheme (in effect, a subsidy) from the government increases, suggesting a misallocation of national resources.

Table 6--Results from scenario 1.1

Item	Area planted and shadow prices		
	Area planted	Shadow price	Reduced cost
	Feddan	LS/feddan	LS/feddan
Cotton (MS)	11.00	254.16	226.0
Groundnuts	5.50	104.90	76.9
Dura	5.50	--	111.3
Total	22.00		

Item	Labor use and cost				
	Labor use				Labor costs
	Family 1/	Temporary	Family 2/	Cotton picking	
	Labor days				LS
January	12.6	0	0	84.2	210.500
February	12.6	0	0	26.5	66.125
March	12.6	44.7	29.4	2.6	184.000
April	12.6	0	0	47.9	119.750
May	12.6	0	0	0	0
June	12.6	18.2	0	0	36.400
July	12.6	87.5	0	0	175.000
August	12.6	118.6	0	0	237.260
September	12.6	82.5	0	0	164.990
October	10.7	46.5	0	0	93.000
November	12.6	58.9	0	0	117.800
December	12.6	99.1	0	0	198.100
Total	149.3	556.0	29.4	161.2	1,602.925

Item	Water use by crop		
	Cotton	Groundnuts	Dura
	Number of irrigations 3/		
January	1	0	0
February	1	0	0
March	1	0	0
April	0	0	0
May	0	0	0
June	0	1	0
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	1	0	0
December	1	0	0

See footnotes at end of table.

Continued--

Table 6--Results from scenario 1.1--Continued

Item	Production, gross income, and net income
Production:	
Cotton	78 kantars
Groundnuts	77 sacks
Dura	44 sacks
	LS
Gross income from:	
Cotton	6,560
Groundnuts	1,078
Dura	1,232
Total	8,870
Individual account costs: 4/	
Cotton	3,080
Groundnuts	367
Dura	327
Total	3,774
Total labor costs	1,603
Formal credit costs	1,200
Net farm income	2,293

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

Table 7--Results from scenario 1.2

Item	Area planted and shadow prices		
	Area planted	Shadow price	Reduced cost
	Feddan	-----LS/feddan-----	
Cotton (MS)	11	--	115
Groundnuts	0	--	--
Dura	11	--	--
Total	22	All land 111.3	--

Item	Labor use and cost				
	Labor use				Labor costs
	Family 1/	Temporary	Family 2/	Cotton picking	
	---------------Labor days---------------				LS
January	12.6	0	0	84.20	210.500
February	12.6	0	0	26.45	66.125
March	12.6	44.712	29.4	2.55	184.000
April	12.6	0	0	47.90	119.750
May	12.6	0	0	0	0
June	12.6	18.200	0	0	36.400
July	12.6	89.600	0	0	144.200
August	12.6	117.355	0	0	255.960
September	12.6	81.707	0	0	176.540
October	6.3	45.200	0	0	93.000
November	12.6	60.325	0	0	96.900
December	12.6	97.250	0	0	224.500
Total	144.9	554.349	29.4	161.10	1,607.875

Item	Water use by crop		
	Cotton	Groundnuts	Dura
		Number of irrigations 3/	
January	1	0	0
February	1	0	0
March	1	0	0
April	0	0	0
May	0	0	0
June	0	1	1
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	1	0	0
December	1	0	0

See footnotes at end of table.

Continued--

Table 6--Results from scenario 1.1--Continued

Item	Production, gross income, and net income
Production:	
Cotton	78 kantars
Groundnuts	77 sacks
Dura	44 sacks
	LS
Gross income from:	
Cotton	6,560
Groundnuts	1,078
Dura	1,232
Total	8,870
Individual account costs: 4/	
Cotton	3,080
Groundnuts	367
Dura	327
Total	3,774
Total labor costs	1,603
Formal credit costs	1,200
Net farm income	2,293

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

Table 7--Results from scenario 1.2

Item	Area planted and shadow prices		
	Area planted	Shadow price	Reduced cost
	Feddan	-----LS/feddan-----	
Cotton (MS)	11	--	115
Groundnuts	0	--	--
Dura	11	--	--
Total	22	All land 111.3	--

Item	Labor use and cost				
	Labor use				Labor costs
	Family 1/	Temporary	Family 2/	Cotton picking	
	---------------Labor days---------------				LS
January	12.6	0	0	84.20	210.500
February	12.6	0	0	26.45	66.125
March	12.6	44.712	29.4	2.55	184.000
April	12.6	0	0	47.90	119.750
May	12.6	0	0	0	0
June	12.6	18.200	0	0	36.400
July	12.6	89.600	0	0	144.200
August	12.6	117.355	0	0	255.960
September	12.6	81.707	0	0	176.540
October	6.3	45.200	0	0	93.000
November	12.6	60.325	0	0	96.900
December	12.6	97.250	0	0	224.500
Total	144.9	554.349	29.4	161.10	1,607.875

Item	Water use by crop		
	Cotton	Groundnuts	Dura
	Number of irrigations 3/		
January	1	0	0
February	1	0	0
March	1	0	0
April	0	0	0
May	0	0	0
June	0	1	1
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	1	0	0
December	1	0	0

See footnotes at end of table.

Continued--

Table 7--Results from scenario 1.2--Continued

Item	Production, gross income, and net income
Production:	
Cotton	78.1 kantars
Groundnuts	0 sacks
Dura	88 sacks
	LS
Gross income from:	
Cotton	6,560.40
Groundnuts	0
Dura	2,464.00
Total	9,024.40
Individual account costs: 4/	
Cotton	3,080.44
Groundnuts	366.00
Dura	653.40
Total	4,099.84
Total labor costs	1,608.00
Formal credit costs	1,200.00
Net farm income	2,482.70

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

Table 8--Results from scenario 1.3

Item	Area planted and shadow prices		
	Area planted	Shadow price	Reduced cost
	Feddan	LS/feddan	
Cotton (MS)	16	254.16	--
Groundnuts	0	104.90	--
Dura	6	--	--
Total	22	All land 203.8	--

Item	Labor use and cost				
	Labor use				Labor costs
	Family 1/	Temporary	Family 2/	Cotton picking	
	Labor days				LS
January	12.6	0	0	128.2	320.50
February	12.6	0	0	44.2	110.50
March	12.6	19.40	29.4	22.8	184.00
April	12.6	0	0	75.4	188.50
May	12.6	0	0	0	0
June	12.6	32.20	0	0	64.40
July	12.6	71.60	0	0	143.20
August	12.6	126.88	0	0	253.76
September	12.6	94.62	0	0	189.24
October	9.3	46.50	0	0	93.00
November	12.6	30.20	0	0	60.40
December	12.6	92.00	0	0	184.00
Total	147.9	513.40	29.4	270.6	1,791.50

Item	Water use by crop		
	Cotton	Groundnuts	Dura
	Number of irrigations 3/		
January	1	0	0
February	1	0	0
March	1	0	0
April	0	0	0
May	0	0	0
June	0	1	0
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	1	0	0
December	1	0	0

See footnotes at end of table.

Continued--

Table 8--Results from scenario 1.3--Continued

Item	Production, gross income, and net income
Production:	
Cotton	113.6 kantars
Groundnuts	0 sacks
Dura	48 sacks
	LS
Gross income from:	
Cotton	9,542.40
Groundnuts	0
Dura	1,344.00
Total	10,886.40
Individual account costs: 4/	
Cotton	4,480.64
Groundnuts	0
Dura	356.40
Total	4,837.04
Total labor costs	1,791.50
Formal credit costs	1,200.00
Net farm income	3,057.86

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

Table 9--Results from scenario 2.1

Item	Area planted	Shadow price	Reduced cost
	Area planted and shadow prices		
	Feddan	------LS/feddan------	
Cotton (MS)	0	--	--
Groundnuts	0	--	--
Dura	22	--	--
Total	22	All land 367	--

Item	Labor use: Family 1/	Labor use: Temporary	Labor use: Family 2/	Labor use: Cotton picking	Labor costs
	Labor use and cost				
	---------------Labor days---------------				LS
January	0	0	0	0	0
February	0	0	0	0	0
March	0	92.0	0	0	184.0
April	0	0	0	0	0
May	0	0	0	0	0
June	0	0	0	0	0
July	12.6	73.2	0	0	146.4
August	12.6	130.4	0	0	260.8
September	12.6	74.3	0	0	148.6
October	0	46.2	0	0	93.0
November	12.6	88.6	0	0	177.2
December	12.6	156.8	0	0	313.6
Total	63.0	661.5	0	0	1,323.6

Item	Cotton	Groundnuts	Dura
	Water use by crop		
	Number of irrigations 3/		
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	1	0
July	2.0	1	1
August	1.0	1	1
September	1.0	1	1
October	1.0	1	1
November	0	0	0
December	0	0	0

See footnotes at end of table.

Continued--

Table 9--Results from scenario 2.1--Continued

Item	Production, gross income, and net income
Production:	
Cotton	0
Groundnuts	0
Dura	176 sacks
	LS
Gross income from:	
Cotton	0
Groundnuts	0
Dura	10,560.000
Total	10,560.000
Individual account costs: 4/	
Cotton	0
Groundnuts	0
Dura	1,306.800
Total	1,306.800
Total labor costs	1,323.600
Formal credit costs	1,200.000
Net farm income	4,446.185

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

Table 10--Results from scenario 2.2

Item	Area planted and shadow prices		
	Area planted	Shadow price	Reduced cost
	Feddan	LS/feddan	
Cotton (MS)	0	--	--
Groundnuts	20	--	--
Dura	2	--	--
Total	22	All land 367	--

Item	Labor use and cost				
	Labor use				Labor costs
	Family 1/	Temporary	Family 2/	Cotton picking	
	Labor days				LS
January	0	0	0	0	0
February	0	0	0	0	0
March	0	92.0	0	0	184.00
April	0	0	0	0	0
May	0	0	0	0	0
June	0	0	0	0	0
July	12.6	73.2	0	0	146.45
August	12.6	130.4	0	0	260.51
September	12.6	74.3	0	0	148.00
October	0	46.2	0	0	93.00
November	12.6	88.6	0	0	177.90
December	12.6	156.8	0	0	313.50
Total	63.0	661.5	0	0	1,323.36

Item	Water use by crop		
	Cotton	Groundnuts	Dura
	Number of irrigations 3/		
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	1	0
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	0	0	0
December	0	0	0

See footnotes at end of table.

Continued--

Table 10--Results from scenario 2.2--Continued

Item	Production, gross income, and net income
Production:	
Cotton	5/
Groundnuts	0
Dura	176 sacks
	LS
Gross income from:	
Cotton	0
Groundnuts	0
Dura	10,560.000
Total	10,560.000
Individual account costs: 4/	
Cotton	0
Groundnuts	0
Dura	1,306.800
Total	1,306.800
Total labor costs	1,323.360
Formal credit costs	1,200.000
Net farm income	4,446.185

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

5/ Opportunity cost for 1 kantar of cotton was LS512.

Table 11--Results from scenario 2.3

Item	Area planted	Shadow price	Reduced cost
	Feddan	------LS/feddan------	
Cotton (MS)	11.0	--	-284.9
Groundnuts	5.5	--	--
Dura	5.5	--	139.4
Total	22.0	All land 192.0	--

Item	Labor use: Family 1/	Labor use: Temporary	Labor use: Family 2/	Labor use: Cotton picking	Labor costs
	---------------Labor days	---------------			LS
January	12.6	0	0	84.2	210.500
February	12.6	0	0	26.5	66.125
March	12.6	44.7	29.4	2.6	184.000
April	12.6	0	0	47.9	119.750
May	12.6	0	0	0	0
June	12.6	18.2	0	0	36.400
July	12.6	87.5	0	0	175.000
August	12.6	118.6	0	0	237.260
September	12.6	82.5	0	0	164.990
October	10.7	46.5	0	0	93.000
November	12.6	58.9	0	0	117.800
December	12.6	99.1	0	0	198.100
Total	149.3	556.0	29.4	161.2	1,602.925

Item	Water use by crop: Cotton	Groundnuts	Dura
		Number of irrigations 3/	
January	1	0	0
February	1	0	0
March	1	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	2	1	1
August	1	1	1
September	1	1	1
October	1	1	1
November	1	1	0
December	1	0	0

See footnotes at end of table.

Continued--

Table 11—Results from scenario 2.3--Continued

Item	Production, gross income, and net income
Production:	
Cotton	78.1 kantars
Groundnuts	77 sacks
Dura	44 sacks
	LS
Gross income from:	
Cotton	4,686.000
Groundnuts	1,925.000
Dura	2,640.000
Total	9,251.000
Individual account costs: 4/	
Cotton	4,708.440
Groundnuts	575.850
Dura	519.200
Total	5,803.490
Total labor costs	1,603.000
Formal credit costs	1,200.000
Net farm income	644.585

-- = Not applicable.

1/ Refers to labor at zero wage rate. The shadow price is LS2.0 for all months when the level is 12.6. The shadow price for January and February is LS2.5.

2/ Refers to family labor that is paid a wage.

3/ At the rate of 400 cubic meters of water per feddan.

4/ See table 3.

CONCLUSIONS

Analysis of farm-level resource use and efficiency is a first step in analyzing the irrigated subsector of Sudan. Construction and use of a linear programming farm-level model helps analyze issues, such as conflicts between scheme and tenant objectives, incentive effects, and choice of technology. At present, scheme- and subsector-level decisionmakers determine cropping area allocations and price levels for cotton and scheme-provided inputs. Hence, they restrict the ability of tenants to respond to changing incentives. But scheme management can also control the structure of incentives through controlling price levels. Tenants will lose income and the economy will suffer foreign exchange losses if the scheme continues to control prices, but aligns them with world prices (as in the case of cotton).

While it may be difficult for a scheme like Rahad to move to a completely free environment of decisionmaking, the scheme can adjust cropping patterns, as has been done in the past for dura. Similarly, a realignment in cotton prices would be necessary to affect resource allocation at the farm level. Integrating the Rahad model with the Gezira model to form an irrigated subsector model will allow quantifying results. Integrating models will also show subsector response to changing cropping patterns across and in schemes, and implications for the capacity of the irrigated subsector to generate foreign exchange.

REFERENCES

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(3) D'Silva, B., Kamil I. Hassan, and others. "Choice of Harvesting Technology in Sudanese Irrigated Agriculture." Unpublished field survey data.

(4) Elseed, Gussim A. A. "Labor Supply Situation and Family Labor Participation in the Rahad Irrigation Project." Unpublished Masters thesis, Univ. Khartoum, Sudan, 1983.

(5) Sudan, Rahad Scheme, Socio-Economic Unit. Unpublished data.

(6) World Bank. Unpublished data.

APPENDIX: GAMS Computer Printout of the Base Run

```
GAMS 2.00 PC-86                                    90/01/01 02:21:20
G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
C O M P I L A T I O N

 *  THIS IS A LINEAR PROGRAMMING FARM LEVEL MODEL FOR THE RAHAD SCHEME
 *  AND INCLUDES CHARACTERISTICS SUCH AS IRRIGATION AND THREE TYPES OF
 *  LABOR, AND TAKES INTO ACCOUNT FORMAL CREDIT AS WELL AS MODELS THE
 *  INDIVIDUAL ACCOUNT*
 *

  SET C CROP-COMMODITY  /COTTMS, GNUTS, DURA /

      TM TIME PERIODS  /7,8,9,10,11,12,1,2,3,4,5,6 /

       Z DUMMY /ZER, ONE /

       OPER COSTS /MECH, MATER, LWC /

     TABLE IACCT(OPER,C)

                  COTTMS    GNUTS  DURA

     MECH           27.36    18.2    18.2
     MATER          204.68   15.5    9.2
     LWC            48.0     33.0    32.


        TABLE  ZERO(TM,Z)

                    ZER    ONE


          7         0       1
          8         1       0
          9         1       0
          10        1       0
          11        1       0
          12        1       0
          1         0       1
          2         0       1
          3         0       1
          4         0       1
          5         0       1
          6         0       1


       TABLE LAB(TM,C) DUMMY FOR COTTON PICKING

                COTTMS   GNUTS  DURA
        7        1.
        8        1
        9        1
        10       1
        11
        12       0        1       1
         1       0        1       1
         2       0        1       1
         3       0        1       1
         4       0        1       1
```

```
       5    0       1      1
       6    0       1      1

TABLE A(TM,C)  MONTHS OF LAND OCC BY CROP (FEDD)

          COTTMS  GNUTS  DURA
  7         1.
  8         1.
  9         1.
 10         1.
 11
 12                 .5
  1        .5       1       .5
  2        1        1       1
  3        1        1       1
  4        1        1       1
  5        1        1       1
  6        1        .5      1


TABLE  LC(TM,C)  CROP LABOR REQUIREMENTS (MDAYS PER FEDDAN)

          COTTMS  GNUTS  DURA
 7          8.8
8          3.55
9          4.05
10         5.5
11
12         2.8
1          3.8     6.7    3.9
2          6.28    4.8    6.5
3          5.22    2.9    3.95
4          2.7     2.9    2.1
5           .95    6.5    4.6
6          3.65    5.3    7.7

TABLE    WC(TM,C)  CROP WATER REQUIREMENTS(1000 M3 PER FEDDAN)

            COTTMS   GNUTS   DURA
7        600
8        794
9        995
10
11
12                  407
1        600        700       1135
2        452        868       762
3        725        924       958
4        975        680       718
5        885
6        542
```

```
        SCALARS  LAND    FRMSIZ (FEDDANS)                          /22/
                 FAMLAB FAMILY LABOR AVAIL (DAYS PER MONTH) /84/
                 RWAGE   RESER WAGE RATE (LS PER DAY)             /3/
                 LANDCT  CFRMSIZ(FEDDANS)                         /11/
                 LANDGN  GNFRMS(FEDDANS)                         /5.5/
                 LANDDR  DRFRMS(FEDDANS)                         /5.5/
                 TWAGE   TEMP WAGE RATE (LS PER DAY)       /2/
                 CWAGE   COTTON PICKING WAGE (LS PER DAY) /2.5/
                 FLYSIZ  FAMILY SIZE (ADJUSTED NUMBER)    /4/

        PARAMETERS   YIELD(C)  CROP YIELD (UNITS PER FEDDAN) /
                               COTTMS = 7.1
                               GNUTS = 14
                               DURA = 8 /

                     PRICE(C)  CROP PRICES (LS PER UNIT) /
                               COTTMS = 84
                               GNUTS = 16
                               DURA = 28 /
        PARAMETERS   FAMZER   FAMILY LABOR AT ZERO OPPOR COST
                     MAXFAM   MAXIMUM FAMILY LABOR AVAILABLE ;
         FAMZER = .15*FAMLAB;
         MAXFAM = .35*FAMLAB  ;


        VARIABLES    YFARM      FARM INCOME     (LS)
                     REV(C)     VALUE OF PROD  (LS)
                     LABCOST    LABOR COST      (LS)
                     XCROP(C)   CROP ACTIVITY  (FEDDANS)
                     TLAB(TM)   TEMP LABOR (DAYS)
                     FLAB(TM)   FAMILY LABOR(DAYS)
                     HFLAB(TM) FAMILY LABOR AT OPP COST
                     CPICKL(TM) COTTON PICKING LABOR
                     SALES(C)   CROP SALES(LS)
                     CTIRR(TM) COTTON IRR
                     GNIRR(TM) GNUT IRR
                     DRIRR(TM) DURA IRR
                     WTR1(TM)   WATER TRANSFER
                     WTR2(TM)   WATER TRANS 2ND
                     FBOR1(TM)   FORMAL BORROWING - FIRST PERIOD
                     FBOR2(TM)   FORMAL BORROWING - SECOND PERIOD
                     ICOST(C)    INDIV ACCT COSTS FOR EACH CROP
                     OUTPUT(C) PHYSICAL OUTPUT
        POSITIVE VARIABLE     XCROP,TLAB,FLAB,HFLAB,CPICKL,SALES,XCROP,

                            FBOR1,FBOR2,CTIRR,DRIRR,GNIRR,OUTPUT,WTR1,WTR2


        EQUATIONS   LANDC   LAND BALANCE (FEDDANS)
                    LAB1C(TM)  LABOR BALANCE (DAYS)
                    LAB2C(TM) COTTON PICKING LABOR BALANCE
                    AREV(C)       REVENUE ACCNTG  (LS)
                    ALAB          LABOR COST ACCNTG (LS)
                    INCOME        INCOME DEF  (LS)
                    MBALSO       MATERIAL BALANCE OF SORGHUM
```

```
                       WT1         WATER BALANCE1
                       WT2         WATER BALANCE2
                       FB1         FORMAL BALANCE1
                       FB2         FORMAL BALANCE2
                       FCOST       INDIV ACCT COSTS
                       OUTP(C)     OUTPUT BALANCE;
        LANDC..          SUM(C,XCROP(C)) =L= LAND;
        LAB1C(TM)$LAB(TM,"GNUTS")..   SUM(C,XCROP(C)*LC(TM,C)) =L= FLAB(TM)
                                                  + TLAB(TM) + HFLAB(TM) ;
        LAB2C(TM)$LAB(TM,"COTTMS")..  SUM(C,XCROP(C)*LC(TM,C)) =L= FLAB(TM)
                                                  + HFLAB(TM) + CPICKL(TM);
        OUTP(C)..        OUTPUT(C) =E= XCROP(C)*YIELD(C);
        AREV(C)..        REV(C) =E= OUTPUT(C)*PRICE(C);
        ALAB(TM)..       LABCOST(TM) =E= TLAB(TM)*TWAGE + HFLAB(TM)* RWAGE  +
                                                        CPICKL(TM)*CWAGE;

        FCOST(C)..       ICOST(C) =E= SUM(OPER,IACCT(OPER,C)*XCROP(C));
        INCOME..         YFARM =E= SUM(C,REV(C))-SUM(TM,LABCOST(TM))
                              -SUM(C,ICOST(C))-SUM(TM,FBOR1(TM)+FBOR2(TM));

        MBALSO..         XCROP("COTTMS")*2 + FLYSIZ*4  =G= OUTPUT("DURA");
        WT1(TM)$ZERO(TM,"ZER")..       WTR1(TM+1) + SUM(C,XCROP(C)*WC(TM,C))
                                                                          -
                                  CTIRR(TM)*4400 - GNIRR(TM)*2200 -
                                                        DRIRR(TM)*2200 =G=
                                   WTR1(TM) ;
        WT2(TM)$ZERO(TM,"ONE")..         WTR2(TM) + SUM(C,XCROP(C)*WC(TM,C))
                                                          - CTIRR(TM)*4400
                                     - GNIRR(TM)*2200 - DRIRR(TM)*2200
                                                          =G= WTR2(TM-1);
        FB1(TM)$ZERO(TM,"ZER")..       FBOR1(TM+1) + LABCOST(TM) =G= FBOR1(TM)
                                                                          ;
        FB2(TM)$ZERO(TM,"ONE")..       FBOR2(TM) + LABCOST(TM) =G= FBOR2(TM-1)
                                                                          ;
        XCROP.UP("COTTMS") = LANDCT;
        XCROP.UP("GNUTS") = LANDGN;
        XCROP.UP("DURA") = LANDDR;
        FLAB.UP(TM) = FAMLAB;
        HFLAB.UP(TM) = MAXFAM;
        CTIRR.UP("1") = 2;
        CTIRR.UP("2") = 1;
        CTIRR.UP("3") = 1;
        CTIRR.UP("4") = 1;
        CTIRR.UP("5") = 1;
        CTIRR.UP("6") = 1;
        CTIRR.UP("7") = 1;
        GNIRR.FX("12") = 1;
        GNIRR.UP("1") = 1;
        GNIRR.UP("2") = 1;
        GNIRR.UP("3") = 1;
        GNIRR.UP("4") = 1;
        GNIRR.UP("5") = 1;
        DRIRR.UP("1") = 1;
        DRIRR.UP("2") = 1;
        DRIRR.UP("3") = 1;
```

```
       DRIRR.UP("4") = 1;
       FLAB.UP(TM) = FAMZER;
       FBOR1.FX("8") = 183;
       FBOR1.FX("9") = 184;
       FBOR2.FX("1") = 42;
       FBOR2.FX("2") = 163;
       FBOR2.FX("3") = 93;
       FBOR2.FX("5") = 69;
       FBOR2.FX("6") = 222;
       FBOR2.FX("7") = 244;
       MODEL RMODEL4   FOURTH DEMO MODEL /ALL/

       SOLVE RMODEL4 USING LP MAXIMIZING YFARM;
```

```
SYMBOL         TYPE    REFERENCES

A              PARAM   DECLARED       59
ALAB           EQU     DECLARED      162   DEFINED       176
AREV           EQU     DECLARED      161   DEFINED       175
C              SET     DECLARED        7       REF        15       43       59
                             76       92       121       126      137      139
                            144      152       153       161      170      171
                          2*172    2*173     3*174     3*175    3*178    2*179
                          2*182    2*185   CONTROL       171      172      173
                            174      175       178     2*179      182      185
CPICKL         VAR     DECLARED      143  IMPL-ASN       222      REF      154
                            173      176
CTIRR          VAR     DECLARED      145  IMPL-ASN       222 ASSIGNED      194
                            195      196       197       198      199      200
                            REF      155       183       185
CWAGE          PARAM   DECLARED      118       REF       176
DRIRR          VAR     DECLARED      147  IMPL-ASN       222 ASSIGNED      207
                            208      209       210       REF      155      183
                            186
FAMLAB         PARAM   DECLARED      112       REF       132      133      192
FAMZER         PARAM   DECLARED      130  ASSIGNED       132      REF      211
FB1            EQU     DECLARED      167   DEFINED       187
FB2            EQU     DECLARED      168   DEFINED       188
FBOR1          VAR     DECLARED      150  IMPL-ASN       222 ASSIGNED      212
                            213      REF       155       179    2*187
FBOR2          VAR     DECLARED      151  IMPL-ASN       222 ASSIGNED      214
                            215      216       217       218      219
                            REF      155       179     2*188
FCOST          EQU     DECLARED      169   DEFINED       178
FLAB           VAR     DECLARED      141  IMPL-ASN       222 ASSIGNED      192
                            211      REF       154       172      173
FLYSIZ         PARAM   DECLARED      119       REF       181
GNIRR          VAR     DECLARED      146  IMPL-ASN       222 ASSIGNED      201
                            202      203       204       205      206
                            REF      155       183       186
HFLAB          VAR     DECLARED      142  IMPL-ASN       222 ASSIGNED      193
                            REF      154       172       173      176
IACCT          PARAM   DECLARED       15       REF       173
ICOST          VAR     DECLARED      152  IMPL-ASN       222      REF      178
                            179
INCOME         EQU     DECLARED      163   DEFINED       179
LAB            PARAM   DECLARED       43       REF       172      173
LAB1C          EQU     DECLARED      159   DEFINED       172
LAB2C          EQU     DECLARED      160   DEFINED       173
LABCOST        VAR     DECLARED      138  IMPL-ASN       222      REF      176
                            179      187       188
LAND           PARAM   DECLARED      111       REF       171
LANDC          EQU     DECLARED      158   DEFINED       171
LANDCT         PARAM   DECLARED      114       REF       189
LANDDR         PARAM   DECLARED      116       REF       191
LANDGN         PARAM   DECLARED      115       REF       190
LC             PARAM   DECLARED       76       REF       172      173
MAXFAM         PARAM   DECLARED      131  ASSIGNED       133      REF      193
MBAL30         EQU     DECLARED      164   DEFINED       181
```

```
SYMBOL        TYPE    REFERENCES

OPER          SET     DECLARED        13        REF         15        178
                       CONTROL       178
OUTP          EQU     DECLARED       170   DEFINED         174
OUTPUT        VAR     DECLARED       153  IMPL-ASN         222        REF        155
                           174       175       181
PRICE         PARAM   DECLARED       126        REF        175
REV           VAR     DECLARED       137  IMPL-ASN         222        REF        175
                           179
RMODEL4       MODEL   DECLARED       220        REF        222
RWAGE         PARAM   DECLARED       113        REF        176
SALES         VAR     DECLARED       144        REF        154
TLAB          VAR     DECLARED       140  IMPL-ASN         222        REF        154
                           172       176
TM            SET     DECLARED         9        REF         24         43         59
                            76        92       140         141        142        143
                           145       146       147         148        149        150
                           151       159       160       5*172      5*173      4*176
                         3*179     3*182     3*183         184      4*185      3*186
                         4*187     4*188   CONTROL         172        173        176
                         2*179       182       185         187        188        192
                           193       211
TWAGE         PARAM   DECLARED       117        REF        176
WC            PARAM   DECLARED        92        REF        182        185
WT1           EQU     DECLARED       165   DEFINED         182
WT2           EQU     DECLARED       166   DEFINED         185
WTR1          VAR     DECLARED       148  IMPL-ASN         222        REF        155
                           182       184
WTR2          VAR     DECLARED       149  IMPL-ASN         222        REF        155
                           185       186
XCROP         VAR     DECLARED       139  IMPL-ASN         222   ASSIGNED        189
                           190       191       REF       2*154        171        172
                           173       174       178         181        182        185
YFARM         VAR     DECLARED       136  IMPL-ASN         222        REF        179
                           222
YIELD         PARAM   DECLARED       121        REF        174
Z             SET     DECLARED        11        REF         24
ZERO          PARAM   DECLARED        24        REF        182        185        187
                           188


SETS

C             CROP-COMMODITY
OPER          COSTS
TM            TIME PERIODS
Z             DUMMY


PARAMETERS

A             MONTHS OF LAND OCC BY CROP (FEDD)
CWAGE         COTTON PICKING WAGE (LS PER DAY)
FAMLAB        FAMILY LABOR AVAIL (DAYS PER MONTH)
```

PARAMETERS

```
FAMZER      FAMILY LABOR AT ZERO OPPOR COST
FLYSIZ      FAMILY SIZE (ADJUSTED NUMBER)
IACCT
LAB         DUMMY FOR COTTON PICKING
LAND        FRMSIZ (FEDDANS)
LANDCT      CFRMSIZ(FEDDANS)
LANDDR      DRFRMS(FEDDANS)
LANDGN      GNFRMS(FEDDANS)
LC          CROP LABOR REQUIREMENTS (MDAYS PER FEDDAN)
MAXFAM      MAXIMUM FAMILY LABOR AVAILABLE
PRICE       CROP PRICES (LS PER UNIT)
RWAGE       RESER WAGE RATE (LS PER DAY)
TWAGE       TEMP WAGE RATE (LS PER DAY)
WC          CROP WATER REQUIREMENTS(1000 M3 PER FEDDAN)
YIELD       CROP YIELD (UNITS PER FEDDAN)
ZERO
```

VARIABLES

```
CPICKL      COTTON PICKING LABOR
CTIRR       COTTON IRR
DRIRR       DURA IRR
FBOR1       FORMAL BORROWING - FIRST PERIOD
FBOR2       FORMAL BORROWING - SECOND PERIOD
FLAB        FAMILY LABOR(DAYS)
GNIRR       GNUT IRR
HFLAB       FAMILY LABOR AT OPP COST
ICOST       INDIV ACCT COSTS FOR EACH CROP
LABCOST     LABOR COST     (LS)
OUTPUT      PHYSICAL OUTPUT
REV         VALUE OF PROD  (LS)
SALES       CROP SALES(LS)
TLAB        TEMP LABOR (DAYS)
WTR1        WATER TRANSFER
WTR2        WATER TRANS 2ND
XCROP       CROP ACTIVITY  (FEDDANS)
YFARM       FARM INCOME    (LS)
```

EQUATIONS

```
ALAB        LABOR COST ACCNTG (LS)
AREV        REVENUE ACCNTG  (LS)
FB1         FORMAL BALANCE1
FB2         FORMAL BALANCE2
FCOST       INDIV ACCT COSTS
INCOME      INCOME DEF  (LS)
LAB1C       LABOR BALANCE (DAYS)
LAB2C       COTTON PICKING LABOR BALANCE
LANDC       LAND BALANCE (FEDDANS)
MBALSO      MATERIAL BALANCE OF SORGHUM
OUTP        OUTPUT BALANCE
```

EQUATIONS

```
WT1          WATER BALANCE1
WT2          WATER BALANCE2
```

MODELS

```
RMODEL4      FOURTH DEMO MODEL
```

COMPILATION TIME =   9.976 MINUTES

```
---- LANDC        =L=  LAND BALANCE (FEDDANS)

LANDC..  XCROP(COTTMS) + XCROP(GNUTS) + XCROP(DURA) =L= 22 ;

---- LAB1C        =L=  LABOR BALANCE (DAYS)

LAB1C(12)..  2.8*XCROP(COTTMS) - TLAB(12) - FLAB(12) - HFLAB(12) =L= 0 ;

LAB1C(1)..  3.8*XCROP(COTTMS) + 6.7*XCROP(GNUTS) + 3.9*XCROP(DURA) - TLAB(1)

      - FLAB(1) - HFLAB(1) =L= 0 ;

LAB1C(2)..  6.28*XCROP(COTTMS) + 4.8*XCROP(GNUTS) + 6.5*XCROP(DURA) - TLAB(2)

      - FLAB(2) - HFLAB(2) =L= 0 ;
REMAINING 4 ENTRIES SKIPPED

---- LAB2C        =L=  COTTON PICKING LABOR BALANCE

LAB2C(7)..  8.8*XCROP(COTTMS) - FLAB(7) - HFLAB(7) - CPICKL(7) =L= 0 ;

LAB2C(8)..  3.55*XCROP(COTTMS) - FLAB(8) - HFLAB(8) - CPICKL(8) =L= 0 ;

LAB2C(9)..  4.05*XCROP(COTTMS) - FLAB(9) - HFLAB(9) - CPICKL(9) =L= 0 ;
REMAINING ENTRY SKIPPED

---- AREV         =E=  REVENUE ACCNTG  (LS)

AREV(COTTMS)..  REV(COTTMS) - 84*OUTPUT(COTTMS) =E= 0 ;

AREV(GNUTS)..  REV(GNUTS) - 16*OUTPUT(GNUTS) =E= 0 ;

AREV(DURA)..  REV(DURA) - 28*OUTPUT(DURA) =E= 0 ;
```

```
---- ALAB         =E=  LABOR COST ACCNTG (LS)

ALAB(7)..  LABCOST(7) - 2*TLAB(7) - 3*HFLAB(7) - 2.5*CPICKL(7) =E= 0 ;

ALAB(8)..  LABCOST(8) - 2*TLAB(8) - 3*HFLAB(8) - 2.5*CPICKL(8) =E= 0 ;

ALAB(9)..  LABCOST(9) - 2*TLAB(9) - 3*HFLAB(9) - 2.5*CPICKL(9) =E= 0 ;
REMAINING 9 ENTRIES SKIPPED

---- INCOME       =E=  INCOME DEF  (LS)

INCOME..  YFARM - REV(COTTMS) - REV(GNUTS) - REV(DURA) + LABCOST(7)
      + LABCOST(8) + LABCOST(9) + LABCOST(10) + LABCOST(11) + LABCOST(12)
      + LABCOST(1) + LABCOST(2) + LABCOST(3) + LABCOST(4) + LABCOST(5)
      + LABCOST(6) + FBOR1(7) + FBOR1(8) + FBOR1(9) + FBOR1(10) + FBOR1(11)
      + FBOR1(12) + FBOR1(1) + FBOR1(2) + FBOR1(3) + FBOR1(4) + FBOR1(5)
      + FBOR1(6) + FBOR2(7) + FBOR2(8) + FBOR2(9) + FBOR2(10) + FBOR2(11)
      + FBOR2(12) + FBOR2(1) + FBOR2(2) + FBOR2(3) + FBOR2(4) + FBOR2(5)
      + FBOR2(6) + ICOST(COTTMS) + ICOST(GNUTS) + ICOST(DURA) =E= 0 ;

---- MBALSO       =G=  MATERIAL BALANCE OF SORGHUM

MBALSO..  2*XCROP(COTTMS) - OUTPUT(DURA) =G= -16 ;

---- WT1          =G=  WATER BALANCE1

WT1(8)..  794*XCROP(COTTMS) - 4400*CTIRR(8) - 2200*GNIRR(8) - 2200*DRIRR(8)
      - WTR1(8) + WTR1(9) =G= 0 ;

WT1(9)..  995*XCROP(COTTMS) - 4400*CTIRR(9) - 2200*GNIRR(9) - 2200*DRIRR(9)
      - WTR1(9) + WTR1(10) =G= 0 ;
```

```
    WT1          =G=  WATER BALANCE1

WT1(10)..  - 4400*CTIRR(10) - 2200*GNIRR(10) - 2200*DRIRR(10) - WTR1(10)

      + WTR1(11) =G= 0 ;

REMAINING 2 ENTRIES SKIPPED

---- WT2          =G=  WATER BALANCE2

WT2(7)..  600*XCROP(COTTMS) - 4400*CTIRR(7) - 2200*GNIRR(7) - 2200*DRIRR(7)

      + WTR2(7) =G= 0 ;

WT2(1)..  600*XCROP(COTTMS) + 700*XCROP(GNUTS) + 1135*XCROP(DURA)

      - 4400*CTIRR(1) - 2200*GNIRR(1) - 2200*DRIRR(1) - WTR2(12) + WTR2(1)

      =G= 0 ;

WT2(2)..  452*XCROP(COTTMS) + 868*XCROP(GNUTS) + 762*XCROP(DURA)

      - 4400*CTIRR(2) - 2200*GNIRR(2) - 2200*DRIRR(2) - WTR2(1) + WTR2(2) =G=

     0 ;
REMAINING 4 ENTRIES SKIPPED

---- FB1          =G=  FORMAL BALANCE1

FB1(8)..  LABCOST(8) - FBOR1(8) + FBOR1(9) =G= 0 ;

FB1(9)..  LABCOST(9) - FBOR1(9) + FBOR1(10) =G= 0 ;

FB1(10)..  LABCOST(10) - FBOR1(10) + FBOR1(11) =G= 0 ;
REMAINING 2 ENTRIES SKIPPED

---- FB2          =G=  FORMAL BALANCE2

FB2(7)..  LABCOST(7) + FBOR2(7) =G= 0 ;
```

```
     FB2           =G=  FORMAL BALANCE2

FB2(1)..  LABCOST(1) - FBOR2(12) + FBOR2(1) =G= 0 ;

FB2(2)..  LABCOST(2) - FBOR2(1) + FBOR2(2) =G= 0 ;

REMAINING 4 ENTRIES SKIPPED

---- FCOST         =E=  INDIV ACCT COSTS

FCOST(COTTMS)..  - 280.04*XCROP(COTTMS) + ICOST(COTTMS) =E= 0 ;

FCOST(GNUTS)..  - 66.7*XCROP(GNUTS) + ICOST(GNUTS) =E= 0 ;

FCOST(DURA)..  - 59.4*XCROP(DURA) + ICOST(DURA) =E= 0 ;

---- OUTP          =E=  OUTPUT BALANCE

OUTP(COTTMS)..  - 7.1*XCROP(COTTMS) + OUTPUT(COTTMS) =E= 0 ;

OUTP(GNUTS)..  - 14*XCROP(GNUTS) + OUTPUT(GNUTS) =E= 0 ;

OUTP(DURA)..  - 8*XCROP(DURA) + OUTPUT(DURA) =E= 0 ;
```

```
---- YFARM       FARM INCOME    (LS)


YFARM
  .LO =          -INF , .L =              0, .UP =           +INF
       1                INCOME


---- REV         VALUE OF PROD  (LS)


REV(COTTMS)
  .LO =          -INF , .L =              0, .UP =           +INF
       1                AREV(COTTMS)
      -1                INCOME

REV(GNUTS)
  .LO =          -INF , .L =              0, .UP =           +INF
       1                AREV(GNUTS)
      -1                INCOME

REV(DURA)
  .LO =          -INF , .L =              0, .UP =           +INF
       1                AREV(DURA)
      -1                INCOME


---- LABCOST     LABOR COST     (LS)


LABCOST(7)
  .LO =          -INF , .L =              0, .UP =           +INF
       1                ALAB(7)
       1                INCOME
       1                FB2(7)

LABCOST(8)
  .LO =          -INF , .L =              0, .UP =           +INF
       1                ALAB(8)
       1                INCOME
       1                FB1(8)

LABCOST(9)
  .LO =          -INF , .L =              0, .UP =           +INF
       1                ALAB(9)
       1                INCOME
       1                FB1(9)

REMAINING 9 ENTRIES SKIPPED
```

```
---- XCROP         CROP ACTIVITY  (FEDDANS)


XCROP(COTTMS)
  .LO =               0, .L =              0, .UP =             11
        1               LANDC
        2.8             LAB1C(12)
        3.8             LAB1C(1)
        6.28            LAB1C(2)
        5.22            LAB1C(3)
        2.7             LAB1C(4)
        0.95            LAB1C(5)
        3.65            LAB1C(6)
        8.8             LAB2C(7)
        3.55            LAB2C(8)
        4.05            LAB2C(9)
        5.5             LAB2C(10)
        2               MBALSO
      794               WT1(8)
      995               WT1(9)
      600               WT2(7)
      600               WT2(1)
      452               WT2(2)
      725               WT2(3)
      975               WT2(4)
      885               WT2(5)
      542               WT2(6)
     -280.04            FCOST(COTTMS)
       -7.1             OUTP(COTTMS)

XCROP(GNUTS)
  .LO =               0, .L =              0, .UP =            5.5
        1               LANDC
        6.7             LAB1C(1)
        4.8             LAB1C(2)
        2.9             LAB1C(3)
        2.9             LAB1C(4)
        6.5             LAB1C(5)
        5.3             LAB1C(6)
      407               WT1(12)
      700               WT2(1)
      368               WT2(2)
      924               WT2(3)
      680               WT2(4)
      -66.7             FCOST(GNUTS)
      -14               OUTP(GNUTS)

XCROP(DURA)
  .LO =               0, .L =              0, .UP =            5.5
        1               LANDC
        3.9             LAB1C(1)
        6.5             LAB1C(2)
        3.95            LAB1C(3)
        2.1             LAB1C(4)
        4.6             LAB1C(5)
```

```
     XCROP      CROP ACTIVITY  (FEDDANS)


       7.7             LAB1C(6)
     1135              WT2(1)
      762              WT2(2)
      958              WT2(3)
      718              WT2(4)
      -59.4            FCOST(DURA)
       -8              OUTP(DURA)

---- TLAB       TEMP LABOR (DAYS)


TLAB(7)
  .LO =              0, .L =            0, .UP =          +INF
        -2              ALAB(7)

TLAB(8)
  .LO =              0, .L =            0, .UP =          +INF
        -2              ALAB(8)

TLAB(9)
  .LO =              0, .L =            0, .UP =          +INF
        -2              ALAB(9)

REMAINING 9 ENTRIES SKIPPED


---- FLAB       FAMILY LABOR(DAYS)


FLAB(7)
  .LO =              0, .L =            0, .UP =          12.6
        -1              LAB2C(7)

FLAB(8)
  .LO =              0, .L =            0, .UP =          12.6
        -1              LAB2C(8)

FLAB(9)
  .LO =              0, .L =            0, .UP =          12.6
        -1              LAB2C(9)

REMAINING 8 ENTRIES SKIPPED


---- HFLAB      FAMILY LABOR AT OPP COST


HFLAB(7)
  .LO =              0, .L =            0, .UP =          29.4
        -1              LAB2C(7)
        -3              ALAB(7)
```

```
     HFLAB      FAMILY LABOR AT OPP COST


HFLAB(8)
  .LO =               0, .L =            0, .UP =         29.4
       -1                LAB2C(8)
       -3                ALAB(8)

HFLAB(9)
  .LO =               0, .L =            0, .UP =         29.4
       -1                LAB2C(9)
       -3                ALAB(9)

REMAINING 9 ENTRIES SKIPPED


---- CPICKL     COTTON PICKING LABOR


CPICKL(7)
  .LO =               0, .L =            0, .UP =         +INF
       -1                LAB2C(7)
       -2.5              ALAB(7)

CPICKL(8)
  .LO =               0, .L =            0, .UP =         +INF
       -1                LAB2C(8)
       -2.5              ALAB(8)

CPICKL(9)
  .LO =               0, .L =            0, .UP =         +INF
       -1                LAB2C(9)
       -2.5              ALAB(9)

REMAINING 9 ENTRIES SKIPPED


---- CTIRR      COTTON IRR


CTIRR(7)
  .LO =               0, .L =            0, .UP =            1
    -4400                WT2(7)

CTIRR(8)
  .LO =               0, .L =            0, .UP =         +INF
    -4400                WT1(8)

CTIRR(9)
  .LO =               0, .L =            0, .UP =         +INF
    -4400                WT1(9)

REMAINING 9 ENTRIES SKIPPED
```

```
---- GNIRR       GNUT IRR

GNIRR(7)
   .LO =               0, .L =               0, .UP =           +INF
     -2200               WT2(7)

GNIRR(8)
   .LO =               0, .L =               0, .UP =           +INF
     -2200               WT1(8)

GNIRR(9)
   .LO =               0, .L =               0, .UP =           +INF
     -2200               WT1(9)

REMAINING 9 ENTRIES SKIPPED

---- DRIRR       DURA IRR

DRIRR(7)
   .LO =               0, .L =               0, .UP =           +INF
     -2200               WT2(7)

DRIRR(8)
   .LO =               0, .L =               0, .UP =           +INF
     -2200               WT1(8)

DRIRR(9)
   .LO =               0, .L =               0, .UP =           +INF
     -2200               WT1(9)

REMAINING 9 ENTRIES SKIPPED

---- WTR1        WATER TRANSFER

WTR1(8)
   .LO =               0, .L =               0, .UP =           +INF
        -1               WT1(8)

WTR1(9)
   .LO =               0, .L =               0, .UP =           +INF
         1               WT1(8)
        -1               WT1(9)

WTR1(10)
   .LO =               0, .L =               0, .UP =           +INF
         1               WT1(9)
        -1               WT1(10)

REMAINING 3 ENTRIES SKIPPED
```

```
---- WTR2        WATER TRANS 2ND


WTR2(7)
  .LO =               0, .L =               0, .UP =           +INF
         1              WT2(7)

WTR2(12)
  .LO =               0, .L =               0, .UP =           +INF
        -1              WT2(1)

WTR2(1)
  .LO =               0, .L =               0, .UP =           +INF
         1              WT2(1)
        -1              WT2(2)

REMAINING 5 ENTRIES SKIPPED


---- FBOR1       FORMAL BORROWING - FIRST PERIOD


FBOR1(7)
  .LO =               0, .L =               0, .UP =           +INF
         1              INCOME

FBOR1(8)
  .LO =             183, .L =             183, .UP =            183
         1              INCOME
        -1              FB1(8)

FBOR1(9)
  .LO =             184, .L =             184, .UP =            184
         1              INCOME
         1              FB1(8)
        -1              FB1(9)

REMAINING 9 ENTRIES SKIPPED


---- FBOR2       FORMAL BORROWING - SECOND PERIOD


FBOR2(7)
  .LO =             244, .L =             244, .UP =            244
         1              INCOME
         1              FB2(7)

FBOR2(8)
  .LO =               0, .L =               0, .UP =           +INF
         1              INCOME
```

```
     FBOR2        FORMAL BORROWING - SECOND PERIOD


FBOR2(9)
  .LO =               0, .L =                0, .UP =            +INF
        1                INCOME

REMAINING 9 ENTRIES SKIPPED


---- ICOST        INDIV ACCT COSTS FOR EACH CROP


ICOST(COTTMS)
  .LO =            -INF , .L =               0, .UP =            +INF
        1                INCOME
        1                FCOST(COTTMS)

ICOST(GNUTS)
  .LO =            -INF , .L =               0, .UP =            +INF
        1                INCOME
        1                FCOST(GNUTS)

ICOST(DURA)
  .LO =            -INF , .L =               0, .UP =            +INF
        1                INCOME
        1                FCOST(DURA)


---- OUTPUT       PHYSICAL OUTPUT


OUTPUT(COTTMS)
  .LO =               0, .L =                0, .UP =            +INF
      -84                AREV(COTTMS)
        1                OUTP(COTTMS)

OUTPUT(GNUTS)
  .LO =               0, .L =                0, .UP =            +INF
      -16                AREV(GNUTS)
        1                OUTP(GNUTS)

OUTPUT(DURA)
  .LO =               0, .L =                0, .UP =            +INF
      -28                AREV(DURA)
       -1                MBALSO
        1                OUTP(DURA)
```

```
MODEL STATISTICS

NUMBER OF MAJOR ROWS = 13
NUMBER OF MINOR ROWS = 59
NUMBER OF MAJOR COLS = 17
NUMBER OF MINOR COLS = 146
NUMBER OF NON-ZEROES = 282
MODEL GENERATION     =        12.774 MINUTES


EXECUTION TIME       =        13.242 MINUTES
TARTING DATA READ...
ORK SPACE NEEDED (ESTIMATE)    --     7309 WORDS.
ORK SPACE AVAILABLE            --    40000 WORDS.
ROBLEM READ IN, STARTING SOLVE...
NVERTING...
TERATION    20 NUM NONOPT    10  OBJECTIVE   140.
TERATION    40 NUM NONOPT     2  OBJECTIVE   .135E+04
NVERTING...
ONE. SOLVER STATUS: 1 NORMAL COMPLETION
      MODEL STATUS: 1 OPTIMAL
BJECTIVE VALUE     2364.
amse

>echo off
```

S O L V E S U M M A R Y

MODEL	RMODEL4	OBJECTIVE	YFARM
TYPE	LP	DIRECTION	MAXIMIZE
SOLVER	MINOS3	FROM LINE	222

**** SOLVER STATUS 1 NORMAL COMPLETION
**** MODEL STATUS 1 OPTIMAL
**** OBJECTIVE VALUE 2364.0098

RESOURCE USAGE, LIMIT 1.250 1000.000
ITERATION COUNT, LIMIT 50 1000

MINOS 3.4/ALTERED

B. A. Murtagh and M. A. Saunders,
Department of Operations Research,
Stanford University,
Stanford California 94305 U.S.A.

WORK SPACE NEEDED (ESTIMATE) -- 7309 WORDS.
WORK SPACE AVAILABLE -- 40000 WORDS.

EXIT -- OPTIMAL SOLUTION FOUND.

---- EQU LANDC LAND BALANCE (FEDDANS)

LOWER	LEVEL	UPPER	MARGINAL
-INF	21.250	22.000	.

---- EQU LAB1C LABOR BALANCE (DAYS)

	LOWER	LEVEL	UPPER	MARGINAL
12	-INF	.	.	2.000
1	-INF	.	.	2.000
2	-INF	.	.	2.000
3	-INF	.	.	2.000
4	-INF	.	.	EPS
5	-INF	.	.	2.000
6	-INF	.	.	2.000

---- EQU LAB2C COTTON PICKING LABOR BALANCE

	LOWER	LEVEL	UPPER	MARGINAL
7	-INF	.	.	2.500
8	-INF	.	.	2.500
9	-INF	.	.	EPS
10	-INF	.	.	2.500

---- EQU AREV   REVENUE ACCNTG (LS)

	LOWER	LEVEL	UPPER	MARGINAL
COTTMS	.	.	.	1.000
GNUTS	.	.	.	1.000
DURA	.	.	.	1.000

---- EQU ALAB   LABOR COST ACCNTG (LS)

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	.	-1.000
8	.	.	.	-1.000
9	.	.	.	EPS
10	.	.	.	-1.000
11	.	.	.	-1.000
12	.	.	.	-1.000
1	.	.	.	-1.000
2	.	.	.	-1.000
3	.	.	.	-1.000
4	.	.	.	EPS
5	.	.	.	-1.000
6	.	.	.	-1.000

---- EQU INCOME   INCOME DEF (LS)

LOWER	LEVEL	UPPER	MARGINAL
.	.	.	1.000

---- EQU MBALSO   MATERIAL BALANCE OF SORGHUM

LOWER	LEVEL	UPPER	MARGINAL
-16.000	-16.000	+INF	-13.912

---- EQU WT1   WATER BALANCE1

	LOWER	LEVEL	UPPER	MARGINAL
8	.	.	+INF	EPS
9	.	.	+INF	EPS
10	.	.	+INF	EPS
11	.	.	+INF	EPS
12	.	.	+INF	EPS

---- EQU WT2 WATER BALANCE2

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	+INF	EPS
1	.	.	+INF	EPS
2	.	13373.000	+INF	.
3	.	.	+INF	EPS
4	.	9075.500	+INF	.
5	.	.	+INF	EPS
6	.	.	+INF	EPS

---- EQU FB1 FORMAL BALANCE1

	LOWER	LEVEL	UPPER	MARGINAL
8	.	67.125	+INF	.
9	.	.	+INF	-1.000
10	.	119.750	+INF	.
11	.	.	+INF	.
12	.	36.400	+INF	.

---- EQU FB2 FORMAL BALANCE2

	LOWER	LEVEL	UPPER	MARGINAL
7	.	454.500	+INF	.
1	.	211.150	+INF	.
2	.	348.510	+INF	.
3	.	89.065	+INF	.
4	.	.	+INF	-1.000
5	.	179.900	+INF	.
6	.	339.550	+INF	.

---- EQU FCOST INDIV ACCT COSTS

	LOWER	LEVEL	UPPER	MARGINAL
COTTMS	.	.	.	-1.000
GNUTS	.	.	.	-1.000
DURA	.	.	.	-1.000

---- EQU OUTP OUTPUT BALANCE

	LOWER	LEVEL	UPPER	MARGINAL
COTTMS	.	.	.	84.000
GNUTS	.	.	.	16.000
DURA	.	.	.	14.083

---- VAR YFARM FARM INCOME (LS)

LOWER	LEVEL	UPPER	MARGINAL
-INF	2364.010	+INF	.

---- VAR REV VALUE OF PROD (LS)

	LOWER	LEVEL	UPPER	MARGINAL
COTTMS	-INF	6560.400	+INF	.
GNUTS	-INF	1232.000	+INF	.
DURA	-INF	1064.000	+INF	.

---- VAR LABCOST LABOR COST (LS)

	LOWER	LEVEL	UPPER	MARGINAL
7	-INF	210.500	+INF	.
8	-INF	66.125	+INF	.
9	-INF	184.000	+INF	.
10	-INF	119.750	+INF	.
11	-INF	.	+INF	.
12	-INF	36.400	+INF	.
1	-INF	169.150	+INF	.
2	-INF	227.510	+INF	.
3	-INF	159.065	+INF	.
4	-INF	93.000	+INF	.
5	-INF	110.900	+INF	.
6	-INF	186.550	+INF	.

---- VAR XCROP CROP ACTIVITY (FEDDANS)

	LOWER	LEVEL	UPPER	MARGINAL
COTTMS	.	11.000	11.000	254.160
GNUTS	.	5.500	5.500	104.900
DURA	.	4.750	5.500	.

---- VAR TLAB TEMP LABOR (DAYS)

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	+INF	-2.000
8	.	.	+INF	-2.000
9	.	44.712	+INF	.
10	.	.	+INF	-2.000
11	.	.	+INF	-2.000
12	.	18.200	+INF	.
1	.	84.575	+INF	.
2	.	113.755	+INF	.

SOLUTION REPORT SOLVE RMODEL4 USING LP FROM LINE 222

VAR TLAB TEMP LABOR (DAYS)

	LOWER	LEVEL	UPPER	MARGINAL
3	.	79.532	+INF	.
4	.	46.500	+INF	.
5	.	55.450	+INF	.
6	.	93.275	+INF	.

---- VAR FLAB FAMILY LABOR(DAYS)

	LOWER	LEVEL	UPPER	MARGINAL
7	.	12.600	12.600	2.500
8	.	12.600	12.600	2.500
9	.	12.600	12.600	EPS
10	.	12.600	12.600	2.500
12	.	12.600	12.600	2.000
1	.	12.600	12.600	2.000
2	.	12.600	12.600	2.000
3	.	12.600	12.600	2.000
4	.	9.125	12.600	.
5	.	12.600	12.600	2.000
6	.	12.600	12.600	2.000

---- VAR HFLAB FAMILY LABOR AT OPP COST

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	29.400	-0.500
8	.	.	29.400	-0.500
9	.	29.400	29.400	EPS
10	.	.	29.400	-0.500
11	.	.	29.400	-3.000
12	.	.	29.400	-1.000
1	.	.	29.400	-1.000
2	.	.	29.400	-1.000
3	.	.	29.400	-1.000
4	.	.	29.400	EPS
5	.	.	29.400	-1.000
6	.	.	29.400	-1.000

---- VAR CPICKL COTTON PICKING LABOR

	LOWER	LEVEL	UPPER	MARGINAL
7	.	84.200	+INF	.
8	.	26.450	+INF	.
9	.	2.550	+INF	.
10	.	47.900	+INF	.
11	.	.	+INF	-2.500
12	.	.	+INF	-2.500

VAR CPICKL COTTON PICKING LABOR

	LOWER	LEVEL	UPPER	MARGINAL
1	.	.	+INF	-2.500
2	.	.	+INF	-2.500
3	.	.	+INF	-2.500
4	.	.	+INF	EPS
5	.	.	+INF	-2.500
6	.	.	+INF	-2.500

---- VAR CTIRR COTTON IRR

	LOWER	LEVEL	UPPER	MARGINAL
7	.	1.000	1.000	EPS
8	.	1.985	+INF	.
9	.	2.487	+INF	.
10	.	.	+INF	.
11	.	.	+INF	.
12	.	0.009	+INF	.
1	.	2.000	2.000	EPS
2	.	1.000	1.000	EPS
3	.	1.000	1.000	EPS
4	.	1.000	1.000	EPS
5	.	1.000	1.000	EPS
6	.	1.000	1.000	EPS

---- VAR GNIRR GNUT IRR

	LOWER	LEVEL	UPPER	MARGINAL
7	.	1.000	+INF	.
8	.	.	+INF	EPS
9	.	.	+INF	EPS
10	.	.	+INF	EPS
11	.	.	+INF	EPS
12	1.000	1.000	1.000	EPS
1	.	1.000	1.000	EPS
2	.	1.000	1.000	EPS
3	.	1.000	1.000	EPS
4	.	1.000	1.000	EPS
5	.	1.000	1.000	EPS
6	.	0.710	+INF	.

---- VAR DRIRR DURA IRR

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	+INF	EPS
8	.	.	+INF	EPS
9	.	.	+INF	EPS

SOLUTION REPORT SOLVE RMODEL4 USING LP FROM LINE 222

VAR DRIRR DURA IRR

	LOWER	LEVEL	UPPER	MARGINAL
10	.	.	+INF	EPS
11	.	.	+INF	EPS
12	.	.	+INF	EPS
1	.	1.000	1.000	EPS
2	.	1.000	1.000	EPS
3	.	1.000	1.000	EPS
4	.	1.000	1.000	EPS
5	.	1.425	+INF	.
6	.	.	+INF	EPS

---- VAR WTR1 WATER TRANSFER

	LOWER	LEVEL	UPPER	MARGINAL
8	.	.	+INF	EPS
9	.	.	+INF	EPS
10	.	.	+INF	EPS
11	.	.	+INF	EPS
12	.	.	+INF	EPS
1	.	.	+INF	EPS

---- VAR WTR2 WATER TRANS 2ND

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	+INF	EPS
12	.	2641.250	+INF	.
1	.	.	+INF	EPS
2	.	8807.500	+INF	.
3	.	.	+INF	EPS
4	.	.	+INF	EPS
5	.	.	+INF	EPS
6	.	.	+INF	EPS

---- VAR FBOR1 FORMAL BORROWING - FIRST PERIOD

	LOWER	LEVEL	UPPER	MARGINAL
7	.	.	+INF	-1.000
8	183.000	183.000	183.000	-1.000
9	184.000	184.000	184.000	-2.000
10	.	.	+INF	EPS
11	.	.	+INF	-1.000
12	.	.	+INF	-1.000
1	.	.	+INF	-1.000
2	.	.	+INF	-1.000
3	.	.	+INF	-1.000
4	.	.	+INF	-1.000

```
     VAR FBOR1        FORMAL BORROWING - FIRST PERIOD

      LOWER      LEVEL      UPPER     MARGINAL

5       .          .        +INF       -1.000
6       .          .        +INF       -1.000

---- VAR FBOR2        FORMAL BORROWING - SECOND PERIOD

      LOWER      LEVEL      UPPER     MARGINAL

7     244.000    244.000    244.000     -1.000
8       .          .        +INF       -1.000
9       .          .        +INF       -1.000
10      .          .        +INF       -1.000
11      .          .        +INF       -1.000
12      .          .        +INF       -1.000
1      42.000     42.000     42.000     -1.000
2     163.000    163.000    163.000     -1.000
3      93.000     93.000     93.000     -2.000
4       .          .        +INF        EPS
5      69.000     69.000     69.000     -1.000
6     222.000    222.000    222.000     -1.000

---- VAR ICOST        INDIV ACCT COSTS FOR EACH CROP

            LOWER      LEVEL      UPPER     MARGINAL

COTTMS      -INF     3080.440     +INF         .
GNUTS       -INF      366.850     +INF         .
DURA        -INF      282.150     +INF         .

---- VAR OUTPUT       PHYSICAL OUTPUT

            LOWER      LEVEL      UPPER     MARGINAL

COTTMS        .        78.100     +INF         .
GNUTS         .        77.000     +INF         .
DURA          .        38.000     +INF         .

**** REPORT SUMMARY :          0     NONOPT ****
                               0 INFEASIBLE ****
                               0  UNBOUNDED ****
                               0     ERRORS ****
```

```
GAMS 2.00 PC-86                                          80/01/01 02:46:43
G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
E X E C U T I N G


EXECUTION TIME        =        12.009 MINUTES
ALL DONE
```


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