AN ANALYSIS OF SMALLHOLDER RAINFED CROP PRODUCTION SYSTEMS: A CASE STUDY OF THE NUBA MOUNTAINS AREA, WESTERN SUDAN

By

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ABSTRACT

AN ANALYSIS OF SMALLHOLDER RAINFED CROP PRODUCTION SYSTEMS: A CASE STUDY OF THE NUBA MOUNTAINS AREA, WESTERN SUDAN

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The focus of this study is on rainfed crop production systems in the Nuba Mountains area of Western Sudan. The two smallholder farming systems in the area--traditional farming and the Nuba Mountains Agricultural Production Corporation (NMAPC) Modernization schemes--were considered. The objectives of the study were: to identify the present input-output relations and constraints of the two smallholder production systems; and to assess the impact of policies and management alternatives aimed at improving performance in the two production systems.

The general research approach employed representative models to focus on the production system at the farm level. Primary data were generated from two field surveys carried out in the study area. The FAO survey (1978/79) data were combined with data from the researcher's survey (1979/80) to provide a descriptive analysis of the smallholders' environment and production practices. Building on this foundation, the approach utilized descriptive statistics to derive three representative farm production categories mainly on the basis of farm level resource differences.

These three categories were then represented as sub-models in each of the two linear programming production models (traditional and NMAPC) that were constructed.

In the LP models, the objective function was to maximize net farm income subject to satisfying the minimum consumption requirements of the farming household. To account for the seasonality of production, the activities and resources of the LP models were disaggregated by monthly periods. The traditional and NMAPC LP models differ from each other in activities, constraints, and input-output coefficients. In particular, the NMAPC LP model incorporated the mechanized cultivation activities and the institutional features (tenancy size and crop mix) that were introduced by the NMAPC program. The analysis and results of the base production plans of the two LP models were used as departure points for later model experiments.

Analysis of the traditional farm model showed the cropping pattern of the smallholder to be dominated by sorghum. Net returns are very low, a product of the low productivity of land and labor. Low productivity and returns are the result of low crop yields and seasonal labor constraints. Further experiments revealed that: (1) farming returns are highly sensitive to crop yield levels; (2) short-term credit can help smallholders augment their labor resources and expand the area cultivated, resulting in substantial improvement in returns; (3) smallholders currently grow late planted crops to smooth out labor bottlenecks, but through the use of credit for hired labor they can plant earlier and realize higher crop yields; and (4) the current cotton prices would need to be raised substantially to induce traditional farmers to grow cotton.

Analysis of the NMAPC farm model showed that NMAPC participants earn low returns from their scheme plots, due to the relatively small cultivation size and the low productivities of the two crops (cotton and dura) grown. Cotton is especially unprofitable. Several other findings emerged. First, the contemplated expansion of NMAPC tenancy size can be expected to increase participants' returns significantly. However, the increase in cultivation size can also be expected to intensify the labor and operating capital bottlenecks. Second, despite the effect of mechanical ploughing in reducing weeds, the NMAPC participants (especially under the expanded tenancy size) face a labor constraint in weeding. Third, credit is especially needed to finance cotton picking operations. Fourth, for the NMAPC participants, an unrestricted crop mix which includes the introduction of sesame as a third crop is advantageous and more rewarding than the present standard two-crop mix.

The policy implications of the study indicate a need for applied research to improve smallholders' farming; a need to reduce costs of NMAPC and improve its services; and a need for changing the NMAPC's present fixed tenancy size and crop mix policies.

Dedicated with gratitude and appreciation

to my dear parents

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CHAPTER I

INTRODUCTION

Background: Traditional Agriculture in Sudan

Agriculture in the Sudan contributes nearly 40 percent of the Gross Domestic Product, and 80 percent of the population depends on its subsistence on agriculture and related activities. The sector is the major source of exportable commodities accounting for over 90 percent of the country's foreign exchange earnings. Economic activities of other sectors in the economy, especially in transportation and industry, are critically linked with those of agriculture.[1]

The Sudanese record of agricultural development has been characterized by a marked dualism between relatively high income irrigated and mechanized agriculture on the one hand and low income traditional agriculture and livestock raising on the other hand. An evolving consequence of this dualism is the creation of an unbalanced regional growth, with its related social and political problems.[2]

The place of traditional agriculture,[3] and its relative share in area and production of major crops in Sudan is shown in Table 1.1.

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[1] Ministry of National Planning, "The Six-Year Plan for Social and Economic Development, 1977/78-1982/83," Sudan, Vol. II [44].

[2] ILO/UNDP Employment Mission, "Growth, Employment and Equity: A Comprehensive Strategy for the Sudan" (Geneva: ILO, 1976) [30].

[3] The term "traditional" is used within Sudan agriculture to denote the sector of small producers (mostly under rainfed) outside the domain of the "modern" (irrigated and/or mechanized) sector. In the context of this study, the term will be used more specifically to distinguish the small producers in the Nuba Mountains area from the Nuba Mountains Agricultural Production Corporation (NMAPC) schemes' participants.

Table 1.1 Share of Different Production Sectors in Area and Production of Major Crops

Production Sector	3 Year Average 1966/67-1968/69 Area (%)	3 Year Average 1966/67-1968/69 Production (%)	3 Year Average 1973/74-1975/76 Area (%)	3 Year Average 1973/74-1975/76 Production (%)
Irrigated	22.4	53.8	18.5	50.3
Unirrigated	77.6	46.2	81.5	49.7
Public	27.6	54.9	22.3	51.6
Private	72.4	45.1	77.7	48.4
Mechanized	47.2	69.2	45.6	71.2
Traditional	52.8	30.8	54.4	28.8

Source: Six-Year Plan, Table 6 [44, p. 20].

More than 50 percent of the total cropped area is under traditional agriculture, and 6.6 million persons derive their livelihood from crop production in the sector [1]. Income and productivity of traditional farmers are characteristically low. Adam and Khidir report that "the average per capita income of traditional agriculture is about one-third of the level of per capita income in modern agriculture and is only about one-fifth of the aggregate average" [1, p. 3]. Not only is productivity of traditional agriculture low, but more seriously, it has exhibited declining trends in recent years. The current six-year plan notes that "during the last decade certain important structural changes have come about in the crop production subsector..., the most notable change is in productivity of the traditional sector, which went down in relation to the mechanized sector" [44, p. 20].

The need for developing traditional agriculture was indicated as early as the 1960s (Osman [51]), and by many others since then. The ILO in its recent report (1977) argues for this need as a first priority and it emphasizes that "development of traditional agriculture and animal husbandry is vital. This is rooted in sound efficiency criteria and is also a priority on equity grounds" [30, p. 53]. Adams and Howel [3] have questioned the priority issue, and in particular have cautioned against ILO's overoptimism for development of traditional agriculture:

> The western Sudan and traditional agriculture have been neglected not simply because of the determination of governments to promote the modern sector within easy reach of Khartoum, but because of inherent difficulties in doing something effective in areas of low fertility, meager and uncertain rainfall, scattered population, nomadism and shifting agriculture [3, p. 508].

They, nevertheless, agree with the ILO in the need for a comprehensive "all-or-nothing" approach for developing traditional agriculture, to take the form of integrated rural development programs.[1]

For the government, however, the approach and means for developing traditional agriculture, were seen primarily as an extension of the "modern" sector's approach and programs. The accumulated experiences of agricultural development in Sudan have been the creation and development of an institutional and organizational system and expertise that is relatively effective in carrying out and executing programs and projects in the modern subsector (large-scale irrigation and mechanization projects). In particular, these developments in agriculture followed closely the original Gezira "model."[2]

This fact has important implications for the development of traditional agriculture in general, and for this study in particular. For, as will be discussed below, it is against this background that the Sudanese planning machinery has framed and launched programs for the "modernization" of traditional agriculture.

The Setting: Policy Issues and Programs

The current Sudanese six-year plan (1977/83) for social and economic development gives explicit recognition, among the stated objectives for agriculture, to the "development and modernization of traditional farming, improvement of conditions for nomads, and the modernization of

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[1] Examples of programs endorsed by ILO [30], and Adams and Howel [3], include: Hunting Technical Services' Southern Darfour, Savanna, and Jebel Marra Development Plans, for western Sudan.

[2] Large-scale irrigated agriculture was started by the Gezira scheme (1925). The "model" was closely replicated in subsequent developments such as Managil Extension (1956), Guneid (1967), New Halfa (1964), Suki (1971) and Rahad (1977). All of the schemes follow, more or less, the original Gezira in the design of their organizational set-ups, tenant-management production relations and cropping patterns.

pastorial activities" [44, p. 6]. The strategy adopted in the plan for modernization of traditional agriculture includes:

- (i) Consolidating the studies and researches already done or underway, to determine suitable projects for mechanization of traditional agriculture.
- (ii) Establishing agriculture complexes and a network of research stations in all rainfed crop areas.
- (iii) Establishing modern ranches in savanna region.
- (iv) Encouraging and assisting the establishment of large agricultural cooperatives.
- (v) Encouraging the development of close relations between modern agricultural schemes (like Rahad) and the neighboring traditional agriculture areas, so that the latter will benefit from the production systems used in these schemes [44, p. 11].

A major program that was implemented in the spirit of the above strategy is the modernization schemes of the Nuba Mountains Agricultural Production Corporation (NMAPC).[1] Started in the early 1970s in the Nuba Mountains area of South Kordofan Province, the program was directed towards modernizing traditional agriculture in the area. Taking essentially the public irrigated model format, the main component of the modernization program is provision of mechanized cultivation to the smallholder participants. The NMAPC's six-year plan proposal for the modernization program is shown in Table 1.2. The biggest item in the proposed capital costs (66.7 percent) was for agricultural machinery. Sixty tractors/discs were to be added to the corporation's stock annually, to reach a total capacity of 360 tractor/discs by the end of the plan period in 1982/83, at which time a total of 480,000 feddans were expected to be under cultivation. Although mechanized cultivation was being extended to new NMAPC schemes, the realized expansion of the

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[1] A brief history and background note on the NMAPC, together with the specific modernization objectives, are discussed in the first part of Chapter VI.

Table 1.2 NMAPC Six-Year Plan Proposal for Modernization of Agriculture: Target Area Phasing of Capital Equipment, and Total Costs, 1977/78 to 1982/83

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	Total	Total Cost (LS'000)[a]
Area (feddans)[b]	80,000	160,000	240,000	320,000	400,000	480,000	480,000	
Agricultural implements								
Tractors	60	60	60	60	60	60	360	
Crawlers	6	-	-	-	-	-	6	
Wide level discs	60	60	60	60	60	60	360	
Sprayers	700	700	700	700	600	600	4,000	3,509.0
Tankers (fuel)								
4,000 gal. benzine	1	-	-	-	-	-	1	
1,200 gal. diesel	1	1	2	2	2	2	10	
500 gal. diesel	1	1	1	2	2	2	9	
Trailers	1	1	2	2	2	2	10	3,509.0
Transport								
Lerry (5-7 tons)	1	1	1	2	2	2	9	
Pick-ups	6	6	6	5	6	6	35	
Bus (32 seats)	1	-	-	1	-	-	2	
Tankers (fuel)	1	-	1	1	2	1	6	
Mobile workshop vehicles	1	-	1	-	1	-	3	
Plant protection vehicles (unimty)	1	-	-	1	-	-	2	523.6
Buildings								
Senior grade houses	3	3	3	3	3	4	19	
Medium grade houses	5	5	5	5	5	5	30	
Junior grade houses	4	4	4	4	4	4	24	
Labour quarters	2	1	1	1	1	1	7	
Steres	2	1	1	1	1	1	7	
Offices	1	1	2	2	2	1	9	
Workshops	1	-	1	-	1	-	3	1,219.0
Capital costs (LS'000)	1,444.3	671.7	892.2	720.2	834.4	688.9		5,256.6
Recurrent costs (LS'000)[c]	157.6	208.0	290.8	371.5	426.4	493.3		1,942.4
TOTAL COST (LS'000)	1,601.9	879.7	1,183.0	1,091.7	1,260.8	1,182.2		7,199.0

Source: NMAPC

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[a] One Ls = $2.00.
[b] One feddan = 1.038 acres
[c] Includes costs of operating tractors, vehicles, repair and maintenance, and salaries and wages.

program fell far below the original proposal.[1] The 10-year experience of the modernization program will be discussed in detail later; there are, however, evolving policy concerns at two different, but related levels:

1. At the planning or top governmental levels, questions are being raised about the financial viability of the NMAPC (and the other subsidiary corporations of the dissolved Agricultural Production Corporation), and the extent to which the public fund can continue to shoulder their large and continuing deficits.[2]
2. At the operational level concerns exist about the corporation's performance related on the one hand to its technical, organizational, and administrative capacities, and on the other hand to performance and productivity of its participating farmers.[3]

Both policy issues are relevant to this study. However, the focus of this study is micro-oriented, it concentrates on studying the traditional and NMAPC production models at the farm level. Such a micro-orientation is necessary for studying the NMAPC modernization model by permitting evaluation of the model

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[1] By 1979/80 there was a total of 62 schemes operating in the eight stations of NMAPC, utilizing a total of 140 tractors and commanding a total area of only 72,868 feddans.

[2] For example, by the Minister of Agriculture, in a visit to the NMAPC after receiving a World Bank mission report regarding the issue.

[3] The modernization program suffered a great set-back in 1974/75 when almost all schemes were shut down. The reason given by NMAPC administration was the accumulated and mounting farmers' debits (for mechanized cultivation) owed to the corporation.

from the farmer's perspective. The basic components of the NMAPC are examined as they affect the farm level. These include the following components and/or issues:

1. Land ownership and production relations (as they affect tenant security and tenant-management relations).
2. Scale of operation (tenancy size and feddanage expansion).
3. Crop composition (mainly the role and size of the cotton component).
4. Mechanized cultivation.
5. Provision of credit.
6. Input supply and subsidies.
7. Product prices (especially that of cotton).
8. Farm income and returns.

Another important policy issue, with special relevance to traditional farmers in the area, concerns measures to increase cotton crop output. Historically, the largest share of short staple cotton output of Sudan is produced in the Nuba Mountains by traditional farmers.[1] Although the current Sudanese six-year plan targeted 24.3 percent annual increase in output of short stable cotton,[2] output and areas under the crop in Nuba Mountains area were declining by the late 1970s. This decline continued and has reached such an alarming level, with the crop

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[1] For example, in the seasons 1974/75, 1975/76, the Naba Mountains share in total output of short staple cotton was 56 percent and 74 percent, respectively.

[2] See Six-Year Plan, Table 3: (A) Crop Production Targets [44, p. 7].

almost disappearing from the traditional farmers' areas, that in 1979 a ministrial committee was formed to study and make recommendations for the issue.[1]

Objectives of the Study

The focus of this study is on the production structure and constraints of the smallholders in the Nuba Mountains area. Specifically, the study will seek to:

1. Give a descriptive analysis of smallholder farming systems in the Nuba Mountains area, with special focus on crop production.
2. Formulate representative models of production at the farm level for traditional smallholders and for NMAPC schemes' participants.
3. Analyze the representative production models:
    a. Traditional models:
        (1) Identify the present input-output relations.
        (2) Identify and analyze constraining factors of production.
        (3) Examine the potential for improving the system's performance. This includes experiments of the following:
            (a) Credit experiments.
            (b) Planting-time experiments.
            (c) Cotton price effects.

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[1] See Ministry of Agriculture, Food, and Natural Resources, "A Report of the Committee for Studying and Treating the Causes of Cotton Production Decline in Nuba Mountain Area,"(in Arabic),1979, [39].

b. NMAPC participant models:
    (1) Analyze the input-output relations and performance of the current NMAPC farm model.
    (2) Analyze the flexibilities and constraints, especially in comparison with the traditional model.
    (3) Analyze the proposed expanded version of the NMAPC farm model. This includes experiments on:
        (a) Expansion of tenancy size.
        (b) Crop composition.
        (c) Credit.
        (d) Cotton price effects.

4. Discuss and analyze the implications of the above analysis for national and regional rural development programs, with emphasis on the lessons of the NMAPC experience.

Organization of the Study

Chapter II gives a general description of the research methodology followed in this study. It discusses the linear programming analytic approach used and the data sources and collection methods.

Chapter III provides the descriptive background for the study. General characteristics of the smallholder farming systems are discussed with emphasis on the production aspects. Chapter III lays the foundation for the selection and construction of the representative production models.

Details of the representative production models are discussed in Chapter IV. The LP structure, estimation methods and assumptions are discussed.

Specific analysis and experiments with the traditional and NMAPC models are given in Chapter V and VI, respectively. Chapter V is devoted to the analysis of the traditional model. Its features and constraints are taken as a departure point for selective experiments in this chapter and for the analysis of the NMAPC in Chapter VI. Emphasis in the latter chapter is on the effects of NMAPC on the revealed constraints. It also discusses new policies and farm plans proposed by the NMAPC.

The analysis in both Chapter V and VI is related to farm level concerns and issues. A summary of the results and conclusions is given in the final Chapter VII, which also includes discussion of the limitations of the study, lessons, generalizations, and recommendations for future research.

CHAPTER II

RESEARCH METHODOLOGY

The purpose of this chapter is to describe the general research methodology adopted. First, a brief note about the choice of the study area and a summary of the general analytical approach is given. Next, the linear programming (LP) model, which is the main tool of the analysis, is discussed. Finally, data sources and data collection methods are described.

The Study Area

As mentioned in Chapter I, the problem will be addressed through a case study of the Nuba Mountains area of South Kordofan Province, Western Sudan. The following points are the major reasons for choosing this area:

1. The bulk of agricultural activity and potential of the Sudan is concentrated in the Central Clay Plains (CCP), which run across the country in an east-west direction. In particular, the majority of the traditional crop farming systems are located in the CCP region. The Nuba Mountains area, located in the western part of the CCP region, is fairly representative of its general ecological characteristics, and to a large extent of its rainfed agriculture.

2. The study area exemplifies the problems and potentials of developing traditional agriculture.
3. The main government program (and policy) for the development of traditional smallholder agriculture consists of introducing mechanization mainly under government administered schemes. The modernization schemes of the Nuba Mountains Agricultural Corporation (NMAPC) have been in operation since the early 1970's. Its past and current performances offers an opportunity to empirically investigate and study the effectiveness and limitations of the program in the context of developing traditional agriculture.
4. The Food and Agriculture Organization (FAO) conducted a major farm management survey in the Nuba Mountains area in 1978/79 season, covering both traditional and NMAPC participant farmers. This survey was done in cooperation with the Department of Rural Economy, Faculty of Agriculture, University of Khartoum. The researcher through his association with the Department of Rural Economy, was familiar with this survey and in discussion with some members of the department was offered the opportunity to use this data.
5. Lastly, the Nuba Mountains area has recently been the site of a number of foreign research projects,[1] experimenting with different technologies and/or institutional arrangements for

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[1] These include mainly: A European Development Fund/SATEC project, the British Overseas Development Administration (ODA) projects, and the West German Technical Aid-GTZ project. They are discussed in somewhat more detail in Appendix IV.

improving smallholder agriculture. These projects are still in progress; however, some of their tentative findings ([38], [42], and [43]) are referred to in this study.

Summary of the Research Approach

The general research approach employs representative farm models to focus on crop production at the farm level. Primary data were generated from two field surveys carried out in the area . The FAO survey (1978/79) data was combined with the data from the researcher's survey (1979/80) to develop the descriptive analysis of smallholder production given in Chapter III. Building on this foundation, the approach utilizes descriptive statistics to arrive at representative production models. Three categories of production models are derived mainly on the basis of farm level resource differences. Somewhat different input-output coefficients are used for the NMAPC participants models. The use of LP to model farm production is discussed in Chapter IV. The analysis then concentrates on the constraints of the farm system in the basic models. This discussion of constraints at the farm level is used as a departure point for further analysis and experiments on selected management strategies and policy interventions. Analysis of the NMAPC production models in Chapter VI focuses on the promised expansion and 'full-phase' features of the NMAPC schemes.

Analysis of both the traditional and NMAPC smallholder models was related to the policy issues and programs. In particular, the results of NMAPC analysis are emphasized. Some lessons and generalizations relevant to other similar savanna areas are discussed within the context of the study. Limitations of the study and suggestions for future research design and directions are also discussed in the last chapter.

The Analytic Approach

The choice of an analytic approach depends primarily on purpose of the study, the data available, and the nature of structural components and coefficients being sought to elucidate a particular problem. The problem addressed in this study calls for a comprehensive technique that can handle a variety of farm production activities and constraints. Linear programming represents such a technique. The flexibility of the approach to incorporate realistic and/or empirical constraints has greatly facilitated its use in modeling representative farm situations.[1] LP has been used extensively to study farming and production processes under African savanna conditions. Figure 2.1 is a diagram of a representative farm model. The LP models developed for the representative farms incorporate the following important features of smallholder production:

1. Diversity of the cropping pattern found in the Nuba Mountains area.
2. Seasonality of the production process, as influenced by the rainfall pattern of the area. The time distribution of the agricultural operations is explicitly incorporated by the model.[2] Seasonal input constraints are represented mainly

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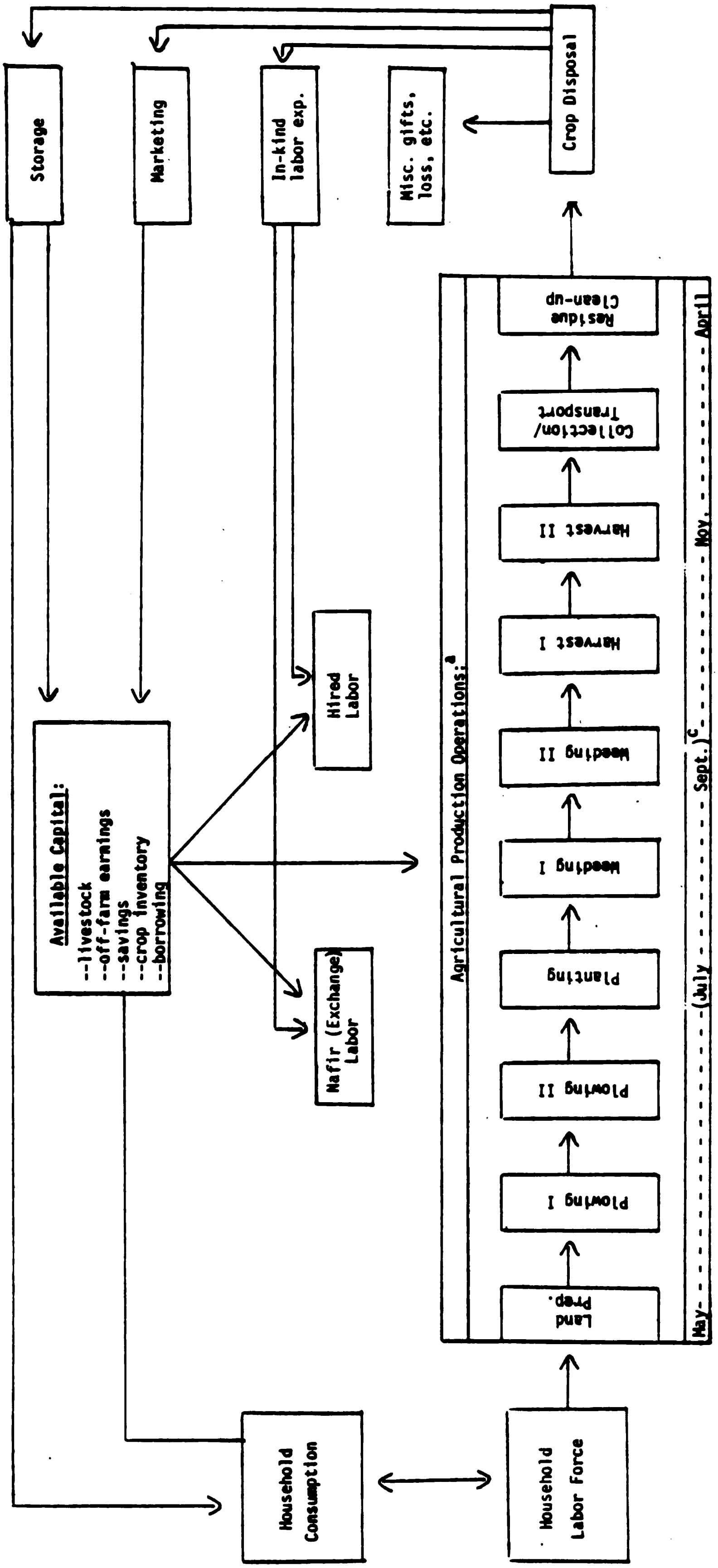
[1] This refers in particular to the institutional or observed constraints of the farm environment.

[2] In addition, the planting-time experiment discussed in Chapter V specifically considers the timing aspect and consequences of the agricultural operations. Analysis and assumptions for this experiment are based on experimental research and data presented in Appendix II.



[a] Crops include: cotton, sorghum, sesame and ground nuts.

[b] Plowing I and II are under N-MAPC models only.

[c] Effective rainfall months.

Figure 2.1 Diagramatic Representation of the Farm Production Model

through the monthly distribution and availability of labor and operating capital.

3. Subsistence dura (sorghum) consumption needs are represented by an explicit constraint in the model.
4. Farmers are assumed to be risk-averse. However, the only risk considered is the weather-induced effect on yield variability. The main representation of this issue is through the safety-first requirement implied by the dura consumption constraint. This strategy which is based on an empirical foundation is a realistic specification.

In addition to the analysis of basic models of smallholder production, the LP models were also used in a number of experiments to analyze selected management and/or policy intervention alternatives.[1] The detailed features of the basic LP models and these experiments are discussed in Chapter IV.

Limitations of the Analytic Approach

In general the limitations of linear programming are related to the validity of the assumptions incorporated in the LP model.[2] An important limitation of the standard LP model is that it does not include any

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[1] With LP it is relatively easy to vary available prices and resources as well as input coefficients in order to simulate various management and/or policy alternatives.

[2] In the standard LP model which maximizes (minimizes) a linear-objective-function subject to some linear constraints, several basic assumptions are made: (1) additivity and linearity of activities; (2) divisibility of activities and resources; (3) finiteness of alternative activities and resource restrictions; and (4) single-value expectations; i.e., resource supplies, input coefficients, and prices are known with certainty [27].

allowance for risk, which is central to decision making among smallholder farmers [11, 53]. In this study, the objective function which maximizes net returns from crops subject to satisfying sorghum consumption requirements, closely simulates the decision behavior of the smallholders in the area.[1] In other words, the objective function maximizes net returns subject to a safety-first constraint. This formulation has been found to be appropriate in a number of similar empirical studies [11, 53].

Another related issue concerns the type of technology that is represented by the LP assumptions.[2] Given the small scale of traditional smallholders in the area and the dominance of hand-hoe cultivation, the linear and additive scale of production seems an appropriate representation of the technology. In other words, the physical returns and resources required do change proportionally as the cultivation size is increased or decreased. Perhaps an important limitation, though not directly related to the LP format, is the limited representation of the weather-induced yield variability in the model. This could have been improved by incorporation in the model of a simulation component.[3] However, lack of data needed for such an approach made this alternative infeasible. Emphasis was given instead to management factors, together with sensitivity analysis of yield levels in relation to variations in annual rainfall.

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[1] The revenue maximization and security objectives of the smallholder production are discussed in somewhat more detail in Chapter IV.

[2] Namely the constancy and additivity in production technology. However, the LP technique and its different versions offers some means of treating some of the nonlinear/nonconstant implied technologies.

[3] For an example of studies using such an approach see Crawford [18] and Lynam [35].

Sources of Data

Two primary sources of survey data are used in this study. One survey was conducted by the FAO in the 1978-79 season; another supplementary survey was carried by the researcher during the 1979-80 season. The following is a detailed description of the two data sources:

FAO Survey

The survey was carried out during February through March, 1979. Interviews were conducted by students of the Department of Rural Economy, University of Khartoum and members of the Statistics Department, Ministry of Agriculture, under the supervision of the FAO and staff of the Rural Economy Department.

The survey obtained basic farm management data, using a recently developed FAO "Farm Management Data Collection and Analysis System" [23]. A single-visit survey method was used. The two main categories of data sought in the survey pertain to resource inventory data (farm labor, land, livestock, tools, etc.) and resource utilization data (input-output of labor, crops, livestock, etc.). The data on the latter category was disaggregated on monthly basis. The two main classes of farmers surveyed were: traditional smallholders and NMAPC schemes participants. The eight regions of the Nuba Mountains area were covered in the survey. The sample distribution of smallholders by farm type and region is shown in Table 2.1.

Table 2.1 Smallholders Sample Distribution by Farm Type and Region: FAO Survey, 1979

Region	Traditional Farmers	MNAPC Participants	Total
Kadugli	34	21	55
Lagawa	29	10	39
Talodi	18	11	29
Kalogi	12	11	23
Abu Gebha	24	16	40
Abassya	4	14	18
Um Brembita	24	11	35
Dilling	4	4	8
Total	149	98	247

The Researcher's Survey

With the FAO survey data in hand,[1] the researcher conducted another survey for the following purposes:

1. To obtain a first-hand familiarity with the area and its different regions.
2. To collect additional data for the study. Emphasis was given to the following:
   a) Input-output relations for only the four main crops considered in this study (i.e., sorghum, cotton, sesame, and groundnuts).
   b) Data pertaining to mechanization, available through regional offices of the NMAPC.

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[1] Through his association with the Department of Economy, University of Khartoum, the researcher had access to this data before his own survey was carried. This enabled him to meet and discuss with some members of the survey team the nature of the information collected. This discussion was helpful for the researcher in designing and conducting his own survey (i.e., sampling frameworks, locations, route of travel as well as other logistical matters).

c) Updated marketing information for the above four crops.

d) Food and in particular grain (sorghum) consumption of household units.

The Survey

Assisted by two interviewers (one university graduate and one high secondary school graduate), the researcher conducted the survey in the Nuba Mountains area from May 1, 1980 to July 1, 1980. The eight regions of the area were covered one at a time, in the following order: Abassya, Um Brembita, Abu Gebha, Kalogi, Talodi, Kadugli, Lagawa, and Dilling. Relevant information from government offices and departments (especially those of NMAPC) was obtained while at each region.

The Population

Administratively, the Nuba Mountains area is part of South Kordofan Province. The latter is composed of four administrative districts; Eastern, Western, Southern and Northern (see Map 2, Appendix I). The eight regions of the Nuba Mountains are distributed by district as follows:

South Kordofan Province District			
Eastern	Western	Southern	Northern
Abassya Um Brembita Abu Gebha	Lagawa	Kalogi Talodi Kadugli	Dilling

The two sub-classes of smallholders of interest in this study are traditional farmers and NMAPC schemes participants. The exact number of smallholders in each of the eight regions is not known. An estimate of traditional farmers in the province according to the South Kordofan Farmers Union (SKFU) is 380,000. The Nuba Mountains Farmer's Union comprises the majority of the SKFU's total members.

The NMAPC schemes participants on the other hand are known and recorded for each scheme in the eight regional stations of the NMAPC.

Sampling Design and Method

Geographic location was used as the first stratifying variable. Samples of traditional and NMAPC participants were taken from each region separately. The sampling method was as follows.

After discussion with the agricultural officers of the regional station, a purposive selection of one or two NMAPC schemes was made. Criteria for selection of these schemes included factors such as nearness, conditions and access to the fields (the survey was at the beginning of the rainy season), and scheme crop rotation.[1] A simple random sample was then taken from the list of participants in each scheme.

For the traditional smallholders, a purposive selection of one or two villages was taken from each region. Criteria for selection of villages were similar to those of NMAPC schemes. After discussion with the village head a list of the farmers was prepared and a random sample drawn. Smallholders who held plots in the NMAPC schemes were not interviewed; only farmers with traditional plots were included.

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[1] Biases resulting from this purposive selection were judged to be minimal. Diversity in agricultural and smallholders conditions within each region is generally small. This is especially true for the NMAPC schemes which are operated under many standard features and similar conditions (see discussion in Chapter VI).

Sample Size

Statistical theory can help determine the desired sample size from a given population, based on information about the criterion variable used for selection. Ideally, the distribution of this variable in the population in question, together with desired levels of accuracy of results and analysis should be known in advance. In most situations, as in this case, it is difficult to obtain this information in advance. Further, and most likely, a multiplicity of variables (household size, cropping pattern, domestic organization, etc.) rather than only one variable are of interest in investigating farming and production systems. In this study, practical considerations such as budget, time, conditions of the fields in the rainy season, and judgment, were the main factors that determined the sample size. The distribution of farmers by farm type and region in the final sample was as shown in Table 2.2.

Table 2.2 Smallholders Sample Distribution by Farm Type and Region: Researcher's Survey, 1980

Region	Traditional Farmers	MNAPC Participants	Total
Abassya	7	1	8
Um Brembita	3	4	7
Abu Gebha	9	9	18
Kalogi	10	10	20
Talodi	9	8	17
Kadugli	36	31	67
Lagawa	9	10	17
Dilling	16	16	32
Total	99	89	188

Data Collection

Discussions with some of the members who participated in the previous FAO survey were helpful in developing questionnaires for this survey. Interviewers were introduced to the questionnaires first in Khartoum, where it was explained and discussed with them. Upon arrival in the field, during the first days at Abassya, questionnares were again tested and discussed with interviewers.

Farmers were interviewed at their farms or in the villages. To facilitate communication, the purpose of the survey was first explained to the head of the village (Shiekh), when first preparing the list of farmers and choosing the sample. The Shiekh in turn introduced the interviewers to the farmers and briefly explained the purpose of the survey to them. More explanation were then made by the interviewers to each individual farmer before recording the information.

For the NMAPC participants, the agricultural inspector of the station or the agricultural officer resident in the field (Khabir) took the role of the village head in explaining and introducing the interviewers.

Other Sources of Data

Besides the two primary sources of data just described, numerous other sources of data were used in this study. These include:

1. NMAPC official records at the regional field stations and headquarters.
2. Agricultural Research Corporation
    a) Kadugli Research Station
    b) Headquarters at Wad Madni

3. Agricultural Bank of Sudan
    a) Dilling Branch
4. Meteorology Department
    a) Headquarters at Khartoum
5. Mechanized Farming Corporation
    a) Dilling Branch
    b) State Farm at Habila (Dilling area)
6. South Kordofan Province, Commissioner's Office
    a) Agricultural Service Department
    b) Cooperative Department
    c) Planning and Development Department
7. Proceedings and Discussions of NMAPC Working Agricultural Conference (June, 1980).
8. Informal interviews with officials at NMAPC and other government departments.
9. Reports, working papers, and discussions with members of foreign research and development projects in the region.
    a) Hunting Technical Services Ltd.
    b) German Technical Aid Project
    c) The EEC (SATEC) project
10. Other miscellaneous reports and documents.

CHAPTER III

CHARACTERISTICS OF SMALLHOLDER AGRICULTURAL PRODUCTION SYSTEMS IN NUBA MOUNTAINS AREA

This chapter is intended to serve two primary purposes:

1. to give an understanding of the general context within which the farming units operate by describing the nature, amounts and variability of its resources, agricultural activities and production; and
2. to serve as a base for the design of the LP production models and the following LP analysis presented in Chapter V and VI.

The first part describes the climatological environment (climate, rainfall, soils and vegetation) of the area. Next, both traditional and NMAPC agricultural production systems are discussed.

Climatological Environment

Boundary

The Nuba Mountains area is a hilly area in the north central part of South Kordofan Province (see Map 1, Appendix 1). It is part of the central clay plains of the Sudan which extends from the east to the west of the country.

Latitude 12° 10' N forms the dividing line between the sandy steppes of North Kordofan and the clay plains of South Kordofan. The southern boundary of the latter province is Bahr-el-Arab, which is at latitude 10^0 25 N.

Climate

The area is located in the savanna belt of the northern hemisphere tropics, having a continental climate classified by Meigis [37] as "hot semi-arid." The main influence in the climate of the area is brought about by the migratory movement of the Intertropical Convergence Zone (ITCZ), [41]. The ITCZ moves from north to south and back again each year.

This movement of the ITCZ is associated with a shift of wind direction from north to south, carrying moist air over the area. This occurs around mid-April and brings in the first erratic showers, signaling the beginning of the rainy season, which continues until the end of October.

By the end of October the wind changes from a southerly to a northerly direction, bringing dry air to the area. This is the beginning of the dry period which extends fron November through mid-April, where again the area falls under the influence of the ITCZ and the cycle is repeated.

Rainfall

Amount and distribution of rainfall are the most important factors influencing economic activity and social life in the region. In particular, important aspects of agricultural production (activities, operation timing, yields, etc.) are determined to a large extent by these factors.

Although the rainy season extends from May until October, most of the rainfall occurs between July and September. The amount of rain increases southward. In the north of the region average rainfall is 500 mm, it increases to 800 mm in the Southern Jebels. Within the Nuba Mountains area, there is less variation in amount of annual rainfall. Annual rainfall data for four stations in the region are shown in Figure 3.1. The stations: Dilling, Abassya, Lagawa, and Kadugli are located in the North, East, West, and South divisions respectively. Except for Kadugli (South), which has an average annual rainfall of 720 mm, the rest of the stations have an average rainfall slightly above 600 mm.

A study (HTS [38]) into the variability of annual rainfall in the area showed that in the north, where the mean annual rainfall is 500 mm, it can be expected to be less than 365 mm in 20 percent of years, and less than 640 in 80 percent of the years. In the south where mean annual rainfall is 800 mm, annual rainfall of 695 mm or less can be expected in 20 percent of years, and annual rainfall of 895 mm or less in 80 percent of years. The study concluded that "there is no firm evidence of any long-term cyclicity in the rainfall fluctuations occurring in the savanna regions" [38, p. 23].

However, despite this relative stability of long-term and annual distribution of rainfall, the monthly rainfall distribution is highly variable. For example, HTS [38] estimated that for the Kadugli area, on average 11 percent of the annual rainfall falls in May (with coefficient of variation (C.V.) of 0.75); 14 percent falls in June (C.V. = 0.4), and 62.5 percent in the months of July, August and September (C.V. = 0.35 - 0.4), and the remainder falls in October (C.V. = 0.5).

It is worth mentioning here that these patterns of rainfall distribution and characteristics has important implications for crop yield levels and husbandry practices. First, although annual rainfall has a low probability of declining to levels that would result in crop failure, annual rainfall variations results in substantial variation in yields.

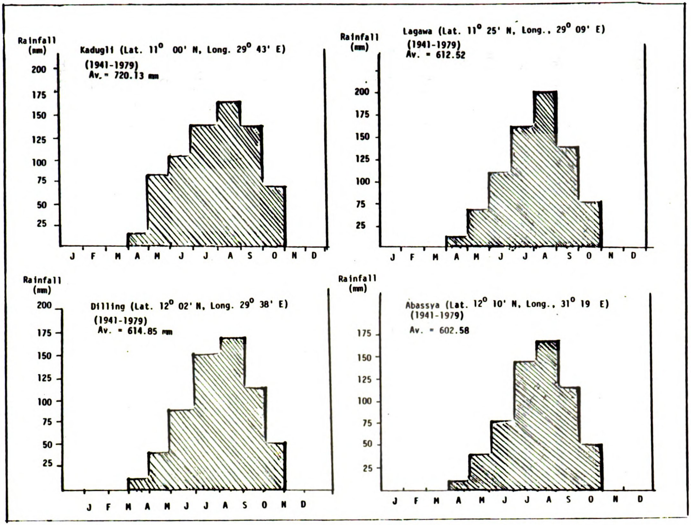

Figure 3.1 Rainfall Monthly Distribution for Four Stations in the Nuba Mountains Area, Constructed from Data Provided by Meteorology Department, Khartoum

Second, aside from these between-years variations, there is high variability in the monthly rainfall distributions. This greatly influences the pattern and timing of agricultural operations, especially those taking place at the beginning of the growing season (i.e., land preparation and planting).

Soils

The Nuba Mountains are outcrops of resistant Basement Complex rocks, mainly granites, mica schists and quartzites. The topography varies from undulating to rugged rising to a height of a few hundred feed up to 3,000 feet above the plain. The jebels and associated foothills occupy 40 percent of the area. These jebels are separated by a series of gently undulating or almost flat intermontane plains occupying the remaining 60 percent of the area.

The distribution of soils in the region is complex. The nature of these soils follow more or less their location with respect to the jebels, footslopes and planes.[1] Six classes of soil types has been defined for the area (HTS [38], AHT [41]), with the aim of considering their agricultural potential. All of these subsoils except the dark cracking clays has limiting physical and/or chemical properties that render them of low agricultural potential in crop farming.[2] They are suited and used for

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[1] This distribution, in a form of catenary sequence, determines their texture and clay content (for a diagramatic representation of this, see HTS [38], p. 16).

[2] The dark cracking clays are the Nb3 soils according to the HTS [38] classification; or the S2 soils according to AHT [41], which follows the Sudanese suitability classification.

dewlings, limited grazing sites and to a lesser extent for fruit and vegetable production, the latter being in and around flood plains, which comprises 5 percent of the area.

The soils with the greatest potential and used for crop production, are the dark cracking clays also known as vertisols or black cotton soils. Covering 40 percent of the area and more than half of the intermontane plain, these soils occur mostly in the middle and lower slopes and in the valley bottoms. These soils support 80 percent of cropping in the region. Almost all the smallholder agriculture and NMAPC schemes are located in these soils.

This class of soils with a high clay content (60 percent), generally has no limiting chemical properties (i.e., nonsaline and nonsodic), although nitrogen and phosphorous are low. The main difficulty in managing these soils is due to their physical structure. Quick ceiling of the cracks leads to run-off and serious erosion caused by additional accumulating water. The greatest difficulty however is attributed to the extremes of consistency exhibited by these soils. They are very hard when dry and very plastic when wet. This has an important implication for land preparation and tillage operations, whether performed by man or machines and leaves a short time to perform tillage under optimal soil condition.

Under existing farming practiced in the area the fertility of these soils depends primarily on the management practices. In the present system no fertilizers are used, instead the land is cultivated for 2-4 years and then allowed to rest for roughly an equivalent period of time before it is brought back for cultivation again.

Vegetation

Vegetation growth in the area follows the savanna pattern. These are mostly of the accaia species. AHT [41] contains a concise account of the exploitable vegetation resources in the Nuba Mountain area.[1] These resources also offer substantial off-season employment to farmers in the region. The most important of these: firewood and charcoal (mostly *Accacia seyal*), timber for building (various species including *Boragrus aethiopiam* (daleib), bark for ropes (*Accacia Senegal*, *Adonsonia digitata* as others), *A. senegal* is also used for gum, bamboo poles (*Oxythenantera abyssinica*, grass fencing (sheragnia) (namely *Hyparrhenia spp*) [38].

The vegetative growth of shrubs and trees also constitute an important investment by the farmer in the form of land clearance, when the land is brought into cultivation for the first time.

Traditional Smallholder Agriculture

Household Characteristics

Household, for the purpose of this study, refers to the unit of family members who live and eat together. This unit includes a "household head" who is the decision maker in all aspects pertaining to the well being of the family. In particular the household head has the responsibility of making decisions concerning the agricultural production and its related activities.

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[1] See Ministry of Agriculture Food and Natural Resources, "Nuba Mountains Region, Development Potential Survey, Annex 1-5," prepared by *AGRAR-UND HYDROTECHNIK ESSN. FRG*, Sudan, 1977, [41].

Household Head Characteristics:

1. Age. All of the household heads interviewed in the researcher's survey (1979/80) were males,[1] 93 percent of whom were in the age bracket of 16-65 years. The remaining 7 percent were above 65 years old.

2. Educational Achievement. Analysis of the educational achievement of the household heads interviewed shows that 80 percent of them have no formal education. Eight percent had "Khalwa" education,[2] and 12 percent had some primary school education. Such a distribution is typical of traditional farmers in the developing countries. Education, being an important form of investment in human capital, is thought to be an important factor because it increases the individual's awareness of alternatives, facilitates learning and adoption of new ideas and in general tends to increase the productivity of human capital. In a number of farm and production studies, educational achievement has been used as a proxy for managerial ability. Because of the difficulty of equating school years to managerial ability, such a formulation is likely to result in an insignificant coefficient.[3] In this study, it is argued that production

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[1] Very few of the NMAPC tenancies were registered in the name of women, in which case they are either managed jointly or exclusively by the husband.

[2] Khalwa is a 1-3 year religious education in basic reading and writing.

[3] Other studies (e.g., Massel and Johnson [36]) using farmer's experience and skills, as proxies for management reported highly significant coefficients.

decisions are related not only to education, but rather to the resource endowment, constraints and opportunities that face the farmer. It is better to address the impact of these factors on managerial decisions directly.

3. Off-Farm Occupations. Table 3.1 shows the distribution of off-farm occupation by status and season for the household heads. The nature of the seasonal crop production in Nuba Mountains has two important implications. First, many persons (13 percent of those interviewed) whose main occupation is not agriculture,[1] are involved in agricultural production during the season. Second, and most importantly, is the fact that smallholders are involved in a number of off-farm activities when the growing season is over. Although the off-farm employment is concentrated in the off-season, a number of smallholder farmers (15 percent) work as hired laborers in agriculture during the growing season. This situation arises mostly because of cash requirements for consumption or production developing early in the season (early to mid-August). This issue is discussed later in conjunction with the credit situation.

The type of off-farm/off-season employment in the region is mostly influenced by the savanna climate of the area. Cutting wood/hay, fencing, charcoal burning, honey collection, gum arabic collection, rope marking, etc., are the most common activities. At present, very few farmers (7 percent) migrate from their localities to work as hired laborers in

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[1] Those reporting a permanent job (mostly trade and government jobs) during the season (see Table 3.1).

Table 3.1 Off-Farm Occupations: Distribution by Status and Season

Off-Farm Occupation:	% of[b] Household Heads	# of Household Heads	Status of Occupation[a]					
			Permanent		Seasonal		Occasional	
			Not During Season	During[c] Season	Not During Season	During Season	Not During Season	During Season
Agricultural:								
1. Mechanized Sub-sector	9.8	14			8	1	1	4
2. MIAPC	16.1	23				15		8
3. Traditional	12.6	18				11		7
Livestock:								
1. Husbandry	2.1	3			3			
2. Trade	2.8	4		1	3			
Nonagricultural:								
1. Trade	12.6	18	1	13	4			
2. Cutting Wood/Hay	11.2	16			8		8	
3. Water Delivery	5.0	7			5		2	
4. Government Job	10.5	15		10	3			2
5. Miscellaneous[d]	33.6	48		2	32	1	11	2

Source: survey data (1979/80).

[a] Status considered as: Permanent = if involved in it the whole year.
Seasonal = if activity restricted to, or after growing season.
Occasional = if not in continual basis or less than a week in a month.

[b] Based on responses not respondents.

[c] Whether or not during the crop growing season.

[d] Such as, honey collection, house building, charcoal burning, shoemaker, laborer in the market, well digging, etc.

the larger-scale mechanized farming of Mechanized Farming Corporation (MFC) in the North and Eastern parts of South Kordofan Province.[1]

Household Composition and Demographic Characteristics

Table 3.2 shows the distribution of household members in relation to the head. Although the average household head is shown to have more than one wife, this statistic is influenced by a few (23 percent) household heads reporting more than one wife.[2] The wife plays an important role in agricultural production, not only by helping the husband in the work of the agricultural plots, but also by undertaking the responsibility of cultivating the "Jubraka" (small home plot). Another important aspect in the role of the wife is that of her kinship relation in regard to the availability of the "Nafir" (communal or exchange labor).[3]

The demographic characteristics of the survey (1979/80) sample are shown in Table 3.3. The sex ratio indicates a marked dominance of males in the household.[4] It should be noted that this statistic is influenced mainly by the dominance of sons over daughters in the household membership (see Table 3.2).

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[1] Dilling, Habila and El-Beida mechanized farms. Affan [4] discusses some of the socioeconomic aspects of traditional farmers' employment in Habila mechanized areas.

[2] Those reporting two, three, or four wives were 20, 2, and 1 percent, respectively.

[3] Especially among the Nuba ethnic groups [38].

[4] This was also found to be true at the province (South Kordofan) level in Sudan's second population census (1977).

Table 3.2 Average Household Size and Composition

Region	# of Households	Relation to Household Head: Wife	Son	Daughter	Relative	Household Size
Abassya	8	1.13	2.50	1.75	0.50	6.88
Um Brembeta	7	1.57	2.57	2.57	0.43	8.14
Abu Gebha	18	1.17	2.56	2.17	1.04	7.61
Kalogi	20	1.20	2.35	2.00	0.60	7.15
Talodi	17	1.29	2.18	2.17	0.35	6.94
Kadugli	65	1.23	2.39	2.20	0.35	7.17
Lagawa	19	1.16	1.68	1.00	1.00	5.86
Dilling	31	1.36	2.68	2.61	0.58	8.23
All Regions	188	1.23	2.33	2.07	0.52	7.18

Source: Computed from survey data (1979/80).

Table 3.3 Household Demographic Characteristics

Characteristic	Abassya	Um Brembeta	Abu Gebha	Kalogi	Talodi	Kadugli	Lagawa	Dilling
1. Sex Ratio ($\frac{\#M}{\#F}$ x 100)	1.68	.86	1.2	1.53	1.07	1.11	1.52	1.11
2. Proportion of M ($\frac{\#M}{total}$ x 100)	.53	.44	.51	.52	.51	.51	.57	.47
3. Dependent Child # (0-14 years)	21	28	68	61	62	218	40	134
%	.31	.46	.49	.41	.49	.42	.30	.51
4. Dependent Aged # (> 65 yrs.)	3	1	5	5	2	11	4	9
%	.07	.14	.03	.04	.02	.03	.04	.03
5. Active Population # (15-65 years)	31	28	64	77	53	236	67	102
%	.61	.52	.47	.54	.49	.53	.65	.42
6. Dependency Ratio [(3+4) ÷ 5]	.79	1.16	1.5	1.05	1.45	1.17	.72	1.7
7. Average Family Size	6.87	8.14	7.61	7.15	6.94	7.17	5.84	8.23

Source: Computed from survey data (1979/80).

An interesting characteristic, as can be seen from the table, is the high proportion of dependent children (0-16 years old), which goes as high as 50 percent in Dilling region. This feature is more or less typical of developing country populations.

An important implication of this feature is that it results in a high dependency ratio. This would be especially true if coupled with a high dependent-aged ratio. The latter ratio was found to be small in this case (only around 4 percent). Still the figures for the dependency ratio were markedly high for all regions.

The high proportion of children also has a major influence on the remaining two important characteristics, i.e., the family size and the active population statistics.

Active population ratio (16-65 years) or what is sometimes referred to as economically active population ratio, gains its importance from the fact that it is commonly used to make inferences about the productive capacity of the household.[1] In traditional agricultural settings, this is deficient in many aspects. Most important criticisms include such as: it includes individuals (such as women) who participate minimally in the economic activity(s) under consideration and others (such as students) who participate, if any, only on part time basis. Also it excludes individuals less than fifteen years (and less importantly those above sixty-five years) which is not uncommon in developing countries to start working. Finally, this index (economic active population

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[1] Sometimes used for a region or a country likewise, as was the case in Sudan's second population census (1977).

16-65) is deficient in that it does not give consideration to domestic organization and other labor recruiting institutions relevant to the household (e.g. hired and communal "Nafir" labor, which are discussed in detail later in this chapter).

The alternative adopted in this study is to make use of the observed family labor utilization and distribution in the course of the analysis. The active population ratio in this case, and as mentioned above, is greatly influenced by the high dependent children ratio. The highest active population ratio was observed in Lagawa (65 percent) and lowest (42 percent) in Dilling region. We note that this is consistent with the inverse effect of dependent children; the latter ratio was lowest in Lagawa (30 percent) and highest in Dilling (51 percent).

Lastly, the observed high proportion of dependent children, influences in a straight forward fashion the overall family size of the household. As can be seen from Table 3.3, the average family size is around seven members.

Household Grain Consumption

Consumption is the goal and center of the household unit activities. In traditional agricultural settings consumption decisions and activities are interwoven in a complex fashion. In this case consumption requirements and preferences are reflected directly in the crops grown and areas devoted to them in the production sphere. Almost all crops grown by smallholders in the Nuba Mountains area are partially used in consumption (e.g., sorghum, sesame, groundnuts, lubia, etc.). However, sorghum (dura), holds a special place in the production/consumption complex of the household.

More than 80 percent of the cultivated area in the Nuba Mountains area is under dura. Beside its varied consumption uses as the basic staple food, dura has other important uses for the household. It is used to meet certain social and ceremonial obligations, in-kind payment of hired labor, and is sometimes used (in a form of barter exchange) to pay for goods bought at village shops.

This background note is intended to provide understanding of the special place that dura has in the smallholder's cropping plans and rotation. This will be discussed in more detail later, but another methodological point of relevance here is the behavioral assumption (pointed out in the previous chapter) that farmers, as one way of risk management decide on the production of dura such that at least household requirements are secured. This assumption is based on the observed and on-going tradition of retaining portions of the produced dura.[1] Table 3.4 shows the quantities initially retained at the household and their percentage of the total production. The table also shows the average annual consumption of dura by the household. Resulting estimates of consumption seem large and are also extremely variable (see standard errors). These estimates are further discussed, compared and adjusted later, when developing the dura consumption constraints in the LP models (Chapter IV).

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[1] Farmers store dura at home in a structure locally known as "Seiba."

Table 3.4 Household Annual Dura Consumption and Initially Stored Quantities

Region	Household Stored Dura[a]		Annual Consumption
	Quantity (90-kg Sacks)	% of Production	Quantity (Malwas)[b]
Abassya	12.14 (2.42)	86.74 (2.79)	409.5 (89.36)
Um Brembita	21.25 (15.34)	52.97 (16.72)	702.00 (134.26)
Abu Gebha	25.28 (5.25)	68.84 (5.77)	697.67 (62.86)
Kalogi	13.37 (1.84)	64.66 (4.93)	536.90 (46.64)
Talodi	30.30 (11.09)	59.10 (9.26)	434.35 (40.55)
Kadugli	8.48 (6.82)	87.84 (2.57)	513.80 (35.70)
Lagawa	12.19 (3.31)	58.70 (6.77)	403.00 (42.14)
Dilling	13.25 (1.89)	63.80 (5.8)	556.12 (55.51)

( ) = Standard error.

Source: Computed, survey data (1979/80).

[a] Refers to quantities initially retained from the harvest, but not necessarily consumed at the household.

[b] Malwa is a local volume measure = 1.4 liters; approximately, the 90-kg dura sack has 30 malwas.

Land Ownership and Cultivation Characteristics

Historically there has been no land shortage in the Nuba Mountains regions. Recently, however, a number of developments are just beginning to alter this situation. Notably of these are: the continuous expansion of large scale mechanization (especially in the northern and eastern parts of the region),[1] introduction and expansion of NMAPC schemes, small but consistent rise in settlement rate of nomadic tribes, and finally the internal pressures and dynamics of population under these difficulty-managed savanna land.

All these contribute to change the land availability situation, but it has not reached a problematic or limiting extent yet.

Land Ownership

Ownership of land in the area is on a noncontractual basis. This is accomplished within the sphere of the village by either inheriting the land or clearing it (from trees and bushes) [21]. Authority over land is also recognized by the different villages in a traditional way.[2]

Another issue relating to the rights of land concerns the nomadic groups in the area, as they pass and enter cultivated land. This has

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[1] These include not only official MFC schemes, but also the continually expanding numbers of private schemes under the so-called "undemarkated schemes." As of June, 1980, the number of registered such scheme in South Kordofan Province reached 209 (each with an area of 1,000 or 1,500 feddans).

[2] This among other things created a big problem for NMAPC in exercising authority over land and its allocation between different individuals and different villages (see discussion in Chapter VI). Land rights of a certain tribe and/or village can not easily be allocated to farmers of another tribe or village.

resulted in frequent and rising conflicts between the pastorialits and cultivators [30]. At present this still remains a problem and no rules are set to deal with it other than the traditional attempts of tribal recognition of rights of those involved. NMAPC as will be discussed later, also has not achieved a reasonable solution to this problem.

Cultivated Land

1. Land Size. Basically there are two types of cultivated plots for the smallholder in the area.
    a. Jubraka: This is a backyard garden or small plot, usually situated at or very near to the home. Table 3.5 shows the average size of these plots for the different regions. As can be seen from the table these plots are usually of small size (around one third of a feddan).[1] The wife usually has the responsibility of cultivating this plot. The tradition is to grow a number of crops (dura, maize, cucumber, okra, lubia, etc.) sown in a mixture, very early in the season. This way crops can mature and support the household for some period (5-6 weeks), before the harvest of the other field plots.[2]
    b. Saraya: These field plots originate from land brought into cultivation either from fallow (under the system of shifting

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[1] One feddan = 1.038 acres.

[2] Much of the Jubraka crops are of the quick-maturing types and are also consumed in a vegetable form (i.e., before full maturation).

Table 3.5 Average Area of Jubraka (House Plot) for the Different Regions

Region	Area (feddans)
Abassya	0.26
Um Brembita	0.48
Abu Gebha	0.21
Kalogi	0.37
Talodi	0.30
Kadugli	0.34
Lagawa	0.46
Dilling	0.31

Source: Computed from the survey data (1979/80).

cultivation), or a new cleared land. In the first year of cultivation, the land is referred to as "Harig,"[1] in the second and subsequent years it is called Saraya. All potential for expanded land base as referred to in this study comes from these lands. Table 3.6 shows the size distribution of the smallholders cultivated plots in the area. Eighty-three percent of the farmers cultivate less than 15 feddans, and more than two-thirds of the farmers with less than 10 feddan cultivation size. Further, the picture for each of the eight regions is more or less the same.

2. Multiplicity and Distance of Plots. An additional feature, which is common to savanna agricultural systems is that farmers tend to cultivate more than one plot of land. This is primarily because of the fallowing and the search for suitable soil areas. Table 3.7 shows that 40 percent of the farmers cultivate two separate plots, 21 percent have three plots, and 6 percent cultivate four or more plots.

With the exception of the Jubraka which as mentioned above is usually situated right or near the house, these plots are all situated outside the village. Table 3.8 shows the distance of these plots from the residence. As can be seen from the table more than half of these plots are far, with the majority (48 percent) being very far. This has an important implication for access to these lands and for time spent in travelling to and from fields.

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[1] The name Harig (meaning burning) refers to the land preparation method, which is through burning of the grasses.

Table 3.6 Size Distribution of Plots Cultivated by the Smallholders in the Area: 1979/80 Season

Region	Total Area of Cultivated Plots in Feddans:													
	(0-5.0)		(5.1-10.0)		(10.1-15.0)		(15.1-20.0)		(20.1-30.0)		(30.1-50.0)		(> 50.1)	
	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%
Abassya	1	12.5	5	62.5	2	25.0								
Um Brembeta	1	16.7	1	16.7	1	16.7	1	16.7					2	33.3
Abu Gebha	3	17.6	7	41.2	6	35.3	1	5.9						
Kalogi	3	15.8	8	42.1	2	10.5	3	15.8	2	10.5	1	5.3		
Talodi	1	7.7	3	23.1	4	30.8	2	15.4	1	7.7	1	7.7	1	7.7
Kadugli	35	58.3	19	31.7	5	8.3	1	1.7						
Lagawa	4	25.0	7	43.8	2	12.5	3	18.8						
Dilling	3	13.6	8	36.4	3	13.6	4	18.2	2	9.1			2	9.1
All Regions	51	58.0	58	36.0	25	15.5	15	9.3	5	3.1	2	1.2	5	3.1

Source: Computed from survey data (1979/80).

Table 3.7 Number and Percent of Farmers with Multiple Plot Cultivation by Region

Region	Number of Farmers Cultivating Separate Plots:									
	1 Plot		2 Plots		3 Plots		4 Plots		5 Plots	
	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%
Abassya	1	12.5	5	62.5	2	25.0				
Um Brembeta	1	14.3	1	14.3	5	71.4				
Abu Gebha	2	11.1	5	27.8	11	61.1				
Kalogi	1	6.0	7	35.0	8	40.0	4	20.0		
Talodi	4	23.5	8	47.1	2	11.8	2	11.8	1	5.9
Kadugli	28	41.8	28	41.8	9	13.4	1	1.5		
Lagawa	7	36.8	8	42.1	2	10.5			2	10.5
Dilling	15	46.9	14	43.8	1	3.1	2	6.3		
All Regions	59	31.4	76	40.4	40	21.3	9	4.8	3	1.6

Source: Computed from survey data (1979/80).

Table 3.8 Distance of Cultivated Plots from Villages for the Different Regions

Region	Number and Percent of Farmers Cultivating Plots:							
	V. Near[a]		Near[b]		Far[c]		V. Far[d]	
	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%
Abassya	4	50.0	1	12.5			3	37.5
Um Brembeta			1	14.3	1	14.3	5	71.6
Abu Gebha	5	27.8	8	44.4	2	11.1	3	16.7
Kalogi			6	33.3	1	5.6	11	61.1
Talodi	3	17.6	4	23.5			10	58.8
Kadugli	8	12.1	20	30.3	8	12.1	30	45.5
Lagawa	1	5.3	8	42.1	1	5.3	9	47.4
Dilling	5	15.6	8	25.0	2	6.3	17	53.1
All Regions	26	14.1	56	30.3	15	8.1	88	47.6

Source: Computed from survey data (1979/80).

[a] V. Near = less than 15 minutes by foot/10 minutes by donkey.

[b] Near = 15-30 minutes by foot/10-20 minutes by donkey.

[c] Far = 30-45 minutes by foot/20-30 minutes by donkey.

[d] V. Far = more than 45 minutes by foot/30 minutes by donkey.

Another implication of this is the difficulty and cost entailed in the transport of food and drinks to these fields and transport of the harvest to the home or to the market.

Agricultural Technology and Crop Practices

Traditional smallholder agriculture can be described as consisting of small operating units, low level of capital inputs, dominance of hand labor, and generally low and unstable production. What follows is a brief description of smallholders' farm capital outlays, rotations and dominant crops, the set of agricultural operations adopted, and the farm labor organization.

Farm Capital

The level of capital investment and usage for smallholders in the Nuba Mountains area is very low. The bulk of capital outlays are operating capital (cash expenses), used mainly to pay for hired labor and expenses of the Nafir (communal or exchange) labor. Fixed capital items include primarily the hand tools with which all field operations are carried out.[1] Almost all farmers also have a "Seiba" (a cylinderical grass and mud structure) for storage of sorghum at home.

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[1] Only few hand tools are used. These include: long-handled flat hoes (Siluka) for checkrow planting, short-handled flat hoes for weeding (Jerraya), short-handled hoes with a strong angled blade (Sakaba) for cutting down sorghum stalks and light bushes, a range of knives, axes, blades or sickles for harvest, flat wooden paddles for threshing sorghum and long two-pronged rakes for cleaning fields of crop residues [38].

Operating capital is one of the most important factors in the performance of smallholder agriculture in the area. Its level and timely availability, greatly affects the size and efficiency of the operating units.

Its special importance is not only for meeting productive expenses, but also for meeting urgent consumption needs. Consumption needs tend to coincide with the seasonal needs to cover production expenses. For the most part farmers meet these demands for capital through borrowing from local money lenders, under what is locally known as the "shiel" system. Under this system, money lenders who are mostly village merchants and shopkeepers, advance cash or goods to the farmer. The latter in turn has to pledge his prospective crop at a value substantially lower than market price.[1] The implied interest rate differs according to location and time of borrowing but is usually substantial.[2] When the farmers do not get involved in sheil, they often are forced to work as hired laborers for others in order to obtain their needed cash.[3]

Operating capital needs of traditional smallholders are predominantly for meeting labor expenses. Hired labor is paid in cash with or without

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[1] "The surveys carried out by the Agricultural Bank of Sudan in S. Kordofan Province showed that about 50 percent of the cultivators received sheil and realized only 50 percent of the market price for their produce" [8, pp. 95-96].

[2] The implied interest rate usually declines as the harvest time approaches, but it can reach as high as 300 percent for loans made at the peak of the season [38].

[3] Sometimes the two go together when "the sheil merchant who is often a large farmer, gives no loans before his own farm work is done. The smallholder may have to work for the large farmers before he can get any loans" [8, p. 95].

additional pay in-kind. Nafir labor is paid solely in-kind (food and drinks). Occasional expenditures are made on items such as seeds, chemical insecticides, sacks, and transport of crops to home or markets. The dominance of operating capital use in labor expenses reflects the fact that at present, hand labor is the principal production input for smallholders in the area. Table 3.9 shows the average expenses per feddan for the different crops disaggregated by operation. Weeding and harvest, which are the most labor demanding operations, are also the most expensive. The variability in the average expenses (see ranges in Table 3.9), is related to the composition of the farm labor force; which at one extreme could be composed of entirely hired labor, and on the other extreme of entirely (unpaid) family labor.[1]

Formal sources of credit to smallholders in the area are virtually nonexistant. However, the Dilling Branch of the Agricultural Bank of the Sudan (ABS), has recently conducted a trial experiment to extend credit to smallholders through cooperative societies.[2] Results of the experiment were encouraging for expansion of the program [8]. Another potential source of formal credit exists for the NMAPC schemes participants. At present however, only mechanized cultivation is done for the participants on credit basis. The issue of NMAPC participant's credit will be discussed more in Chapter VI.

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[1] Family labor was not costed in the calculation of the average expenses shown in Table 3.9.

[2] The issue of credit and the ABS trial experiments are discussed in more detail in Chapter V.

Table 3.9 Average Expenses Per Feddan for the Different Crops by Operation (In Ls: 1 Ls = $2.0)

Operation	Sorghum	Sesame	Groundnuts	Cotton[a]
Land Preparation	0.45 (3.0)	0.07 (1.11)	0.90 (4.76)	--
Planting	0.29 (2.0)	0.39 (4.0)	0.55 (2.25)	0.29 (2.0)
Weeding 1st	1.14 (5.46)	1.18 (7.27)	1.57 (4.48)	0.95 (8.0)
Weeding 2nd	0.59 (3.29)	0.18 (1.40)	0.99 (3.67)	0.43 (3.75)
Harvest 1st	1.11 (6.67)	0.51 (2.8)	0.71 (4.0)	1.31 (7.2)
Harvest 2nd	1.01 (5.16)	0.36 (5.0)	0.53 (3.68)	--
Collection and Transport	1.0 (6.67)	0.57 (3.33)	0.66 (3.0)	0.95 (5.0)
Clean up (Al-awdi)	--	--	--	0.83 (3.10)

(   ) = Range of the estimate, i.e., difference between largest and smallest value reported. The ranges in the above table indicate a highly skewed distribution with a few high values. The reason for this as indicated in the text, is because of the differences in labor composition of the farming households.

Source: Computed from survey data (1979/80).

[a] Estimates from the NMAPC participants' sub-sample.

Rotations and Dominant Crops

Rotations and crop composition are influenced by physical environment, the state of technology, market opportunities, dietary preferences and resource base at the farm level.

Rotations

The agricultural system of smallholders in the area is characterized by shifting cultivation. This system is forced to adapt to the conditions of: lack of animal manure or use of commercial fertilizers; absence of appropriate rotation that can sustain yields for longer periods; and absence of pressure on land. This last factor, has been undergoing changes recently. Although it has not reached limiting magnitudes yet, its effects are beginning to show by an increase in the cropping periods and a decrease in the fallowing.

No definite rotation is practiced by the farmers in the area. The most common rotations that are followed loosely by the farmers include: sorghum-sesame-fallow-fallow; or a modification of this, sorghum-sesame/sorghum-sesame/sorghum, followed by a fallow. Cotton used to be grown by farmers in the area as a third crop in the rotation. Recently the relative decline of cotton growing by traditional farmers has resulted in an increase in the proportion of sorghum on land presently under cultivation [38]. When soil conditions permit, groundnuts may be introduced into the rotation. At present however, few farmers grow groundnuts and only in a limited scale.[1]

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[1] As indicated in the next section, groundnuts are grown relatively more extensively by the farmers in the northern part of the area (Dilling and Abassya regions).

Dominant Crops

The dominant crops of the Nuba Mountains regions include: cotton, sorghum, sesame, and to a relatively less extent groundnuts. Other minor crops include: millet, lubia (vigna), and maize. Horticultural crops are limited, more or less, to flood plain areas, and are of even less importance.

Table 3.10 shows the area and production trends of the four main crops in the regions of the area. Noticeable from the table is the decline of cotton feddanage in all regions; to such an extent that cotton growing is almost disappearing from traditional smallholder agriculture. The primary reason for this, is the decline in the farmer's price of cotton, in real terms and relative to other crops prices [39]. This issue, being of current policy concern, will be discussed in more detail in Chapters V and VI. As can be seen from the table, the crop feddanage is dominated by sorghum, followed by sesame. Groundnuts, although grown in all eight regions, is concentrated in the northern regions (Dilling and Abassya). The light loamy soils in these northern regions are more suited to the production of groundnuts.

Agricultural Practices

The following is a brief description of the varieties grown, the set of agricultural operations, their labor requirements, the agricultural calendar, and the level of crop yields attained.

Crop Varieties

With the exception of cotton, there is no certified crop variety grown by the smallholders in the area. In addition there is considerable

Table 3.10 Crop Area in Feddans and Average Production by Region (1974/75-1978/79)

Region	Season	Cotton		Dura		Sesame		Groundnuts	
		Area	Avg. Prod.[a]	Area	Avg. Prod.[b]	Area	Avg. Prod.[c]	Area	Avg. Prod.[d]
Kadugli	1974/75	31917	4	122966	7	23098	3	8208	6
	1975/76	57287	3.5	17960	8.5	25590	2	7532	6.2
	1976/77	35200	3	96876	8	8141	8	4505	8
	1977/78	22401	2.8	69729	10	14377	2	7955	6
	1978/79	14419	2.5	99299	10.8	11432	6.5	7923	6
Lagawa	1974/75	4650	-	18621	8	7707	3.5	4187	8
	1975/76	6400	-	20100	8	8800	3.5	7500	8
	1976/77	2686	-	23200	6	8356	4	6926	6
	1977/78	1450	1.7	20400	8	8400	3	8000	8
	1978/79	800	3.5	21500	10	8000	3.5	7000	9
Dilling	1974/75	4124	2.4	38636	9	19615	4	36082	10
	1975/76	4990	2.6	38752	6	12549	2.5	22157	7
	1976/77	3294	2.9	20264	4	8150	2.5	11010	6
	1977/78	1284	3	20193	6	10375	3.6	13813	7.5
	1978/79	1733	3	20088	10	8137	2.5	8224	7.5
Talodi	1974/75	20000	2.2	30112	-	2543	3	5899	7
	1975/76	20966	2.3	36903	7	1754	3	5688	7
	1976/77	11551	3.7	32080	8	616	5	3087	5
	1977/78	5129	3.5	26003	-	871	5.4	1847	5.8
	1978/79	7450	5.5	23780	9.3	930	3.2	2110	7.9
Kalogi	1974/75	16163	2.5	49797	7	13646	4	1381	7
	1975/76	12976	3	38937	6	6783	4	1830	4
	1976/77	13220	-	37295	-	9326	-	1170	-
	1977/78	7386	2.9	37051	6	11662	5	837	7
	1978/79	8029	3.5	41965	8	15619	4.5	1224	7.5
Abu Gebha	1974/75	21918	4	30565	14.5	25310	5.5	1354	12
	1975/76	2733	3	42941	10	31217	5	1779	15
	1976/77	4962	3	41128	12	26901	4	278	4
	1977/78	7532	3	34305	7	18795	4	2299	5.5
	1978/79	4314	2	58200	11	35186	4.4	2667	9
Um Brembita	1974/75	2143	1.11	35647	10	17966	3	2364	10
	1975/76	1532	2.7	35490	10	18969	2	3560	12
	1976/77	1700	2.4	37617	8	14777	3	3719	10
	1977/78	1480	1.2	31199	8	14596	2	3473	8
	1978/79	350	2.5	36864	12	12122	3.5	4473	10
Abassya	1974/75	2300	1.5	60454	7	31724	3	120585	7
	1975/76	164	3	58516	11.5	20418	3.5	20025	10
	1976/77	119	4	53230	11	16049	3	19450	4
	1977/78	1089	2.4	40521	9	11463	3	17705	4
	1978/79	518	3	85224	8.5	23605	3	32129	6

Source: NMAPC records.

[a] In small kantars (45 kg).

[b] In 90 kg sacks.

[c] In 75 kg sacks.

[d] In small kantars (45 kg).

diversity in the agronomic characteristics and genetic nature of the varieties grown. Most are of indigenous or local types commonly known as "Baladi" varieties.

1. Cotton. Cotton grown in the Nuba Mountains area is the short staple, American type cotton. The variety in use at present (Albar A(57)12)[1], was developed by Kadugli Research Station (KRS), which has operated as a breeding station for cotton under rainfed conditions.

   With optimum planting time (recommended as July 1), the currently used variety has a maturity period of 150-155 days.

2. Sorghum. There is considerable genetic and agronomic diversity of sorghum varieties grown in the area. Classified according to the maturity period, these varieties are grouped into:

   a) Early-maturing varieties (100-110 days). These are dwarf white-seeded varieties. They were first introduced in the large scale mechanized sub-sector; their uniformity in maturity and height make them suitable for mechanized harvesting. "Um Brenien" and "Gadum-el-Hamam" are the leading varieties in this category. Very few smallholders in the area grow these varieties, but under NMAPC schemes, officials encourage their adoption and use. The quality of dietary

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[1] Variety development and improvement research at KRS, has already succeeded in developing a new variety (BAR 24/4H), which in limited tests has outperformed the variety in use (Albar A(57)12) in a number of respects (yield, ginning percentage, lint and fiber qualities) and pending future quality tests might substitute the existing variety [6].

characteristics of these varieties is widely believed by farmers to be inferior to other varieties, a factor that has prevented its widespread use.

b) Medium-maturing varieties (120-130 days). Popular varieties in this category include the easily threshed "Karamuka," "Marig," and "Bakhit." These are most common in the north.

c) Late-maturing varieties (150-160 days). Important varieties of this type are "Kurgi," "Kulum," and "Magoy." These are mostly grown in western and southern parts of the area.

3. Sesame. Considerable genetic diversity also exists in sesame. This is more manifested in other agronomic characteristics (pod shape, seed color, and branching style), rather than in height or period of maturity. Most varieties mature between 90 and 110 days. All varieties grown are dehiscent (opening of pods) and quick in shattering seeds upon maturation, a feature thus, with important implications for timeliness of the harvest operations.

4. Groundnuts. Only two main types are grown in the area. A local spreading variety known as "Baladi," and the newly introduced, erect type, "Barberton" [38].

Agricultural Operations

1. Land Preparation. Land preparation methods depend on whether the cultivated plot is "Harig" or "Saraya."

   a) Harig: refers to first cultivation year (either from fallow or new land). Land preparation in these plots involve setting of fire to kill the flush of weeds and grasses that emerge after early showers of the rainy season.

b) Saraya: denotes plots in second and subsequent years of cultivation. If the land was well weeded in the previous seasons, limited land preparation is required. Sweeping and burning of stalks and crop residues is undertaken either after the harvest or prior to planting. This operation generally is not very laborious, except for cotton. The clean up operation after cotton (locally known as "Al-awdi), involves pulling the cotton stalks and burning the residue. NMAPC administration which supervises the operation, sets May 31 for finishing the clean up. Allowing at least one month of open land, reduces the transmittal of cotton diseases from one season to the next. Another reason mentioned by the administration is that cotton stalks on poorly cleaned schemes greatly hamper the mechanical cultivation operations in the coming season. Farmers in the NMAPC schemes are very reluctant to carry out this operation, and the administration often resorts to judiciary powers to enforce it.[1]

2. <u>Planting</u>. Crops are planted usually in a single stand and crop mixing is seldom practiced.[2] Checkrow planting is advised for all crops. However, at present this is followed only for sorghum and groundnuts; sesame and cotton are broadcasted. Checkrow planting is especially recommended for cotton, and the current practice of

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[1] Through local and traditional courts which fine violating farmers.

[2] Crop mixing, however, is the standard in planting of the "Jubraka."

broadcasting is very much blamed, among other things, for the observed poor crops.

Also, another important aspect of the planting operation is its timing. Although, this is dependent on rains, recommended sowing dates are: July 1 for cotton, early-June for sorghum and sesame, and late-June to mid-July for groundnuts [6, 7].

3. Weeding. This is the most labor intensive operation of the cultivation process. When land is first brought into cultivation (fallow or new land) burning is used as a weeding method. In subsequent years, this method would not be effective because density of weeds and grasses is too low, rendering the burning control method ineffective and hand weeding as the only alternative. In general weeding levels and timings are related to a number of factors. These include: previous season management, current season rainfall, timing of the operation, availability of family labor and/or operating capital, crop establishment level and anticipated returns from the operation.[1] At present up to two weedings are followed. Very few farmers in the sample reported carrying out a third weeding operation.
4. Harvest. Except for cotton, harvest is usually composed of two operations. The first is cutting of sorghum and sesame, and pulling of groundnuts. After being left to dry for sometime

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[1] Failing or poorly established crops are customarily left unweeded.

(around a month for sorghum,[1] and 1-2 weeks for sesame and groundnuts), the second operation commences. It involves threshing for sorghum and sesame, and stripping of pods from groundnuts. Although, two hand pickings are recommended for cotton, at present only one pick is practiced.

Sesame harvest presents a special problem. The dehisence (opening of pods) and quick shattering of seeds upon maturation, requires the harvest of the crop within a relatively short time, making the operation a labor intensive activity.

Table 3.11 shows the average labor requirements per feddan for the different operations. Weeding is the most labor-demanding activity, followed by harvest. No separate land preparation for cotton is done other than pulling of cotton stalks and clean up (Al-awdi).

Agricultural Operations Calendar

An important aspect of an agricultural operation is its timing. This is of even greater importance under rainfed conditions. It is therefore, important to consider timing as an explicit management practice.

Table 3.12 shows the calendar times of the different operations for the sample of the traditional smallholders. Although some operations are carried as early as April (land preparation), and some as late as March (cotton picking), the bulk of the operations are concentrated in the period from June to December. This concentrated pattern (especially in June-August), which is primarily a factor of the climate, results in intensifying the seasonal constraints in labor.

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[1] Except for the variety "Karmuka" which is usually threshed within a week of cutting.

Table 3.11 Average Labor Requirements Per Feddan by Crop Operation (in 7-Hour Man Days)

Operation	Sorghum	Sesame	Groundnuts	Cotton[a]
Land Preparation	3.80	2.80	3.83	--
Planting	2.92	2.53	4.77	1.15
Weeding 1st	7.48	7.61	10.37	4.45
Weeding 2nd[b]	3.94	3.60	8.36	2.40
Harvest 1st	5.60	6.05	5.32	8.67
Harvest 2nd	3.49	2.23	5.77	--
Clean up (Al-awdi)	--	--	--	3.84

Source: Computed from survey data (1979/80).

[a] Estimates from the NMAPC participants' sub-sample.

[b] Very few farmers practiced a third weeding. Percentage of farmers reporting second weeding: sorghum = 60%; sesame = 56%, groundnuts = 76%; cotton = 53%.

Table 3.12 Agricultural Calendar Time of Operations by Crop

	Sorghum		Sesame		Groundnuts		Cotton[a]	
	Month[b]	Range[c]	Month	Range	Month	Range	Month	Range
Land Preparation	Apr. (50.7)	Dec.-Jun. (3.0)(12.0)	Apr. (33.0)	Jan.-Jul. (4.0)(4.0)	Jun. (43.0)	Apr.-Jul. (29.0)(7.0)	-	-
Planting	Jun. (71.6)	May-Aug. (10.0)(6.2)	Jun. (51.0)	Jul.-Aug. (37.0)(11.0)	Jun. (50.0)	Jul.-Aug. (44.0)(6.0)	Aug. (48.9)	Jul.-Sep. (37.0)(15.0)
Weeding 1st	Jul. (44.0)	Aug.-Sep. (31.0)(2.5)	Jul. (62.0)	Aug.-Sep. (32.0)(51.0)	Jul. (50.0)	Jun.-Aug. (17.0)(33.0)	Aug. (57.0)	Jul.-Cot. (5.0)(2.0)
Weeding 2nd	Aug. (37.8)	Jul.-Cot. (1.0)(7.0)	Aug. (52.0)	Jul.-Sep. (10.0)(38.0)	Aug. (64.0)	Jun.-Sep. (7.0)(7.0)	Sep. (37.0)	Aug.-Dec. (27.0)(2.0)
Harvest 1st	Nov. (51.0)	Oct.-Feb. (2.0)(5.0)	Oct. (56.0)	Sep.-Nov. (3.0)(41.0)	Oct. (56.0)	Oct.-Nov. (56.0)(34.0)	Jan. (37.0)	Dec.-Mar. (17.0)(2.0)
Harvest 2nd	Dec. (32.0)	Nov.-Apr. (15.0)(3.0)	Nov. (62.0)	Oct.-Feb. (15.0)(3.0)	Nov. (83.0)	Oct.-Jan. (10.7)(7.0)	-	-
Clean up (Al-awdi)	-	-	-	-	-	-	Apr. (59.0)	Feb.-Jun. (4.0)(2.0)

(   ) = % of farmers carrying the operation in the respective months.

Source: Computed from the survey data (1979/80).

[a] Estimates from the NMAPC participants' sub-sample.

[b] Modal calendar time (i.e., most frequent).

[c] Earliest to latest calendar time.

Land preparation is split between those who carry out the operation after harvest, and those who carry it out just before next year's planting. Cotton clean up (Al-awdi) in the NMAPC schemes, by law belongs to the first group and should be finished by May 31. The harvest operations are more or less streched out. This is mainly because of the relatively short growing period of sesame and groundnuts, and the delayed cotton picking. For cotton, only one (instead of the recommended two) picking is carried out.

Crop Yield Levels

Yield levels attained by smallholders in the Nuba Mountains area are variable. Among the important determinants of yield is the amount and distribution of rainfall [6, 21]. Table 3.13 shows the yield levels obtained by the traditional farmers in 1979/80 season.[1] Cotton yield levels (missing from the table) are reported later in connection with the NMAPC participants' production. In Chapter V, sensitivity analysis on crop yield levels, is used to examine effects on farmer's returns and cropping pattern.[2]

Farm Labor and Organization

In the Nuba Mountains area, there are three types of labor involved in performing the agricultural operations: family labor, hired labor, and "Nafir" labor.

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[1] For this season, amount and rainfall distribution were not favorable.

[2] This used to simulate 25 and 50 percent reductions in yield levels, corresponding to variations in annual rainfall levels.

Table 3.13 Average Yield Levels for the Traditional Smallholders by Region

Region	Sorghum (90 kg Sacks)	Sesame (75 kg Sacks)	Groundnuts (100 lb. Kantars)
Abassya	3.87	1.29	9.34
Um Brembeta	3.05	1.47	--
Abu Gebha	6.01	2.92	--
Kalogi	2.63	1.38	10.0
Talodi	6.59	5.82	--
Kadugli	4.73	3.47	13.03
Lagawa	4.56	2.16	9.87
Dilling	3.98	1.00	3.75

(--) = Not Available

Source: Computed from survey data (1979/80).

1. Family Labor (FL). FL is used here to define the labor resource provided by any of the household members. Historically and traditionally this is the main source of labor available to the household [21]. Labor contributed by this category is not paid directly, but rather is compensated by returns to the whole household.

   Availability of this type of labor is related to the size, age and sex composition, and domestic organization of the household. As have already been pointed out, households in the area have high ratio of dependent children, and that the wife in addition to her domestic roles is responsible for the cultivation of the "Jubraka." However, it needs to be pointed out this is not meant to imply a rigid role specification. For it is not uncommon for the husband to help in weeding of the "Jubraka"; the wife to participate in planting and weeding of field plots; or for the children to help on a part-time basis, or in delivery of food and water to the fields.

2. Hired Labor (HL). This category refers to that part of the labor which is governed essentially by a market institution.

   It is this source of labor, which a farmer can rely on for needs beyond the available family labor, being constrained probably only by his operating and cash resources. Unlike "Nafir" labor, which tends to be employed mainly in the labor intensive operations (e.g., weeding and harvest), HL is employed in the whole range of the agricultural operations.

Payment of HL is usually on a cash basis, however payment might include an in-kind component (food and drinks). Sometimes the in-kind component is paid from the crop itself (especially in harvest of sorghum and sesame). Wage rates are contracted in different ways:

a) by area, usually "Mukhamas" or "Habil,"[1] for weeding opertions;

b) by production (usually per sack, or volume of cotton picked), at harvest; or

c) by unit time, usually "Dahawa,"[2] as in planting and weeding.

Although wage rates are usually in conformity given seasons, localities or villages, due considerations are given to the variations of the same job (e.g., distance to cultivated plots from villages, intensity of weeds in weeding operations), and these are reflected in the wage rates payed. Table 3.14 shows the hired labor wage rates by region, crop, and operation. Differences in wage rates in the area is not affected so much by region, as it is by the variation of the within-region. The latter takes into account the type of crop, operation and time, and the nature of the contracting agreement.

3. Nafir Labor (NL). Nafir (cooperation or exchange labor) is one of the traditional aspects of the Nuba Mountains society.

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[1] Mukhamas = 1.75 feddans; Habil = 0.1 feddan.

[2] Dahawa is approximately from morning till noon.

3.14 Wages Rates Per Man-Day by Region, Crop and Operation (In Ls: 1 Ls = 82.0)

	Land Preparation	Planting	Weeding 1st	Weeding 2nd	Harvest 1st	Harvest 2nd
Abassya						
a:					1.00	.63
b:						
c:						
d:		1.33	1.25		1.00	.50
Um Brembeta						
a:		.50-.95	.51-.80	.40-.85	.57-1.00	.57-1.25
b:		1.75	1.00		.83	
c:						
d:		1.00	1.66			
Abu Gebha						
a:	.35		.52-.87	.54-.87	1.74	1.20-1.75
b:						
c:						
d:		.24-1.00	.33-.73	.37-.75	.40-.67	.50-.87
Kalogi						
a:						
b:	.40-.60	.37-.40	.44-.75	.50-.75	.43-.52	.53-1.35
c:	.42	.33-.61	.56	.54-1.13	.50	
d:		1.00			.18-.60	.83-.83
Talodi						
a:	.39-.75	.19-.56	.28-.70	.30-.87	.32-.89	.42-1.67
b:		1.00	.65			
c:						
d:		.80-.83	.36-.44	.81	.16-.26	.31-.90
Kadugli						
a:	.35	.90	.85	.46	.50	.57
b:		.50				.50
c:					.50	
d:		.50-1.00	.50-1.33	.40-1.00	.40	.50-1.25
Lagawa						
a:	.51-.56	.25-.66	.57	.40	.75	.74
b:		1.00	.38-.62		.60	.50-.83
c:	.41-1.00	.45	.50-1.00	.50-1.00	.41	.38-.42
d:		.50	.50	.45		.45-.50
Dilling						
a:	.42-.60	.44-.53	.50-.93	.62-1.16	.70	.50-1.00
b:			.72		.45	.50
c:		.40-.70	.31-.85	.50-.73	.44-.67	.51
d:		.83	.66	.60	.42	.87

Source: Computed from survey data (1979/80).

a = Sorghum
b = Sesame
c = Groundnuts
d = Cotton, estimates from NMAPC sub-sample, harvest 2nd estimate is for clean up (Al-awdi)

This cooperative institution is prevalent in many parts of the Sudan and in many other African countries.

Its cooperative nature makes it suitable to labor intensive activities, especially those with a short time span. In the area NL tends to be concentrated in weeding and harvest operations. It is also concentrated in food crops, especially sorghum (see Table 3.15). The institutional nature of NL is also illustrated in the rewarding of their services. The incentive system is not the market, but rather, is social approval, obligation, and reciprocity. That is why no direct wage is paid for the group participating in the Nafir, but a farmer provides a meal (food and drinks) for his fellow villagers who provide labor. Costs incurred by the farmer are related to his economic ability and tend to be proportional to the number of people participating in the Nafir. The availability and supply of NL is dependent on the size of the village/community, and its domestic and productive organization.

Table 3.15 summarizes the utilization of the three types of labor by crop and operation. As can be expected, in this smallholder case there is a marked dominance of the family labor for nearly all operations of the four crops. Second to family labor in importance and utilization is the hired labor. Hired labor use is distributed among all operations, unlike Nafir labor which tends to be concentrated in labor intensive activities for food crops.

Table 3.15 Labor Use Distribution by Type of Labor, Crop and Operation[a]

	Sorghum			Groundnuts			Sesame			Cotton[b]		
	FL%	HL%	NL%	FL%	HL%	NL%	FL%	HL%	NL%	FL%	HL%	NL%
Land Preparation	69.5	23.7	6.8	60.5	39.6	11.7	94.1	5.9	0.0	100.0[c]	0.0	0.0
Planting	79.7	17.7	2.6	67.7	28.4	3.9	79.6	16.9	3.5	68.8	26.5	4.6
Weeding 1st	61.0	26.9	12.0	55.7	39.1	5.2	66.3	22.4	11.4	68.7	26.4	4.9
Weeding 2nd	69.6	22.3	8.1	68.4	26.6	5.0	86.7	13.3	0.0	77.5	21.6	1.0
Harvest 1st	52.8	27.9	20.0	58.8	41.2	12.3	78.2	19.5	2.3	61.3	30.9	7.8
Harvest 2nd[d]	46.4	29.7	23.8	65.8	34.3	0.0	89.3	10.7	0.0	59.5	39.0	8.5

Source: Computed from the survey data (1979/80).

[a] FL = Family Labor; HL = Hired Labor; and NL = Nafir Labor

[b] Estimates from the NMAPC participants' sub-sample.

[c] Only one case.

[d] For cotton refers to clean-up (Al-wadi).

Prices and Market Organization

Marketing of livestock and crops in the Nuba Mountains is constrained by logistical and organizational problems. These are due in part to the remoteness of the area with its poorly developed infrastructure.[1] The other aspects of the marketing problems are related to the small scale nature of agricultural production and its scattered supply patterns. All crops in the area (with the exception of cotton) contribute to both household consumption and market. The distribution employed in some literature between cash and subsistence crops, has no relevance for the context of this study.

Farmers in the area are concious and responsive to the price structure of their crops. This is reflected in their choice of crops and the area they devote to each. Cotton is a case in point, the historic decline in real returns from cotton has lead to its virtual disappearance from the traditional sub-sector [39].

The price system is subject to control and regulation in the government's price policy. These policy measures differentiate between cotton and other crops.

Cotton marketing which is intended primarily for export is undertaken by the government. Its transport, ginning and marketing costs are debited

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[1] This aspect of the problem is especially important for livestock, which are marketed in large urban centers in the north of Sudan (mostly at the capital). At present, the practice is to trek the animals over these long distances, resulting in weight loss, disease and death of a significant number of animals.

to the so-called "joint-account" system.[1] This joint account is held between the government, represented by NMAPC and the farmers. The costs incurred under this account system are subtracted from the gross proceeds of cotton, and the remaining net returns are divided between the NMAPC and the farmers according to a formula. The price of cotton is calculated on f.o.b. basis at Port Sudan.[2] Payment to farmers, is further, based on the quality of cotton they have delivered. There are three established grades; I, II, and III, each with a fixed price.

As for the other crops, the government role is confined to a regulatory function. This involves the setting of minimum prices of all main crops (it includes crops under discussion here i.e., sorghum, sesame and groundnuts) for the so-called "auction markets." (These are located at major centers, the only one in Nuba Mountains area is at Kadugli, which is the provincial capital for S. Kordofan). The prices announced each year by the Ministry of Commerce, are related to the expected world market prices expressed as f.o.b. at Port Sudan. This system of minimum prices is ensured by having the government trading companies buy quantities that are offered but not bought by private traders at these prices.

However, it remains to be said that the "auction markets" system has little direct relevance or impact for the smallholders in the area First, there is only one auction market in the area (in Kadugli), and transport costs from the different regions are prohibitive for the

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[1] The joint account system is discussed in more detail in Chapter VI. The corporation law defining this system is also given in Appendix III.

[2] Major port of the Sudan, located at the Red Sea.

smallholders given their small scattered production. Second, and more important, is the fact that the smallholder's disposal and marketing of crops is not independent of their subsistence and production. As we have indicated earlier in discussing cash needs and credit, a significant number of smallholders during the course of production become indebted to the local money lenders (sheil), and commit their marketable products to these lenders. A study by HTS [38] describes another form of marketing involving barter of crops, which is also common in the area:

> There is another form of barter of crops which is probably even more prevalent than sheil. Most shopkeepers accept crops in lieu of cash payment for goods. The customer brings a standard measure, normally one malwa of sorghum, sesame, lubia, groundnuts or okra, and receives goods of equivalent value. The exchange value of crop bartered is invariably less than the selling price. A significant portion of the marketed production is probably transacted in this way, with the shopkeeper acting partly as a middle-man who later sells the crop at an auction market or direct to a major merchant, and partly as a speculator anticipating that the crop can be sold locally at a higher price later in the season [38, p. 59].

Some farmers also market a part of their crops directly to their fellow villagers, acting as retailers. This is done at home in the village, or when transport can be arranged in the nearest local market.

Table 3.16 shows the prices received by the smallholders in the area for the season 1979/80. The prices received by the farmers depend on the one hand on the nature of the marketing arrangement (e.g. sheil, barter, direct retailing, etc.), and on the other hand on where and when sales take place. The best prices a smallholder can get are those prevailing few months after harvest, at the auction market [38]. The prices shown for cotton are from the NMAPC participants' sub-sample, and they

Table 3.16 Average Prices Received by the Smallholders in the Area for the 1979/80 Season

(in Ls: 1 Ls = $2.0)

Region	Sorghum (per 90 kg Sack)	Sesame (per 100 lb. Kantar)	Groundnuts (per 100 lb. Kantar)	Cotton[a] (per 100 lb. Kantar)
Abassya	8.50	12.50	5.00	3.90
Um Brembeta	4.50	11.50		4.20
Abu Gebha	3.00	9.77		3.74
Kalogi	4.32	11.67	2.00	3.84
Talodi	4.71	12.97		3.95
Kadugli	7.60	7.50	6.00	3.99
Lagawa	7.56	14.00	4.85	4.10
Dilling	8.70	15.00	5.18	3.96

Source: Computed from the survey data (1979/80).

[a] Estimates from the NMAPC participants' sub-sample. Prices are weighted average of three grades of cotton. The fixed price offered by NMAPC for the three grades respectively was: Grade I = 4.25; Grade II = 3.25; and Grade III = 2.75. These prices do not include local transport costs (i.e., from the field to the nearest collection center).

represent a weighted average of the three grades they have produced. The NMAPC cotton price policy is discussed in more detail in Chapter VI.

Contrasting Features of NMAPC Smallholder's Agriculture

The NMAPC, its role and organization is discussed in more detail in Chapter VI. What this section intends to give is a brief description of features that are particular to NMAPC smallholder participants (as opposed to traditional smallholders), with regard to their agriculture. In general, these features have not introduced (at least so far) any major change in the nature of the agricultural systems. They are designed primarily to promote the growth of cotton crop and are characterized mainly by the introduction of mechanical land preparation.

Land Ownership

Like all public agricultural corporations in the Sudan, NMAPC retains the ownership and title of all the scheme land, with farmers recognized as tenants. Among other aims of this policy, it is thought to ensure running these public schemes according to specified governmental rules (especially in distribution of land), and to enforce the prescribed set of agricultural rotations and operations.

Farmers of NMAPC dispute this status of land ownership and often claim the title for land individually, or collectively for different schemes under NMAPC.[1] This situation arises because of the way schemes are cleared (from bushes and trees) and registered under the NMAPC. It

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[1] Problems of EL-garug scheme in the Kadugli region is one of many examples related to this issue.

is the farmers who collectively clear the land; NMAPC then supervises the scheme and divides the land (as tenancies) among the participating farmers. The net result of the disputed land ownership issue, has been reflected in an unclear production relation between the corporation and the farmers.[1] This has also caused a number of complications and problems in administration and management of many NMAPC schemes [46].

Rotations and Crops

In its full development NMAPC plans to have a 15 feddan for each tenant to be grown in a three-course rotation of cotton-sorghum-fallow. With 5 feddans for each component in the rotation, participants are expected to cultivate a total of 10 feddans (divided equally between cotton and sorghum) each year.

However, at present neither of these two aspects have been realized. No fallowing is practiced, instead a continuous two-course rotation of cotton-sorghum is followed; and land size cultivated per tenant is less than 10 feddans. Table 3.17 shows the tenant land size distribution at the different stations of NMAPC. Seventy-five percent of the tenants cultivated less than 10 feddans in the season 1979/80. For the few tenants reporting a land size of more than 15 feddans, the land actually belongs to more than one individual (e.g., husband and wife and/or brothers, etc.) and is worked jointly.

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[1] Among other reasons, the NMAPC administration emphasizes the present range production relations, for not extending credit to the farmers to cover critical operations (e.g. weeding and cotton picking).

Table 3,17 Size Distribution of Land Cultivated by NMAPC Tenants: 1979/80 Season

NMAPC Station	Total Area of Cultivated Land in Feddans:											
	(0-5.0)		(5.1-10.0)		(10.1-15.0)		(15.1-20.0)		(20.1-30.0)		(30.1-50.0)	
	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%	No. of Farmers	%
Abassya	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Um Brembeta	1	20.0	3	60.0	1	20.0	0	0.0	0	0.0	0	0.0
Abu Gebha	0	0.0	2	22.2	2	22.2	2	22.2	1	11.1	2	22.2
Kalogi	0	0.0	12	92.3	1	7.7	0	0.0	0	0.0	0	0.0
Talodi	1	12.5	3	37.5	2	25.0	2	25.0	0	0.0	0	0.0
Kadugli	17	54.0	9	29.0	2	6.5	3	9.7	0	0.0	0	0.0
Lagawa	2	20.0	3	30.0	4	40.0	0	0.0	0	0.0	1	10.0
Dilling	1	5.9	15	88.2	1	5.9	0	0.0	0	0.0	0	0.0
All Stations	23	24.5	47	50.0	13	13.0	7	7.4	1	1.1	3	3.2

Source: Computed from survey data 1979/80).

The main component of the NMAPC modernization program is the mechanical cultivation services it offers to participants. Theoretical claims for the yield-related advantages of mechanical land preparation, together with the current problematic situation of these services in the NMAPC schemes, are discussed in more detail in Chapter VI. Table 3.18 shows the average per feddan yield levels of sorghum and cotton for NMAPC participants. At present, NMAPC participants' yield levels are not much different from traditional farmers (see Table 3.18). Other factors blamed for low yields under NMAPC are discussed later in Chapter VI.

Agricultural Services

In addition to mechanized cultivation, NMAPC offers to its participants chemically treated seeds, cotton pest control, and credit services. These services are briefly described below.

Mechanized Cultivation

NMAPC offers to its participants as a central agricultural service, mechanized land preparation. The operation is performed by a disc/seeder (a wide-level disc harrow) mounted on a tractor. It involves essentially shallow discing of the soil, with the aim of preparing the seed bed and controling weed growth. In the case of sorghum, planting is also done mechanically, usually simultaneous with the second discing. Two discings are stipulated; however, at present due to lateness of operation, gasoline shortages and mechanical break-downs, very few schemes are disced twice.

Table 3.18 Average Yields Per Feddan for NMAPC Participants: 1979/80 Season

NMAPC Station	Sorghum (90 kg Sacks)	Cotton (Small Kantar = 100 lbs.)
Abassya	4.50	2.00
Um Brembita	1.71	0.54
Abu Gebeha	6.24	2.26
Kulogi	4.47	2.87
Talodi	2.37	2.38
Kadugli	1.58	1.89
Lagawa	3.52	2.61
Dilling	4.53	2.54

Source: Computed from the survey data (1979/80).

The present practice of NMAPC is to prepare the land for cotton first (to ensure it is planted), before preparation of land for sorghum. The NMAPC charges a flat rate of Ls 1.00 per feddan for one discing and Ls 1.60 for two. It is relevant here to mention that under the present system, there are many organizational problems, resulting in late and low quality performance of these operations. This has created an element of disatisfaction among farmers with the NMAPC system.

Provision of Seeds

The NMAPC provides chemically treated cotton seeds, free of charge, to both traditional and NMAPC farmers. In recent years, the NMAPC have been encouraging participants to grow improved sorghum varieties, by providing the short maturing varieties (Umbenien and Gradam-el-Hamam) to the farmers at cost. NMAPC has no seed multiplication facility, and varietal degeneration has already been observed for both cotton and sorghum [38].

Cotton Pests Control

The cotton crop is attacked by two main pests: flea beetle in the early stages of growth and cotton bollworms around late September and October [6]. Thymul 35%, using ULV sprayers, was found to give good results in control of both pests. The NMAPC recommends two sprayings for the cotton crop. However, at present only around 50 percent of the crop is treated, and this with one spraying at the rate of one liter per feddan. The NMAPC provides the chemicals and sprayers, and requires the farmers to do the job themselves, under the supervision of the crop protection department. Timing and management of the operation was reported as being unsatisfactory [38].

Another minor cotton pest, is the cotton redstainer bug. The NMAPC controls this pest by spraying trees and shrubs near the schemes, through an intensive campaign in the dry period. Costs of this campaign are assessed to all farmers collectively and are debited to the "joint account" described earlier.

Tenant's Credit

At present, participants are offered credit facilities only for mechanical land preparation costs, usually subtracted from the farmer's share of his cotton return. If the farmer is not growing cotton, or if his share will not cover these costs, he is expected to pay in cash at harvest time. The payment record is unsatisfactory, and farmers debits are transferred from one season to the other.[1]

Farmers hope that NMAPC will begin extending credit to cover other agricultural operations, namely weeding and harvest. Under its constitution (as in other agricultural public schemes) NMAPC has the potential of doing this. However, implementation is hindered by the unclear production relationship (especially the issue of land ownership), and by the poor repayment performance of the land preparation services.

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[1] The NMAPC administration mention the mounting farmers debits, as the reason for shutting down almost all schemes in the 1974/75 season.

CHAPTER IV

REPRESENTATIVE PRODUCTION MODELS AND THEIR LINEAR PROGRAMMING STRUCTURE

The previous chapter presented a general description of smallholder agriculture and its environment in the Nuba Mountains. The material in this chapter is divided in three parts. The first part is a discussion of smallholder farming systems in the area, and the representative production models used to analyze these farm systems. The second part presents the structure of the formal linear programming (LP) models (objective function, activity and constraint sets), and the procedures used to estimate model coefficients. The last part describes the changes made in the basic LP models to allow the conduct of experiments which address the major research objectives.

Smallholder Farming Systems and Representative Production Models

An important purpose of this study is to identify and examine in a quantitative sense the smallholder's production structure and constraints. This includes investigating the effects of certain policies and/or technologies on the existing smallholder system. The program of NMAPC represents an important departure from traditional farming, hence it is treated as a separate production system. Therefore, traditional farming and NMAPC modernization schemes are the two smallholder farming systems in the region which are modeled.

Similarities of important production characteristics within each of the two systems render a representative farm model approach well suited for the intended analysis. Many of the significant conceptual and methodological problems of the representative model approach center around the criteria for classifying groups of farms on the one hand, and on the choice and simulation of a model(s) to be representative of each group on the other hand, Collinson [17]. However, in this case, as in many traditional smallholder settings, it is relatively simple to identify and simulate representative conditions. As Collinson has noted:

> Most of the obstacles to using representative farm techniques derive from the problems of selecting criteria for grouping the farm population. These problems are created by the proliferation of market opportunities and technical possibilities in advanced agriculture which distort the pattern that would result from natural advantages of climate and soil [17, p. 103].

However, despite general similarities characterizing smallholder production within each of the two farming systems, there remain some important differences in production structure and constraints that should be incorporated in the representative production models. Such differences are primarily in the level of resources of the individual smallholders. Differences in area cultivated in turn reflect the variability of labor resources among smallholders. With land being relatively abundant in the region, labor is the principal scarce factor of production for the smallholders. In addition to influencing the cultivation size and enterprise combinations at the farm level, the availability of labor also interacts with other factors to determine the labor utilization profile in smallholder production. The latter has important implications for the design of the representative model.

Classification by cultivation size is useful since area cultivated is correlated with other farm resource use levels. For example the simple correlation coefficient (r) between the cultivation size (GRLND) and total labor (TL) use at the farm level was found to be 0.73 (i.e., $r_{GRLND,\ TL} = 0.73$)[1]. Cultivation size is also highly correlated with total operating capital (OC) use ($r_{GRLND,\ OC} = 0.78$)[2]. This indirectly reflects the influence of labor, essentially because hired labor (HL) is the principal item to which OC is devoted. The correlation coefficient of the latter two variables was found to be very high ($r_{OC,\ HL} = 0.96$).

For these reasons, the cultivation size criterion was used to select three categories of representative resource conditions for the analysis of the two smallholder production systems in the region, i.e., the traditional and NMAPC systems. The choice of three categories (to represent small, medium, and large resource endowments) was based on the following considerations:

1. Three categories of farm level resources are deemed sufficient for representing the important differences relating to scale and cultivation size within each of the two smallholder systems. It was considered that using fewer than three levels might not capture the important differences across the sample populations.

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[1] In fact an even higher correlation could probably have been obtained if TL (the sum of family, hired, and nafir labor use) was disaggregated by certain periods (namely the labor intensive periods). Use has been made of this observation in formulating the family labor resource constraints of the production models (see next part of this chapter).

[2] As explained later, total cash expenditure (in agricultural operations) is used as a proxy for OC.

On the other hand, more than three categories would not add enough to the analysis to justify the cost and effort involved.

2. As discussed below, differences in cultivated area, reflected in these farm categories, are also reasonably reflective of the other important differences in household characteristics (demographic composition, consumption, off-farm work opportunities, etc.) which also must be controlled for in the production models.
3. Although the NMAPC smallholder system is planned and operated with a standard size and crop composition, the use of the three resource categories in the NMAPC smallholder production model allows an analysis of the merits of current and proposed NMAPC farm plans and policies.

The production resources and characteristics of the three farm size categories are shown in Table 4.1. As already discussed in Chapter III, dura dominates the cropping pattern in the area. Cotton has almost disappeared from the traditional smallholder area.

Family labor use as a percent of total labor decreases as the cultivation size increases. It is high in category I, less so in category II, and least important in category III. Hired labor use is the reverse of this case; it is high in the large category III, less so in the medium category II, and very low in the smallest category I. Nafir labor is a different case in both absolute and relative terms, its use being the highest for medium sized farms in category II.

The large size of the labor expense share in operating capital expenditure is clearly shown across all the three categories. Other

Table 4.1 Production Resources and Characteristics: Distribution by Farm Size Category, for Farms Surveyed

Characteristic	Category I (0.10-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
No. of Holdings	51	43	19
Percent of Total	45.1	38.1	16.8
Resource Use[a]			
Land Use (feddan)	3.10 (1.4)	6.59 (1.3)	14.37 (3.1)
Cotton[b]	0	0.11 (0.4)	0.28 (0.9)
Dura	1.93 (1.4)	4.15 (1.2)	9.28 (2.6)
Groundnuts	0	0.89 (1.3)	1.05 (2.4)
Sesame	1.18 (0.4)	1.4 (1.4)	3.76 (2.5)
Labor Use (man-days)	133.75 (63.7)	165.40 (59.2)	250.67 (131.4)
Family Labor	112.25 (77.7)	96.40 (37.2)	133.00 (77.2)
Hired Labor	3.00 (3.0)	30.20 (28.7)	106.83 (150.3)
Nafir Labor	18.50 (23.9)	38.8 (40.1)	10.83 (25.0)
Labor inputs/feddan	43.15	25.10	17.44
Operating Capital (LS)	7.85 (5.9)	40.99 (31.6)	92.95 (109.5)
Labor Expense[c]	6.57 (6.5)	34.03 (26.4)	79.40 (103.2)
Seeds	0	1.13 (2.8)	5.96 (8.7)
Chemicals	0	0.16 (0.3)	0.34 (0.3)
Sacks	1.28 (1.5)	5.67 (7.03)	7.26 (11.3)
OC/feddan	2.53	6.22	6.47

( ) = Standard Deviations

Source: Computed from survey data (1979/80).

[a] Estimates from 42 cases with complete labor records.

[b] Figures are missing or small since very few (only 6 farmers) of the traditional sub-sample grew cotton.

[c] Includes transport of crops to home or market.

purchased inputs vary directly with farm size; being highest in the largest category III, and almost zero in the smallest category I.

Selected household characteristics corresponding to the three categories of production are given in Table 4.2. Both average family size and number of active workers are directly correlated with farm size. Average family size varies from 5.25 (in category I) to 7.08 members (in category III). This variation in family size between the three farm size categories is directly correlated with household consumption levels. Dura consumption, expenditure on food, and other annual expenditures are all directly related to the family size. The differences in dura consumption levels (in 90 kg sacks) between the three farm size categories are incorporated in the minimum dura consumption constraints of the LP models. However, the absolute amounts of the dura consumption of the three categories are adjusted by judgement to be 8, 10, and 12 sacks, respectively.[1]

Crop sales by the household are also directly related to the farm size category. This is not only because of the obvious increase in cultivation size, but more importantly because of the increase in dura production (see Table 4.2), and therefore the increase in potentially marketable portions (i.e., after allowance for household consumption needs) of dura in the relatively larger farms (category II and III).

Livestock holdings show the same direct relation across categories. Investment in livestock, as previously indicated, is one of the

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[1] Given the variances of the dura consumption estimates (see standard deviations, Table 4.2), these levels are still within the observed range. Additional discussion and justification of these levels is given in the next part of this chapter.

Table 4.2 Selected Household Characteristics: Distribution by Farm Size Category, for Farms Surveyed

	Category I (0.10-5.0 fed.)		Category II (5.1-9.9 fed.)		Category III (10.0-25.9 fed.)	
Demographic						
Average Family Size	5.25 (3.8)		5.93 (2.7)		7.08 (2.2)	
Active Population[a]	2.50 (0.6)		2.93 (0.9)		3.33 (1.7)	
Consumer Equivalents[b]	4.05 (2.4)		4.41 (1.6)		5.13 (2.0)	
Household Consumption						
Dura (90-kg sacks)	7.05 (2.1)		8.76 (4.0)		11.57 (6.2)	
Food Expenditure[c] (Ls)	260.0 (0.0)		274.04 (20.8)		282.16 (22.36)	
Annual Expenditure[d] (Ls)	27.75 (40.3)		95.53 (91.5)		113.42 (62.3)	
Dura Production (90-kg sacks)	9.25 (4.3)		18.60 (11.8)		37.67 (29.6)	
Crops Sales (Ls)	15.00 (30.0)		68.80 (89.6)		144.69 (113.1)	
Livestock Holdings (No.)						
Cattle	1.27 (3.5)		5.71 (9.3)		5.53 (12.8)	
Sheep	1.30 (6.3)		0		4.86 (14.9)	
Goats	4.61 (8.3)		8.58 (8.1)		7.95 (7.5)	
Donkeys	0.09 (0.3)		0.38 (0.6)		0.82 (0.8)	
Household Head Off-Farm Occupation[e]	"0"	"1"	"0"	"1"	"0"	"1"
1. Wage Labor in MFC	26	2	17	3	22	2
2. Wage Labor in NMAPC	23	5	18	2	21	3
3. Wage Labor in Traditional	25	3	18	2	20	4
4. Trade	24	4	19	1	18	6
5. Cutting Wood/Hay	27	1	17	3	23	1
6. Bringing Water	25	1	19	1	23	1
7. Government Job	23	5	17	3	23	1
8. Miscellaneous[f]	14	14	10	10	19	5
9. Livestock Husbandry	28	0	20	0	24	0
10. Livestock Trade	28	0	20	0	24	0

( ) = Standard Deviations

Source: Computed from survey data (1979/80).

[a] Defined as males and females in the age bracket 15-65 years.

[b] A weighting procedure suggested by FAO was used. Weights used were as follows: males and females (0-4 years) = .2; males and females (5-9 years) = 0.5; males (10-14 years) = .75; females (10-14 years) = .7; males and females (15 years and above) = 1.0 [61, p. 138].

[c] Annual expenditure on: meat, vegetables, oil, and tea.

[d] Annual expenditure on: clothes, health, children education, household physical maintenance, and cermonial.

[e] "1" = if involved in occupation; "0" = if not. This is based on responses, not respondents.

[f] Include occupations such as honey collections, house building, charcoal burning, shoemaker, labor in the market, well digging, etc.

important measures taken by the smallholders to counteract risks and uncertainties associated with crop production.

Off-farm employment opportunities have been discussed in Chapter III. The distribution of off-farm activities by category, as seen from Table 4.2, shows some contrasting features. Very few farmers in category III engage in the common pattern of off-farm work, namely off-season work in hay or wood cutting, charcoal, rope-making, hut building, and other miscellaneous jobs. A majority of individuals in this category are traders and shopkeepers.

By contrast, the individuals in category I, beyond their participation in the common pattern of off-farm work, are relatively more engaged in work as agricultural laborers outside their own plots. Nineteen percent of this work is done during the growing season.

The next part of this chapter will present the formal LP model. The features and characteristics of the three production size categories will be detailed. This will be done in the context of the two production models (traditional and NMAPC) of the Nuba Mountains area.

Structure of the LP Models

Introduction

In this section the details of the production models are discussed in terms of the three major parts of the LP model: the objective function, the activity set, and the constraints set. First, a general outline of the basic production model and its variations is given.

Figure 4.1 is a schematic representation of the basic production model. The agricultural operations of the four crops are represented as different activities. Two sets of the same activities are included to

				Crop [CN,DR,GN,SM] PRODN.:[a]										Hired Labor In:										Nafir Labor In:										Transfer OC From, To:														
	UNIT	SIGNS	RHS	LND PRP	PLOW I	PLOW II	PLNT	WED I	WED II	SPRY I	SPRY II	HVST I	HVST II	JUN.	JUL.	AUG.	.	.	.	.	.	APR.	MAY	JUN.	JUL	AUG.	.	.	.	.	.	APR.	MAY	JUN./JUL	JUL./AUG	.	.	.	.	.	APR./MAY	END CPTL	SELL CN	SELL DR	SELL GN	SELL SM	BUY DR	CONSM DR
Objective Function				0	-$	-$	-$	0	0	0	0	0	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	-$	0	0	0	0	0	0	0	0	0	$	$	$	$	-$	0
Constraints:																																																
Land	FED	≤	β_i	1'																																												
	FED																																															
Agric. 1	FED	≤	0	-1	1																																											
Operations	FED				-1	1																																										
Balance 10	FED																																															
	FED	≤	0									-1	1																																			
Production	SACK	≤	0										-C																														1	1	1	1	-1	1
[CN,DR,GN,SM]	SACK																																															
Consumption (DR)		=	β_i																																													1
Jun.	m.d.	≤	β_i	C										-1										-1																								
Total	m.d.						C			C					-1										-1																							
Labor[b]	m.d.							C	C																																							
	m.d.										C	C										-1											-1																
May	m.d.	≤	β_i										C										-1										-1															
Jun.	m.d.	≤	β_i																					1																								
	m.d.																								1																							
Nafir	m.d.																																															
Labor	m.d.																															1																
May	m.d.	≤	β_i																														1															
Jun.		≤	β_i											$										$										-1	1													
	Ls				$	$									$										$										-1	1												
Operating Capital	Ls						$																																					-$	-$			
Apr.	Ls	≤																				$										$								-1	1				-$			
May	Ls	≥	β_i										$										$										$								-1	1				-$		

[a] CN = Cotton; DR = Dura; GN = Ground Nuts; and SM = Sesame.

[b] Initial levels of total labor (TL), representing family labor (FL supply).

$ = Monetary coefficient.

C = Coefficient not equal to zero, one, or minus one.

β_i = Level of the resource in the model (RHS).

Figure 4.1 Schematic Representation of the Basic LP Model

represent 'early' and 'late' cultivation. The main difference between these two agricultural operations sets is their labor time distribution. Table 4.3 gives the timing of these crop operations by model periods. Also, in the basic LP model, labor in both the activity and constraint sets is disaggregated by the three types of labor [i.e., family, hired, and nafir (exchange labor)] and by the twelve monthly model periods.

This basic model is modified in a number of experiments to permit analysis of the following:

1. Traditional Smallholders
   a) Analysis of the three production size categories.
   b) Crop yield sensitivity analysis.
   c) Planting time experiments.
   d) Credit experiments.
   e) Cotton price variation experiment.
2. NMAPC Participants
   a) 'Status-quo' model analysis.
   b) 'Full-phase' model analysis.
   c) Credit experiments.
   d) Cotton price variation experiment.

The Objective Function

The identification and specification of small farmers' production objective(s) represent a special problem which has been the subject of much theoretical and empirical study. Two main objectives have received much emphasis in modeling small farmer decision making. These two objectives are:

Table 4.3 Distribution of Cultivation Operations by Crop and Model Period

Model Period		Basic Agricultural Operations							
		Cotton		Sorghum		Ground Nuts		Sesame	
No.	Month	Early	Late	Early	Late	Early	Late	Early	Late
1	Jun.	Planting		Planting		Planting		Planting	
2*	Jul.	Weeding I	Planting	Weeding I	Planting Weeding I	Weeding I	Planting	Weeding I	Planting
3*	Aug.	Weeding II	Weeding I	Weeding II	Weeding II	Weeding II	Weeding I	Weeding II	Weeding I
4*	Sep.		Weeding II				Weeding II		Weeding II
5*	Oct.					Pulling Threshing		Cutting	
6*	Nov.			Cutting			Pulling	Thresing	Cutting
7*	Dec.	Picking		Thresing	Cutting		Threshing		Threshing
8	Jan.		Picking		Threshing				
9	Feb.								
10	Mar.		Land Prepartion						
11	Apr.			Land Preparation		Land Preparation	Land Preparation	Land Preparation	
12	May	Land Preparation			Land Preparation				Land Preparation

Source: Constructed from 1979/80 Survey Data.

[a] Early and Late according to time of planting.

*Split in half for the planting time experiments.

1. The maximization of some formulation of profits, output, or income.[1]
2. The satisfaction of basic family consumption requirements.

The first objective (profit-maximization) was derived from the theory of the firm. Objections to the use of the profit-maximizing goal in analyzing traditional smallholder production question the validity of the theory's assumptions when applied to the case of the small farmer "firm." Production in the latter case, it has been argued, differs in the nature of its resources, organization, objectives, and the place it holds within the complex of the traditional household.[2]

Production function studies have generally assumed some maximization of profits or net revenue [19, 36]. In these studies the test for profit-maximizing behavior involves analyzing the resource allocation of the smallholder. A necessary and sufficient condition of profit-maximization requires equality of the marginal value product (MVP) and marginal factor cost (MFC), both for each input and across the inputs set .

Although these restrictive conditions were not found to apply entirely in all of these studies, still, many of the inputs were found to be allocated efficiently by farmers [36]. Also, incorporation of the second objective (consumption/security) results in different optimal conditions. As Massel and Johnson note:

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[1] Utility maximization has been shown to be the general case (Dillon and Anderson [19]) of which profit maximization is one of the special cases.

[2] For examples of the earliest literature discussing the issue, see Chaynov [14], and Roden in Clifton [15].

> But if the farmer emphasizes security rather than profit maximization, the standards of efficiency are different. One cannot gauge efficiency by examining economic performance in a single year only; rather it is necessary to have time series data to permit analysis of the farmer's success over time in achieving self-sufficiency....or else to have information on variability of crop yields and prices [36, p. 29].

A further criticism of the profit maximizing objective, in the context of smallholder production, has been offered by Lipton [34]. In the case of farmers producing in a risky production environment, he states:

> Owing to rainfall variability, there is no unique marginal physical product (MPP) associated with any factor, but only a probability distribution of MPP. By acting as if he used the calculus of expected values, an optimizing peasant can nevertheless find a long-run, profit maximizing algorithm analogous to marginal value product equalization. However, in the nonequatorial tropics, rainfall variance is much higher than in most temperate agricultures, so that for rainfall and hence MPP's - expected value is a much poorer predictor of actual value. In particular, the smaller is mean rainfall, the greater is the coefficient of variability [34, p. 330].

Under such a condition, Lipton proposes instead a "survival algorithm" that constitutes an "explanation of rational, security-centered peasant conduct."

Many empirical tests and studies by Norman [48], Wolgin [60], and others conducted in less 'risky' environments seem to support the relevance of both profit maximization and security objectives. In this view, the smallholder is considered as an "efficient, risk-averse" producer.

In the Nuba Mountains area, both objectives are relevant, hence they are incorporated in this study. In addition to the safety-first feature described below, the smallholder in the area practices other security strategies which are not represented explicitly in the model. For example, production on the "Jubraka" (home plot) is mainly oriented towards the household consumption/security objective. Livestock ownership and investments also constitute an important strategy followed by smallholders in ensuring against risks of their crop production activities.

The LP models used in this study maximize net revenue from crops, but ensure the production of sorghum to at least satisfy household consumption needs. This, in other words, is net revenue maximization subject to a safety-first constraint. Other risk-elements are also considered in special experiments analyzing crop yield sensitivity and planting-time strategies.

Mathematically, the statement of the objective function and the LP problem is as follows:

$$\max \quad R = \sum_{i=1}^{n} c_i x_i$$

$$\text{s.t.} \quad \sum_{i=1}^{n} a_{ij} x_i \leq b_i \qquad \text{and } x_i \geq 0$$

where:

R = Net revenue, or total returns to fixed inputs (i.e., to family labor and land).

C_i = Net revenue/feddan (i.e., Gross Revenue-Variable Costs) of the ith activity.

a_{ij} = Per feddan input-output coefficient of the jth resource used or contributed by the ith activity.

b_i = Vector of resource availability.

x_i = Level of activity.

The following two sections give a description of the structure and estimation of the activities and constraints used in the model.

The Activity Set

The activity set includes the following activities:

1. Crop Production Activities
2. Labor Hiring Activities
3. Dura Consumption and Buying Activities
4. Selling Activities
5. Transfer Activities

1. Crop Production Activities

The crop production activities are the core of the model. As such, their specification determines to a large extent how well the model represents the two smallholder farming systems considered in this study. Collinson [17] discusses three methods of choosing a representative model:

a) The choice of selected farm(s) which are representative.

b) The use of averages (or any other measure of central tendancy) in constructing the representative model.

c) Synthetic (component by component) construction and estimation of the representative model.

In practice, the use of the selection method is greatly limited by the need to specify and weight the criteria to be used in arriving at a representative farm(s) (Collinson [17]).[1] The use of the other two

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[1] Not only are these difficult to arrive at, but the method requires the tabulation and ranking of all sample farms (by these criteria) in order that a representative one(s) can be chosen.

methods is much more common. Generally, depending on the sample in question, the use of averages in synthesizing a model unit from survey data brings with it the problem of aggregation bias. An important aspect of this bias is reflected in the constructed average profile misrepresenting the observed labor use profile. This problem would be more pronounced and serious if the interfarm differences in agricultural operations timing (agricultural calendar) are large. In such a situation, peak periods in one farm are offset (through the averaging process) by slack periods in another so that the whole labor profile is flattened. The third method of constructing a representative model, which is essentially a modification of the averaging method, is particularly relevant and appropriate in dealing with this problem. This was the method used in this study.

For the two farming systems in the area, three components of the production activities interact to determine the shape and hence representativeness of the resulting labor profile.[1]

a) Agricultural operations.

The NMAPC smallholder models differ from the traditional model by including only dura and cotton in the rotation. Two additional activities representing mechanical ploughing are also added to the NMAPC models.

b) Calendar of agricultural activities.

The timing of the above operations is an important element of the labor profile. This component of the production activities was estimated

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[1] From the supply side, the distribution of family labor (by period for the three categories) is obviously crucial, and is discussed under the constraint set.

from the survey data using modal times of these operations.[1] Two timing schemes, "early" and "late" (based on the time of planting), are represented in the traditional models. The second scheme ("late") was added after initial tests and runs with the basic model and was found to be useful in improving the representativeness of the model in general and that of the cropping pattern and labor profile in particular.

In contrast, the NMAPC smallholder model includes only one calendar of operations. The NMAPC of mechanical ploughing activities, which are done very early in the season, results in a generally similar time pattern of activities for all NMAPC participants.

In the design of the LP model, the operations of any one calendar are forced together in sequential order (see balance constraints discussed later), but the program is allowed to choose either "early" or "late" operations for crops entering the optimal solution.

c) The per feddan labor coefficients of the agricultural activities.

This third component of the production activities affects the labor profile in a more visible and straightforward manner. Averages from a selected group of fields (discussed below) were used to estimate these coefficients. Other sources were used as the basis for adjusting the estimated coefficients. Ensuring a representative cropping pattern did much to achieve representative labor profiles.

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[1] The mode and the second most frequent value were used.

Table 4.4 gives a summary budget for crops grown in the two systems. The labor cost component actually depends on the type of labor allocated to the production of any one crop. The three types of labor available to the smallholder (family, nafir, and hired labor) are represented in the model. Their levels and distribution by model period (for the three categories) are discussed later under the constraint set. In Table 4.4 it was assumed that 25 percent of total labor is hired, in order to facilitate the comparison of total costs and returns both between crops and for the two systems.

The disaggregation of total labor by different activities across the model periods is shown in tables 4.5, 4.6, 4.7 and 4.8. These tables show the production activities of the traditional farm model for cotton, dura, groundnuts, and sesame, respectively. Differences pertaining to the NMAPC model are also shown, and discussed in detail later. In what follows we discuss the procedures and assumptions adopted in the estimation of coefficients for these production activities.

In general, estimation of coefficients involves not only statistical rigor but also appropriate subjective judgements. In the case of this study, FAO survey data were available to compare, cross check, and adjust the coefficients estimated from this researcher's 1979/80 survey data, using 71 selected fields with complete labor use records.[1] Estimation of these coefficients was based on statistical averages. The input-output coefficients are calculated on per feddan basis which is the

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[1] Each of the 71 fields has at least a complete labor record for one crop, but not all fields have complete labor records for all four crops considered.

Table 4.4 Per Feddan Crop Budgets for Traditional and NMAPC Systems

Items	Traditional				NMAPC	
	Cotton	Dura	Ground-nuts	Sesame	Cotton	Dura
Variable Costs (Ls)						
Tractor Ploughing[a]	-	-	-	-	1.6	1.6
Seeds/Chem.	0.0	0.50	5.17	0.57	0.0	0.50
Total Labor (m.d.)	43.54	28.91	35.28	29.75	29.70	20.22
Hired Labor[b] (LS)	7.24	4.81	5.87	4.95	4.95	3.36
Sacks/Transport	1.96	3.96	6.63	2.57	1.96	3.96
Total V.C.	9.19	9.27	17.67	8.09	8.50	9.42
Returns (Ls)						
Yield (Sacks)[c]	3.0	4.78	6.16	2.79	2.23	3.58
Price/Sack	3.80	6.60	4.70	9.20	3.80	6.60
Gross Returns	11.40	31.55	28.95	25.67	8.47	23.63
Gross Margins[d]	2.21	22.28	11.28	17.58	- .03	14.21

Source: Computed from (1979/80) survey data.

[a] A fixed charge of Ls 1.60 per feddan. One Ls = $2.0.

[b] Assuming 25 percent of the required labor is supplied by hired labor at an average cost of LS 0.665 per man day.

[c] Sack weights of different crops
Cotton = one Kantar (45.0 kg)
Dura = 90 kg
Groundnuts = 45 kg
Sesame = 75 kg

[d] Actual gross margin would vary according to the percentage use of hired labor (see b), but the figures are indicative of the relative profitability of the different crops.

Table 4.5 Cotton Production Activities

			B_i[a]	c_j	Early Cotton													Late Cotton				
					LND PRP	PLOW I*	PLOW II*	PLNT	WED I	WED II	SPRY I*	SPRY II*	HVST I	HVST II	LND PRP	PLOW I*	PLOW II*	PLNT	WED I	WED II	SPRY I*	SPRAY II*
					0	-1.0	-.6	0	0	0	0	0	0	-1.96	0	-1.0	-.6	0	0	0	0	0
Land		≤		9.90	1										1							
TL-Jun.[b]	6	<	m.d.	20				2.27														
Jul.	7	<	m.d.	36					6.35									2.27				
Aug.	8	<	m.d.	36						5.78									6.35			
Sep.	9	<	m.d.	36							.12									5.78	.12	
Oct.	10	<	m.d.	20																		.12
Nov.	11	<	m.d.	22																		
Dec.	12	<	m.d.	22																		
Jan.	1	<	m.d.	22										18.3								
Feb.	2	<	m.d.	20																		
Mar.	3	<	m.d.	20																		
Apr.	4	<	m.d.	20																		
TL-May	5	<	m.d.	20	10.6																	
OC-Jun.	6	<	Ls	27.83																		
Jul.	7	<	Ls	0																		
Aug.	8	<	Ls	0																		
Sept.	9	<	Ls	0																		
Oct.	10	<	Ls	0																		
Nov.	11	<	Ls	0																		
Dec.	12	<	Ls	0										1.96								
Jan.	1	<	Ls	0																		
Feb.	2	<	Ls	0																		
Mar.	3	<	Ls	0		1.0	.6															
Apr.	4	<	Ls	0																		
May	5	<	Ls	0																		
End CPTL		>		27.83																		
CN PRODN		<	KNT	0										-3.0								

Source: Computed

*Operational only under NNAPC models.

[a] Resource levels for category II.

[b] Initial levels of total labor (TL) representing family labor (FL supply).

Table 4.6 Dura Production Activities

				Early Dura								LATE DURA										
	B	a	cj	LND PRP 0	PLOW I* -1.0	PLOW II* -.6	PLNT -.5	WED I 0	WED II 0	HVST I 0	HVST II -3.96	LND PRP 0	PLOW I* -1.0	PLOW II* -.6	PLNT -.5	WED I 0	WED II 0	HVST I 0	HVST II -3.96	SEL DR 6.6	BUY DR -11.0	CON DR 0
Land	≤	FED	9.90	1								1										
TL-Jun.	≤		20				3.16															
Jul.	≤		36					7.54							3.16	7.54						
Aug.	≤		36						4.32								4.32					
Sep.	≤		36																			
Oct.	≤		20																			
Nov.	≤		22							6.41												
Dec.	≤		22								4.34							6.41				
Jan.	≤		22																4.34			
Feb.	≤		20																			
Mar.	≤		20																			
Apr.[b]	≤		20																			
TL-May	≤		20									3.14										
OC-Jun.	≤		27.83				.5															
Jul.	≤		0												.5							
Aug.	≤		0																			
Sep.	≤		0																			
Oct.	≤		0																			
Nov.	≤		0																			
Dec.	≤		0																			
Jan.	≤		0								3.96								3.96	-6.6		
Feb.	≤		0																			
Mar.	≤		0		1.0	.6							1.0	.6								
Apr.	≤		0																			
May	≤		0																			
End CPTL	≥		27.83																			
DR PRODN	≤	SAR	0								-4.78								-4.78	1	-1	+1
DR CONSMN	=	SAR	8.00																			1

Source: Computed

*Operational only under NMAPC models.

[a] Resource levels for category II.

[b] Initial levels of total labor (TL) representing family labor (FL supply).

Table 4.7 Groundnut Production Activities

				Early Ground Nuts								LATE GROUND NUTS								
	B_i[a]		c_j	LND PRP	PLOW I*	PLOW II*	PLNT	WED I	WED II	HVST I	HVST II	LND PRP	PLOW I*	PLOW II*	PLNT	WED I	WED II	HVST I	HVST II	SEL GN
				0	-1.0	-.6	-5.17	0	0	0	-6.63	0	-1.0	-.6	-5.17	0	0	0	-6.63	4.7
Land	<	FED	9.90																	
TL-Jun.	<	FED	20	5.36			3.44													
Jul.	<	FED	36					11.84							3.44					
Aug.	<	FED	36						2.35							11.84				
Sep.	<	FED	36														2.35			
Oct.	<	FED	20							6.27	6.02									
Nov.	<	FED	22															6.02		
Dec.	<	FED	22																	
Jan.	<	m.d.	22																	
Feb.	<	m.d.	20																	
Mar.	<	m.d.	20																	
Apr.[b]	<	m.d.	20									5.36								
TL-May	<	m.d.	20																	
Jun.	<	Ls	27.83				5.17								5.17					
Jul.	<	Ls	0																	
Aug.	<	Ls	0																	
Sep.	<	Ls	0																	
Oct.	<	Ls	0								6.63									
Nov.	<	Ls	0																6.63	-4.7
Dec.	<	Ls	0																	
Jan.	<	Ls	0																	
Feb.	<	Ls	0																	
Mar.	<	Ls	0																	
Apr.	<	Ls	0																	
OC-May	<	Ls	0																	
End CPTL	>	Ls	27.83																	
GN PRODN	<	10mt	0								-6.16								-6.16	1

Source: Computed

*Operational only under MMAPC models.

[a] Resource levels for category II.

[b] Initial levels of total labor (TL) representing family labor (FL supply).

Table 4.8 Sesame Production Activities

		B_i[a]	c_j	Early Sesame								LATE SESAME								
				LND PRP	PLOW I*	PLOW II*	PLNT	WED I	WED II	HVST I	HVST II	LND PRP	PLOW I*	PLOW II*	PLNT	WED I	WED II	HVST I	HVST II	SEL SM
				0	-1.0	-.6	-.57	0	0	0	-2.57	0	-1.0	-.6	-.57	0	0	0	-2.57	9.2
Land	≤	FED	9.9	1								1								
TL-Jun.	≤	FED	20																	
Jul.	≤	FED	36				3.38						3.38							
Aug.	≤	FED	36					10.29						10.29						
Sep.	≤	FED	36						4.06						4.06					
Oct.	≤	FED	20																	
Nov.	≤	FED	22							7.49						7.49				
Dec.	≤	FED	22								2.67						2.67			
Jan.	≤	m.d	22																	
Feb.	≤	m.d	20																	
Mar.[b]	≤	m.d	20																	
Apr.	≤	m.d	20	1.86																
TL-May	≤	m.d	20									1.86								
Jun.	≤	Ls	27.83				.57													
Jul.	≤	Ls	0												.57					
Aug.	≤	Ls	0																	
Sep.	≤	Ls	0																	
Oct.	≤	Ls	0								2 .57									
Nov.	≤	Ls	0																	
Dec.	≤	Ls	0																2.57	9.2
Jan.	≤	Ls	0																	
Feb.	≤	Ls	0																	
Mar.	≤	Ls	0																	
Apr.	≤	Ls	0																	
OC-May	≤	Ls	0																	
End CPTL	≥	Ls	27.83																	
SM PRODN	≤	KMT	0								-2.79								-2.79	1

Source: Computed

*Operational only under NMAPC models.

[a] Resource levels for category II.

[b] Initial levels of total labor (TL) representing family labor (FL supply).

unit of the production activities. In tables 4.5, 4.6, 4.7 and 4.8 coefficients are assigned a positive or negative sign to indicate the use of or addition to a particular resource inventory, respectively.

a) Objective function coefficients:

All coefficients of the crop production activities except for planting (PLNT) and second harvest (HVST II) operations carry a zero value in the objective function. This is because the only cash cost component of these operations is that of hired and nafir labor, which is accounted for by the hired labor (HL) and nafir labor (NL) activities in the model. The objective function coefficients for planting represent the average cost (in Ls) of seeds and chemical dressing per feddan. As for second harvest (HVST II) the estimate is for the cost of sacks and transport from the field to the home (in case of dura) or market (in case of other crops).[1]

b) Labor coefficients:

Coefficients are average total man-days per feddan for the particular operation. A man-day is equivalent to seven hours of work provided by adult males, but females and children also participate. In computing man-days, labor for weeding provided by children (male and female, 0-15 years of age) is discounted by a factor of 0.5, based on the assumed lower productivity of this group in weeding. The labor input contributed by all three types of labor: family labor (FL), hired labor (HL), and nafir labor (NL), was totalled in deriving the average per feddan coefficients.

---

[1] In the case of cotton this would be the nearest collection center where local cotton markets are established.

Table 4.9 compares the per feddan labor coefficients estimated from available sources. As one might expect there is no exact equality between the three sets of available estimates, but overall they compare reasonably.

c) Operating Capital Coefficients

Operating capital (OC) is used mainly for hired labor expenses; these are accounted for directly through the hired and nafir labor (HL, NL) activities of the model which draw directly from the available OC resource stream. Other cash requirements are those of planting and harvest operations. Planting (PLNT) includes seeds/chemical dressing. As for harvest (HVST II), the coefficient represents the costs of sacks and transport.

2. Labor Hiring Activities

Twelve activities (one per month) for both hired labor (HL) and nafir labor (NL) are incorporated in the model. Table 4.10 shows the labor activities portion of the LP tableau. The unit of the activity is man-day (equivalent to seven hours a day). The availability and use of these resources is governed in the model partly by the availability of operating capital (OC).[1] No limits were set on the use of HL (other than that implied by the availability of OC); however, the NL activities are restricted to the upper limit specified by the corresponding constraint set.

---

[1] Including replenishment of OC inventory internally in the model (through crop sales) or through borrowing activities (in some of the experiments).

Table 4.9 Comparison of Per Feddan Labor Coefficients from Three Sources

Operation	Estimates (in m.d.'s) From:										
	Researcher's Survey[1]				FAO Survey[2]				HTS[3]		
	Cotton	Dura	G. Nuts	Sesame	Cotton	Dura	G. Nuts	Sesame	Cotton	Dura/ Sesame[a]	G. Nuts
Land Preparation		3.16	5.36	1.86	1.8	2.2	3.9	1.9			
Planting	2.27	3.16	3.44	3.38	2.3	3.0	4.9	2.4			
Weeding	12.13	11.86	14.19	14.35	9.2	11.2	16.5	10.4	6.32	1.76	
(weeding I)	6.35	7.54	11.84	10.29							
(weeding II)	5.78	4.32	2.35	4.06							
Harvest	18.3	10.75	12.29	11.17	9.9	7.3	14.4	8.6	6.87	10.34	
(harvest I)		6.41	6.27	7.49							
(harvest II)		4.34	6.02	3.68							
Harvest Stalk[b] Disposal	10.6								19.1	5.7	

Sources: [1] Traditional sub-sample, Researcher's survey, 1979/80.

[2] Traditional sub-sample, FAO survey, 1978/79.

[3] Converted to per feddan estimates from Hunting Technical Services [38, p. 70].

[a] Not a mixture but estimates are combined for a feddan with 75 percent area under dura and 25 percent under sesame.

[b] Includes land preparation in HTS; and land preparation for cotton in the Researcher's survey.

Table 4.10 Labor Activities

				Hired Labor												Nafir Labor											
	B_i[a]		c_j	HL1	HL2	HL3	HL4	HL5	HL6	HL7	HL8	HL9	HL10	HL11	HL12	NL1	NL2	NL3	NL4	NL5	NL6	NL7	NL8	NL9	NL10	NL11	NL12
				-.52	-.60	-.65	-.59	-.57	-.68	-.91	-.87	-.75	-.61	-.56	-.67	-.33	-.33	-.33	-.33	-.33	-.33	-.33	-.33	-.33	-.33	-.33	-.33
TL[b]-Jun.	≤	m.d.	20	-1												-1											
Jul.	≤	m.d.	36		-1												-1										
Aug.	≤	m.d.	36			-1												-1									
Sep.	≤	m.d.	36				-1												-1								
Oct.	≤	m.d.	20					-1												-1							
Nov.	≤	m.d.	22						-1												-1						
Dec.	≤	m.d.	22							-1												-1					
Jan.	≤	m.d.	22								-1												-1				
Feb.	≤	m.d.	20									-1												-1			
Mar.	≤	m.d.	20										-1												-1		
Apr.	≤	m.d.	20											-1												-1	
TL -May	≤	m.d.	20												-1												-1
NL -Jun.	≤	m.d.	5.6													1											
Jul.	≤	m.d.	4.6														1										
Aug.	≤	m.d.	3.6															1									
Sep.	≤	m.d.	0																1								
Oct.	≤	m.d.	0																	1							
Nov.	≤	m.d.	5.7																		1						
Dec.	≤	m.d.	7.6																			1					
Jan.	≤	m.d.	4.1																				1				
Feb.	≤	m.d.	0																					1			
Mar.	≤	m.d.	0																						1		
Apr.	≤	m.d.	0																							1	
NL -May	≤	m.d.	0																								1
OC -Jun.	≤	Ls	27.83	.52												.33											
Jul.	≤	Ls	0		.60												.33										
Aug.	≤	Ls	0			.65												.33									
Sep.	≤	Ls	0				.59												.33								
Oct.	≤	Ls	0					.57												.33							
Nov.	≤	Ls	0						.68												.33						
Dec.	≤	Ls	0							.91												.33					
Jan.	≤	Ls	0								.87												.33				
Feb.	≤	Ls	0									.75												.33			
Mar.	≤	Ls	0										.61												.33		
Apr.	≤	Ls	0											.56												.33	
OC -May	≤	Ls	0												.67												.33
End CPTL	≥	Ls	27.83																								

Source: Computed

[a] Resource levels for category II.

[b] Initial levels of total labor (TL), representing family labor (FL supply).

a) Objective Function Coefficients

Coefficients for HL are averages of monthly wage rates, estimated from this researcher's 1979/80 survey data. For HL, both cash and in-kind expenses are incurred. For convenience here, in-kind amounts were translated into cash values in Ls. Also, activities which in reality are not paid per man-day, but per unit land (as sometimes for weeding), or per unit production (as in threshing and cotton picking for example), are also converted in the model to a per man day basis. For nafir labor (NL), the estimated average value of the in-kind costs per man-day (Ls 0.33) was applied in the objective function with no monthly variation in the rate.

b) Input-Output Coefficients

Both HL and NL activities directly supply the total labor (TL) resource inventory.[1] This is represented in Table 4.10 by a series of negative ones (-1) to indicate addition to the TL resource. In the OC rows, the HL and NL coefficients are the corresponding wage rates that appear in the objective function.

3. Dura Buying and Consumption Activities

A dura consumption activity is included in the model. The consumption activity has a unit of one sack (90.0 kg), with a zero value in the objective function, implying no cost to the household from the activity. It has a coefficient of positive one (+1) with the dura consumption constraint, to indicate satisfaction of the constraint by one unit.

---

[1] The initial supply (right hand side) values for the total labor rows are estimated averages of family labor (FL).

A dura buying activity is also included in the model, to be activated only if farm production falls short of satisfying the required level of dura consumption. It has a coefficient of -1 in the consumption constraint row, indicating the replenishing of the dura inventory by one unit (90 kg sack). It has an objective function coefficient of negative Ls 11.0. This implies a price per sack of dura much higher than harvest prices which farmers receive for dura sold. The reason for this is that it represents the more likely situation of farmers buying dura well after the harvest period, when prices rise much higher than their harvest levels.

4. Selling Activities

Four selling activities for cotton, dura, groundnuts, and sesame are represented in the model. These are shown in Tables 4.5, 4.6, 4.7 and 4.8, respectively. Selling is assumed to take place immediately following harvest. Prices used are the average prices received by the farmers in the area in the season 1979/80. These are represented as positive coefficients in the objective function. They also appear as negative coefficients, replenishing the OC streams, corresponding to the selling months.

5. Transfer Activities

These are activities which allow the passing of unused capital from one period to the next. The last activity carries over accumulated capital to the next season. These activities have a zero value in the objective function and a series of +1 and -1 coefficients in the corresponding OC periods.[1]

The Constraint Set

The constraint set of the model includes the following restrictions:

1. Farm Level Resources
    a) Land Restrictions
    b) Labor Restrictions
    c) Operating Capital Restrictions
2. Minimum Dura Consumption
3. Operations Balance Constraints
4. Non-Negativity Constraints

1. Farm Level Resources

The first part of this chapter has discussed the availability and distribution of farm resources for the three farm size categories. In what follows we describe the level of each resource made available in each model period by farm size category.

a) Land Restrictions

Chapter III described the land situation in the area. It was emphasized that there is no current land shortage, and that limitations of land size are largely those brought about by the limitations of other production inputs (namely labor and operating capital).

---

[1] These activities are shown together with the capital borrowing activities discussed in the next part of this chapter (see Table 4.17).

Land referred to in this context consists of the field plots, locally known as Saraya. Such land is assumed to be homogenous. No distinction by soil type is employed in the model. The upper limit (in feddans) of each farm size category was used as the limit in the restriction. For the NMAPC models, the average of the existing farm size and the proposed tenancy size under full-phase development was used. Land restriction limits in the basic LP models are shown in Table 4.11.

Table 4.11 Land Restrictions Limits in the Basic LP Models

Model	Restriction Limit (in feddans)
Traditional:	
(i) Category I	5.0
(ii) Category II	9.9
(iii) Category III	25.9
NMAPC:	
(i) Status-Quo	6.0
(ii) Full-Phase	10.0

b) Labor Restrictions

(1) Family Labor

To derive the family labor supply for the three production categories, assumptions based on the observed average labor use profile are employed. The FAO survey data, which has a larger sample size than this researcher's survey and a higher percentage of cases with complete labor records, was used. Table 4.12 gives the monthly distribution of family labor use by

Table 4.12 Monthly Distribution of Family Labor Use by Production Category (in man-days): Sample Averages

Month	Category I (0.0-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Jan.	16.5	14.2	18.2
Feb.	5.8	11.5	28.5
Mar.	4.4	8.1	14.8
Apr.	4.8	12.7	16.4
May	7.8	15.7	22.6
Jun.	13.7	23.7	34.3
Jul.	22.6	45.1	53.9
Aug.	24.8	42.1	62.7
Sep.	16.8	21.2	46.3
Oct.	10.9	19.8	24.9
Nov.	12.2	23.2	26.8
Dec.	12.1	19.5	25.2
TOTAL	152.9 (125.2)	262.6 (226.6)	387.4 (365.8)

(   ) = Standard Deviations

Source: Computed, FAO survey (1978/79).

production category. Figure 4.2 illustrates the observed labor profile graphically.

Three distinct labor periods can be observed. The first period extends from last season's harvest operation until the beginning of the current year cropping season, which is from February through June. This period is characterized by the lowest labor use by the household.[1] The second period is the planting and weeding period (from July through September). This is the most labor intensive period. The third and last period is that of harvest and post-harvest activities (from November through January). This is again a labor intensive period, but less so than the second period.

Based on the characteristics of the labor use profile described above, Table 4.13 shows the family labor supply levels in the LP models by category and model period. The figures are based on averages from the FAO survey data.[2]

(2) Hired Labor

No restrictions on the amount of HL are employed in the LP models. HL use in the models is limited only by the availability of operating capital.

---

[1] October labor use also fits the pattern of this period. It represents a slack between the weeding period and the harvest period.

[2] In the first period (February through June) and during October, family labor supply is adjusted (upwards) to be 20 man-days per month for each of the three categories.

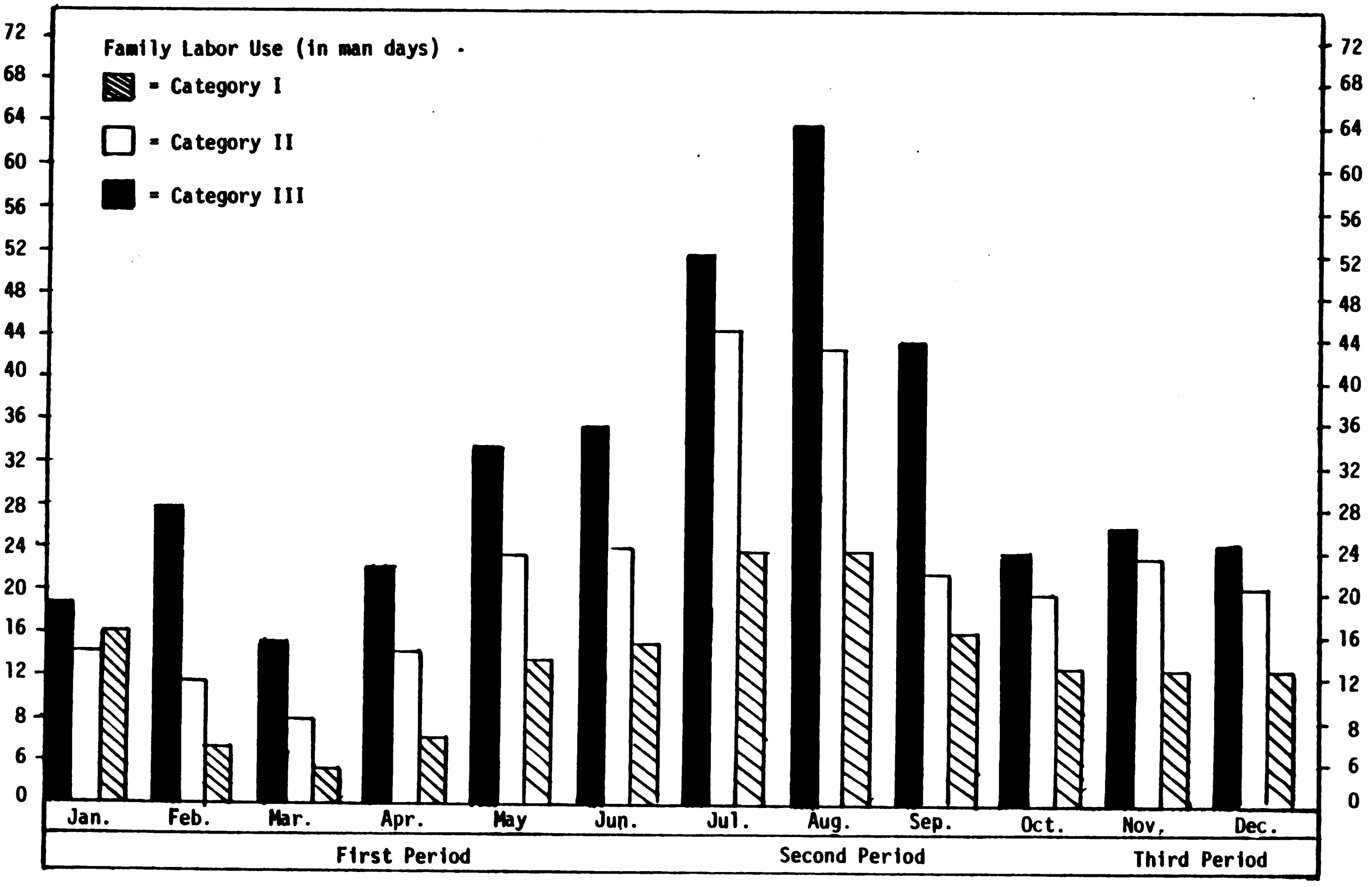

Figure 4.2 Graphical Representation of Average Observed Family Labor Use

Table 4.13 Family Labor Supply (in Man-Days) in the LP Models: By Production Category and Model Period

Period No.	Month	Category I (0.0-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
1	Jun.	20.0	20.0	20.0
2	Jul.	22.0	36.0	54.0
3	Aug.	22.0	36.0	54.0
4	Sep.	22.0	36.0	54.0
5	Oct.	20.0	20.0	20.0
6	Nov.	20.0	22.0	26.0
7	Dec.	20.0	22.0	26.0
8	Jan.	20.0	22.0	26.0
9	Feb.	20.0	20.0	20.0
10	Mar.	20.0	20.0	20.0
11	Apr.	20.0	20.0	20.0
12	May	20.0	20.0	20.0

(3) Nafir Labor

Unlike hired labor, nafir labor (NL) is governed by different institutional arrangements which limit its availability. Usually this type of labor is available during periods of peak demand for planting, weeding, and harvesting. Limits employed in the models are derived from this researcher's survey data for the three farm size categories shown in Table 4.14.

Table 4.14 Nafir Labor Availability (in Man-Days) in the LP Models: By Production Category and Model Period

Period No.	Month	Category I (0.0-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
2	Jun.	3.33	5.58	2.70
3	Aug.	3.33	4.58	2.70
4	Sep.	3.33	3.53	0.00
6	Nov.	3.33	5.42	1.67
7	Dec.	3.33	9.21	8.20
8	Jan.	0.00	4.10	1.30

c) Operating Capital Restrictions

In Chapter III, the sources and uses of OC are discussed. Smallholders in the region need cash for both consumption and production uses. The sources are also varied, including savings, crop and livestock sales, off-farm earnings, and borrowing. Borrowing from traditional money lenders (the "sheil" system) is widespread [8].

In general, the estimation of operating capital availability is a difficult problem in a small farm setting. For this study, amounts spent on crop production estimated from this researcher's survey data were used as a proxy for farm OC. The estimated figures were Ls 6.93, Ls 27.83, and Ls 152.27, for the three categories, respectively. All OC is made available in the first period (June), and unused amounts are transferred as needed to the subsequent periods. The supply of OC in the models is augmented by crop sales later in the season, and by capital borrowing activities in the credit experiments. An ending capital restriction is imposed in the models to ensure that an amount at least equal to the starting OC is available for the next season.

2. Minimum Dura Consumption

The importance of dura consumption for smallholders in the area has already been discussed in Chapter III. It was also pointed out that devoting a minimum feddanage of dura to at least satisfy household consumption needs is one of the risk strategies practiced by the smallholder. A study in Eastern Sudan [40] estimated that 14 sacks of sorghum are consumed by a slightly larger than seven member household. Average dura consumption estimates from this researcher's survey (see Table 4.2) were 7.05, 8.76 and 11.57 sacks for the three farm size categories, respectively. These figures were adjusted based on average family sizes (5, 6 and 7 members) and it is assumed in the models that an amount equal to eight, ten, and twelve sacks (90 kg) must be devoted to consumption in categories I, II, and III, respectively.[1]

3. Agricultural Operations Balance Constraints

These constraints are employed in the model to force the cultivation for a particular crop timing to occur together in the proper sequence. A series of (-1) and (+1) coefficients are used to place land at the disposal of an agricultural operation, and to transfer it to the next operation, respectively.

---

[1] These levels are judged to be reasonably on the safe side of consumption, since they don't include the "Jubraka" (household plot) production. The latter (not accounted for in the models), is devoted mainly to household consumption early in the season (August-October).

4. Non-Negativity Constraints

This set of LP constraints requires that no activity be operated at a negative level.

Experiments and Changes Made in the Basic LP Model

The basic model described above was modified in order to carry out the planting time and credit experiments, and to represent the NMAPC farming system.

NMAPC Models

Only cotton and dura crops are grown in the NMAPC schemes. Both the time distribution of the agricultural operations and the input-output coefficients are different in the NMAPC model. Chapter III compares the NMAPC and traditional smallholder farming systems. Further description of NMAPC farming system is given in Chapter VI.

Changes made in the basic model in order to represent NMAPC farming conditions are as follows.

a) Land Size and Crop Composition

Both the tenancy land size and crop composition are determined by NMAPC. The initial "status-quo" model has a size of six feddans, divided equally between cotton and dura. The contemplated "full-phase" model has a size of fifteen feddans, to be grown with cotton and dura (five feddans each), and five feddans to be left fallow in the rotation.

b) Mechanized Cultivation

Two mechanical plowing activities are added. On NMAPC farms, simultaneous with the second plowing operation, dura planting is done mechanically through a mounted box (seeder) in the tractor. Therefore the dura planting coefficient is zero. The cost of these operations in practice is subtracted from the farmer's cotton returns at the end of the season.[1] These costs are Ls 1.0 and Ls 0.6 for the first and second plowing, respectively. In the LP models these charges are costed to the objective function and to the OC of March.

c) Agricultural Operations Calendar

Only one calendar of operations is represented in the NMAPC models, since the delaying of the mechanical plowing (under the control of NMAPC) results in a late and similar activity calendar for all participants. In the NMAPC models, operations are assumed to take place as shown in Table 4.15.

Table 4.15 Agricultural Operations Calendar in the NMAPC LP Models

Activity	Activity Time For: Cotton	Activity Time For: Dura
PLNT	August	August
WEED I	August	August
WEED II	September	September
HVST I	January	December
HVST II[a]	May	January

[a] For cotton this refers to cotton stalk-uprooting and disposal ("AL-awdi").

---

[1] If a farmer is not growing cotton, he is supposed to pay these costs in cash at the end of the season (around March).

d) Input-Output Coefficients

The labor and yield coefficients for the NMAPC model are also different from those of the traditional model. Based on estimates from the 1979/80 survey data, the weeding, harvest, and yield coefficients of the NMAPC model are given in Table 4.16.

Table 4.16 Labor and Yield Coefficients in the NMAPC LP Models

Item	Cotton	Dura
Labor[a]		
WEED I	4.45	4.87
WEED II	2.40	2.66
HVST I	13.30	4.29
HVST II	7.04	2.19
Yield[b]	2.23	3.58

[a] As before, labor units are 7 hour man-days.

[b] Cotton yield in small kantars (100 lb); dura yields in sacks (90 kg).

Credit Experiments

Capital borrowing and repayment activities are added to both traditional and NMAPC models in experiments to evaluate the potential contribution of credit. As described in Chapter III, only non-formal credit sources are available to smallholders in the area at present. However, NMAPC contemplates extending credit to its tenants in the future.

Table 4.17 shows the borrowing activities together with the original capital transfer activities. The unit of borrowing, transfer, and repayment activities is one Ls. Coefficients are a series of negative ones (-1) to indicate addition to the corresponding monthly OC resources. A series of positive (1.07) coefficients ensures the repayment of principal plus seven percent per year. Objective function coefficients of the borrowing activities (-.07) represent an annual interest rate of seven percent.[1] The figure was chosen because it is the official interest rate charged by the Agricultural Bank of Sudan for short term loans. It will be discussed later in the context of interpretation of model results.

Planting Time Experiments

These experiments are designed to shed light on the effect of three different planting times. Each of the three time of planting sequences has different yield coefficients. Therefore a third calendar of operations was added, and coefficients of weeding, harvest and transport were adjusted proportionally.[2] Resource availabilities are disaggregated in half monthly periods for selected months (July through December) for the purpose of these experiments.

A summary of the changes in model design made for these experiments is given before the results analysis in the next chapter. The basis of the experiment's assumptions and the full account of experimental data used are given in Appendix II.

---

[1] Actually the use of the same objective function coefficient (-.07) for all borrowing activities slightly over estimates the cost of borrowing for the later borrowing activities. However, given the small interest rate used, resulting discrepancies are insignificant.

[2] For dura only one timely weeding is required in these experiments (see discussion in Appendix II).

Table 4.17 Borrowing and Capital Transfer Activities

			c_j / B_i[a]	Borrowing Capital												Capital Transfer												
				BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9	BC10	BC11	BC12	CT1/2	CT2/3	CT3/4	CT4/5	CT 5/11 9	CT 6/7	CT7/8	CT8/9	CT 9/10	CT10/11	CT11/12	End CPTL	Repay
				-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07	0	0	0	0	0	0	0	0	0	0	0	0	0
OC-Jun.	≤	Ls	27.83	-1												1												
Jul.	≤	Ls	0		-1											-1	1											
Aug.	≤	Ls	0			-1											-1	1										
Sep.	≤	Ls	0				-1											-1	1									
Oct.	≤	Ls	0					-1											-1	1								
Nov.	≤	Ls	0						-1											-1	1							
Dec.	≤	Ls	0							-1											-1	1						
Jan.	≤	Ls	0								-1											-1	1					
Feb.	≤	Ls	0									-1											-1	1				
Mar.	≤	Ls	0										-1											-1	1			
Apr.	≤	Ls	0											-1											-1	1		
OC-May	≤	Ls	0												-1											-1	1	
End CPTL	≥	Ls	27.83																								-1	
CPTL Repay	≤	Ls	0	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07													-1

Source: Computed

[a] Resource levels for category II.

CHAPTER V

TRADITIONAL SMALLHOLDER PRODUCTION: A LINEAR PROGRAMMING ANALYSIS

The previous chapter described the production models and their LP structure. This chapter utilizes the linear programming models to analyze smallholder production.[1] Information drawn from the LP solution includes the value of the objective function, the optimal enterprise combination, levels of resource use and their respective marginal productivities (MVP's), the nonoptimal activities with the cost of forcing each of them into the optimal solution, and the stability limits of the optimal plan. The analysis here focuses on the optimal cropping pattern and the associated resource use and productivities. Resulting changes in farm income are also discussed.

The organization of the analysis and discussion in this chapter generally follows the order of objectives stated in the first chapter. In the first part the base models of the three traditional production categories are discussed, together with results from hypothesized changes in rainfall variability. The second and third parts investigate resource use and productivities under credit-aided resource expansion and planting

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[1] The LP program used was the AG ECON LINEAR PROGRAMMING PACKAGE Ver. 2.20 (Stephen B. Harsh and J. Roy Black, 1975)[28].

time experiments. The fourth part discusses cotton production problems in traditional agriculture, and presents results of the cotton price variation experiment. Within the above analysis, relevant policy issues are discussed. A brief summary of the results is given in the last part of this chapter.

Basic Solutions and Optimal Production Plans for the Traditional Smallholder Categories

The validity of optimal solutions derived from LP models is in general limited by the degree of accuracy and representativeness of the model's assumptions and coefficients. This, in addition to the normative nature of the LP analysis in general, suggests a need for caution in using these optimal solutions for interpretation and inferences regarding the farmer's behavior.

The optimal solutions and production plans of the three traditional smallholder farm size categories are given in Table 5.1.

Cropping Patterns

Despite the tendancy of LP to generate highly specialized enterprise plans, the results obtained in this case are fairly comparable to the observed cropping patterns of smallholders in the region.[1] This is due to the dominance of dura and dura-sesame combinations in the cropping pattern. The dura consumption constraint might be expected to explain the large share of dura feddanage in the plans, but in fact this is mostly due to the relative probability of the crop since in all three farm size

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[1] Comparisons with the observed situations are made with Table 4.1 (Chapter IV) for cropping pattern, and with Table 3.12 (Chapter III) for the time distribution of the cropping pattern.

Table 5.1 Basic Optimal Production Plans for the Three Categories of Traditional Smallholders

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern:				
Early Dura (DR_1)	Feddan	3.94	5.91	12.05
Early Sesame (SM_1)	Feddan	--	0.69	2.67
Late Dura (DR_2)	Feddan	--	2.32	6.29
Late Sesame (SM_2)	Feddan	0.49	0.25	2.42
Resource Use:				
Total Land	Feddan	4.42	8.85	23.88
Family Labor	Man-Day	110.03	178.93	275.81
Hired Labor	Man-Day	11.51	56.50	403.88
Nafir Labor	Man-Day	6.66	21.50	14.90
Total Labor	Man-Day	128.20	256.92	694.59
Total Operating Capital	Ls	28.61	83.36	374.46
Objective Function Value:	Ls	55.19	124.55	269.75
Total Gross Margin[a]	Ls	107.99	190.55	348.95
Average Productivities:[b]				
Per Feddan	Ls	7.35	6.60	6.20
Per Man-Day	Ls	0.84	0.73	0.49

Source: Computed

[a] Includes the value of dura retained for household consumption.

[b] See the text for assumptions and procedures for calculating these averages.

categories dura feddanage is well above the levels required to satisfy household dura consumption. The relative share of sesame in the optimal cropping patterns for the three categories is less than in the observed situation by 27 percent for category I, 10 percent for category II, and only 5 percent for category III. However, for both observed and computed optimal cropping patterns of the three categories, the absolute size of sesame represents small feddanage (especially for category I and II). This situation, despite the seeming relative profitability of the crop,[1] is mainly attributed to the labor intensive and time exacting demands incurred at sesame harvest.

Groundnuts does not appear in the optimal solution for any of the categories. In the observed situation farmers may devote a small area to the crop. Relatively large groundnut areas are observed only in the northern regions (Northern Abassya and Dilling) where there are suitable loamy soils.

Cotton does not enter any of the three optimal plans. This agrees with the empirical observation that cotton is almost disappearing from traditional farms. As the issue is of great importance to the government, the fourth part of this chapter will analyze government cotton price policy in a parametric price programming experiment.

An important feature that is displayed by the solutions is the time distribution of the cropping patterns. Both early and late schedules of cropping were observed in the 1979/80 survey, but the major portion of cropping (80 percent and 88 percent for dura and sesame, respectively) is

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[1] For a picture of the relative profitability of the four crops considered, see Table 4.4

done in the early schedule. In the LP optimal plans, however, 100 percent, 72 percent, and 66 percent of dura (for the three categories, respectively) is in the early schedule; and for category II and III, which grew sesame, 72 percent and 52 percent, respectively, is done in the early schedule. In practice, adoption of both early and late cropping schedules by the smallholders in the area results from the need to smooth out the stringent labor bottlenecks, especially those developing early in the season. As discussed earlier in Chapter III, this practice is aided by the use of different time maturing varieties. The issue of cropping schedule time is further analyzed in an experiment presented in the third part of this chapter.

Resource Use

Levels of resource use for the three production categories are shown in Table 5.1. Total land use is 4.42, 8.85 and 23.88 feddans for the three categories, respectively. These figures represent 88 percent, 89 percent, and 92 percent of the total allowable land in these models, respectively. Total labor used in each category is exactly proportional to cropped land sizes, amounting to 29 man-days per feddan. Family labor use in the three categories is 110, 179 and 276 man-days, respectively. Nafir labor use is highest in category II, but in all three categories its relative share in the total labor input is very small. Hired labor increases more than proportionally when moving from the smallest to the largest category. Its relative share in the total labor input is 9 percent for category I, 22 percent for category II, and 58 percent for category III. This is essentially because of differences in availabilities of operating capital (OC) for the three categories. The amounts available in the models were Ls 6.93, Ls 27.83, and Ls 152.7, respectively. However, the actual amounts used in the optimal plans (shown in Table 5.1) are higher. This situation is allowed for in the models through supply of additional OC from crop sales later in the season, for example sales of sesame, which occur as early as November.

Returns and Average Productivities

Monetary returns from the optimal plans are Ls 55.18, Ls 124.55, and Ls 269.75. Total gross margin figures, which include the value of dura produced but retained for household consumption, are Ls 107.99, Ls 109.55, and Ls 348.95. Such low returns are typical of the smallholder farming in the area and they have a number of important implications which will be discussed later. These low returns are the product of low productivities of both land and labor, resulting from low crop yields. Average productivities for land and labor are given in Table 5.1. Drawing on Parhusip [53, pp. 88-89], the following procedures and assumptions were adopted in computing these averages:

1. The market value of dura retained for household consumption (8, 10, and 12 sacks for the three categories, respectively) is added to the corresponding objective function value to obtain total gross margin (TGM), or total value product (TVP) less the variable costs (VC). This procedure reflects the total returns to both land and labor.
2. In computing the average returns to land and labor, an interest rate of 7 percent per year is charged on initial amounts of operating capital (OC) in the models. Although the intent is to account for the opportunity cost of capital used in the

production process, the 7 percent rate used probably underestimates the real cost or productivity of OC, especially when inflation is taken into account.[1] However, no reliable estimate of the real rate is available, and the use of any other figure is esentially an arbitrary one.[2] This particular figure is chosen because it is the official rate charged by the Agricultural Bank of Sudan for short-term (up to 14 months) loans.

3. To compute the average returns to land, not only capital costs but also all labor costs must be accounted for. It is assumed that the prevailing wage rates of hired labor (HL) in the area reflect the opportunity cost of labor provided by the three types of labor (family, hired, and nafir) represented in the models. Hence, total labor used in the optimal plans (provided by the three types of labor) is costed at the prevailing wage rates of HL. This procedure amounts to costing family labor (FL), which is not costed in the LP model,[3] at the corresponding HL wage rates,

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[1] No official statistic for inflation in the Sudan is available; however, it is believed to be running well above 50 percent for the past few years.

[2] An idea about the productivity of capital within the smallholder farming in the area can be had from the model results (discussed later with the credit experiment) on shadow prices of capital in the different periods.

[3] This is not because, as some have argued (see discussion of the issue in Eicher and Witt [20]), of zero marginal productivity, but because family labor is viewed here to be rewarded by net returns from crop sales and by the dura consumption portion retained from production.

and adjusting the nafir labor (NL) fixed charge of Ls 0.33 to the corresponding HL wage rates.[1]

4. In computing average returns to labor, no cost is assumed for land and other fixed assets. This judgment derives from the abundance of land in the region at the present, and from the small level and value of fixed assets (mainly hand tools) utilized in smallholder farming in the area.

5. With the above four points in mind, the average productivities shown in Table 5.1 are calculated according to the following formula:

   Average Productivity per Feddan = [TGM - (FL costed at HL rates + NL cost adjusted to the HL rates) - (OC x .07)] ÷ No. of feddans cropped

   Average Productivity per Man-Day = [TGM - (OC x .07)] ÷ Total Labor (in man-days)

Computed average productivities for both land and labor (see Table 5.1) are very low by comparison to returns under irrigated farming.[2] This situation is a result of the low physical crop yields obtainable under the environment of the region, and the seasonal constraints which limit expansion of cropped area. This latter factor is of particular importance and will be discussed in the subsequent analysis. A number of

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[1] As explained earlier (see part two in Chapter IV) nafir (exchange) labor (NL) is paid only in-kind (food and drinks), and the value of these expenses was estimated as Ls 0.33 per man-day; this rate is then applied uniformly to objective function coefficients of NL activities.

[2] For example, Zaki [61] estimated the mean net returns to household labor per feddan in the Rahad Irrigation Project (Eastern Sudan) from the rotation crops as follows: cotton = Ls 74.69; groundnuts = Ls 31.70; leguminous fodder = Ls 22.52.

important implications arise from the situation of low productivity and returns of smallholders' farming in the area.

First, under such circumstances, alternative sources of income for the smallholder are a necessity to meet household consumption obligations.[1] One such important source of income to smallholders in the area is off-farm employment. Off-farm work, as described in Chapter III, is concentrated in the off-season period and is markedly influenced by the general savanna climate of the area. An estimate of the share of off-farm earnings relative to the total household income is available from the FAO survey data. For the three categories the percentages are as follows: 37 percent, 23 percent, and 33 percent, respectively.[2] The larger share (in absolute value) for individuals in category III reflects their relatively better position in off-farm occupations (shopkeeping and trade), as pointed out earlier. Another source of income to smallholders is livestock sales. Smallholder investment in livestock constitutes one strategy against risks and low returns from cropping activities.[3] This source of income is tapped especially in "bad" cropping years. One final alternative source that smallholders in the area often resort to,

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[1] The average consumption expenditure levels for the three categories are given in Table 4.2 (Chapter IV).

[2] In absolute value the respective amounts for the three categories are Ls 46.82, Ls 43.8, and Ls 105.69.

[3] Almost all smallholders interviewed in the researcher's survey (1979/80) gave this as the primary reason for investing in and keeping animals (especially cattle and goats).

mostly during the growing season, is borrowing from local money lenders (under the "sheil" system) in the form of both cash and goods [8, 38].

Second, the present low productivity and returns of the smallholder farming clearly indicates the need for improved production technology. It is for this reason that the NMAPC modernization program has been introduced. The record of the NMAPC is discussed in the next chapter. However, in this chapter, two experiments (given in the second and third parts, respectively) are directed towards investigating possibilities of increasing smallholder productivity and returns.

Seasonal Constraints and Marginal Productivities

The previous section has emphasized the low productivity and returns of smallholder farming. It was pointed out that in general this situation is attributable to the low physical crop yields obtainable under the environment of the region. It was also argued that seasonal labor constraints limit the extent of what could be a somewhat compensating effect through either increasing the size of cropped area, or achieving per feddan increases in yield through better (labor intensive) management levels.

Table 5.2 gives the marginal productivities of the resources used in the optimal production plans for the three categories. There are two noteworthy points that should be observed in the interpretation of these MVP's:

Table 5.2 Shadow Prices for the Limiting Resources: Basic Production Plans of Traditional Smallholders

		Shadow Prices (in Ls)		
Resource	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Family Labor				
Jan.	Man-Day	--	--	0.457
Apr.	Man-Day	--	--	0.560
May	Man-Day	--	--	0.670
Jun.	Man-Day	--	0.637	0.967
Jul.	Man-Day	2.390	1.476	1.046
Aug.	Man-Day	0.744	1.001	1.134
Oct.	Man-Day	--	--	0.449
Nov.	Man-Day	0.680	0.729	0.762
Dec.	Man-Day	--	0.975	1.019
Nafir Labor				
Jan.	Man-Day	--	--	0.127
Apr.	Man-Day	--	--	0.230
May	Man-Day	--	--	0.340
Jun.	Man-Day	--	--	0.331
Jul.	Man-Day	1.076	0.664	0.471
Aug.	Man-Day	--	0.189	0.558
Nov.	Man-Day	.350	0.375	0.392
Dec.	Man-Day	--	0.621	0.649
Operating Capital				
Jun.	Ls	2.964	1.459	0.744
Jul.	Ls	2.964	1.459	0.744
Aug.	Ls	2.964	1.459	0.744
Sep.	Ls	0.0001	0.071	0.744
Oct.	Ls	0.0001	0.071	0.744
Nov.	Ls	0.0001	0.071	0.120
Dec.	Ls	0.0001	0.071	0.120
Jan.	Ls	0.0001	0.0001	0.0001
Feb.	Ls	0.0001	0.0001	0.0001
Mar.	Ls	0.0001	0.0001	0.0001
May	Ls	0.0001	0.0001	0.0001

Source: Computed

1. According to economic theory, MVP is defined as the total value product (TVP) obtained from the use of an additional (marginal) unit of the input in question, other inputs held constant.[1] However, in LP with the linear and fixed proportion production function, inputs are not held constant but rather they are increased in a fixed proportional manner in order to obtain an additional unit of output.[2] Nonetheless, within the context of LP, shadow prices (MVP's) are useful in making inferences about resource productivities. For the farm situation at hand, these MVP's indicate the increase in the objective function value (farm income) that would obtain if a particular resource is expanded by one unit. Hence, they reflect the maximum price a farmer would be willing to pay to augment a given resource. According to this evaluation, an MVP equal to zero means that the given resource is not constraining, while a positive MVP indicates scarcity of the resource. The higher the MVP, the

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[1] Mathematically this is represented by differentiating the TVP function, in order to obtain the partial derivative with respect to the input in question:

$$TVP = f(x_1, x_2 \ldots x_n | x_{n+1} \ldots x_m)$$

$$MVP_{xi} = \frac{\partial TVP}{\partial_{xi}} = f'_{xi}; \; i = 1, 2, \ldots n$$

f = TVP function

f'_{xi} = partial derivative with respect to input (xi); and i = 1, 2 ... n, is the set of variable inputs.

[2] For the LP technology, which represents a fixed proportion production function, MVP's are defined only at corner points (proportionate inputs combination) and zero elsewhere.

more scarce and hence the more valuable/productive the given resource is. This is the rule for augmenting a resource and expanding output in the LP context. The valuation of MVP in the LP context is unique within a specific range of resource levels in the model. Usually when a given resource is increased, another resource becomes limiting, and consequently the resulting MVP's of all resources change.

2. The yields and returns used here correspond to rainfall conditions and levels for the 1979/80 season. Different conditions and rainfall levels would result in different yields and hence, different MVP's for the resources.

Table 5.2 shows the MVP's of the resources used in the optimal production plans. The basic limiting resources in the smallholder production are the labor resources. OC resources are also limiting, which leads to an indirect labor constraint since labor is the basic resource OC is expended on. Land is not limiting.

Family labor is limiting mainly in two periods: June through August, and November through December. As one might expect from previous discussions, these correspond to the most labor intensive periods in the grown season. The first period, early in the season, is when weeding takes place. The second period, late in the season, comprises harvest and crop disposal. Across all three categories, these two periods are the main constraining periods. For the largest category III, family labor is also constraining in a third period (April-May), which is the preseason period of land preparation. This is because of the relatively large cropped area for this category.

The MVP's corresponding to the two periods just discussed are positive, and high in comparison with the respective monthly hired labor wage rates, in all three categories. This indicates that expansion of the labor resource during these periods would be profitable. In fact, in these basic optimal plans, nafir and hired labor use occured mainly during these two periods. For category I, HL man-days were divided approximately equally between July (first period) and November (second period). In category II, HL man-days were allocated 61 percent in July and 39 percent in November and December. For category III, where HL came in months other than those of the two periods, 86 percent of HL still occurred in these two periods, with 50 percent in July and August and the remaining 36 percent in November and December. As noted, nafir labor provision is largely limited to the two peak periods. The MVP's were expectedly high in July (first period) and November/December (second period).

The OC MVP's are positive and extremely high for all three categories in the early months of the season (June through September), and then they drop abruptly to almost zero. The reason for this is the scarcity of cash required to pay for labor in the first period, whose MVP's indicate its profitability as discussed above. Low MVP's of OC in the second period, however, probably occur because no direct returns can be achieved by using OC later in the model year. The other likely reason is that later in the season the OC inventory is replenished through sales of the sesame crop (which was in the solution of all categories) which occurs as early as November. This effect has an important implication for credit needs and is discussed later in the credit-aided resource expansion experiment.

The labor MVP's examined in this section suggest that technologies that are oriented towards breaking labor constraints in the two peak periods might be the most rewarding for smallholders. The use of chemical weeding and the use of stationary or combine grain harvesting would tend to relieve the first and second labor constraints. Needless to say, the development and adoption of such technologies depends on their technical and economic feasibility. At present the work by Hamdoun [26] on chemical herbicides indicates some potential if the current problems related to chemical use are overcome.[1]

With family and nafir labor being fixed through the set of institutional factors discussed before, expansion of the labor resource would depend on expanding the use of hired labor. The extent and benefits of such an approach are examined through a credit-aided resource expansion experiment in the next part of this chapter.

Rainfall-Induced Yield Variability

In this section we investigate the situation of smallholder's returns under conditions of "bad" rainfall years. In the area, extremely drastic rainfall years are rare [38]. Consequently, incidences of

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[1] At the research level the basic problem observed is that of plant toxicity, its long residual effects under rainfed conditions, and the human hazards it poses (for details see Hamdoun [26]). At the field level expected problems are those of management and application [25]. Water shortage at field sites in the area is an example of potential problems that need to be overcome to make such a technique practical.

complete crop failure due to rainfall are few, and probably obtain only coupled with poor or no crop management. Nonetheless, it is instructive to investigage less than favorable rainfall years as the major factor in depressed cropped yields. This is done here through simple sensitivity analysis around the yield coefficients in the models. Twenty-five percent and 50 percent reductions in yield levels are assumed for situation A, and situation B, respectively.[1] The optimal production plans for situation A and B are given in Tables 5.3 and 5.4, respectively.

Situation A:

a) Cropping Pattern

Dura feddanage showed little change, with most being grown in the early schedule as before. The sesame share increased almost by 50 percent for category I, while slightly dropping for both category II and III. Interestingly, cotton entered the solution of category III; however, only 6 percent of the cropped land is devoted to cotton, grown in the late schedule.

b) Resource Use

Total cropped area went up slightly for all three categories, which was made possible through the reduction of required harvest labor of crops. In terms of labor composition, the share of NL remained approximately the same, while that of HL dropped in all three categories. FL dropped slightly for category I and II, and increased slightly for category III. In all three categories OC dropped reflecting reductions of HL use.

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[1] In both cases, harvest and transport coefficients of the production activities in the models was adjusted downwards by the same proportions.

Table 5.3 Optimal Production Plans for the Three Categories of Traditional Smallholders: Under Twenty-Five Percent Yield Reduction

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern:				
Early Dura (DR_1)	Feddan	3.64	6.12	10.74
Early Sesame (SM_1)	Feddan	--	0.35	3.56
Late Dura (DR_2)	Feddan	--	2.33	8.37
Late Sesame (SM_2)	Feddan	0.93	0.17	0.42
Late Cotton (CN_2)	Feddan	--	--	1.45
Resource Use:				
Total Land	Feddan	4.57	8.96	24.54
Family Labor	Man-Day	106.81	173.72	307.61
Hired Labor	Man-Day	3.97	39.88	280.16
Nafir Labor	Man-Day	9.41	21.50	13.60
Total Labor	Man-Day	120.19	235.10	601.37
Total Operating Capital	Ls	19.54	71.19	324.63
Returns:				
Objective Function Value	Ls	26.91	72.80	138.34
Total Gross Margin[a]	Ls	79.61	138.80	217.54

Source: Computed

[a] Includes the value of dura retained for household consumption.

Table 5.4 Optimal Production Plans for the Three Categories of Traditional Smallholders: Under Fifty Percent Yield Reduction

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern:				
Early Dura (DR_1)	Feddan	3.72	6.37	6.37
Early Sesame (SM_1)	Feddan	--	--	--
Late Dura (DR_2)	Feddan	--	2.26	5.12
Late Sesame (SM_2)	Feddan	0.90	0.41	1.48
Resource Use:				
Total Land	Feddan	4.62	9.30	13.19
Family Labor	Man-Day	98.54	170.46	273.21
Hired Labor	Man-Day	3.93	34.05	58.92
Nafir Labor	Man-Day	6.66	8.37	11.03
Total Labor	Man-Day	109.13	212.88	343.16
Total Operating Capital	Ls	23.93	63.11	95.38
Returns:				
Objective Function Value	Ls	-10.82	12.30	25.66
Total Gross Margin[a]	Ls	35.48	78.30	104.86

Source: Computed

[a] Includes the value of dura retained for household consumption; in Category I the value of 0.98 dura sack bought is not included.

c) Monetary Returns

With a 25 percent reduction in yield levels, the objective function values were 51 percent, 41 percent and 49 percent lower for the three categories respectively, indicating the sensitivity of returns to reduced rainfall and hence reduced crop yields.

<u>Situation B</u>:

a) Cropping Pattern

The share of dura in the crop mixture remained approximately the same for categories I and II, while dropping substantially for category III. The latter was caused mainly by the overall reduction in cropped land size for category III. The sesame area dropped in all three categories, especially so in category III.

b) Resource Use

While total cropped land went slightly up for categories I and II, it dropped significantly (by 45 percent) for category III. For the first two categories the increase could be explained as one way of compensating for the severely depressed crop yields. However, with yields reduced by half, the profitability of HL in category III is substantially reduced. Since HL normally makes up 60 percent of the total labor force in this category, there results a large reduction in cropped area. FL and NL remained at approximately the same levels for the three categories. The HL share is reduced greatly in all three, being highest (85 percent) for category III.

c) Monetary Returns

The same trend is observed as in situation A. With a 50 percent reduction in yield levels, objective function values were reduced by 120 percent (with a negative objective function value),[1] 91 percent, and 90 percent for categories I, II and III, respectively.

The results of modelling situations A and B reveal the sensitivity of smallholder returns to physical crop yields. A given drop in yields leads to a proportionally greater drop in returns.

Credit and Land Expansion Experiment: Traditional Model

The primary objective of this experiment is to examine the effects on crop mixture, returns and seasonal labor use of an expansion of land availability and provision of credit. The main component of this experiment is introduction of capital borrowing activities (with 7 percent annual interest rate)[2]. Land availability is also increased by 50 percent for each of the three production categories. The optimal plans resulting from this experiment are given in Table 5.5.

Cropping Pattern

The dura crop is still dominant, being grown in both early and late schedules. For category III the majority of dura is in the early schedule. By comparison to the basic model results, the area under sesame increases substantially for categories I and II to 2.67 feddans; while the category III sesame area dropped to almost half, from 5.09 to 2.67

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[1] With the dura production in category I less than the specified consumption level (8 sacks), the difference (0.98 sack) had to be bought, resulting in the negative objective function value.

[2] The reason for using this particular rate, as discussed before, is that it represents the official rate charged by the Agricultural Bank of Sudan for short-term (up to 14 months) loans.

Table 5.5 Optimal Production Plans for the Credit and Land Expansion Experiment: Traditional Model[a]

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
<u>Cropping Pattern</u>:				
Early Dura (DR_1)	Feddan	2.53	5.81	29.81
Early Sesame (SM_1)	Feddan	2.67	2.67	2.67
Late Dura (DR_2)	Feddan	2.30	6.37	6.37
Late Sesame (SM_2)	Feddan	--	--	--
<u>Resource Use</u>:				
Total Land	Feddan	7.50	14.85	38.85
Family Labor	Man-Day	151.13	218.00	266.00
Hired Labor	Man-Day	54.61	182.33	844.47
Nafir Labor	Man-Day	13.32	31.20	14.90
Total Labor	Man-Day	219.06	431.53	1125.37
Total Operating Capital:	Ls	70.29	700.56	756.07
Initial Capital	Ls	6.93	27.83	152.70
Crop Sales	Ls	30.36	108.43	256.45
Borrowed Capital	Ls	30.85	60.10	324.23
Interest Paid	Ls	2.16	4.21	22.70
<u>Returns</u>:				
Objective Function Value	Ls	97.81	186.22	374.67
Total Gross Margin[b]	Ls	150.61	252.22	453.86

Source: Computed

[a] Introduction of capital borrowing activities, with the availability of land increased by 50 percent in the three categories.

[b] Includes the value of dura retained for household consumption.

feddans. All three categories therefore grow 2.67 feddans of sesame. The explanation for this as suggested by the changes in resource use levels (discussed below), is that the resulting increase in family labor use in categories I and II helped in raising their sesame feddanage, and that the decrease in family labor use which occurred in category III had the reverse effect. The particular figure of 2.67 suggests a limit for the optimum area of sesame grown by family labor under conditions of unrestricted availability of hired labor.

Resource Use

With the supply of land increased by 50 percent, the respective cropped areas for the three categories were 7.5, 14.85 and 38.85 feddans. This is made possible by more hiring of labor. The hired labor share in the total labor force increased substantially in all three categories, being 25 percent, 42 percent, and 75 percent, respectively. The increase in land and hired labor also made it possible to utilize more of the existing family labor. For categories I and II, FL man-days in this plan compared to the original plan increased 37 percent and 21 percent, respectively. For category III, where there is substantial HL, FL man-days dropped by 4 percent.

Borrowed capital amounts were Ls 30.85, Ls 60.10 and Ls 324.23 for the three categories, respectively. These amounts represent those needed just for production purposes, and hence could be regarded as the lower limits for any meaningful credit expansion, since smallholders also borrow for consumption purposes. Capital borrowing occurred early in the season (June) to cover OC needs of the first period (June-October). The second period OC needs are mostly for harvest and transport expenditures, and these were met in the model through crop sales (especially of sesame which occurs as early as November). Smallholders in the area generally borrow through the "sheil" system mainly in the first period when (as a HTS study notes) interest rates on borrowing are very high:

> Sheil credit, usually advanced in-kind, is characterized by very high interest rates which reach their maximum (up to 300 percent per annum) in mid-August and start to decline once the harvest season commences in mid to late September [38, p. 108].

Effects on Seasonal Constraints

Table 5.6 gives the MVP's of the resources used in the optimal plans in this experiment. With all of the land being exhausted, its MVP is Ls 11.35, Ls 7.38, and Ls 6.80 for categories I and II, and III, respectively. The differences by category are due to the fact that if an additional feddan is brought into production it can be worked with a higher share of family labor in category I, and to a lesser extent in category II, than in category III, where family labor resource is already fully utilized. Reliance must therefore be mainly on the relatively costly hired labor.

The two labor constraint periods observed in the basic plan are also noticeable in this plan: July-August (first period) and November-December (second period). The difference in this case, however, is that through hiring of labor the value of the MVP's is much lower than in the basic model. With the labor MVP's in this plan being equal to or less than the corresponding HL wage rates (except for July and August MVP's,

Table 5.6 Shadow Prices for the Limiting Resources: Credit and Land Expansion Experiment, Traditional Model

Resource	Unit	Shadow Prices (in Ls) Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Land	Feddan	11.35	7.38	6.80
Family Labor				
Jan.	Man-Day	--	0.87	0.87
Apr.	Man-Day	--	0.56	0.56
May	Man-Day	--	0.05	0.11
Jun.	Man-Day	--	0.56	0.55
Jul.	Man-Day	0.64	0.64	0.64
Aug.	Man-Day	0.69	0.70	0.69
Oct.	Man-Day	0.01	0.13	0.40
Nov.	Man-Day	0.61	0.68	0.73
Dec.	Man-Day	0.91	0.91	0.97
Nafir Labor				
Jan.	Man-Day	--	0.54	0.54
Apr.	Man-Day	--	0.23	0.23
Jun.	Man-Day	--	0.20	0.20
Jul.	Man-Day	0.29	0.28	0.28
Aug.	Man-Day	0.34	0.34	0.34
Oct.	Man-Day	--	--	0.04
Nov.	Man-Day	0.28	0.35	0.37
Dec.	Man-Day	0.58	0.58	0.62
Operating Capital				
Jun.	Ls	0.07	0.07	0.07
Jul.	Ls	0.07	0.07	0.07
Aug.	Ls	0.07	0.07	0.07
Sep.	Ls	0.0001	0.07	0.07
Oct.	Ls	0.0001	0.0001	0.07
Nov.	Ls	0.0001	0.0001	0.07
Dec.	Ls	0.0001	0.0001	0.0001
Jan.	Ls	0.0001	0.0001	0.0001
Feb.	Ls	0.0001	0.0001	0.0001
Mar.	Ls	0.0001	0.0001	0.0001
Apr.	Ls	0.0001	0.0001	0.0001
May	Ls	0.0001	0.0001	0.0001

Source: Computed

which are marginally higher than their corresponding wage rates), HL use and profitability to further augment labor resources in these periods is greatly diminished.

Returns with Credit

In this credit experiment, the resulting returns (total gross margins) were Ls 150.61, Ls 252.22, and Ls 453.86, for the three categories respectively. These levels represent substantial increases from the base plans of 77 percent, 50 percent, and 39 percent for categories I, II and III, respectively. Increases were highest in category I and II, where labor and capital are most limited in the basic model. It is noteworthy that in these two categories (I and II), the increase of land and hired labor availability made it possible to use more of the existing family labor resource (by 37 percent and 21 percent for the two categories, respectively), as compared to the base plan.

Smallholders' Credit Situation and Possibilities

The analysis in this part has shown that credit use can increase the low farming returns of smallholders in the area. Although the interest rate charged for borrowed capital in this experiment was 7 percent (to represent the official rate of the Agricultural Bank of Sudan for short-term loans), it is worth noting that the MVP's from the base optimal solution (Table 5.2) indicate the profitability of borrowed capital, within the smallholder system, at extremely high rates: 296 percent, 145 percent, and 74 percent for categories I, II and III, respectively. It is further evident that the profitability of borrowed capital is highest in category I and II, where OC is most limited, and hence credit use is most rewarding. Another important result revealed in the analysis is that credit is mainly needed in the first period (June-October), when smallholders in this period require not only production credit but also consumption credit to see them through harvest. The second period OC requirements could be financed, as farmers normally do, through initial crop sales. In this context, the inclusion of sesame in the cropping plan (with its crop sales occurring as early as November) is particularly important and useful.

Smallholders at present have no access to formal credit and many of them resort to traditional money lenders under the prevalent "sheil" system in the area [8, 38]. Although the establishment of the Agricultural Bank of Sudan (ABS) in 1957 was intended to provide formal credit to smallholders, and despite the fact that the by-laws of the ABS state that "preference for loans should be given to small and medium sized farmers and to cooperatives" [8, p. 107], the ABS historical record was disappointing to smallholders. Instead, the majority of ABS investments and activities were directed towards financing large private cotton schemes in the White Nile and Blue Nile provinces, and later towards private large-scale mechanized rainfed schemes.[1] The need by the ABS for tangible security requirements was identified by Stickley and Abdallah [58] as the main reason limiting the participation of small farmers.

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[1] A concise review of ABS history and investment activities is given in Ahmed [8, pp. 76-86].

In the Nuba Mountains area, the Dilling Branch of the ABS was established in 1970. The activities of the Dilling Branch were concentrated in offering short and medium term loans to private large scale farmers in the mechanized areas of Habela and its extensions.[1] Before 1977 no attempts were made by the Dilling Branch to extend credit to smallholders in the area. Ahmed indicated that "the high cost incurred in providing finance to small undefined areas was the main reason that discouraged lending" [8, p. 113].

In 1977, however, the Dilling Branch of ABS introduced what was considered by Ahmed, in his study of "Lender Behavior and the Recent Performance of Rural Financial Markets the Sudan," as "the first serious attempt in the Sudan to provide institutional credit to typical small farmers" [8, pp. 113-114]. In this attempt, credit was extended to traditional smallholders through their cooperative societies, where intensive credit supervision was used to replace collateral requirements.[2] The first trial conducted in the 1977/78 season was limited to the finance (with a total amount of Ls 14,838) of harvest operations for groundnuts

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[1] For example, all of the short-term dura production loans, which is the main line of activity for the Dilling Branch, are advanced to owners of large schemes (1000 to 1500 feddans) in Habela and other mechanized schemes in the area. For the 1979/80 season the total amount of dura cultivation loans advanced was Ls 608,366.85 (loans granted on the basis of Ls 2,350.0 per 1000 feddans) and the total for dura harvest loans was Ls 432,792.65 (loans granted on the basis of Ls 1.85 per dura sack).

[2] A coordinated effort involving ABS officials, staff of Cooperative Department, staff of Crop Protection and Extension from Ministry of Agriculture, in coordination with village heads (Sheikhs) was used in supervision of this credit program.

and sesame crops of 658 smallholder members of two cooperatives in Um Ruaba area. The following 1978/79 season the scope of the trial was enlarged (with an amount of Ls 80,000) to increase participating smallholders to 972 cooperative members, and to finance both cultivation and harvest operations for the two crops.[1] With the record of these two seasons showing 100 percent repayment of loans, the bank was encouraged to increase the scope of its smallholder credit for the 1979/80 season to include 1300 small farmers in 20 villages. In the same season the program was extended to include 650 smallholder cooperative members in 24 villages in El-Debaibat area, north of Dilling.

The promising potential of cooperatives in securing smallholders' access to formal sources of credit is revealed in this recent ABS Dilling Branch experience, cited by Ahmed:

> Innovations intended to reduce lending and borrowing costs should promote the development of cooperative societies, who in turn, could extend services to a large number of farmers. The Um Ruaba pilot project introduced by the ABS revealed the possibility of extending comparatively small amounts of credit (an average of $200) to a large number of farmers [8, p. 208].

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[1] Loans are granted on the basis of Ls 10.0 per Mukhamas (1.75 feddans) for cultivation of sesame, and Ls 18.0 per Mukhamas of groundnuts. Harvest loans are granted on the basis of Ls 6.53 per Mukhamas of sesame, and Ls 19.49 per Mukhamas of groundnuts.

With the growing number of smallholder cooperatives in the area,[1] providing the framework for expanding the ABS smallholder credit program, the extent of such efforts could be substantially increased. Already, this experience of lending through cooperatives encouraged the World Bank to consider financing traditional agriculture in the Sudan through the ABS with a little less than Ls 7 million in a three-year program as part of an Agricultural Services Project [8].

Planting-Time Experiments and Model Results

The previous part examined the effect on productivity and returns in the traditional farming model through provision of formal credit and a 50 percent increase in land availability. This section focuses on the impact on productivity of changes in time of planting. One of the widely claimed reasons for the low productivity of smallholders is their inability to take timely decisions and their poor crop management practices.

The Experiment

The planting-time experiment is based on the important husbandry practices of smallholders in the area. These include: choice of crop variety, planting time, and weeding rates/times. These factors have already been discussed in Chapter III. Table 5.7 summarizes the implications of these factors as deduced from experimental material and research.

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[1] As of June 1980, the number of registered cooperatives operating in the four districts of South Kordofan Province was 170 cooperatives with total membership of slightly less than 30 thousand. The majority (80 percent) of these cooperatives at the present are "consumption" cooperatives, which are primarily involved in procurement and distribution of consumer goods.

The supporting research, experiments, and data are given in Appendix II. These comprise experiments carried out at the Kadugli Research Station located in the Nuba Mountains area, and the Kenana Research Station located in the central-eastern Savanna of the Sudan. It is important to comment briefly on two methodological points:

1. Being mindful of the limitations of the experiments discussed in this section and Appendix II, they still remain useful in highlighting the implications of timing sequences included in this experiment.
2. In particular there is the much more difficult question of relating yield levels obtained under experimental environments to actual farm conditions. Judgment and comparison with other sources [6, 38] are used in the choice of realistic yield levels that could be achieved by farmers under optimum conditions (suffix I yield levels in Table 5.7), while using research implications for the rate and timing of operations in addition to the yield discounting factors for delayed schedules (suffixes II and III yield levels in Table 5.7).

In the LP model modified for this experiment (see discussion in the last part of Chapter IV), three timing sequences are incorporated. In addition, coefficients of weeding, harvest, and transport corresponding to yield levels in this experiment are adjusted accordingly. It should be noted that in this experiment (see Table 5.7), following the assumptions developed in Appendix II, dura (short-maturing variety) requires

Table 5.7 Expected Yield of Crops by Time of Planting

Timing Sequence	Crop Operation					Expected Yield[a]	
	Planting	Weeding I	Weeding II	Harvest I	Harvest II	(kg. fed.)	(sacks[b] fed.)
Cotton I[c]	Jul. 1	Jul. 15	Jul. 30	Nov. 1	Dec. 1	378.0	8.40
Cotton II	Jul. 15	Aug. 1	Aug. 15	Nov. 15	Dec. 15	251.6	5.59
Cotton III	Aug. 1	Aug. 15	Sep. 1	Dec. 1	Jan. 1	125.6	2.79
Dura I[d]	Jul. 1	Jul. 15		Oct. 21	Nov. 15	600.3	6.67
Dura II	Jul. 15	Aug. 1		Nov. 7	Dec. 1	399.6	4.44
Dura III	Aug. 1	Aug. 15		Nov. 21	Dec. 15	200.7	2.23
Sesame I[e]	Jul. 1	Jul. 15	Jul. 13	Oct. 7	Oct. 15-21	251.3	3.35
Sesame II	Jul. 15	Aug. 1	Aug. 15	Oct. 21	Nov. 1	238.5	3.18
Sesame III	Aug. 1	Aug. 15	Sep. 1	Nov. 7	Nov. 15-21	229.5	3.06
Groundnut I[f]	Jul. 1	Jul. 7	Aug. 15	Oct. 15	Oct. 21	350.1	7.78
Groundnut II	Jul. 15	Jul. 21	Sep. 1	Nov. 1	Nov. 7	240.8	5.35
Grountnut III	Aug. 1	Aug. 7	Sep. 15	Nov. 15	Nov. 21	120.2	2.67

Source: Deduced from experimental material and assumptions discussed in Appendix II.

[a] Crop yields of suffix I are the assumed levels obtainable by farmers under optimum conditions ; those of suffixes II and III are obtained using discounting factors deduced from experimental results discussed in Appendix II.

[b] Sack equivalent for the different crops is as follows: cotton = 45 kg.; dura = 90 kg.; sesame = 75 kg.; and groundnuts = 45 kg.

[c] Variety ALBAR, with 25 percent of cotton picking done in Harvest I.

[d] Short-maturing variety (G. Hamam); only one weeding required, two weeks from planting.

[e] Short-maturing variety (Herari)

[f] Local variety or Barberton.

only one weeding, two weeks from planting. Capital borrowing activities (as before, with 7 percent annual interest rate) were later added to the LP model of this experiment to investigate the implications of the planting-time sequences when a formal credit option is available.

Results of LP Analysis

Optimal Production Plans:

Optimal production plans for the planting-time experiment are given in Table 5.8. Despite the high physical yields associated with early planting of crops, the results reveal that it is optimal for smallholders to grow crops in the late planted (second and third) schedules. The optimality of late planting arises from the stringent time requirements of early planting and its interaction with seasonal resource availabilities. Planting crops at different times is one way smallholders can smooth out these seasonal bottlenecks. Nonetheless, all three farm size categories made use of the high physical yields of the early planted crops, as much as their resources could allow; category III, which has the highest resource endowment, was able to grow 75 percent of its crops in the early schedule.

The resource use figures for these plans, in comparison with the basic plans (see Table 5.1) show the size of cropped area slightly increasing for category I, while dropping 20 percent for category II and 27 percent for category III. This result is explained by the extent to which the three farm size categories made use of the relatively labor intensive, early planted schedule in this experiment; category II and III grew the majority of their crops (51 and 75 percent, respectively) in the

Table 5.8 Optimal Solution for the Traditional Model in the Planting Time Experiment

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern:[a]				
Cotton I	Feddan	0.15	0.15	--
Dura I	Feddan	1.35	2.91	10.30
Sesame I	Feddan	0.06	0.58	2.63
Dura II	Feddan	0.83	1.14	1.30
Cotton III	Feddan	0.18	1.53	1.58
Sesame III	Feddan	0.96	0.67	1.64
Resource Use:				
Total Land	Feddan	4.91	7.07	17.46
Family Labor	Man-Day	116.60	190.98	252.64
Hired Labor	Man-Day	6.71	42.10	297.62
Nafir Labor	Man-Day	3.34	6.95	4.20
Total Labor	Man-Day	126.65	247.09	554.46
Total Operating Capital	Ls	19.51	56.46	262.75
Returns:				
Objective Function Value	Ls	48.91	101.01	303.74
Total Gross Margin[b]	Ls	101.71	167.01	382.94

Source: Computed

[a] Suffixes I, II and III refer to time of planting as defined in Table 5.7.

[b] Includes value of dura retained for household consumption.

early schedule, resulting in a decrease of their respective cropped areas, while in category I, which grew only 31 percent of its crops in the early schedule, this was compensated for by the increase of its cropped area. The total labor use was slightly reduced for category I and II (by 1 percent and 3 percent, respectively) but significantly for category II (by 20 percent). While reduction of cropped area (in category II and III) helps explain part of the observed reduction of labor use, the primary influence is the reduced labor requirements for weeding dura. (It should be recalled that only one timely weeding operating is required in these planting sequences). As in the original plans, dura dominates the cropping pattern. Reduced harvest labor requirements (for crops grown in the second and especially the third sequence) could be a factor too, but given their small share of total cropped area, this is of small significance.

The returns picture (in comparison with the original plans) also captures the interaction of the new resource requirements and labor time distribution of these three planting time sequences, with the resource availabilities of the smallholders. For categories I and II, returns are down by 11 percent and 19 percent, respectively. However, it should be noted that the production opportunities (and corresponding yield coefficients) are modeled differently in this experiment. The returns in category III, whose resource availabilities are more suited to take advantage of early planting, have risen by 13 percent despite the sizeable (27 percent) reduction of its cropped area.

Effects on Seasonal Constraints:

The limiting resources and their corresponding shadow prices for the planting time experiment are given in Table 5.9. Given the present resource availabilities of the smallholders, early planting places an extra strain on the already observed labor constraint periods. The labor MVP's in the second half of July and the first half of August (the first peak period) are highest. The second peak period is pushed back to include the second half of October until the end of November, corresponding to harvest of early planted crops. The MVP's of labor in both periods are high (relative to prevailing hired labor wages), being highest for the most resource-scarce farm size category. In addition, the operating capital MVP's for almost all the cropping season (June through the first half of November) are also positive and high. The importance of seasonal constraints in this version of the model, and the rewards captured by relaxing them, are demonstrated by the next experiment.

Credit with Planting-Time Experiment Results:

To allow the augmenting of labor resources in the constraining periods through hired labor, credit is made available in the models through addition of borrowing activities. Optimal plans for this version of the model are given in Table 5.10.

With seasonal labor constraints largely overcome through the use of hired labor, sizeable returns resulted in the optimal plans. The profitability of dura, especially that of the early schedule (Dura I), makes it dominate the cropping pattern. While this situation is a bit unrealistic in comparison to both actual practice of farmers and other model solutions discussed so far, it demonstrates the effect of breaking

Table 5.9 Shadow Prices for the Limiting Resources: The Planting Time Experiment

Resource[a]	Unit	Shadow Prices (in Ls)		
		Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Family Labor				
Apr.	Man-Day	--	--	0.560
May.	Man-Day	--	0.141	0.210
Jul.1	Man-Day	--	--	1.241
Jul.2	Man-Day	1.887	1.633	1.241
Aug.1	Man-Day	1.654	1.769	1.344
Aug.2	Man-Day	0.764	0.412	0.526
Oct.1	Man-Day	--	--	1.179
Oct.2	Man-Day	1.792	1.550	1.179
Nov.1	Man-Day	0.024	0.034	0.678
Nov.2	Man-Day	--	0.938	1.059
Dec.1	Man-Day	0.040	0.154	--
Dec.2	Man-Day	--	--	--
Nafir Labor				
Apr.	Man-Day	--	--	0.230
Jul.1	Man-Day	--	--	0.558
Jul.2	Man-Day	0.849	0.735	0.558
Aug.1	Man-Day	--	0.871	0.662
Oct.1	Man-Day	--	--	0.496
Oct.2	Man-Day	0.754	0.653	0.496
Nov.2	Man-Day	--	0.483	0.545
Operating Capital				
Jun.-Nov.1	Ls	2.145	1.722	1.068
Nov.2	Ls	0.542	0.379	0.558
Dec.1	Ls	0.542	0.379	0.558
Dec.2	Ls	0.542	0.379	0.558
Jan.	Ls	0.0001	0.0001	0.0001
Feb.	Ls	0.0001	0.0001	0.0001
Mar.	Ls	0.0001	0.0001	0.0001
Apr.	Ls	0.0001	0.0001	0.0001
May	Ls	0.0001	0.0001	0.0001

Source: Computed

[a] Suffixes 1 and 2 refer to first and second half of the month for July through December.

Table 5.10 Optimum Production Plans: The Planting Time Experiment with Credit Option

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern:[a]				
Dura I	Feddan	3.85	8.01	23.72
Dura II	Feddan	1.15	1.89	2.18
Resource Use:				
Total Land	Feddan	5.00	9.90	25.90
Family Labor	Man-Day	86.50	124.70	149.50
Hired Labor	Man-Day	64.86	174.56	645.33
Nafir Labor	Man-Day	3.34	7.68	2.80
Total Labor	Man-Day	154.70	306.94	797.63
Total Operating Capital:	Ls	71.79	172.22	564.60
Initial Capital	Ls	6.93	27.83	152.70
Crop Sales	Ls	--	--	--
Borrowed Capital	Ls	60.99	129.92	355.16
Interest Paid	Ls	4.27	9.09	24.86
Returns:				
Objective Function Value	Ls	78.55	189.83	464.22
Total Gross Margin[b]	Ls	131.35	235.83	543.42

Source: Computed

[a] Suffix I, II and III refer to time of planting as defined in Table 5.7.

[b] Includes value of dura retained for household consumption.

seasonal labor constraints. The resource use figures show the somewhat higher labor levels employed in these plans. Not only are these levels high relative to total labor use in the three categories, but they require the recruitment and utilization of this labor during the two short peak labor constraint periods. In reality, achieving the benefits from such a management scheme would be limited by the scarcity of credit.

Cotton Price Variation Experiment

It should be recalled that the cotton crop, in agreement with the empirical situation, did not enter in any of the smallholder categories original plans (see Table 5.1) and was absent also from all model versions and solutions discussed so far.[1] This situation, being of important policy concern as indicated earlier (see Chapter I), will be taken for detailed analysis in this part. First, a brief background note on cotton problems in the area is given. Next, the results of the cotton price programming experiment are discussed.

Background on Cotton Problems in the Area

Unlike all other crops grown in the area, the cotton crop is entirely a cash crop aimed for the export market. The establishment of the cotton growing industry in the Nuba Mountains area dates back to the early 1920's, as described by Tothill:

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[1] With the exception of two solutions (see Table 5.3 and 5.8), where insignificant feddanage was devoted to the cotton crop.

> In pursuance of the policy of "turning swords into plough shares"[1] the government [British Colonial era] decided in 1928 to endeavor to introduce the growing of cotton as a cash crop. It was accordingly decided that observational plots of American type cotton should be grown by the government during the rains of 1924. The results were promising, and it was decided that the Department of Agriculture and Forests should go ahead and endeavor to establish a cotton growing industry....about that time a further attempt was made to initiate a company which would finance and handle the growing cotton industry [59, p. 842].

Although the "endeavors" were presented as serving the interests of national and regional security, as well as those of the local population, by establishing cotton as a cash crop, it is clear that the colonial interests were the overriding reason behind the effort.[2] Despite the rapid expansion of areas under the crop in subsequent years, and the institutionalization of the cotton industry since then, potential problems of cotton in the local setting were perceived early on. The view then, however, was overoptimistic with regard to cotton; given the cultivator's high cash returns expected from the new cotton crop, its expected wide adoption by cultivators in the area was expected to come at the expense of other crops, as Tothill explains:

> When propoganda for more cotton was being spread, care was taken to emphasize the principle that it should not be grown instead of dura, the main food crop, but in addition to the usual areas under food crops [59, p. 843].

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[1] Reference is made to the "unruly" Nuba people and the government need to secure peace in the area.

[2] Representatives of England-based industries (Lanchshire industries and spinners) were among the originators of the idea [59].

Needless to say, the unfolding of events in the historical record of cotton in the area, especially in recent years, rendered the above concern irrelevant. Instead, the growing importance of other crops in the smallholder farming system, together with the high inflation rates of recent years, have led to the decline in cotton production [38, 39].[1] The decline in cotton production reached serious proportions in the late 1970's, with the crop almost disappearing from traditional smallholder areas. In 1979, a ministerial committee was formed to study and make recommendations regarding the decline of cotton production in the Nuba Mountains area. The committee report [39] singled out the unrewarding farm-gate cotton price as the main cause of cotton decline in traditional agriculture. Another factor mentioned was the increasing cost of production for cotton (mostly labor costs). The corresponding recommendation was for a higher cotton price. Recommended prices for cotton delivered by farmers were: Ls 7.00, Ls 4.50 and Ls 3.50 per kantar (45 kg) of cotton for grade I, II and III, respectively.[2] To raise the current level of prices (Ls 4.25, Ls 3.25, and Ls 2.75 for the three grades, respectively) to the recommended level, and since the NMAPC pricing system cannot put this into effect given the current production levels, it was suggested that the resulting deficit from adopting the recommended prices be absorbed by the government, until such time when it is no longer

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[1] The HTS study [38] estimated that for the period 1968/69 to 1978/79, the price of seed cotton has decreased in real terms (allowing for inflation) by some 60 percent, while the price of dura has risen by about 20 percent.

[2] Generally, over 90 percent of cotton produced falls in the first two grades.

necessary to have government support, and the system is able to pay such prices by itself.[1]

Beyond the main recommendation for higher cotton prices, the committee report also gave some recommendations to improve cotton production within the NMAPC modernization schemes. The latter, mostly organizational and administrative in nature, are discussed in the next chapter. Below, we focus on the effect of changing cotton prices and discuss the results of the experiment for the traditional smallholder models.

Experiment Results

With the above background, LP analysis is used to examine the effect of varying cotton prices on the cotton feddanage within the smallholder models. The procedure used is parametric programming, sometimes referred to as variable price programming or price ranging. Such a procedure is generally used to estimate the normative supply function of a commodity [32]; the optimal output of the commodity is derived by varying its price, within an appropriate range, while other prices are held constant. Before proceeding to present results and analysis of this experiment, it is important to note the following two points regarding this experiment:

1. The supply response resulting from variable price programming is generally limited by its static and normative nature (in the sense of being what farmers ought to be producing).[2]

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[1] The present NMAPC cotton pricing system, which is crucially dependent on total cotton production in the area, is described and discussed in detail in the next chapter. It was estimated that the present system can afford to offer the recommended prices, without government support, when production of cotton in the Nuba Mountains area reaches at least the 400,000 kantars level [39].

[2] And is also believed to result in an upward bias of some degree [32].

2. Supply responses to price changes could theoretically be partitioned into yield and area responses. The first may stem from an intensified or new input use, and the second may stem from substitution between crops, expansion of cropped areas, or changes in cropping intensity [33]. The yield response, within the context of cotton problems in traditional agriculture, is of relatively less importance at the present.[1] While it is conceivable that intensified and more skillful labor use might result in higher cotton yields, at the present the real issue and the policy concern is that of crop substitution and massive reductions in cotton area. In this situation, it is more realistic to examine the feddanage response to cotton price changes.

Cotton area responses for the traditional farm models are graphed in Figure 5.1. The results and conclusions drawn from this experiment can be summarized as follows:

1. There are differences in the feddanage response to higher price between the three farm size categories. Such differences are a result of differences in resource availabilities between the three categories (especially the labor resources, and the proportions of hired labor employed). Particular differences are:

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[1] However, yield response is of utmost importance within the context of NMAPC smallholder schemes. With the participants cotton areas determined by the NMAPC, price policy incentives aimed at increasing cotton output would have to induce per unit land yield increases. This point is further discussed, in the next chapter, within the context of NMAPC farm model's cotton price variation experiment.

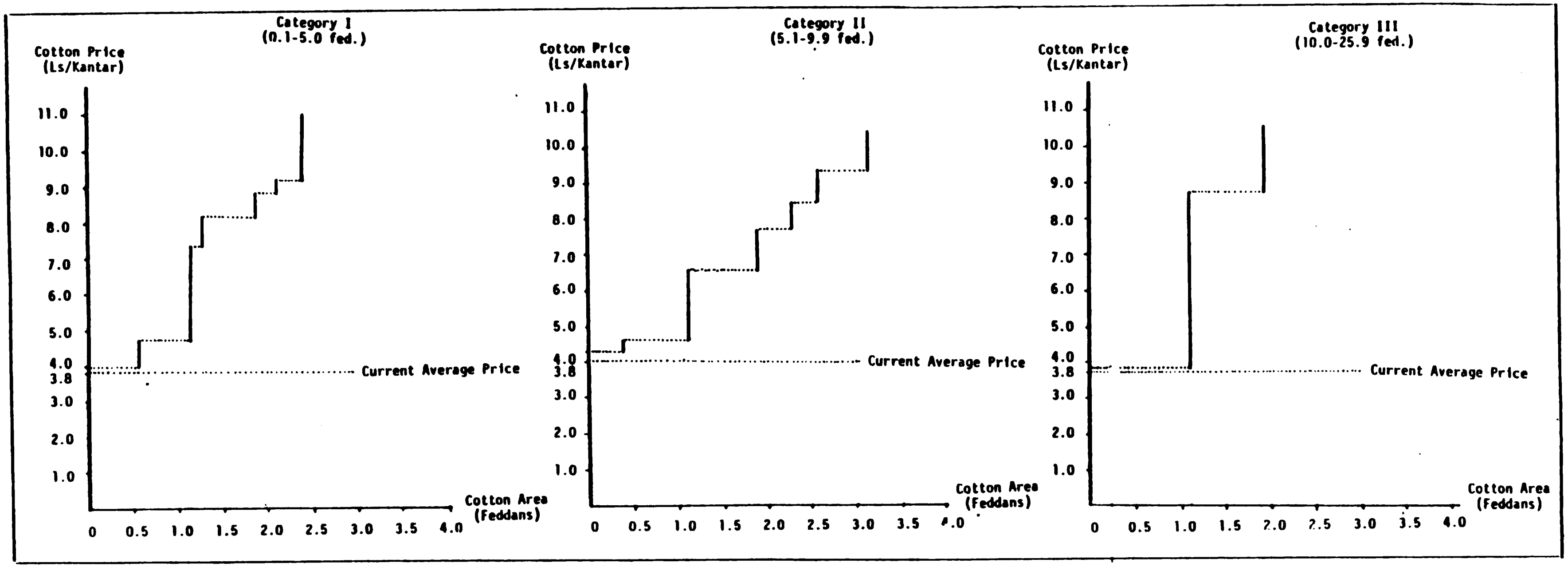

Figure 5.1 Cotton Area Response to Cotton Price Changes: Traditional Farm Model

   a) At slightly higher than the current price and around the price of Ls 4.0 per kantar, cotton enters the solution of all three categories. At this initial level cotton feddanage is very small; 0.43 and 0.53 feddans for categories I and II, respectively, and only around one feddan in category III (5 percent of its total cropped area). This share for category III also remains stable over a relatively large price range (Ls 3.86 to Ls 8.43).
   b) To increase cotton feddanage to one feddan, an average price of Ls 7.00 is needed in categories I and II.
   c) To increase cotton feddanage beyond one feddan, higher prices are required. At around Ls 10.00 per kantar, cotton feddanage is raised to two feddans in categories I and III, and to three feddans in category II.
2. Prices higher than Ls 10.0 are not only unlikely at present but also the response they generate becomes smaller.
3. From the above, it can be concluded that although a small increase in price causes the cotton crop to enter solution, substantially higher average prices (Ls 7.0 and Ls 10.0) are needed to induce a one and two feddan area response, respectively.

It should be recalled that prices simulated in this experiment correspond to average cotton prices per kantar, and therefore they might have to be further adjusted to reflect differences between cotton grades (which means slightly higher prices for grade I, and proportionally lower prices for grade II and III). Possibilities of offering cotton prices such as those derived in this experiment are discussed in connection with the NMAPC cotton pricing system given in the next chapter.

Summary

In this chapter, the analysis of results from experiments with the traditional linear programming model are presented. In addition to base plans for the three farm size categories, the following experiments were conducted: hypothesized rainfall-induced yield variability experiment, credit and land expansion experiment, planting-time experiment, credit with planting-time experiment, and cotton price variation experiment.

Results of the base models show the cropping pattern of the smallholders to be dominated by the dura crop, with a small percentage of sesame. Groundnuts and cotton did not enter any of the solutions for the three categories. Eighty-eight percent, 89 percent, and 92 percent of the total available land in the three farm size models, respectively, was used in these basic plans. Resulting returns confirm the typical low productivity and returns of smallholders farming in the area. Total gross margin figures for the three respective farm size categories were Ls 107.99, Ls 190.55, and Ls 348.95. It was shown that these low returns are the product of low productivities for both land and labor, resulting from low crop yields. Computed average productivities for land (per feddan) were Ls 6.20 to Ls 7.35, and for labor (per man-day) were Ls 0.49 to Ls .84, always highest in the smallest farm size category. Analysis of the marginal productivities has shown that the basic limiting resources in the smallholder production are the labor resources. While operating capital is also limiting, this indicates an indirect labor constraint, since labor is the basic resource OC is expended on. Land is not limiting. Family labor is limiting mainly in two periods: the first (June through August), is when weeding takes place, the second (November through December), corresponds to harvest and crop disposal. The family labor MVP's corresponding to these two periods are positive, and high in comparison with the respective monthly hired labor wage rates, indicating that expansion of the labor resource during these periods would be profitable.

Results of the sensitivity analysis used to investigate hypothesized rainfall-induced yield variability, indicate the sensitivity of returns to reduced rainfall and hence reduced crop yields. With 25 percent reduction in yield levels (situation A), resulting objective function values were 51 percent, 41 percent, and 49 percent lower, for the three categories, respectively. In the case of the 50 percent yield levels reduction (situation B), also a proportionally greater drop in returns resulted; by 120 percent, 91 percent and 90 percent for the three categories, respectively.

The credit and land expansion experiment results have shown that credit use can contribute significantly to increase the low farming returns of smallholders in the area. In comparison with the base plans, resulting increases in returns were in the order of 77 percent, 50 percent, and 39 percent for categories I, II, and III, respectively. Although the interest rate charged for borrowed capital in this experiment was 7 percent (representing the official rate of the Agricultural Bank of Sudan for short-term loans), the MVP's from the base optimal plans indicate the profitability of borrowed capital, within the smallholder system, at extremely high rates: 296 percent, 145 percent, and 74 percent for the three farm size categories, respectively. It is further evident that the profitability of borrowed capital is highest in categories I and II, where OC is most limited, and hence credit use is most rewarding. For the latter two categories, in this experiment, the increase of land and hired labor availability made it possible to use more of the existing family labor resource (by 37 percent in category I, and 21 percent in category II) as compared to the base plans. Another important result revealed in the analysis is that credit is mainly needed in the first period (June-October), when smallholders in this period require not only production credit but also consumption credit to see them through harvest. OC requirements of the second period (November-December) are financed, as farmers normally do, through initial crop sales. In this context, the inclusion of sesame in the cropping pattern (with its crop sales occurring as early as November) is particularly important and useful.

Results of the planting-time experiment reveal that despite the high physical yields associated with early planting it is still optimal for smallholders to grow late planted crops. The optimality of such a practice arises from the stringent time requirements of early planting schedule, given the already limiting seasonal availabilities of labor. Simply stated, late planting is one way of smoothing out these bottlenecks. Nevertheless, all three farm size categories made use of the high physical yields of the early planted crops, as much as their resources could allow; category III, which has the highest resource endowment, was able to grow 75 percent of its crops in the early schedule. The returns picture (in comparison with the base plans) also captures the interaction of the new resource requirements and labor time distribution of the three planting time sequences, with the resource availabilities of the smallholders. For categories I and II returns are down by 11 percent and 19 percent, respectively. However, it should be noted that the production opportunities (and corresponding yield coefficients) are modeled differently in this experiment. The returns in category III, whose resource availabilities are more suited to take advantage of early planting, has risen by 13 percent despite the sizeable (27 percent) reduction of its cropped area.

The credit with planting-time experiment results demonstrate the importance and rewards captured by relaxing seasonal labor constraints revealed in the previous experiments. Through credit, hired labor is used to augment labor resources in the constraining period. In comparison to base plans, sizeable increases in returns resulted; 22 percent for category I, 24 percent for category II, and 56 percent for category III. The profitability of dura, especially that of the early schedule (Dura I), makes it dominate the cropping pattern in this experiment.

Results of the cotton price variation experiment reveal that there are differences in the feddanage response to higher price between the three farm size categories. Such differences are a result of their different resource availabilities. In general, the results have shown that at around the price of Ls 4.0 per kantar (45 kg), which is slightly higher than the current average price, cotton would enter the solution of all three categories, but at a very small feddanage.

To increase cotton feddanage to one and two feddans, average prices of about Ls 7.0 and Ls 10.0 per kantar, respectively, are needed. Prices higher than Ls 10.0 per kantar are not only unlikely, but the response they generate is much smaller.

CHAPTER VI

NMAPC AND THE MODERNIZATION OF TRADITIONAL AGRICULTURE IN THE NUBA MOUNTAINS

The previous chapter contains the analysis of the traditional smallholder model. In this chapter we turn to the analysis of the major public sector model proposed for modernizing traditional agriculture.

The first part gives an overview of NMAPC and its present performance record and institutional features as background for the subsequent analysis. The second part discusses the current NMAPC farm model, and compares its important features with those of the basic traditional smallholder model given in the previous chapter. In the third part, analysis of the contemplated full-scale NMAPC farm model is given. The discussion in this part includes a proposed alternative to the planned full-scale NMAPC model. A brief summary of the results is given in the last part of this chapter.

The NMAPC: Background, Present Organization and Current Performance Record

Background

The present Nuba Mountains Corporation has passed through three different stages to reach its present form:

(i) Nuba Mountains Cotton Industry (NMCI): Early 1920's-1966

The company was formed following the success of government trials to grow cotton during the rains of 1924 in the Nuba Mountains area, and the

promising farm production results that were obtained in the following seasons [59]. Necessary structures for collection and processing of cotton were also completed in this period. Eight ginneries were established, located in the present regional stations of NMAPC.[1] The total ginning capacity of these eight gins is 451,500 kantars of cotton fibers per annum [10].

The NMCI was successful in promoting cotton production mainly through expansion of land under the crop.[2] As the name implies, the objectives and functions of the organization were exclusively directed towards the commercial production of cotton. Aside from distribution of cotton seeds free of charge to farmers at the beginning of the season, and limited cotton pest control, the organization had no involvement in production. The commercial operations were successful and the financial status of the corporation was sound [31].

(ii) Nuba Mountains Agricultural Corporation (NMAC): 1967-1970

This second stage of the corporation started in 1967 with changes in the status of the corporation within the Ministry of Agriculture, Food and Natural Resources (MAFNR). A new law required the corporation to broaden its goals to include: improving traditional farming in the area (through agricultural extension to advocate use of better crop rotations, crop protection, etc.), organization of farmers and consolidation of dispersed farms to enable mechanization, and, in general, to raise the socio-economic and cultural standards of living for farmers in the area

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[1] Except for Abassya station which does not have a gin; its cotton is sent to El Semieh.

[2] A peak was reached in cotton production in 1962/63 season when just over one million kantars of cotton were produced in the Nuba Mountains [38].

through provision of social services, drinking water, community development and encouragement of cooperatives [31]. To help the NMAC better manage its relatively enlarged role, a new joint account system was introduced to define the relative shares of NMAC and the farmers in the costs and returns of the cotton crop.[1]

Despite its enlarged role, in practice the NMAC maintained the emphasis of its predecessor on cotton production. However, in this stage cotton production in the area began to decline as smallholders grew less of the crop. The growing importance of other smallholder crops (sesame, groundnuts, and especially dura), the rising cost of labor [31], and a decline (in real terms) of cotton prices [38], were the main reasons for the decline in cotton production. This trend, which continued into the next stage of the corporation, began to show an impact on the corporations' financial records. By 1970, the corporation was just covering its joint-account costs [31].

(iii) Nuba Mountains Agricultural Production Corporation (NMAPC): 1970 to Present

This third and present stage began in 1970 when the corporation was made a subsidiary of the Public Corporation for Agricultural Production (PCAP) by the Corporation Act of 1971.[2] A radical change was made in the corporation's goals and activities. It was intended the NMAPC should serve the following objectives:

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[1] The present joint-account system is described in detail later in this section.

[2] PCAP was dismantled late in 1979, and the NMAPC together with other subsidiary corporations became directly responsible to the Minister of MAFNR.

1. To supervise rainfed agricultural production schemes in the Nuba Mountains area.[1]
2. To encourage the modernization of traditional agriculture by making available mechanization services and other new technologies.
3. In general, to promote sound development of the smallholder sector that will ultimately result in raising the farmer's standard of living.

The Present Organization and Production Record of the NMAPC

There are two important aspects distinguishing the corporation's current goals and activities concerning smallholder agriculture:

(i) Production Relations

The corporation's involvement in shaping the production activities of its participants reached its maximum under the present NMAPC organization. This organization, following the model of the public irrigated agriculture schemes in the Sudan,[2] encompasses all aspects of the tenants' production and marketing. These rules and administrative guidelines define a production relation, common to all public schemes, with land ownership belonging to the government.[3] A partnership system between the government

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[1] NMAPC also continued its predessor's supervision of a small (around 5000 feddans) irrigation scheme (Abu Habel scheme) located at El Semieh.

[2] Pioneered by the Gezira scheme in 1925, this model, as discussed in Chapter I, has greatly influenced the path of agricultural development in Sudan.

[3] Government ownership of land is widely disputed by NMAPC farmer participants. This has reduced the effectiveness of the corporation in enforcing its rules and guidelines.

(represented by the NMAPC) and the farmers (typically referred to as tenants) is instituted. A system of rights and obligations is defined for all parties. The government (through NMAPC) specifies the tenancy size, the rotation (typically revolving around the cotton crop), and the individual crop areas. Generally the partners of this relation are rewarded with the following shares based on the net proceeds of cotton (after deducting joint-account expenses).[1]

Tenant	78%
NMAPC	15%[2]
Social Reserve Fund	2%
Local Government	3%
Tenant Reserve Fund	2%

In return, the tenant is required to supply labor at the field level for specified crops according to the guidelines of the corporation. He is also required to pick the cotton and deliver it to the nearest collection center. The corporation's obligation is the provision of mechanized cultivation services, cotton seeds (free of charge), cotton pest control, and cotton ginning and marketing. To carry out its services and activities, the NMAPC has a departmentalized structure, with representation at the regional station level. Figure 6.1 shows this structure. This present structure has not been entirely successful [38] in carrying out the

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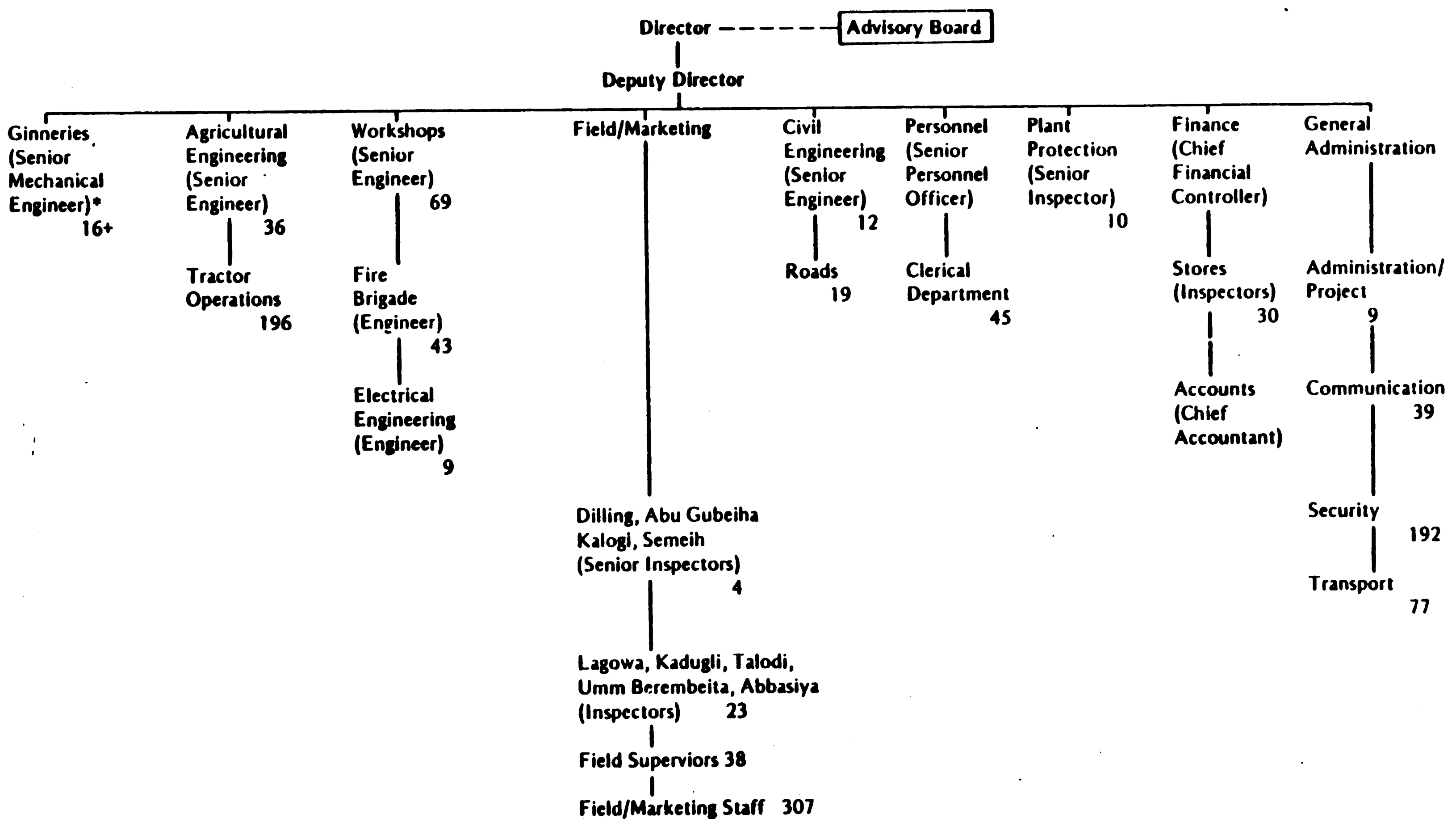
[1] The joint-account system is discussed in conjunction with the coming section in this chapter, on cotton pricing policy; its complete law (as defined in the NMAPC charter) is given in Appendix II.

[2] After covering NMAPC obligations, any surplus from this share would be divided 85% for PAPC budget and 15% as reserve for NMAPC. In reality, the financial record of NMAPC since its establishment has not only showed no surplus, but its annual deficits had to be financed by the government.


Director
Advisory Board
Deputy Director
Ginneries (Senior Mechanical Engineer)* 16+
Agricultural Engineering (Senior Engineer) 36
Tractor Operations 196
Workshops (Senior Engineer) 69
Fire Brigade (Engineer) 43
Electrical Engineering (Engineer) 9
Field/Marketing
Dilling, Abu Gubeiha Kalogi, Semeih (Senior Inspectors) 4
Lagowa, Kadugli, Talodi, Umm Berembeita, Abbasiya (Inspectors) 23
Field Superviors 38
Field/Marketing Staff 307
Civil Engineering (Senior Engineer) 12
Roads 19
Personnel (Senior Personnel Officer)
Clerical Department 45
Plant Protection (Senior Inspector) 10
Finance (Chief Financial Controller)
Stores (Inspectors) 30
Accounts (Chief Accountant)
General Administration
Administration/ Project 9
Communication 39
Security 192
Transport 77

Source: NMAPC Personnel Department

* Position in brackets shows head of section   + Numbers indicate total staff complement in each section (January 1980)

Source: HTS [38, p. 115]

Figure 6.1 Main Managerial Structure of the NMAPC

corporation's activities. Particular difficulties have arisen in the efficiency and coordination of mechanization services. The field (scheme) level managerial functions are under the supervision of a NMAPC inspector aided by the scheme's farmer committee.[1] The function and authority of the committee, and coordination with the NMAPC officers, has been unclear and in many cases problematic [46].

(ii) The Modernization Program

The central activity of the corporation is its modernization program. Started in the season 1970/71, the program aimed at achieving the following objectives [31]:

1. Introduction of machines (tractorization) to raise traditional farmers' productivity and annual income.
2. Consolidation of traditional farms into collective farms as a nucleus for agricultural cooperatives.
3. Provision of social services.
4. Introduction of improved agricultural services, techniques, and rotation to raise the productivity of land and crops.
5. Emphasis on improving production and productivity of cotton, so that the NMAPC can stand in a better financial position.

Not preceeded by a study, the arrival into the region of some sixty tractors/discs signalled the beginning of the modernization program. The actual opening of schemes was largely on an ad-hoc basis and mostly left

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[1] This is composed of 10 members elected by farmers under the supervision of Nuba Mountains Farmers Union. They serve their function on a voluntary basis. These functions are not well defined; at the moment they include helping distribute rotation plots to farmers, supervision of mechanization services, and in general acting as farmers' representatives in supervision of day-to-day field work.

to the discretion of the field stations. In 1970/71, a total of 23 schemes were opened in the eight stations of NMAPC. The general procedure for opening schemes consisted of a group of farmers, after consulting with NMAPC field stations officers, clearing an area (between 1,000 to 2,000 feddans). The scheme was then officially registered and the land divided (as tenancies) between the participating farmers. This procedure of unplanned openings of schemes with associated land ownership problems has persisted with the NMAPC system until now. Future land surveys and land expansions (to complete contemplated rotations) are thus made more difficult [46].

The initial target of this modernization plan was to have 300 tractors/discs, and a total area of 300,000 feddans by 1974/75. Actual expansion of schemes and areas of cotton and dura are shown in Table 6.1. While the areas of crops fluctuate from one year to the other, the intended balance of the two crops (approximately 50 percent each) was maintained over the seasons. As can be seen from the table, this plan suffered a great set-back in 1974/75, when all schemes were shut down except for three schemes in the Kadugli area. The reason given by NMAPC administration was the inability and refusal of farmers to pay their loans for mechanized cultivation which were mounting from previous seasons. While the program continued, a number of schemes were being shut down each year in the different field stations, primarily because farmers were strongly reluctant to grow cotton. There were other problems as well, including tribal/village conflicts over land ownership and distribution, managerial and administrative conflicts, and shortage of drinking water at schemes sites [46].

Table 6.1 NMAPC: Areas of Cotton and Dura (in Feddans) Planted in the Modernization Schemes, 1970/71 to 1976/77

	1970/71		1971/72		1972/73		1973/74		1974/75[a]		1975/76		1976/77	
	Cotton	Dura	Cotton	Dura	Cotton	Dura	Cotton	Dura	Cotton	Dura	Cotton	Dura	Cotton	Dura
Kalugi	1547	1580	3073	3091	3323	3090	4543	1678	2607	484	8316	2737	13270	2000
Kalogi	722	285	3782	2188	3775	3431	1032	687	-	-	2086	813	4291	150
Dilling	-	950	400	1386	2513	-	N.A.	N.A.	-	-	254	2399	5090	180
Talodi	3353	4200	531	1357	676	325	2030	1250	-	-	2518	1760	4515	650
Lagawa	233	993	1361	2606	1897	2320	1573	3205	-	-	2353	1872	5996	2192
Abu Gebeiha	4874	3473	6078	4936	1533	3513	240	1102	-	-	3477	640	3154	-
Abbasia	286	2670	1812	1134	1624	3971	-	1150	-	-	0	1000	-	1900
Um Berembeita	825	179	502	1126	221	2214	-	447	-	-	849	829	1350	-
Abyei[b]	-	-	-	-	-	-	-	-	-	-	-	4127	-	2192
Total	9840	14330	17539	16824	15762	18864	3418	9719	2607	484	19855	16177	37666	9264
Total (both crops)	24170		34363		34626		19137		3901		36032		46930	

Source: NMAPC

[a] As explained in the text, except for three schemes in Kadugli, all modernization schemes were shut down in this season.

[b] Abyei is not an NMAPC station, however, the area is being provided by tractors to grow dura in smallholder schemes.

Despite the problematic record, the modernization program was given special emphasis in the current Six-Year Plan (1977/78-1982/83). The government plan for revitalization of NMAPC was expected to benefit from the findings of the recently started foreign research projects in the area.[1] By 1979/78, a total of 62 schemes were operating in the eight stations of NMAPC, commanding a total area of 72,868 feddans.

Mechanized Cultivation in the NMAPC

The mechanized cultivation service, as pointed out earlier, is considered the corner stone of the NMAPC modernization program. Its presumed capability to "raise traditional farmer productivity," as expressed in the modernization objectives, closely resembles what Binswanger [13] has called the "net contribution view." In general, proponents of this view believe that agriculture is characterized by a power constraint, and that tractor machinery is suited to breaking this power constraint in agriculture, such that a net contribution to production (which otherwise is not possible) is generated [13]. However, the origin of this view, within the Sudanese experience, traces back to the early 1950's when mechanization under rainfed conditions was first introduced in the Gedarif region of eastern Sudan.[2]

To provide a mechanized cultivation service, NMAPC relies on different types of machinery (tractors, discs, and seeders) that are distributed

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[1] Some of the relevant features of these projects to NMAPC modernization program are briefly discussed in Appendix IV.

[2] For an example of early advocates in this regard, see Shazli [52].

throughout its field stations.[1] The mechanical cultivation service consists primarily of shallow ploughing of the soil by the wide level disc. Two discings are stipulated; however, at present due to lateness of operation, gasoline shortages, and mechanical breakdowns, very few schemes are disced twice. In the case of lands designated for dura, the sowing operation is also performed mechanically, through a mounted boxer/seeder on top of the disc, simultaneously with the second discing operation. Ideally, the cultivation operation should achieve a number of objectives including: preventing of soil erosion, conservation of soil moisture, control of newly germinating weeds, eradication of tufted and perennial grasses, and the creation of an adequate tilth for promotion of seed germination [45]. For farmers in the area, weed control is the single most important objective of the operation.

At the present, the field performance of these operations is widely recognized as unsatisfactory. This judgment is based on both the timing and quality of the mechanized cultivation service. The farmers interviewed in the researcher's survey have singled out the service as the most unsatisfactory and problematic. One of the few available records of field performance is that of the Lagawa station for the season 1979/80.[2] It is believed to be typical of field performance in other NMAPC stations. Table 6.2 shows the total ploughed area by each of the thirteen tractors

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[1] By 1979/80, NMAPC had a stock of 140 tractors, composed of five different tractor makes; and 139 discer/seeders of three different makes.

[2] Machinery records (use, performance, maintenance, fuel consumption, etc.) are lacking or incomplete. Efforts to organize and keep such records have recently (1979/80) been initiated by the Agricultural Engineering Section, NMAPC.

Table 6.2 Lagawa Station, NMAPC: Total Ploughed Area of the Modernization Schemes, Season 1979/80[a]

Period	Land Ploughed by Tractors (in Feddans)[b]												
	1	2	3	4	5	6	7	8	9	10	11	12	13
June/29-July/7	274	325	339	481	32		133	140	33	425	130	200	26
July/8-July/16	225	89	68	217	178		48	196	260	235	100		334
July/16-July/21	121	115	113	117	47		86	193	161	280		35	75
July/22-July/31	300	218	118		149	106	338	209	364	265		130	404
Aug./1-Aug./7						99	198	20	15	167		20	149
Aug./8-Aug./15		96				145	372	98		76		54	160
Aug./16-Aug./23							5		86				
Total	921	843	638	815	406	350	1180	861	1220	1426	230	439	1148

Source: Constructed from available records, Agricultural Engineering Section, NMAPC.

[a] Six schemes were operating in the season 1979/80: Hamboul, Muktawa, Arak, Gengaro, Nabagya, and Drungas.

[b] Includes land ploughed twice. Tractor makes (1 through 13) are distributed as follows: Ford (1, 4, 5, 8, 10, 11, 12); John Deere (2, 3, 7, 9, 13); Massey Ferguson (6).

operating at Lagawa in the season 1979/80. As can be seem from the table, ploughing starts early in July and goes beyond the end of August (and sometimes up to September). These delayed operations not only offset any benefits claimed for the mechanical cultivation, but also result in clearly later than optimum sowing times which is a major yield influencing factor. The average total ploughed land per tractor was only around 800 feddans, with a number of tractors performing far less than this level. Another important problem is that the weed control component of the mechanized operation is particularly deficient and less satisfactory. Farmers, who generally view the operation to be the equivalent of "mechanical weeding," are particularly unsatisfied with this aspect of the service. In fact, it is on the basis of this criterion that the scheme's farmer committees would decide on accepting (or rejecting) ploughed land to be distributed to farmers. This has been a matter of frequent disputes and friction between the farmers (represented by farmer committees) and NMAPC officials and operators.

The poor performance of the mechanized cultivation service in the NMAPC at the present is the product of many interacting technical and organizational problems. The most important of these include:

1. Technical problems relating to the suitability of machinery under conditions of the area. In particular, the wide level disc was found to be deficient in controlling weeds [45].
2. The above technical problems are further compounded by the many different makes of machinery in use at the present.

3. Inadequate maintenance, servicing, and workshop facilities, especially at the field level.[1]
4. Inadequate training for mechanics and machinery operators.
5. Late arrival and distribution problems of gasoline and other related products.
6. Inadequate planning and coordination of mechanization services at the field level.
7. Inadequate infrastructure (lack of reasonable housing, health, food and drinking water) at scheme sites which offers an unconducive working environment.[2]
8. Small and irregular scheme lands which pose difficulties for mechanized operations, especially when fields are not well cleaned (from debris, previous cotton harvest stalks).

All of the above problems are well recognized by the corporation [46]. Currently, many efforts are being made to improve the performance of these operations.[3]

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[1] Except for the major workshop at NMAPC headquarters in Kadugli, other field stations are not equipped and manned at the present to handle the frequent breakdowns and problems. Sending tractors to Kadugli during the working season is time consuming and results in loss of valuable machine time at the peak of the working season.

[2] This explains the practice of most schemes to use tractors in what is called "nonproductive" uses, which are often born out of necessity to transport food, water and other emergency needs.

[3] One of the foreign research projects (British ODA project) is aimed at helping NMAPC to improve its mechanization services. See discussion in Appendix IV.

NMAPC Joint Account and Cotton Pricing Policy

The joint account plays the central role in shaping the production relation between the NMAPC and its farmer participants. The total expenditures under this account are deducted first from the gross cotton proceeds and then the remaining sum (net cotton proceeds) is divided between the partners according to the ratios specified in the production relation. In this process, as detailed below, the joint account becomes the single most important factor in determining the cotton prices received by farmers. Because of its special role, the joint account is discussed first, and then the pricing policy of cotton is examined.

The Joint Account System

Article 10 of the NMAPC charter (given in Appendix III) details the laws and procedures governing the institution of the joint account. The main credit item of this account is the total cotton sales of the NMAPC. The debit items for the account include NMAPC production costs (mechanical ploughing and cotton pest control) in addition to all other costs incurred by NMAPC in processing and marketing of the crop (ginning, transport, and marketing). Table 6.3 shows the items and expenses of the NMAPC's joint account based on expected cotton production for the season 1979/80.

In its role as a basis for the NMAPC production in general and in determining cotton prices for farmers in particular, the joint account system suffers from the following drawbacks:

1. The application of the joint account system, which is the basis of the production relations in most of the public irrigated schemes, has a major defect under the conditions of NMAPC.

Table 6.3 NMAPC: Joint Account Expenses Based on Expected Production for the Season 1979/80[a]

Item	Total Expected Expenses (in Ls)	% of Total Expenses	Cost on Per Kantar Basis (in Ls)
Railroad Transport of Cotton	33,075.0	4.5	0.900
Loading Expenses	3,675.0	0.5	0.100
Salaries for Cotton Buying Staff	154,150.0	21.1	-
Hired Labor (field offices)	10,500.0	1.4	0.100
Contracts to Deliver Labor	34,780.0	3.4	0.236
Sacks and Packing Materials	44,100.0	6.0	0.420
Miscellaneous Stores Items	2,625.0	0.4	0.025
Chemical Insecticides	141,120.0	19.3	1.344
Cotton Stainer Buy Campaign	16,000.0	2.2	-
Truck Transport	26,092.0	3.5	0.710
Ginning Charges	98,306.0	13.5	0.936
Openning Roads	35,000.0	4.8	-
Policing Cotton Markets	2,625.0	0.3	0.025
Protection Against Animals	2,625.0	0.3	0.025
Cotton Stalk Uprooting Campaign	15,000.0	2.1	-
Stationery & Office Items	2,625.0	0.3	0.025
Maintenance of Cotton Stores	25,000.0	3.4	-
Opening Fire Lines	50,000.0	6.9	-
Banks Interests	45,000.0	6.1	-
Total	732,298.0	100.0	

Source: NMAPC

[a] Based on an expected production of 105,000 kantars of cotton for the season.

As noted by El Hag [22], the system requires a known and registered farmer group in order to settle the accounts properly. In this case with the exception of the few NMAPC participants, the majority of farmers the NMAPC is dealing with are traditional farmers, who are not only unregistered with NMAPC but whose number (and production), completely out of NMAPC control, varies substantially from one year to the other. As such, the NMAPC has two client group of farmers, its own participants and traditional farmers in the area. However, the present joint account applies the resulting (after joint account expense deduction) cotton prices equally to both farmer groups. The importance to the NMAPC of traditional farmers' cotton production has been demonstrated by the significant and negative impact which resulted in recent years as the areas of traditional cotton substantially declined.

2. Unlike the public irrigated schemes where the participating tenants benefit from a larger range of crops grown and relatively higher productivity levels, the NMAPC participants (and traditional farmers for that matter) are placed at a disadvantage by having only two crops (cotton and dura), while the entire finance of the corporation must be met from cotton. The immediate impact of this is the low cotton prices which farmers receive. The fact that both traditional farmers and NMAPC participants receive the same prices for cotton, despite minimal services offered by NMAPC

to traditional farmers, implies that traditional farmers are subsidizing NMAPC tenants, and are also paying for any inefficiencies NMAPC might have in carrying out its services.

3. The present joint account is burdened with many expense categories and inefficiencies in carrying out many of these services [22], which results in syphoning off a significant portion of cotton gross returns primarily at the expense of the farmers. The full negative impact of this policy is made clear at times of low production, as in recent years. In 1979/80, joint account expenses amounted to 60 percent of total gross returns from cotton. On a per kantar basis (see Appendix III), the joint expenses have risen from an average Ls 3.56 for the last five years to almost double that to reach Ls 6.97 in 1979/80 [39].

NMAPC Cotton Price Policy

The cotton prices received by farmers are determined to a large extent by reference to the joint account system. Other factors that influence prices received by farmers include: international price of cotton, marketing and export costs and commissions, national and local taxes,[1] special funds' deductions, and finally the grades of cotton delivered by

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[1] The local government tax share of 3 percent is deducted directly from the net cotton proceeds.

the farmer.[1] The specific incorporation of all the above factors by the NMAPC in determining farm level cotton price is shown in Table 6.4.

Table 6.4 shows the deductions that are applied to cotton price at the different levels before it finally reaches the farmer price level. For 1979/80, the difference between the per kantar levels of the international price (Ls 34.67) and the farmer price (around Ls 4.00) represents a more than 700 percent marketing margin. However, despite the many deductions which make up this large margin, the joint account remains the most important factor in affecting the farmer's price, with the other deductions having only minimal effect.[2]

Not only do the large expenses of the joint account result in low cotton farmer prices, but in recent years with the substantial decline in cotton production, even these low prices were actually in excess of the "theoretical excess payment" obtained from the formulas shown in Table 6.4. Table 6.5 illustrates this situation. The prices that farmers have been receiving are in effect minimum guaranteed prices offered by the government to persuade farmers to continue growing cotton. Also, as a HTS

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[1] The NMAPC maintains a three-grade system to reflect and encourage the quality of cotton produced and delivered. Generally over 90 percent of the cotton produced falls in the first two grades. For example average percentages of the three grades delivered for the seasons 1977/78 to 1978/79 was as follows: 77 percent Grade I; 20 percent Grade II; 3 percent Grade III.

[2] For example, it was estimated that if development and balancing taxes were removed, cotton prices could only be raised to Ls 5.0, Ls 3.5 and Ls 3.0 per kantar for the three cotton grades, respectively [39].

Table 6.4 NMAPC: Determination of Farm Level Cotton Price

Item	Description
1. Price at Ship (f.o.b. at Port Sudan)	International Price (Ls/kantar)
2. (5% of 1)	Development Tax
3. (1% of 1)	Export Commission
4. [1-(2+3)]	Store Delivery Price
5. (2% of 4)	Marketing Commission
6. (2% of 4)	Reserve Fund
7. (2% of 4)	Balance Tax
8. (.5% of 4)	Equilization Fund
9. [4-(5+6+7+8)]	Producer Accounting Price (Ls/kantar)[a]
10. (9 X Total Cotton Quantity)	Total Cotton Gross Proceeds[b]
11. (10 - Joint Account Cash)	(for items of joint account see Table 6.3)
12. (80% of 11)	Total Sum of Farmers' Share
13. (2% of 12)	Tenant Reserve Fund
14. (12-13)	Total Payable to Farmers
15. (14 ÷ Total Cotton Quantity)	Average Farmer Price (Ls/kantar)[c]

Source: Ministry of Agriculture, Food and Natural Resources [39].

[a] All deductions made up to this price level are calculated on per Kantar basis.

[b] Includes the value of both cotton fibers and seeds.

[c] The average price level is further adjusted to reflect the differences in prices for the three grades.

Table 6.5 NMAPC: Total Cotton Revenue, Joint Account, and Farmers' Prices, 1976/77 to 1978/79

Item	1976/77	1977/78	1978/79
Total Production in Kantars	315,041	247,455	241,649
Total Revenue (Ls'000)	2,259.8	1,815.1	1,940.4
Costs of Joint Account (Ls'000)	1,545.1	1.689.1	1,491.1
Gross Profit (Ls'000)	714.7	125.9	449.3
Farmers' Share (Ls'000)[a]	555.6	98.2	350.5
Resultant Ave. Price Ls/Kantar	1.76	0.40	1.45
Amount Actually Paid to Farmers (Ls'000)	927.2	775.8	758.6
Resultant Ave. Price Ls/Kantar	2.94	3.14	3.14
Theoretical 'Excess Payment' to Farmers (Ls'000)	317.6	677.6	408.1
Theoretical 'Excess Payment' Ls/Kantar	1.18	2.74	1.69

Source: HTS [38, p. 122]

[a] Based on 78% (i.e., not including the remaining 2% of the tenant's share which goes for the Tenant Reserve Fund).

study notes, "if the farmer had been paid the theoretical producer price derived from the joint account, he would in effect have been made financially responsible for any inefficiencies in the marketing system currently operated by the NMAPC" [38, p. 121].

The report of the committee for "Studying and Treating the Causes of Cotton Production Decline in Nuba Mountains Area" [39] has singled out the unrewarding farm-gate cotton price as the main cause of cotton production decline. The report indicated that for cotton to be more profitable to the farmer, especially in the face of rising labor costs, higher prices are needed. Recommended prices for cotton delivered by the farmer were: Ls 7.0, Ls 4.5, and Ls 3.5 per kantar for grade I, II and III, respectively. It was further recommended that, since the NMAPC can not put these prices into effect given the current production levels, the government should absorb the resulting differences in the prices until such time when it is no longer necessary to have government support. This latter situation (i.e., when NMAPC system is able to pay these recommended prices) was estimated as the time when cotton production in the Nuba Mountains area reaches at least the 400,000 kantars level [39].

Concluding Remarks

In this section an overview of the NMAPC was presented. The discussion included the corporation's background, present performance record and institutional features. The macro view presented in this section was intended as a background for the coming analysis. Subsequent sections focus on the NMAPC at the farm level. The following LP analysis covers both the current NMAPC farm model and the contemplated full scale NMAPC model.

Analysis of the Current NMAPC Farm Model

The main features of the NMAPC farm model have been described in Chapter III. Their LP representation and features which differ from the basic traditional model were given in Chapter IV. They include:

1. Land size is restricted to 6 feddans planted only to cotton and dura in equal shares.
2. Two mechanical ploughing activities are added to the model.
3. Labor requirements and yield coefficients are different.
4. Timing of the agricultural operations is also different.

The results of the NMAPC LP model analysis are discussed (with reference to the basic traditional model) in terms of optimum production plans and net returns, seasonal constraints, and cotton response under the NMAPC model.

Optimum Production Plans and Net Returns

Table 6.6 gives the optimal organization of production for the three production categories under the NMAPC farm model. At present, as can be seen from Table 6.6 the six feddans specified in the model require 141 man-days to grow the two crops in the rotation. However, family labor (even in the relatively well-endowed category III) has to be supplemented by the use of hired labor. The percentage share of hired labor in the total labor input is 26 percent for category I, 15 percent for category II, and 14 percent for category III. This is the result of the requirement to grow three feddans of the laborious cotton crop, on the one hand, and the special time distribution of agricultural operations, on the other hand. The latter results mainly from delays in tractor ploughing undertaken by the NMAPC.

Table 6.6 Optimum Production Plans for NMAPC Participants Farm Model

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern				
Cotton	Feddan	3.00	3.00	3.00
Dura	Feddan	3.00	3.00	3.00
Resource Use				
Total Land	Man-Day	6.00	6.00	6.00
Family Labor	Man-Day	100.37	115.37	119.24
Hired Labor	Man-Day	37.03	21.49	20.29
Nafir Labor	Man-Day	3.33	4.10	1.30
Total Labor	Man-Day	140.73	140.96	140.83
Total Operating Capital	Ls	62.10	49.97	47.85
Initial Capital	Ls	6.93	27.83	30.33
Crop Sales	Ls	21.11	2.51	-
Borrowed Capital	Ls	31.83	18.35	16.38
Interest Paid	Ls	2.23	1.28	1.15
Returns				
Objective Function Value	Ls	-18.56	-19.63	-34.62
Total Gross Margin[a]	Ls	34.24	46.37	53.37
Average Productivities[b]				
Per Feddan	Ls	-6.86	-6.82	-5.98
Per Man-Day	Ls	0.22	0.31	0.36

Source: Computed

[a] Includes the value of dura retained for household consumption.

[b] The assumptions and procedures used in calculating these averages are given in Chapter V (first part).

For all three farm sizes, operating capital in the NMAPC model had to be supplemented by borrowing in order to obtain feasible solutions. The extra operating capital is necessary to pay for hired labor. In addition to repayment of borrowed capital in the model, the mechanical ploughing charges (Ls 1.60 per feddan for two discings) which are provided by the NMAPC on credit (with no interest) must also be repaid in the model. In practice, these debts are often defaulted by tenants.[1]

As can be seen from Table 6.6, the farmers' returns from NMAPC plots are very low. Total gross margins (including the value of dura retained for household consumption) are Ls 34.24, Ls 46.37, and Ls 53.37 for the three categories, respectively. The present small cultivation size and low productivity of the two crops are in general the main reason for this. The cotton component in the present rotation is especially unprofitable, and to a large extent is the main cause of the resulting low returns and average productivities. The dura component, on the other hand, is extremely profitable in comparison to cotton. This picture is clearly indicated by the fact that an additional feddan of cotton is associated with losses of between Ls 16.85 and Ls 12.16 (depending on the production category); whereas an additional feddan of dura earns net returns of between Ls 13.43 and Ls 16.76.[2] This contrasting crop composition in the NMAPC required rotation is also reflected in the average productivities shown in Table 6.6. Losses associated with the cotton

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[1] For example, the reason given by NMAPC administration for shutting down almost all NMAPC schemes in the 1974/75, was the mounting farmer debts for ploughing charges.

[2] This is based on the MVP's of the specified cropping pattern restrictions. See Table 6.7.

component, under this system, causes average productivity per feddan to show a loss of between Ls 6.86 to Ls 5.98 (depending on the production category), and average productivity per man-day to be at the low levels of between Ls 0.22 to Ls 0.36.

Not only are the returns and productivities of the present NMAPC farm model low in comparison to the results of the traditional farm model (see first part in Chapter V), but they are even lower than the corresponding levels achieved by public irrigated schemes.[1] However, despite the low productivity and returns associated with the cotton crop, the current and contemplated NMAPC rotations require participants, as in the case of all public irrigated schemes in Sudan, to grow a minimum of 50 percent cotton.

The importance of crop composition (particularly the size of cotton component) is analyzed later in this chapter. First, the cotton growing restriction in the model is lifted and parametric programming is used to estimate cotton prices needed to grow up to the three feddans required in the current NMAPC farm model. Second, within the analysis of the contemplated NMAPC farm model, optimal crop composition is investigated by lifting crop restrictions on cotton and dura and allowing other crops (sesame and groundnuts) in the LP model.

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[1] Cotton productivity and returns are much higher on irrigated schemes. For example, Zaki [61] estimated the mean net returns to household labor per feddan of cotton in the Rahad Irrigation Project (eastern Sudan) to be Ls 74.693.

Given these low returns, why do farmers actively seek to join NMAPC, and what makes them continue with the system?[1] The following are possible explanations:

1. Farmers view the joining of NMAPC as a means of establishing rights to the land under a government-sponsored mechanization scheme. Since these schemes are opened (and are expected to expand) in tribal and/or village lands, individual farmers seek actively to secure a share for themselves (or their families).[2] This desire has been accentuated in recent years by the increasing shortage of land, brought about by the expansion of large-scale mechanization areas under both government and private efforts.[3]
2. Almost all NMAPC participants cultivate private (traditional) plots outside the NMAPC schemes. The present timing of NMAPC cultivation operations allows the smallholder to distribute the

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[1] This is not meant to imply that farmers do not exit from NMAPC. The records of NMAPC show a significant number of closed schemes in all eight stations of the corporation.

[2] This attitude on the part of the individuals is reflected in the small NMAPC land (as low as two feddans) for a participating farmer in some of the schemes. This often results in cases where a greater number of farmers in an area seek to establish a right to tenancy (by participating in cleaning the would-be scheme) but with the final area of the new scheme limited by the tractorization capacity of NMAPC station in the area. In such cases farmers act on the assumption that their small share would be raised in the future to the contemplated full tenancy size of 15 feddans.

[3] The area under large scale mechanization has increased steadily and the trend is clearly on the rise as supported by the national policy which aims at bringing an additional three million feddans under this sub-sector, the bulk of which is planned for western Sudan [44].

work between his private and NMAPC plots, thus spreading out labor peaks. In terms of priorities, however, NMAPC plots rank very low to the smallholder. In a way, this represents a vicious circle: low returns and late services make scheme plots unattractive, so production and net returns are low. The NMAPC, which requires first-priority and full-time work on scheme plots, partly blames this attitude of farmers for the present low returns and poor performance of the corporation [46].

3. In the present cropping plan of NMAPC, farmers benefit from the relatively rewarding crop, while in compliance with the corporation's regulations they give nominal attention to the cotton crop. Accordingly, the participants' monetary returns from their NMAPC plots (usually losses) can not even cover the charges for mechanical cultivation and other services rendered by the corporation.
4. Despite this record, many of the NMAPC participants hope that the system will be changed to meet their needs more effectively. A better organization of agricultural services, and a more rewarding cropping pattern and scale of operation is hoped for. In particular, the mechanized cultivation service is viewed by farmers to be the equivalent of "mechanical weeding." As such, improvements in its efficiency would be of great value.
5. As hypothesized by Goran [29], government schemes in rural areas are seen by farmers as providing benefits beyond the scope of agricultural production. Improvement of existing social services is linked directly to the presence of the government

agricultural schemes and activities.[1] Drinking water, health, schooling, and maintenance of roads (especially during the rainy season) are pressing needs of the smallholders in the area.

Seasonal Constraints Under the Current NMAPC Model

Table 6.7 gives the shadow prices for the optimal solution of the current NMAPC model. The MVP per feddan of cotton shows a loss of Ls 12.16 to Ls 18.85, depending on the production category. On the other hand, the MVP per feddan of dura is between Ls 13.48 and Ls 16.76. These figures substantiate the relative profitability of the two crops given the prices of cotton.

Labor in the current NMAPC farm model is constraining during January and May. Harvest operation of both dura and cotton occur in January, while the laborious operation of cotton stalk uprooting (locally known as "Al awdi") occurs in May. According to NMAPC regulations, uprooting should be completed by all farmers by May 31st. This is to safeguard against carry-over of cotton pests and diseases from one season to the other and to allow at least one month of cotton-free fields before the beginning of the next season. Farmers are reluctant to carry out this operation and usually perform it close to the deadline and often only under the threat of legal action by the NMAPC.[2]

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[1] An example in this context is the lobbying efforts exerted by the people of Um Brembita to keep the ginning factory in their area open, despite low cotton inputs and the running of the unit at well below capcity.

[2] As explained in Chapter III, the NMAPC often resorts to judiciary powers to enforce this operation through local and traditional courts which fine farmers who have not completed the operation by May 31st.

Table 6.7 Shadow Prices for the Limiting Resources: Optimal Production Plans of the Current NMAPC Farm Model

Resource		Unit	Shadow Price (in Ls)		
			Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Crop Restrictions					
Cotton		Feddan	-16.85	-12.16	-12.16
Dura		Feddan	13.48	16.76	16.76
Family Labor	- Jan	Man-Day	0.93	0.93	0.93
	May	Man-Day	0.67	0.72	0.72
	Aug	Man-Day	0.70	-	-
Nafir Labor	- Jan	Man-Day	0.58	0.58	0.58
	May	Man-Day	0.34	0.36	0.36
	Aug	Man-Day	0.34	-	-
Operating Capital	- Jun	Ls	0.07	0.07	0.07
	Jul	Ls	0.07	0.07	0.07
	Aug	Ls	0.07	0.07	0.07
	Sep	Ls	0.07	0.07	0.07
	Oct	Ls	0.07	0.07	0.07
	Nov	Ls	0.07	0.07	0.07
	Dec	Ls	0.07	0.07	0.07
	Jan	Ls	0.07	0.07	0.07
	Feb	Ls	0.0001	0.07	0.07
	Mar	Ls	0.0001	0.07	0.07
	Apr	Ls	0.0001	0.07	0.07
	May	Ls	0.0001	0.07	0.07

Source: Computed

In comparison with the traditional model's two labor constraint periods, the present NMAPC model shows no labor constraints in the first period (June through August) except for category I which has a labor constraint in August. The reason for the disappearance of labor constraints in the first period is twofold. First, the delayed plowing operation results in planting being as late as the end of August (and sometimes early September), so that weeding activities are carried out in September and October. Second, per feddan labor requirements in the NMAPC model are reduced in comparison with the traditional case, owing partly to the effect of mechanical plowing in reducing weeds, and also to low levels of management applied by farmers to NMAPC plots, especially for the cotton crop. Farmers who cultivate both NMAPC and private plots can distribute labor between the two types of plots, and thus avoid bottlenecks. The priority given to the private plots is reflected in the early planting and weeding schedules responsible for the first period labor constraint in the traditional model. The second period labor constraint (November through December) of the traditional model is extended in the NMAPC model to include January (or even February) in order to complete the cotton harvest. Cotton stalk uprooting in May in fact need not be constrained if the operation is spread over a larger period (anytime from March through May).

Due to the incorporation of capital borrowing activities in the present NMAPC model, the MVP's of operating capital reflect the 7 percent interest cost of borrowed money. However, the need for capital to finance the cotton picking operations is the greatest under the NMAPC case. Borrowing occurs only in February for both categories II and III.

Category I, which required additional operating capital early in the season, also borrowed the largest overall sum (Ls 31.83) in June. Although NMAPC extends no credit (except for mechanical ploughing) to smallholder participants at the present, it considers credit for finance of cotton picking operations as a top priority when credit is extended (as contemplated) to finance participants' field operations.

Cotton Price Response Analysis in the NMAPC Model

The price programming experiment carried out in Chapter V has shown that higher than current average prices of cotton are needed to induce traditional farmers to grow the cotton crop. Average prices per kantar needed for 1-2 feddans response in the traditional model were estimated as Ls 7.0 and Ls 10.0, respectively. At the present and in the absence of such prices, traditional farmers simply do not grow cotton. For the NMAPC participant farmers, this option is not available. After nominal compliance with the corporation's rule to plant designated areas with cotton, farmers sometimes employ measures that are self-defeating. These include low levels of husbandry given to the cotton crop with resulting low yields.[1] Higher cotton prices might help induce more careful cultivation practices and hence higher yields. In this context, an experiment designed to examine such higher yield responses to higher prices would have been particularly relevant and illuminating. However, data limitations prevented this approach. Instead the present NMAPC cotton

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[1] A standard NMAPC practice is to withhold distributing the dura plots for farmers until cotton plots are sown. In addition to the neglect of cotton cultivation thereafter, in a number of cases, farmers plant dura over the just sown cotton, with the latter being weeded out soon after germination.

productivity level was used to simulate prices needed to induce growing of different levels of cotton (without forcing cotton in the model) up to the three feddans level required in the model. Therefore, for the purpose of this experiment, the three feddan cotton area restriction in the present NMAPC model was changed from an equality constraint to a less than or equal to constraint.

Results of this price programming experiment for the three production categories are graphed in Figure 6.2. As can be seen from the graphs, there are differences between the three categories in their respective feddanage response to higher cotton prices. These differences, as in the traditional model's price programming experiment, are the result of corresponding differences in their resource (mostly labor) availabilities. At the present average price level (Ls 3.80 per kantar), only around one feddan is grown in category I, and around 1.5 feddan in each of categories II and III. The initial one feddan cotton area in category I is stable over a larger price range, as it takes a price of more than Ls 8.20 to raise cotton area to 1.6 feddans. However, for both categories II and III a price of Ls 7.0 increases cotton area substantially to 2.84 feddans. At the other end of the spectrum, higher prices induce less area response ; to grow the required three feddans, a high price of Ls 11.35 is needed for category I, while a price of Ls 8.89 would suffice for categories II and III.

As noted before, the prices simulated in this analysis represent average prices per kantar of cotton, and as such, they need to be adjusted to reflect, as the NMAPC cotton price policy maintains, differences between cotton grades (which means a slightly higher price for category I and a lower price for grades II and III).

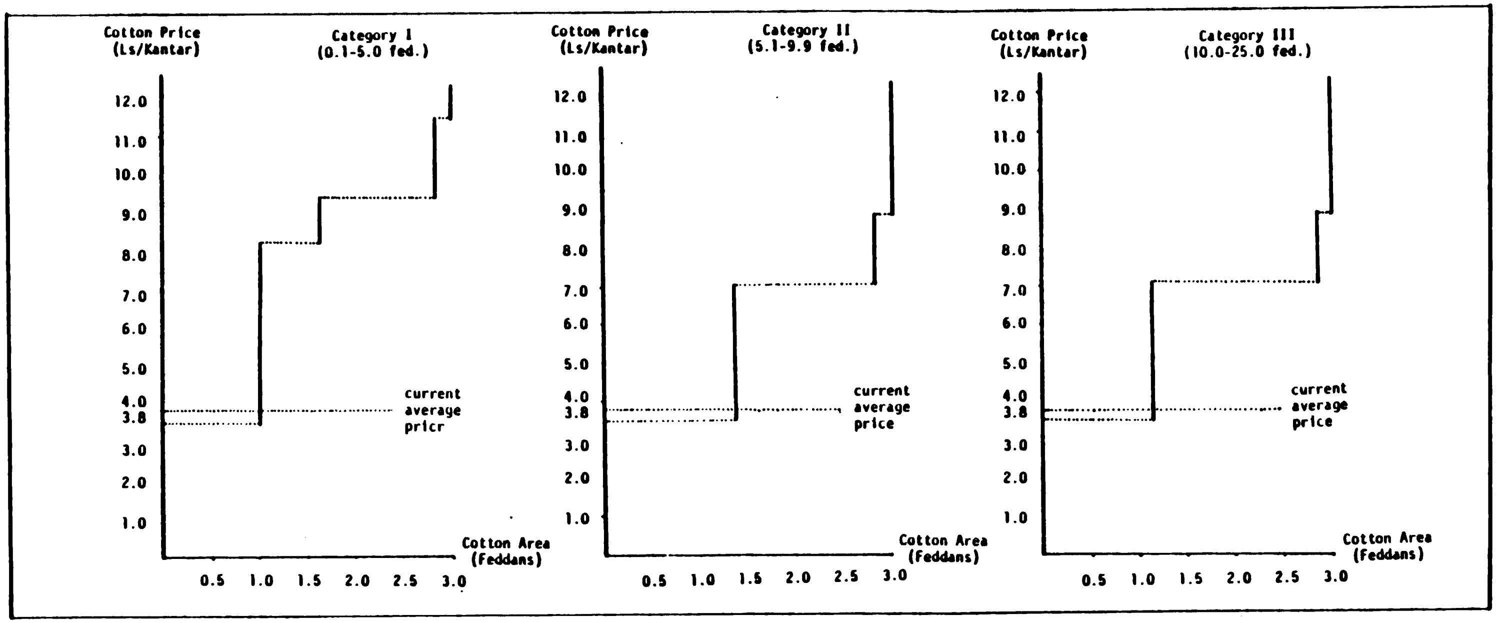

Figure 6.2 Cotton Area Response to Cotton Price Changes: NMAPC Farm Model

Analysis of the Future Full Scale NMAPC Model

The analysis of the NMAPC model is extended in this section to investigate the future full scale model. First, a brief discussion of the features and model specification of the future full scale NMAPC model is presented. Next, the LP results are discussed in terms of the optimal production plans and net returns, seasonal constraints, and a proposed alternative to the future NMAPC model.

The Future Full Scale NMAPC Model

The NMAPC is expected to benefit from the research now underway in the area.[1] In the analysis that follows, however, no changes in crop yields are assumed. Changes in the NMAPC are limited to the following features planned for future implementation:

1. Tenancy size is expanded to the 15 feddans, to be grown in a rotation of cotton, dura, and fallow with five feddans each (i.e., 10 feddans cultivated annually, equally divided between cotton and dura).
2. A second experiment with the model allows all crops to be cultivated, not just cotton and dura. Guided by the cotton price analysis experiments conducted earlier, the cotton price was raised to an average of Ls 10.0 per kantar for this experiment.

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[1] A brief description and discussion of some of the on-going foreign aid research projects is given in Appendix IV.

3. In the future, the NMAPC (as the case in most public irrigated schemes) is expected to offer credit to its participants to meet operating capital requirements. The present NMAPC credit system covers only the mechanized cultivation operations. Recall that the present NMAPC model required credit to get feasible solutions. In the full scale model as before a 7 percent interest rate is specified.

The introduction of one-third (5 feddans) fallow in the future NMAPC rotation is aimed at better maintenance of soil conditions and productivity over time. Since the use of chemical fertilizers is not practiced (or contemplated), fallowing is one way of maintaining soil fertility. Although the fixed tenancy size of 15 feddans is in line with policy decisions in all other public schemes, Zaki [61] criticized the fixed tenancy size standard. In discussing the problem in the context of the Rahad irrigated project (eastern Sudan), he identified three variables affecting the tenancy size:

1. Tenant household size and composition (as both a source of labor and as a consumption group).
2. Income from the tenancy.
3. The impact of crop mix and rotation on labor requirements and returns to labor.

In his analysis of alternative tenancy sizes based on different schemes, and in recognition of households heterogeneity (size and composition), Zaki concluded that "a fixed tenancy size for each tenant is unjustifiable, whether in terms of the tenant's household needs or labor potential supply" [61, p. 164].

In the Nuba Mountains area, the question of desirable cultivation size and crop composition depends on two basic considerations:

1. Productive capacity (mainly labor force) of the household.
2. Income and dura consumption requirements of the household.

Both features were incorporated in the representative LP models.

Optimum Production Plans and Net Returns

The optimum solution of the future full scale NMAPC model for the production categories is shown in Table 6.8. A total of 234 man-days of labor were required for the 10 feddan (equally divided) cotton and dura cropping pattern. Inclusion of the labor intensive cotton crop (5 feddans) in the rotation requires hiring of labor by all three categories. The percentage of hired labor to total labor input rises from 30 percent in category III to a high 47 percent in category I. Labor is hired exclusively during the months of August, January and May. The latter two months correspond to cotton harvest and pest harvest (stalk uprooting) operations, respectively. Category I needed the most operating capital, Ls 66.79, of which Ls 38.29 had to be borrowed.

Farmer returns under the full scale NMAPC model show substantial improvement in comparison with the current NMAPC model (given in Table 6.6). As can be seen from Table 6.8, total gross margins (including the value of dura retained for household consumption) are Ls 93.77, Ls 101.10, and Ls 124.90 for the three categories, respectively. These returns levels, as compared to corresponding levels of the current NMAPC model, represent an increase of 174 percent for category I, 118 percent for category II, and 72 percent for category III. These increases in returns are the result of expansion of cultivation size to the 10 feddan

Table 6.8 Optimal Production Plans for NMAPC Future Full Scale Model

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern				
Cotton	Feddan	5.00	5.00	5.00
Dura	Feddan	5.00	5.00	5.00
Resource Use				
Total Land	Feddan	10.00	10.00	10.00
Family Labor	Man-Day	120.30	141.64	163.65
Hired Labor	Man-Day	109.18	84.90	69.30
Nafir Labor	Man-Day	4.78	7.70	1.30
Total Labor	Man-Day	234.26	234.25	234.25
Total Operating Capital	Ls	66.80	59.47	35.67
Initial Capital	Ls	6.93	27.83	35.67
Crop Sales	Ls	18.89	30.06	-
Borrowed Capital	Ls	38.29	1.47	-
Interest Paid	Ls	2.68	0.10	-
Returns				
Objective Function Value	Ls	40.97	35.10	45.70
Total Gross Margin[a]	Ls	93.77	101.10	124.90

Source: Computed

[a] Includes the value of dura retained for household consumption.

specified for the three production categories in the full scale NMAPC model. Given the different resource availabilities (and dura consumption requirements) of the three production categories, the NMAPC standard of a fixed tenancy size for all participants is clearly unjustifiable. In particular, farmers in categories II and III would benefit from a more flexible tenancy policy that recognizes their relatively higher levels of both labor resource endowments and dura consumption requirements. Another important policy matter, related to the tenancy size impact on participants' returns, is the required crop mix. The NMAPC rule for minimum 50 percent cotton in the two-crop mix was shown in the previous section to have a direct influence on returns. This was explained in the light of the present low cotton yields achieved by farmers and the low cotton prices offered by NMAPC. The relative profitability of dura and cotton, and particularly the losses associated with cotton, are also maintained in the full scale NMAPC model. However, in the case of the full scale model, the expansion of the cultivation size helps to offset some of the losses associated with the cotton component. An additional feddan of cotton in the optimal plans of the full scale NMAPC model is associated with losses of between Ls 1.87 to Ls 5.23 (depending on the production category), while an additional feddan of dura earns net returns of between Ls 10.29 and Ls 12.50.[1] The importance of the crop

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[1] This is based on the MVP's of the specified cropping pattern restrictions. See Table 6.9.

mix, and in particular the size of the cotton component within a more flexible cropping pattern, is investigated as an alternative to the future full scale NMAPC model by a following experiment.

Seasonal Constrains Under the Full Scale NMAPC Model

Table 6.9 gives the shadow prices for the limiting resources under the optimal plan of the full scale NMAPC model. Despite the reduced labor requirements of the NMAPC model (see last section in Chapter IV), the full scale NMAPC model displays basically the same two labor constraint periods of the traditional model. In comparison with the latter model results, the labor peaks are somwehat delayed, starting in August (and September for category I) for the first period, and January (or December for category I) for the second period. The month of May, as was the case in the current NMAPC model, is also labor constraining for all three production categories. This month would not be constraining if the cotton stalk uprooting ("Al-wadi") operation could be spread over the period March through May instead of delaying it to be finished by the NMAPC deadline of May 31st.

The display of the two labor constraint periods, more or less similar to the traditional model, in the NMAPC's full scale model has two important implications. First, unlike the current NMAPC model situation, where NMAPC participants who cultivate both private and NMAPC plots would be able to distribute the work and spread labor peaks between the two types of plots, in the full scale situation this would not be possible. Given the priority attached by farmers to their private plots, cultivating both plot types under the NMAPC full scale situation would likely result in further reduced management levels (especially for

Table 6.9 Shadow Prices for the Limiting Resources in the Full Scale NMAPC Model

			Shadow Prices (in Ls)		
Resource		Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Crop Restrictions					
Cotton		Feddan	-4.59	-5.23	-1.89
Dura		Feddan	10.29	13.48	12.50
Family Labor	- Jan	Man-Day	0.93	0.93	0.87
	May	Man-Day	0.67	0.67	0.67
	Aug	Man-Day	0.70	0.70	0.65
	Sep	Man-Day	0.63	-	-
	Dec	Man-Day	0.35	-	-
Nafir Labor	- Jan	Man-Day	0.58	0.58	0.54
	May	Man-Day	0.34	0.34	0.34
	Aug	Man-Day	0.34	0.34	0.32
	Sep	Man-Day	0.28	-	-
Operating Capital	- Jun-Dec	Ls	0.07	0.07	0.0001
	Jan-May	Ls	0.0001	0.0001	0.0001

Source: Computed

the cotton crop) applied to NMAPC plots. Second, and more importantly, the display of the two labor constraints periods in the full scale NMAPC model indicates that the NMAPC modernization program has not significantly relaxed the main constraints of the smallholder production, as revealed by the analysis of the traditional model given in Chapter V. Although the introduced tractor ploughing, which farmers in the area view as the equivalent of "mechanical weeding," helps in reducing weeds and hence weeding labor requirements, this is not sufficient to remove labor bottlenecks associated with weeding operations. The suggestion given previously within the traditional model analysis, for the need of considering technologies which are particularly oriented towards breaking the labor constraint, is also relevant here. In particular, the work by Hamdoun [26] in chemical weed control has potential for relieving weeding labor constraints. Under the Nuba Mountain conditions some research in this area is already underway.[1]

An Alternative to the Full Scale Model

The preceeding analysis suggests the need for changing the standard fixed tenancy size policy. Tenancy size should recognize the potential labor supply of the household (especially at the two constraint periods) and the household's dura consumption needs.

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[1] The chemical weeding research is conducted presently in the area by a chemical company (Ciba Gigey) under the supervision of Kadugli Research Station.

Another important issue is the required crop pattern. At present the government policy of promoting cotton is at odds with smallholder interests. To shed more light on this issue, an experiment was conducted under the following assumptions:

1. To focus on the issue of crop mix, the 10 feddan size was kept the same, while all crops (cotton, dura, groundnuts, and sesame) were admitted in the determination of the optimal cropping plans, with no restrictions on individual crop areas.
2. As before, no changes in productivity levels are assumed.
3. As before, borrowing is allowed to meet the farmers' operating capital requirements.
4. Guided by the two cotton price programming experiments, the price of cotton in this experiment is assumed to be an average of Ls 10.0 per kantar.

Results of this alternative full scale NMAPC model are shown in Table 6.10. Compared to the results of the planned full scale NMAPC model, this alternative full scale model with unrestricted cropping pattern has several advantages from the farmer's point of view. Relative to the planned NMAPC model, the alternative model generates much higher returns. Percentage increases in returns for categories I, II, and III are 70 percent, 76 percent, and 52 percent, respectively. The higher returns are directly related to improved crop composition. The increased cotton price has little effect (compared to freely admitting all crops) as the areas of cotton in the solutions were all relatively small (under and around one feddan).

Table 6.10 Optimal Production Plans for the NMAPC Full Scale Model with Unrestricted Crop Mix[a]

Item	Unit	Category I (0.1-5.0 fed.)	Category II (5.1-9.9 fed.)	Category III (10.0-25.9 fed.)
Cropping Pattern				
Cotton	Feddan	0.69	0.95	1.07
Dura	Feddan	4.93	4.26	4.80
Sesame	Feddan	4.38	4.78	4.04
Resource Use				
Total Land	Feddan	10.00	10.00	10.00
Family Labor	Man-Day	183.00	218.40	234.79
Hired Labor	Man-Day	42.50	20.52	2.21
Nafir Labor	Man-Day	9.90	5.00	-
Total Labor	Man-Day	235.49	243.92	237.00
Total Operating Capital	Ls	85.98	66.75	53.77
Initial Capital	Ls	6.93	27.83	53.77
Crop Sales	Ls	51.63	38.92	-
Borrowed Capital	Ls	25.63	-	-
Interest Paid	Ls	1.79	-	-
Returns				
Objective Function Value	Ls	105.54	112.05	110.03
Total Gross Margin[b]	Ls	158.34	178.05	189.23

Source: Computed

[a] Total land size 10 feddans, all crops allowed with no individual crop restrictions, and the price of cotton assumed to be Ls 10.0 per kantar.

[b] Includes the value of dura retained for household consumption.

While insignificant changes occurred in the area devoted to dura (the greatest reduction was less than three quarters of a feddan), the cotton area was substantially reduced in all three categories despite its increased price. Land instead was used for the more profitable and well suited sesame crop (more than four feddans). The optimal cotton feddanage varied across the three categories. The less resource-endowed category I cultivates only 0.69 feddan; the area rises to 0.95 feddan in category II and to 1.17 feddans in the most resource-endowed category III.

The unrestricted crop mix in the alternative full scale model is also associated with an improved resource use pattern for the three categories. Compared to the planned NMAPC model, composition and source of labor and operating capital changed favorably (to the farmer) in the alternative model. While total labor requirements to cultivate the 10 feddans remain approximately equal to that in the planned NMAPC model (234 man-days), its composition drastically changes in favor of family labor. Hired labor use under the alternative plan constituted only 18 percent, 8 percent, and 1 percent of total labor use in the three categories, respectively. Family labor rose from the planned NMAPC model levels by 52 percent, 54 percent, and 43 percent, respectively. Introduction of sesame into the alternative model's cropping pattern also has an advantageous impact on operating capital and credit needs. Selling the crop, which occurs as early as November, adds to cash resources and reduces credit needs in the second period when other crop harvest and post harvest activities are undertaken. Only category I resorted to credit, borrowing 30 percent of its needed cash requirements.

Cash availability prior to harvest time not only helps in meeting harvest cash requirements but also favorably affects the marketing strategies of the smallholder. By enabling the smallholder to postpone some of his immediate post harvest sales, he can benefit from the typically much higher prices (for dura in particular) which prevail later.

To summarize, the results indicate that a more diversified cropping pattern is of great importance. This necessitates significant changes in the standard NMAPC two-crop rotation. NMAPC participants' returns could be substantially improved if the cotton component of the rotation is reduced and a third crop (sesame) introduced. The area of each crop (especially that of cotton) should not be fixed. With respect to the cotton crop, the results also suggest an important implication that should be considered within the context of the previously indicated need for changing the fixed tenancy size policy. It is more likely that the NMAPC policy would continue to exercise the rule of designating some specified areas for cotton in the rotation. Under such circumstances it would be better to follow a flexible cotton area specification instead of the present (and planned) 50 percent applied to all farmer participants. Together with the flexible tenancy size, cotton areas within the tenancies should also be proportional to tenancy size.

Summary

In the first section of this chapter, an overview of the NMAPC and its present performance record and institutional features is given as a background for the NMAPC farm model analysis. Both the current

NMAPC farm model and the contemplated full scale model situations were analyzed. LP analysis and experiments were conducted on the following: current NMAPC farm model, cotton price response under the NMAPC model, future full scale NMAPC model, and an alternative to the NMAPC's full scale model.

Results of the current NMAPC model show that 141 man-days are required to grow the specified 6 feddans, which is divided equally between cotton and dura. However, family labor (even in the relatively well-endowed category III) has to be supplemented by the use of hired labor; percentage of hired labor use in the three categories was 26 percent, 15 percent and 14 percent, respectively. This is the result of the requirement to grow three feddans of the laborious cotton crop, and the special time distribution of agricultural operations which results from delayed ploughing operations undertaken by the NMAPC. To pay for hired labor, initial operating capital of all three production categories had to be supplemented by borrowing. Resulting farmer returns were very low. Total gross margin (including the value of dura retained for household consumption) was Ls 34.24, Ls 46.37, and Ls 53.37 for the three categories, respectively. The present small cultivation size and low productivity of the two crops are in general the main reason for this. The cotton component in the present rotation is especially unprofitable; the MVP's of the cotton area restriction show that an additional feddan of cotton would be associated with losses of between Ls 16.85 and Ls 12.96 (depending on the production category). Analysis of the family labor MVP's indicates that labor in the current NMAPC model is constraining during January and May; in January, harvest operations of both dura and cotton are undertaken, while the labor constraint in May corresponds to the laborious cotton stalk uprooting operation. In comparison with the traditional model situation (discussed in Chapter V), the disappearance of the first period's (June-August) labor constraint in the current NMAPC model implies that NMAPC participants can, as they usually do, distribute the work between their NMAPC plots and their private (traditional) plots and thus avoid labor bottlenecks. Operating capital is constraining during the second period (especially in February) when hired labor is needed for the labor intensive cotton picking operation. The need for credit to finance cotton picking in the NMAPC model is shown by the result that borrowing occurred only in February for both categories II and III. Category I, which required additional operating capital early in the season, also borrowed the largest overall sum (Ls 31.83) in June.

The results of cotton price programming with the NMAPC model show that: although NMAPC requires participants to grow at least three feddans of cotton, with the present average cotton price (Ls 3.80 per kantar) and the restriction to grow cotton in the NMAPC model lifted, only around one feddan is grown in category I, and around 1.5 feddan in each of categories II and III. The initial one feddan cotton area in category I is stable over a larger price range, as it takes a price of more than Ls 8.20 to raise cotton area to 1.6 feddans. However, for both categories II and III a price of Ls 7.00 increases cotton area substantially to 2.84 feddans. At the other end of the spectrum, higher prices induce less area responses; to grow the required three feddans, a high price of Ls 11.35 is needed for category I, while a price of Ls 8.89 would suffice for categories II and III. The differences between the three categories in their respective feddanage response to higher cotton prices are the result of corresponding differences in their resource (mostly labor) availabilities.

Results of the future full scale NMAPC model show that as the cultivation size is increased to the planned 10 feddans (also divided equally between cotton and dura), a total of 234 man-days of labor were required. A significant share of the total labor input was hired; the percentage of hired labor use was 30 percent in category III and rose to a high of 47 percent in category I. Labor was hired exclusively during the months of August, January, and May. Resulting farmer returns under the full scale NMAPC model showed substantial improvement in comparison with the current NMAPC model. Total gross margins (including the value of dura retained for household consumption) were Ls 93.77, Ls 101.10 and Ls 124.90 for the three categories, respectively. The increased returns were the result of the expansion of cultivation size to the 10 feddans. Analysis of the MVP's of family labor showed that labor is constraining during August (and September for category I) in the first period, during January (or December for category I) in the second period. In addition, the month of May, as was the case in the current NMAPC model, is also labor constraining for all three production categories. This display of the two labor constraint periods, more or less similar to the traditional model case (discussed in Chapter V), has two important implications: first, unlike the current NMAPC model situation, where NMAPC participants can distribute labor between their privately (traditional) held plots and NMAPC plots and thus avoid bottlenecks, in the NMAPC full scale model situation this is not possible, second, despite the effect of tractor ploughing in reducing weeds and hence weeding labor requirements under the NMAPC model, this is not sufficient to remove the labor bottleneck associated with weeding. As in the current NMAPC model, operating capital in the full scale model is also most constraining in the second period (February in particular), indicating an even greater need (due to increase of cotton area) for credit to finance the cotton picking operation.

The results of the alternative full scale NMAPC model demonstrated the importance of the crop mix. Although the preceeding analysis indicated the need to change the fixed tenancy size (based on recognition of differences among households in labor supply and dura consumption needs), cultivation size was kept the same as in the full scale NMAPC model to focus particularly on the crop mix issue. In this experiment, all crops were allowed (with no individual crop area restriction) and the cotton price was raised to Ls 10.00 per kantar (as suggested by the results of the two cotton price programming experiments conducted earlier). Results of this experiment showed that this alternative full scale model with unrestricted cropping pattern has several advantages over the planned full scale NMAPC model, when judged from the farmer's point of view. Relative to the planned full scale model, the alternative model generated much higher returns: an increase of 70 percent, 76 percent, and 52 percent for the three categories, respectively. The resulting cropping pattern showed little changes in dura area while the area of cotton fell substantially (despite the increase in its price) in all three categories, being replaced by the more profitable sesame crop. Optimal cotton feddanage was 0.69 feddan in category I, 0.95 feddan in category II, and 1.17 feddan in category III. The results also showed that the composition and source of labor and operating capital resources changed favorably (to the farmer) in the alternative model. While total labor requirements to cultivate the 10 feddans remained approximately equal to that in the planned NMAPC model (234 man-days), hired labor constituted only 18 percent, 8 percent, and 1 percent of total labor use in the three categories, respectively. Inclusion of sesame into the alternative model's cropping pattern showed an advantageous impact (through sales of sesame that occur as early as November) in operating capital and credit needs, especially in the second period. Only category I resorted to credit, borrowing 30 percent of its needed cash requirements.

The results also suggested an important implication to be considered in connection with the tenancy size and crop mix policy issues. To tie the two issues together, and under the likely circumstances of continuation of NMAPC's policy of designating cotton areas in its participants rotation, designated cotton areas should be the smallest in small tenancy sizes and proportionally larger in the relatively largest tenancy sizes.

CHAPTER VII

SUMMARY, POLICY IMPLICATIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Summary

The focus of this study is on the rainfed crop production systems of smallholders in the Nuba Mountains area of Western Sudan. The two smallholder systems in the area--traditional farming, and NMAPC modernization schemes--were considered in this study. The objectives of this study were: to identify the present input-output relations and constraints of the two smallholder systems; and to assess the impact of certain policies and/or management alternatives aimed at improving the performance of the two smallholder systems.

The general research approach employed representative farm models to focus on the production system at the farm level. Primary data were generated from two field surveys carried out in the study area. The FAO survey (1978/79) data were combined with the data from the researcher's survey (1979/80) to provide the descriptive analysis of the smallholders' environment and production practices. Building on this foundation, the approach utilized descriptive statistics to derive three representative production categories mainly on the basis of farm size. Each of the three farm size categories were then represented separately (as sub-models) in each of the two (traditional and NMAPC) production models constructed.

Linear programming was used to model the two production systems of the smallholders. In both models (and sub-models) the objective function was to maximize net farm income subject to satisfaction of household dura (sorghum) consumption requirements. This specification, which is based on empirical grounds, has been used in a number of other similar studies. To account for seasonality in the production process, in both models the activities and resources were disaggregated by monthly periods. The traditional and NMAPC farm models differ from each other in activities, constraints, and input-output coefficients. In particular the NMAPC model incorporated features that are unique to NMAPC, including mechanized cultivation activities, a specified land size, and individual crop area restrictions. The basic traditional and NMAPC models were modified in the course of analysis to perform additional experiments. The results of the basic production plans was used as departure points for the experiments that followed. The experiments conducted with the traditional model were: hypothesized rainfall-induced yield variability experiment, credit and land expansion experiment, planting time experiment, credit with planting time experiment, and cotton price variation experiment. Analysis of the NMAPC model included: current NMAPC farm model, cotton price response under the NMAPC model, future full-scale NMAPC model, and a proposed alternative to the NMAPC's full-scale model.

Major findings and conclusions drawn from the linear programming analysis of the two smallholder farm systems were:

Traditional Smallholder Farming

1. The cropping pattern of the smallholder is dominated by dura and includes a small percentage of sesame. Groundnuts and

especially cotton are less profitable. The net returns and resource productivities of smallholder farming are very low. These low returns are the result of low productivities of both land and labor, resulting from low crop yields and seasonal labor constraints, which limit the farmer's ability to increase area cultivated or yields through better (labor intensive) management.

2. Labor is the basic limiting resource in the smallholder production. While operating capital is also limiting, this indicates an indirect labor constraint, since labor is the basic resource operating capital is expended on. Land is not limiting. Family labor is limiting mainly in two periods: the first (June through August) is when weeding takes place, the second (November through December) corresponds to harvest and crop disposal. The family labor MVP's in these two periods are positive and high in comparison with the corresponding hired labor wage rates.
3. While drastic rainfall reductions that result in complete crop failures are rare in the area, rainfall level changes and hence yield level changes have a significant effect on the smallholder returns; a given drop in yield leads to a proportionally greater drop in returns.
4. Short-term credit can help smallholders hire labor, and thus area cultivated and net returns. Credit is needed mainly in the first period (June-August), when the smallholders generally require not only production credit, but also consumption credit to see them through harvest. Operating capital requirements of

the second period (November-December) can be financed, as farmers normally do, through initial crop sales. In this context, the inclusion of early maturing crops (sesame is an example) in the smallholder's cropping pattern is particularly important and useful.

5. Despite the high physical yields associated with early planting, smallholders typically grow late planted crops. This result arises from the stringent time requirements of early planting given the already limiting seasonal labor availabilities of the smallholder. Nonetheless, smallholders make use of the high yields of early planting to the extent that their resources allow. In this context, credit use to hire labor and hence to increase the percentage of early planted crops, significantly increases the smallholders' returns.
6. Although a cotton price slightly higher than the current average (around Ls 4.0 per kantar) could induce the smallholder to grow the crop, his resulting area response is likely to be small (less than a feddan). To induce larger area responses (1-2 feddans) much higher prices (Ls 7.0-Ls 10.0) are needed.

NMAPC Modernization Schemes

1. In cultivating the current average NMAPC plot (six feddans divided equally between cotton and dura), the tenants need to supplement their family labor (by 14 to 26 percent) through the use of hired labor. This situation, despite the relatively small cultivation size and total labor requirements of the plan, is due first to the requirement to grow three feddans of the

laborious cotton crop, and second to the special time distribution of agricultural operations which results from delayed mechanical plowing undertaken by the NMAPC. Participant returns are extremely low in comparison to returns on public irrigated schemes. The present small cultivation size and the low productivity of the two crops are in general the main reasons behind the low returns. The cotton component in the present cropping plan is especially unprofitable. Whereas farmers are required to grow at least three feddans of cotton, it was revealed that at the current average price of cotton (around Ls 3.80 per kantar), a much smaller area (one to one and a half feddans) would be optimal. The minimum required three feddans of cotton is achieved only under much higher prices (around Ls 9.0 to Ls 11.0).

2. For the current NMAPC participants, family labor is constraining during the months of January and May; harvest operations of both dura and cotton are undertaken in January, while the labor constraint in May corresponds to the labor-intensive cotton stalk uprooting operation. Participants' operating capital resources are constraining in the harvest period when they require additional capital especially to finance cotton picking operations.
3. The expansion of NMAPC tenancy size to the contemplated 15 feddan level (to be grown in a three-course rotation with 5 feddans under each of cotton, dura, and fallow) can be expected to increase participants' returns by more than double in comparison with their present returns. However, the increase in the annual

cropping size to 10 feddans can also be expected to intensify the participants' labor and operating capital bottlenecks.

4. Despite the effect of mechanized cultivation in reducing weeds and hence weeding labor requirements, NMAPC participants experience the same two labor constraint periods as traditional farmers, although the weeding labor constraint period is somewhat delayed (to September). This would also be true for the 10 feddan tenancy size.
5. An unrestricted crop mix would be highly advantageous to NMAPC participants, improving participants' returns significantly (by around 50 to 75 percent) over the NMAPC standard crop mix of 5 feddans to each cotton and dura. Dura feddanage would be minimally affected, while that of cotton would be substantially reduced and a third early maturing crop, sesame, would be introduced. With respect to cotton in particular, small areas would be grown by households with small labor resources, while relatively larger areas could be grown by the more labor-endowed households. Although the total labor requirements of the standard and the alternative crop mixes would be approximately the same, to the smallholder participant the alternative favorably changes the composition and source of the needed labor and operating capital resources. In this alternative crop mix, a smaller share of the total labor required would be supplied by hired labor (only 1 to 18 percent); operating capital requirements would be reduced (through reduction of hired labor), and also made available to finance the second period requirements (through sales of the early maturing crop).

Policy Implications

The policy implications derived from the above conclusions are limited by the data reliability, assumptions made, and the analytic approach used. Nonetheless, the study has suggested the likely economic effects of certain important existing, proposed and needed policies.

With respect to the broad goal of developing traditional agriculture, the government should maintain a long-term perspective. Traditional farming exhibits low productivities and returns due to low crop yields and seasonal labor constraints. Neither of these two conditions is likely to be radically changed through a single short-term program. Rather, a long-term dynamic process of applied research and development is needed. In the Nuba Mountains area, a number of domestic and foreign research projects and activities are currently being undertaken.

Within the long-term goal perspective, the general policy priorities should emphasize:

1. Development of better suited crop varieties. In addition to high yields, drought resistance and time of maturity are especially important.
2. A greater research effort in management and agronomy of smallholder crops.
3. Research and development of technologies with the potential of relaxing smallholder labor constraints. The weeding period constraint is the most critical.
4. Recognition by research and development programs of the total system of smallholder production. Incorporating the smallholder's perspective especially requires changes in the present single crop/resource research orientation.

Specific policy issues and implications of present concern in regard to the two smallholder farming systems in the Nuba Mountains area, include:

Traditional Farming

1. Smallholders suffer from inadequate operating capital and lack access to formal sources of credit. Through short-term credit they can augment their resources and hence improve their farming returns through expanding the cropping area and/or increasing yields per unit area. Cooperatives may play an important role in this area; other studies in the area suggest that cooperatives can reduce the high cost of extending credit to smallholders, reduce collateral and security requirements, and reach a large number of small farmers.
2. The unprofitability of cotton to the smallholders, as is well recognized at the present, is the main factor in the decline of cotton area and yields in traditional farming. The cotton pricing policy should aim at a more rewarding farm-level price. Price increases greater than those contemplated by the government would likely be needed if cotton areas in traditional farms are to be increased.

NMAPC Modernization Schemes

1. There is a clear need to change the fixed tenancy size policy. The policy should allow a flexible tenancy size based on the household's potential labor supply (especially in meeting seasonal labor constraints), and income and consumption requirements.

2. The policy towards crop mix is especially important under the Nuba Mountains conditions. The NMAPC should reduce the 50 percent minimum share of cotton and introduce sesame as a third crop into the rotation. Further, the NMAPC should tie the tenancy size and crop mix issues together. If the NMAPC continues to designate cotton areas in its participants' rotation, the designated cotton areas should be smallest in the small tenancy sizes, and proportionally larger in the relatively largest tenancy size.
3. NMAPC should consider extending credit to participants to finance critical agricultural operations.
4. The potential of mechanized cultivation undertaken by the NMAPC appears to be inhibited at the present by many technical and organizational problems. The NMAPC should strengthen the efforts being taken to improve the service.

Limitations and Suggestions for Future Research

The study covered only a one-year crop cycle and is limited as such by the static scope of the approach used, whereas the smallholder production system operates in a dynamic environment. Moreover, smallholder production systems in the area are expected to undergo a number of significant changes in the near future. At present, many domestic and foreign aid research projects and activities of direct impact on smallholder farming are underway or contemplated for the near future in the Nuba Mountains area. Therefore, to account for the limitations of the production models, and to incorporate emerging changes, it is suggested that the production models used in this study be modified and improved upon in other studies in the future. Such studies should benefit from the following modifications:

1. The horizon of the model should be extended to cover at least one cultivation cycle of the land (around 5 years). This would be useful in studying the differences in production and management levels and the interaction between successive years of cultivation. A multi-period linear programming model would be well suited to incorporate this important dynamic feature of production.
2. A better treatment, if necessary data is made available, would explicitly incorporate stochastic crop yields, possibly through a simulation component linked to the production model.
3. If necessary data becomes available, it would be highly advantageous to include more management factors and to represent them as separate activities in such a way as to better understand the critical features and constraints of the smallholder production system.
4. When data is made available from the current research activities on new crops, techniques, and technologies, the model should incorporate these changes.
5. In addition to the above suggestions for the production component, it should be useful to include other household activities. Off-farm activities, nonfood consumption, and livestock investment/disinvestment activities are some of the important areas.

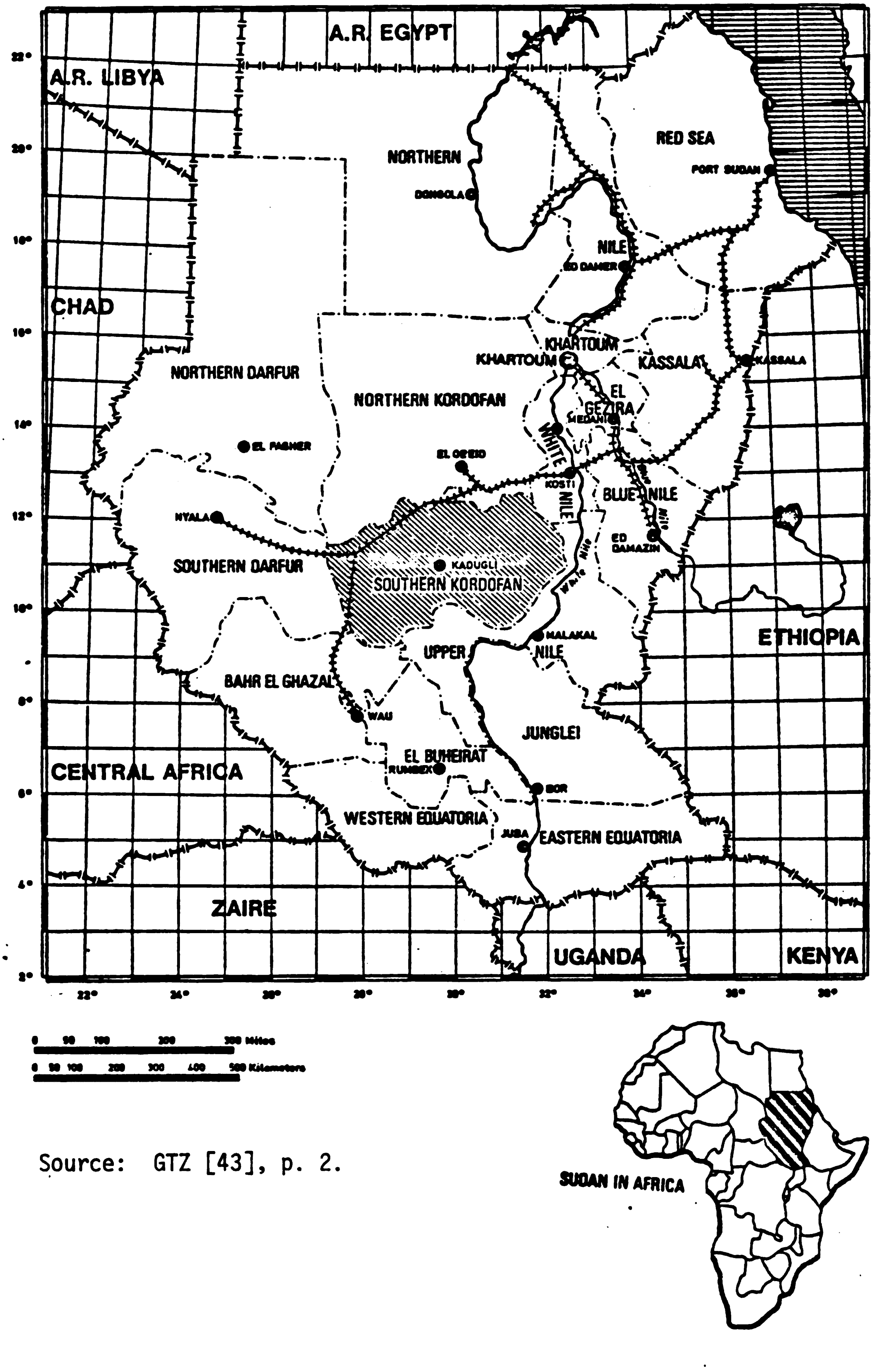
Other studies would very much complement smallholder production studies. In particular, a study oriented towards the marketing strategies and problems of the smallholders is needed. A study with a macro (regional) perspective is also needed to investigate and establish a macro view of the use and potential of the regional resources in the different sub-sectors of agriculture.

APPENDICES

APPENDIX I

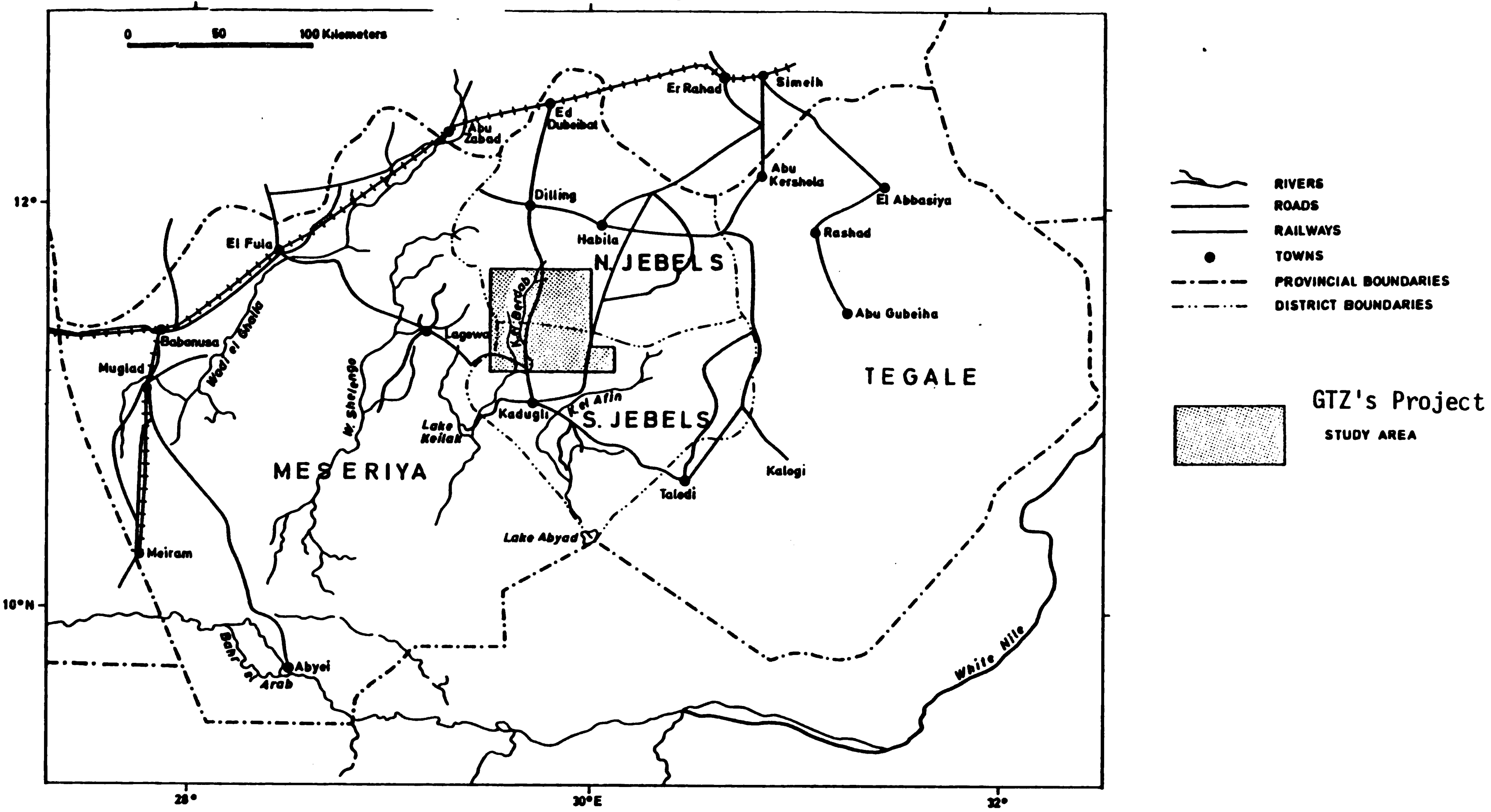
MAPS OF SUDAN AND SOUTH KORDOFAN PROVINCE

SUDAN



Source: GTZ [43], p. 2.

SOUTHERN KORDOFAN



Source: GTZ [43], p. 9.

APPENDIX II

CHAPTER V's PLANTING TIME EXPERIMENTS:
RESEARCH EXPERIMENTS AND DATA

APPENDIX II

CHAPTER V's PLANTING TIME EXPERIMENTS: RESEARCH EXPERIMENTS AND DATA

The material in this appendix describes research experiments and recommendations for the planting time of the major four crops (cotton, dura, sesame, and groundnuts) considered in this study. Recommended planting times and percentage yield reductions associated with selected delayed planting schedules, as represented in the Chapter V's planting time experiments, are deduced from the experimental results discussed below. In addition, weeding times and rates are also described. The results discussed below are from experiments carried out at Kadugli Research Station located in the Nuba Mountains area, and at Kenana Research Station located in the central eastern Savana region of the Sudan.

Time of Planting

1. Cotton

The planting time for cotton is critical and as noted by a Kadugli Research Station report [6]:

> Sowing cotton too early might be risky. Bolls on too early sowings would perhaps open before the end of the rainy season and the produce is thus liable to be of low quality (exposure to rains). Too late sowing might experience unfavorable moisture conditions when rains stop, and might not reach maturity.

Table II.1 shows the results of some cotton planting time experiments carried out at Kadugli Research Station. The July 1st sowing date treatment significantly (P=.001) outyielded other sowing dates treatments for all three seasons. The acreage yield reductions from July 1st level were 37 percent for July 15th, and 65 percent for August 1st. On the basis of these results the following assumptions were adopted:

1. Farmers would grow the recommended cotton variety ALDAR A(57)12.
2. Optimum cotton planting time is July 1st.
3. Planting in July 15 and August 1st reduces optimum yield levels by one 33 percent and 66 percent, respectively.

2. Dura

The planting time of dura has a prime influence on dura grain yields. Tables II.2 and II.3 show the results of some sowing dates experiments. The 1979 annual report of Kadugli Research Station [6] concluded that:

1. Delaying dura sowing dates after mid-time results in a progressive decrease in yields of a magnitude parallel to the time of the delay.
2. T.U.B. (G. Hamam, early maturing variety) is more adaptable to Kadugli conditions.
3. Decrease in yield can be explained by plants having less time for vegetative growth, less plant establishments, and less seed filling and vigour.

On the basis of these results the following assumptions were adopted:

1. Optimum dura planting time is mid-June to early July.
2. Planting in July 15th and August 1st reduces optimum yield levels by 33 percent and 66 percent, respectively.
3. Farmers would grow the short-maturing variety T.U.B. (G. Hamam).

Table II.1 Cotton Sowing Dates Experiments Lint Yield (kg/ha)
Lint Yield (kg/ha)

Season/Variety	Sowing Dates Mid-June	 July 1st[a]	 Mid-July	 Aug. 1st	Sowing Date Mean	
Season 1968/69						
ALBAR A(57)12	146.1	210.9	109.2	28.6	123.7	
BAR	169.4	192.6	66.9	39.7	117.2	SE ± 5.6
Variety Mean	157.8	210.8	88.1	34.2		
			SE ± 8.9			
Season 1969/70						
ALBAR A(57)12	367	491	309	161	332	
BAR	361	328	255	130	368	SE ± 9.0
Variety Mean	364	410	281	140		
			SE ± 21.4			
Season 1970/71						
ALBAR A(57)12	241	265	196	153	214	
BAR	211	211	128	149	175	SE ± 7.9
Variety Mean	225	238	162	151		
			SE ± 15.5			

Source: Kadugli Research Station [6]

[a] July 1st significantly (P=.001) outyielded other treatments in all three seasons.

Table II.2 Dura Sowing Date Experiment, Kadugli and Habila (1979/80) Grain Yield (kg/feddan)

	Kadugli[a]		Habila[b]	
Sowing Dates	Grain Yield	Top Rank	Grain Yield	Top[c] Rank
Mid-June	1237	1		
Mid-July	1005	2		
Early June	1003	2		
Early July	628	3		
Mid-August	497	4	560	3
Mid-July	383	5	685	1
Early September	460	6	278	4
Mid-September	409	7	173	5
Early August	374	8	685	2

Source: Kadugli Research Station [6]

[a] Kadugli: Early sowing was highly significant. Reduction in yield from early July were: 39 percent for mid-July, and 40 percent for early August.

[b] Habila: Trend was the same as in Kadugli but less pronounced because earlier dates were not tested. Reduction in yield from mid-July were: 0 percent for early August, 18 percent for mid-August and 60 percent for early September.

[c] T.U.B. (early-maturing) consistently outyielded DABAR (medium-maturing).

Table II.3 Dura Sowing Date and Seed Rate Experiment, Kadugli (1974/75) [a]
Grain Yield (kg/feddan)

Sowing Date / Seed Rate	Variety T.U.B.				Variety KAO				Mean	
	3/7/74	18/7/74	3/8/74	18/8/74	3/7/74	18/7/74	3/8/74	18/8/74		
4 r.p.f.	483	586	175	154	177	88	114	21	222	
6 r.p.f.	566	307	364	178	111	145	145	21	216	SE ± 22
8 r.p.f.	668	566	139	213	213	192	41	35	249	
Mean	568	486	226	182	167	135	100	26		
				SE ± 26						

Source: Kadugli Research Station [6].

[a] Statistical analysis showed significant differences in grain yield for sowing date and variety (T.U.B. being better) with reduction in yields, 17 percent and 53 percent for 18/7 and 3/8, respectively as an average for the two varieties. No significant difference involving the seed rate or its interactions.

3. Sesame

The sesame crop has received less husbandry research at Kadugli Research Station. Results from a 1974/75 sowing date and seed rate experiment are given in Table II.4. Due to these results the Kadugli Research Station report [6] indicated that because of its short-growing season (90-110 days), sesame is less susceptible to delays in the planting time. For sesame, the following assumptions are adopted:

1. Farmers would grow short-maturing variety Herahiri.
2. Optimum planting date is mid-June to early July.
3. Planting in July 15th and August 1st reduces optimum yield levels by 5 percent and 10 percent, respectively.

4. Groundnuts

The effect of sowing date on groundnut yields is shown in the results of an experiment carried out at Kenana Research Station given in Table II.5. The Kenana Research report [7] concludes:

> The outstanding feature of the results, which was also reported in the first year of this experiment (1963/64), was the extremely sharp drop in top yield by more than 50%, as a result of mere 14 days delay in sowing from July 6th. Delayed sowing depressed pod yield to an even greater extent than top yield.

For groundnuts, the following assumptions were adopted:

1. Farmers would grow either the local variety or "Barberton."
2. Optimum planting date is July 6th.
3. Planting in July 15th and August 1st reduces optimum yields by 33 percent and 66 percent, respectively.

Table II.4 Sesame Sowing Date and Seed Rate Experiment, Kadugli (1974/75)[a]
Yield (kg/feddan)

Sowing Date / Seed Rate	Variety Herahiri			Variety Local Heavy Black				
	16/6/74	3/7/74	21/7/74	16/6/74	3/7/74	21/7/75	Mean	
2 r.p.f.	333	316	294	273	263	247	288	
3 r.p.f.	215	213	210	181	157	125	184	
4 r.p.f.	113	110	95	87	81	71	91	SE ± 14
5 r.p.f.	70	69	66	47	46	29	55	
Mean	183	175	166	147	187	118	154	
			SE ± 14					

Source: Kadugli Research Station [6]

[a] Statistical analysis showed highly significant differences in seed yield between the varieties, seed rate and sowing dates. Reduction in yield from 16/6/74 for 3/7 and 21/7 was 5 percent and 10 percent, respectively for the two varieties. Herahiri, short-maturing variety, outyielded the medium-maturing variety.

Table II.5 The Effect of Sowing Date and Nitrogenous Fertilizer on Four Groundnut Varieties Under Rain, Pod Yield (kg/feddan)

Variety	Sowing Date (D)				Mean		Variety Mean
	6 July		26 July				
	Fertilizer (F)						
	0N	2N	0N	2N	0N	2N	
Barberton	513	629	203	220	585	424	391
Coronet	398	588	235	218	316	403	360
B 730	454	554	214	160	334	357	346
A 33	437	560	194	147	316	354	335
		(SE ± 34)			(SE ± 24)		(SE ± 17)
Mean, D_xF	451	583	212	186	331	385	357
			(SE ± 17)				
Mean, D	517		199				
			(SE ± 12)				

Source: Kenana Research Station [7]

(D = Sowing Date, F = Fertilizer)

Time and Rates of Weeding

To achieve optimum crop yields not only the planting time, but also other subsequent weeding operations must be performed in time. The optimum number of weedings and weeding times for the four crops considered is briefly described below.

1. Cotton

Optimal weeding times and rates for weeding cotton are shown by the experiments carried out in Kenana Research Station, given in Table II.6. The Kenana Research work [7] concluded that two weeding operations to be speced 15 and 30 days from planting, are required for cotton. This recommendation is adopted as an assumption for Chapter V's planting time experiment.

2. Dura

The research work in Kadugli Research Station [6] has shown that:

1. Dura needs one weeding as early as possible (15 days) during crop establishment.
2. Progressive decrease in yield is expected with delayed weedings. The further the delay, the greater the decrease.
3. Delayed weeding decrease yield irrespective of the number of weedings.

These results have been substantiated by work from Kenana Research Station as shown in Table II.7. We adopt the assumption that dura needs only one weeding, two weeks from planting.

3. Sesame and Groundnuts

No experimental work was available on the number of weedings and times for these two crops. We adopt the assumption that two weedings are required for sesame and groundnuts, at 15 and 30 days from planting.

Table II.6 Effect of Time and Number of Weedings on Cotton Plant Population and Seed Cotton Yield

Weeding Treatment (Days from Sowing)	Plant Populations (ooo/ha)				Seed Cotton Yield (kg/ha)			
	1968	1969	1970	Mean	1968	1969	1970	Mean
0	69-97	103-29	74-73	82-66	1026	333	1226	862
15	74-73	96-87	77-59	83-06	2268	850	1464	1527
30	80-21	99-96	75-68	85-28	2363	1499	1849	1904
15, 30	76-40	105-20	79-73	87-11	3434	1940	2511	2628
30, 45	76-16	94-49	79-02	83-22	3346	1742	2599	2562
15, 30, 45	81-87	99-96	81-87	87-90	3625	2197	3420	3081
30, 45, 60	78-30	92-11	80-68	83-70	3275	2278	3303	2952
15, 30, 45, 60	80-68	94-72	79-97	85-12	3518	2618	3339	3158
30, 45, 60, 75	71-16	97-82	83-06	84-01	4053	2232	2892	3059
15, 30, 45, 60, 75	79-73	101-39	79-07	86-73	4267	2761	2946	3325
Mean	76.92	98.58	78.14	84.87	3118	1845	2555	2506
S.E.	± 4.522	± 3.332	± 2.618		+ 347-5	± 227-3	± 328-4	

Source: Hamdoun (1972), [26]

Table II.7 Effect of Time and Number of Weedings on Sorghum Plant Population and Grain Yield

Weeding Treatment (Days from Sowing)	Plant Population (ooo/ha)				Grain Yield (kg/ha)			
	1968	1969	1970	Mean	1968	1969	1970[a]	Mean
0	194 92	167 08	107 10	156 37	802	250	2416	1156
15	274 89	183 26	106 39	188 18	1073	1042	3541	1885
30	155 41	161 84	123 52	146 92	938	888	3958	1928
15, 30	197 06	183 02	124 24	168 11	1092	771	4491	2118
30, 45	180 17	167 08	114 48	153 91	1219	971	3908	2033
15, 30, 45	218 01	194 92	125 19	179 37	1073	916	4198	2062
30, 45, 60	184 45	196 59	115 43	165 44	1209	854	3887	1983
15, 30, 45, 60	194 45	175 17	130 66	166 76	1176	1000	4165	2114
30, 45, 60, 75	167 79	202 06	126 38	165 41	1188	978	3437	2034
15, 30, 45, 60, 75	227 49	199 92	129 71	185 80	1271	992	4208	2157
Mean	199 49	183 09	120 31	167 63	1104	866	3871	1947
S.E.	± 21 658	± 12 376	± 5 236		± 109 5	± 222 6	± 191 6	

Source: Hamdoun (1972), [26]

[a] New variety

Other Agricultural Operations

Harvest operations are to be carried out promptly according to the crops maturity periods. Delayed harvest, especially for sesame, results in substantial losses, as the crop is dehiscent (opening of pods) and quickly shatters the seeds upon maturation.

APPENDIX III

ARTICLE 10 OF THE BASIC NMAPC CHARTER:
THE JOINT ACCOUNT SYSTEM

APPENDIX III

ARTICLE 10 OF THE BASIC NMAPC CHARTER: THE JOINT ACCOUNT SYSTEM[1]

The Joint Account

The corporation (NMAPC) should establish a special account (joint account) to be credited by:

1. The total returns from cotton produced in the Nuba Mountains area. This includes returns of cotton fibers, seeds, skarto, etc.
2. The total returns from any other crop that the operating corporation (NMAPC) may decide to include in the joint account system.
3. The value of any sold machinery, equipment, or materials which have been bought from joint account funds.
4. The value of fines, or compensations, collected for any damages inflicted on the cotton crop or any other crop included in the joint account system.

The corporation (NMAPC) joint account is to be debited by:

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[1] Translated from the Arabic text given in El hag [22], "NMAPC and the Development of Traditional Agriculture: A background review cotton growing and Agricultural Development." Presented in Agricultural Modernization Seminar, Kadugli, 1979.

1. The total costs incurred in sunning and sterilization of cotton seeds, spraying of the cotton crop by insecticides, or cotton protection from pests by any other means.[1]
2. The total costs of cotton packing materials (sacks, strings, etc.).
3. The total costs incurred in establishing cotton local markets, collection, storage and transport.
4. The total costs incurred in cotton ginning, packing and transport.
5. The total costs incurred in storing cotton seeds for any period, as might be necessary.
6. The total costs of any other expenditure incurred in cotton collection, processing,and disposal.[2]
7. The total costs of opening and maintaining cotton roads.[3]

Division of Cotton Net Returns

Cotton net returns (after deduction of the joint-account costs) are to be divided according to the following sharing formula:[4]

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[1] Mainly includes the costs of the cotton stainer-bug campaign undertaken by the NMAPC.

[2] Includes such as labor wages, insurance and sales commissions.

[3] Cotton roads are the roads opened in the different localities in the Nuba Mountains area which are intended to aid in cotton collection and transport to gins.

[4] In case of Abu Habil irrigated scheme, cotton net returns are to be shared 50 percent for NMAPC and 50 percent for the scheme farmers.

NMAPC	15.5%
Tenant Reserve Fund	2.0%
Farmers	78.5%
Social Services Fund	2.0%
People's Local Government	3.0%

Payment of the Farmers' Share

The farmers should be paid as soon as they deliver cotton to the collection centers. Initial payment to farmers should be according to the rates (prices) recommended by the NMAPC administration committee and approved by the board of directors of the Public Corporation for Agricultural Production (PCAP). The resulting surplus (deficit) arising from the initial payment to farmers and the final actual farmers' share (78.5 percent of cotton net returns) should be deposited (subtracted) to the Tenant Reserve Fund.

Division of the NMAPC Share

From the 15.5 percent share of NMAPC, the NMAPC should deduct all total expenditure (use funds and special allocations funds) which have been approved in the fiscal year (in which cotton was produced) budget. Any remaining surplus should be divided as follows:

PCAP	85%
NMAPC Reserve Fund	15%

Agricultural Season Account

At the end of any season, the corporation (NMAPC) should establish a separate account for the season. The corporation should close the farmers' account and pay their final share for the season not later than June 30th of the next year.[1]

Farmers' Debits to NMAPC

If the farmers' share in any one season is not sufficient to cover their debits to NMAPC, the NMAPC may transfer and subtract the remaining debits from the farmers' share for the next, or any other, season.

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[1] This is in case more than 80 percent of the season's cotton crop has been sold.

Table III.1 NMAPC: Total Cotton Purchases, Returns and Joint Account Expenditures (1974/75 - 1978/79)

Season	Total Cotton Purchases (Kantars)	Cotton Returns (Fiber Cotton) (Ls)	Returns Per Kantar Fiber Cotton (Ls)	Total Joint Account Sum (Ls)	Joint Account Per Kantar Fiber (Ls)	Net Returns Per Kantar Fiber (Ls)	Farmers Share Per Kantar Fiber (Ls)
1974/75	211,428.74	934,885.57	4.763	703,260.581	3.449	1.314	1.077
1975/76	319,120.78	2,568,115.02	7.050	1,025,808.44	2.913	4.137	3.392
1976/77	310,974.32	2,478,270.49	8.882	1,037,289.21	3.735	5.147	4.220
1977/78	247,456.97	1,787,118.90	7.221	895,363.29	3.618	3.603	2.882
1978/79	247,248.32	2,113,626.46	8.550	1,013,794.05	4.096	4.454	3.563
Average			7.300		3.562		2.990

Source: Ministry of Agriculture, Food and Natural Resources [39], Report of the Committee for Studying and Treating the Causes of Cotton Production Decline in Nuba Mountains Area, (in Arabic), 1979.

APPENDIX IV

FOREIGN-AID RESEARCH PROJECTS IN THE NUBA MOUNTAINS: OBJECTIVES AND RELATION TO SMALLHOLDER AND NMAPC AGRICULTURE

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FOREIGN-AID RESEARCH PROJECTS IN THE NUBA MOUNTAINS: OBJECTIVES AND RELATION TO SMALLHOLDER AND NMAPC AGRICULTURE

In the 1970's a number of foreign-aid research projects have been initiated in the Nuba Mountains area. Among these, the three major projects targeted at the smallholder farming and/or NMAPC schemes are: the European Development Fund (EDF) Project, the West German Technical Aid (GTZ) Project, and the British Overseas Development Administration (ODA) Project. The following is a brief description of their objectives and contemplated activities.

EDF: Nuba Mountains Rural Development Project

The project was prepared and is being sponsored and implemented by the French Technical Consultants (SATEC). This project is conceived as an agricultural extension and rural development program designed to improve agricultural production with special emphasis on the introduction of animal-drawn farming equipment. As held by SATEC, the introduction of animal-drawn equipment and techniques has the following main advantages: (1) reduces the demand for, and increases the returns to labor (2) creates more rapid agricultural operations; (3) enables farmers to plant on or close to the optimum planting dates; (4) saves the farmer money because animal-drawn equipment is cheap compared with tractors; and (5) gives the farmer full control over the timing of farming operations.

After the testing and demonstration phases of the project implementation, the animal-drawn farming techniques are to be introduced into both NMAPC and traditional agriculture. The proposed format is as follows:

1. Five development schemes are to be established in connection with the NMAPC schemes (one at Kadugli and four in other field stations). An initial cultivation size of 16 feddans per farmer is proposed. As farmers get more experience and skill with animal-drawn techniques, the cultivation size is to be gradually increased up to 26 feddans per farmer.
2. For the traditional cultivation areas, the aim is to establish two development units in areas of light soils. An 18 feddans cultivation size per farmer is proposed to be managed in a three-course rotation (dura, sesame, and groundnuts).

At present, testing of equipment and techniques is the main activity being undertaken. Preliminary test reports have identified a number of technical and equipment problems. The 1979 testing program report [42] concluded with respect to land preparation that:

> It will require a few years of trials on the testing farm to work out a cost/benefit comparison between ploughing costs and yield-cum-income increases. For the immediate future, thus, ploughing could only be recommended to rich farmers who can bear the risk of unconfirmed test [42, p. iii].

The 1979 weeding test results indicated technical problems especially on the clay and "gardened" soils. Weeding in light soils, however, was reported to pose no problems.

GTZ: Pilot Project and Nuba Mountains Region Masterplan for Rural Development

The GTZ project was prepared and is being implemented by the West German engineering consultants Agrar and Hydrotechnik Gmbh (AHT). The project proposes a comprehensive rural development program. A pilot project for developing smallholder agriculture is to be linked and supported by a masterplan aiming at improvements of key sub-sectors (animal husbandry, agro-industries, infrastructure, etc.) in the region. The objectives and assumptions of the pilot project, as identified by the GTZ main report [43] are:

> The proposals, designed to overcome the present deficiencies in the agricultural systems in the Masterplan Area, have to aim at an increase of agricultural production in general as well as at a higher income per farming family. The increase of production and income can be achieved through:
> - increasing the size of farm holdings.
> - increasing the yields per feddan through using improved seeds and crop maintenance.
> - increasing both the above through the introduction of capital-intensive methods (mechanized soil preparation and sowing), [43, p. 65].

Proposed specific measures and detailed strategy of the GTZ project include:

1. Expansion of rainfed mechanized crop production on individual smallholder farms, with some of these farms also including an integrated livestock component.
2. Improvement of crop yields through crop diversification, and the introduction of high yielding, drought-resistant, varieties of crops.
3. Introduction of a legume into the crop rotation to serve both as a fodder crop and in maintenance of soil fertility.

4. Creation of an agricultural machinery pool.
5. Establishment of range management practices.
6. Development of agricultural research programs and on-farm trials to test proposed changes in the existing farming activities and cultivation practices.
7. Organization of seed multiplication, inspection, certification and distribution.
8. Encouragement of farmers' agricultural cooperatives.
9. Increased effectiveness of the present agricultural extension services.
10. Development of an efficient marketing system for all agricultural products, including adequate storage facilities.
11. Improvement of transport and communication facilities.
12. Improvement of the supply and quality of both surface and groundwater to secure all-year-round provision of drinking water.
13. Establishment of better education and health facilities.

At present, however, only limited machinery testing is being carried out under the project. The proposed institutional and organizational setup is similar to that of NMAPC, a point considered by AHT to be useful when actual implementation of the project is undertaken:

> It would be conceivable to make the implementation of both the Masterplan and the Pilot Project the responsibility of the Nuba Mountains Agricultural Corporation,....Basically this program could be interpreted as an especially intensive NMAPC scheme, and it is probable that farmers also see it as such, [43, p. 99].

ODA: Mechanization and Rural Planning Unit Projects

Since its conception, the British ODA program has evolved into two separate projects:[1] an agricultural mechanization project for the NMAPC and a rural planting unit project.

The Mechanization Project for NMAPC

Originally, all components of the ODA's project were directed towards the NMAPC, which was then expected to assume the responsibility of an overall development authority for South Kordofan Province. Later, as NMAPC did not assume this function, ODA decided to focus its program for the NMAPC by strengthening NMAPC mechanization activities. Main components of this program are:

1. Training of tractor operators and mechanics.
2. Strengthening or workshop facilities. This includes provision of specialized equipment to the major workshop at Kadugli, and three mobile workshops to aid maintenance at field schemes.
3. Testing of alternative mechanized cultivation techniques.
4. Evaluating a selected range of appropriate new machines and implements.

This component of the ODA project was delayed and is expected to start in the season 1980/81.

Rural Planning Unit (RPU) Project

As indicated above, this project was originally intended to be implemented within NMAPC, with the aim of aiding the Government of Sudan in

---

[1] A third component (an oil milling study) was part of the initial ODA plans but was subsequently abandoned [38].

planning, monitoring, and promoting agricultural development in South Kordofan Province. At present, the project is operating as a separate entity and is being implemented by the British consultants Hunting Technical Services (HTS). The aim of the project is to establish a Rural Planning Unit, and during the first three years the principal objectives of the RPU, as indicated in HTS [38] would be to:

> a) Train Sudanese counterpart staff to fill the specialist posts in the unit and leave behind an effective rural planning capability.
>
> b) Collect and collate all available agricultural, human and physical resource data and to establish an agricultural data bank for the area. Gaps in data essential for planning would be identified and either surveys mounted from within the RUP resources or recommendations made for specific studies, to make good these deficiencies.
>
> c) Prepare an agricultural development plan for South Kordofan [38, p. 2]

This component of the ODA project is currently underway. Completion of its first phase has resulted in drafting an indicative development plan [38] for South Kordofan Province central districts. The second and third phases are expected to be completed by 1983.

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