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AN ECONOMIC ANALYSIS OF MECHANIZED FOOD PRODUCTION SCHEMES IN THE CENTRAL PLAINS OF THE SUDAN

By

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ABSTRACT

AN ECONOMIC ANALYSIS OF THE MECHANIZED FOOD PRODUCTION SCHEMES IN THE CENTRAL PLAINS OF THE SUDAN

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This study describes and analyzes the mechanized rainfed food production schemes in the Damazine area, Sudan. The study describes the mechanized crop production schemes in the Damazine, evaluates the financial viability of these schemes under partial and full mechanization of sorghum harvesting, assesses the economic viability of the two alternative sorghum harvesting technologies, and makes policy recommendations. The study is based on primary data obtained from a survey of 73 Damazine farmers during the 1983/84 cropping season. Secondary data included published and unpublished government reports and studies.

Static linear programming is used to analyze the income and employment consequences of the farm enterprise under partially and fully mechanized sorghum harvesting technologies. Farm enterprise budgets are developed to measure the relative contribution of each enterprise and to compare the farm's financial profitability under the two alternative sorghum harvesting technologies.

The linear programming analysis indicated that combine sorghum harvesting increased farm income by 30 percent and the efficiency of resources use. Hired labor use per feddan

decreased by 40 percent for the sorghum crop and total hired labor use decreased by 22 percent, when sorghum was combine harvested. The financial analysis of the two production systems indicated that all enterprises under the two harvesting technologies gave positive net returns. Combine harvested farms gave higher return to management than when sorghum was partially machine harvested. In contrast, when all subsidies were accounted for, fully mechanized sorghum generated a net loss compared to net profit for partially mechanized sorghum. The study identified several policy constraints and makes recommendations regarding the need to develop an improved farming system, to staballize the domestic macro policy environment, expand the mechanized farming frontier though the importation of land preparation machinery, rather than by subsidizing labor displacing combine harvesting machinary,to change the local taxes on crop from a per unit of crop produced basis to a per unit of land basis, to use research resources to breed drought resistance and high quality sorghum varieties, improve the cultural practices, and develop a viable crop rotation; and to create an effective and responsive extension service.

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CHAPTER 1

INTRODUCTION

1.1 Agricultural in the Economy of the Sudan

The Sudanese economy is firmly based on agriculture. Sudan has an area of approximately six hundred million feddans.[1] The total arable land is estimated to be 200 million feddans, out of which about 19 feddans (9 percent) is under cultivation (Table 1.1). The total population is estimated at 21 million (1983)[2], equal to about 0.9 cultivated feddans per capita.

Agriculture's contribution to the GDP has increased from 34 percent in 1975 to 37.2 percent in 1982.[3] About 76 percent of the economically active population is engaged in agriculture. Agriculture is the source of 90-95 percent of the country exports, and 90 percent of the raw products processed in the country. Over 50 percent of the government's revenue is generated by agriculture.

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[1] 1 Feddan = 1.038 Acres = 0.42 Hectare = 4200 sq. meters.

[2] Democratic Republic of the Sudan, Ministry of Finance and National Planning, Department of Statistics, Khartoum, Sudan.

[3] Democratic Republic of the Sudan, Ministry of Finance and National Planning, "Economic Survey 1982/83," Khartoum, Sudan (in Arabic).

TABLE 1.1

Land Use in Sudan, 1977.

	------1000's Feddans--------
Total Area	596,021
Land Area	565,714
Area Under Water	30,907
Arable Land and Land Under Permenant Crops	200,000
Arable Land	181,315
Cultivated Land	18,685
Pasture	57,143
Forest and Woodland	217,857
Other	90,714

Source: The Statistics Division,Department of Agricultural Economics,Ministry of Agriculture and Natural Resources, D.R. of the Sudan,Sudan Yearbook of Statistics,1977.

Agriculture consists of four major sectors. First, the irrigated sub-sector include about 4 million feddans, and comprises mainly consolidated schemes irrigated by the Nile waters. Second, as in most developing countries the majority of the population is dependent on some form of traditional agriculture. Mohammed (1982) estimates that more than 50 percent of the total cropped area is under the traditional agriculture sub-sector. The third sub-sector is the livestock sub-sector. This sub-sector has an estimated 19 million cattle, 18 million sheep, 13 million goats, and 3 million camels. The herds are owned mainly by nomads. The fourth sub-sector, the most recent to be developed, is the mechanized crop rainfed schemes (MCPRS) sub-sector. This sub-sector is located in Sudan's Central Clay Plains where rainfall is between 400 mm in the northern areas, and 800 mm in its southern boundaries.

1.2 Importance of the Mechanized Rainfed Sub-Sector

Efforts to mechanized rainfed crop production were initiated during the Second World War. The objective was to supply the British troops in East and North Africa with sorghum,[1] Sudan's staple cereal for which the country was experiencing shortage during the war years. The scheme was

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[1] Sorghum is sorghum vulgane, locally known as "dura."

started in 1944/45 in the eastern part of the country, and by 1960 it hab been extended to other areas of the central clay plains[1] (Figure 1.1).

Today, the area under mechanized rainfed farming is estimated at 6 million feddans, which represents 32 percent of the total cultivated area in Sudan. Sorghum and sesame[2] are the major crops produced in the mechanized rainfed sub-sector. The area under mechanized sorghum represents approximately 89 percent of the total area under sorghum production, and accounts for 82 percent of the total sorghum production in the country (Kursany, 1984). This sub-sector also supplies 40 percent of the country's sesame output. Mechanized sorghum production represented 6 percent of the Sudan's total agricultural export earnings between 1976-1980 and contributed 15 percent of the agricultural export earning in 1980.

The Mechanized Farming Corporation (MFC), which is the government agency overseeing the schemes, estimated that an additional 16 million feddans can be put under mechanized rainfed farming in the Central Clay Plains.

The sub-sector is characterized by large farms of 1000 to 2000 feddans managed by individual farmers. Cultivation

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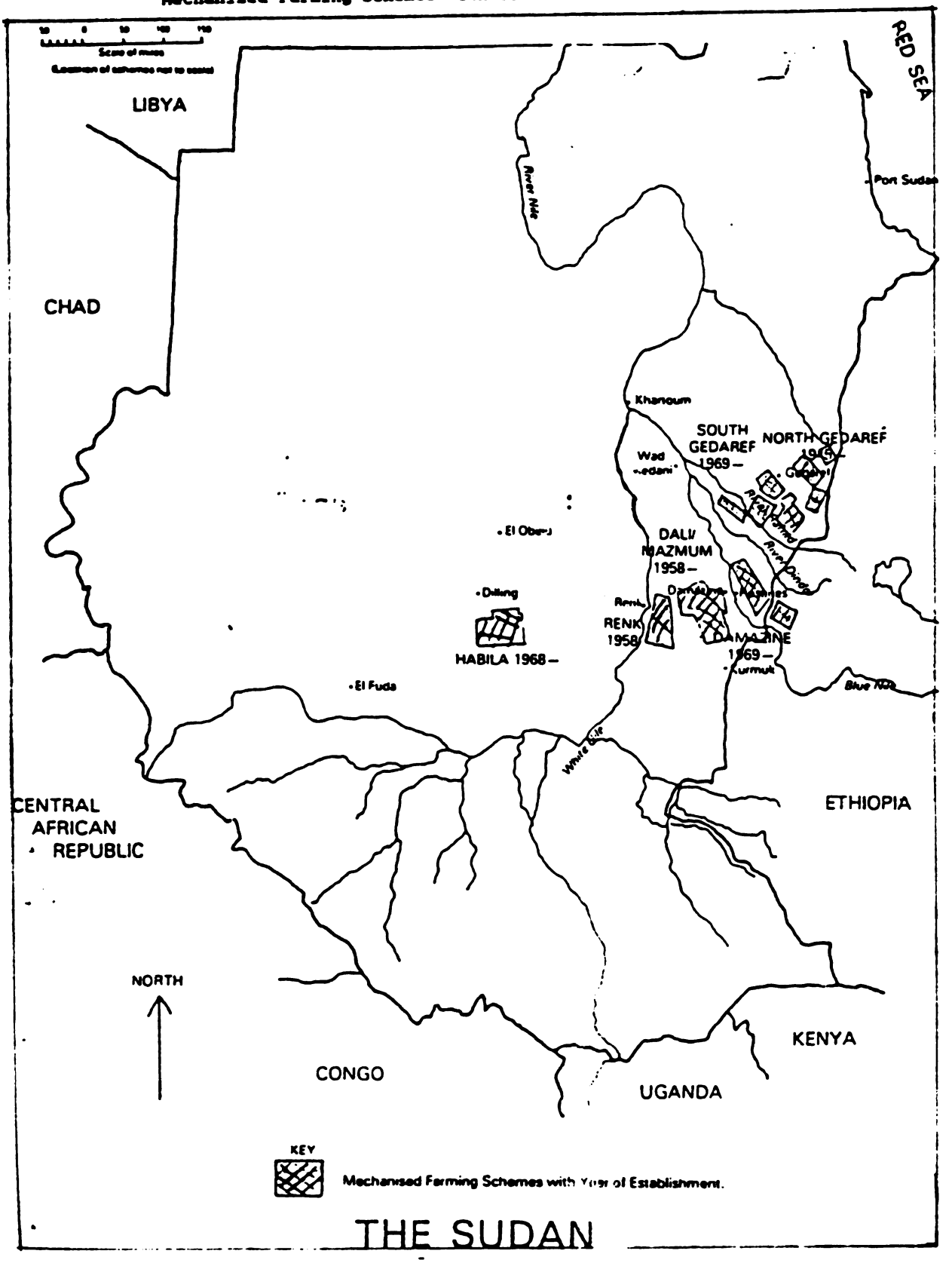
[1] Sudan's Central Clay Plains represent one of the largest reserves of cultivable land in the world (Simpson, 1983). It is about 100 million feddans, and stretches across the central part of the country from east to west.

[2] Sesame is sesamum orientale, which is locally known as "simsim."

FIGURE 1.1

Mechanized Farming Schemes With Year of Establishment, Sudan



is carried out by wheel tractors (70-75 HP) using disc harrows. Weeding is done manually. Harvesting of sorghum is partially mechanized. The crop heads are cut by casual labor, and then threshed by stationary combine harvestors. Sesame is manually harvested.

The term mechanized farming is strictly a misnomer since only land preparation and planting are fully mechanized operation on all farms. The sub-sector is credited with channelling substantial private savings into agriculture, and it makes a valuable contribution to food supplies for both domestic and foreign consumption (ILO, 1976). At the same time, the sub-sector is criticized as a means by which the rich get richer through government subsidies and surface mining of the land (Kursany, 1984).

1.3 An Overview of Some Major Studies of Farm Mechanization in Developing Countries

A review of some of the major studies will help to set the objectives of the study and indicate some of the issues involved.

Dawlaty (1971) in his study of the effects of tractors on farm output, income, and employment found that at the early stages of mechanization in Afghanistan the amount of labor replaced by machines is relatively small. An important effect to mechanization in Afghanistan found by Dawlaty was a shift in tenure patterns from "independent" (Ejaradar)

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tenants to tenants who are less involved in decision making. Landlords who had previously rented all or most of their land became more involved in the management of their farms. Large landholders were found to became more attuned to scientific methods and more aware of economic market forces when they owned tractors. The study also found that tractor use increased cultivatable land areas, particularly in the irrigated areas. In most instances tractor use in Afghanistan was also found to both increase crop yields and increase the demand for labor in operations which were not done by tractors. Also, the research showed that mechanization, which enabled some farmers to increase their farm size, led to the diversification of farm operations, including more labor intensive enterprises. The data for the study were collected through interviews of tractor owners and was not checked with any other source of information. Consequently, one can expect significant bias in the data. Another drawback of the study is that it did not pursue a policy question in the objectives and the author did not explore whether or not the mechanization program was beneficial to the country as a whole.

Singh (1971) studied the effect of technology on farm employment in the states of Punjab and Maharashtra in India. The basic approach used in the study was to attempt to measure the potential impact of high-yielding varieties (HYV) and other important technological changes on farm employment. In the Punjab where HYVs of wheat had spread

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rapidly, wheat threshers were extensively used. It was found that the HYVs increased the demand for labor by themselves, but the pump-sets, threshers and tractors reduced the demand for labor such that the overall demand was reduced. It was projected by the study that by 1983/84 the cropped area will expand by 14 percent and the farm labor force will increase by 10 percent in the Punjab, reflecting a slight decrease in the worker/hectare ratio and an increase in the work duration of a farm laborer from 120 to 130 days per year. In Marharashtra, the study showed that the natural growth of the labor force will provide a surplus of 4.5 million workers by 1984. The labor displacing impact of pump-sets, threshers and tractors will not be of sufficient magnitude to counter-balance the additional demand for labor resulting from the expected increase in the area under HYVs. Yet, this net increase in demand will be too small to have any marked effect on employment of the rapidly growing labor force. With limited scope for irrigation and multiple cropping, on the other hand, the man/land ratio will remain high and the annual average working time of a farm laborer will decline. The impact of technological changes in the two states studied was found to be widely uneven and different. The study made no attempt to go into the impact of technological change in agriculture on employment in the non-farm sector.

Green (1971) studied four different case studies of mechanization in different parts of Ethiopia using secondary

data supported with informal interviews. The cases were described and analyzed for potential benefits, costs and compatibility with some objectives selected from the Ethiopian third five-year plan. Benefit-cost analysis was used to test the financial profitability of mechanization in the four districts studied. The author made some assumptions with regard to crop yields, population growth, labor efficiency, price, etc. on which he based his calculations. Budgeting models were used to generate data for benefit-cost analyses for the strategies suggested in each of the four cases. For Agnale village, only one form of hand-powered technology was studied. High and low production level models were tested. The analysis showed there was high potentials for increasing net returns by introducing unsophisticated improvements into hand-powered systems. Analyses of employment requirements indicated a decline in labor due to improvements assumed to follow in labor efficiency. For the Chilalo Araja case, eight hectare were selected as representative of the district. The two strategies studied were the present bullock technology, compared to improved bullock technology and tractor-hire. Benefit-cost analyses of the two strategies indicate a modest net return for high production levels and a negative returns for low levels. In this system where farms are small and fragmented the analysis suggested that the bullock option was more appropriate than the tractor-hire alternative. The bullock option required less government investment and provided more

employment.

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employment. Benefit-cost analyses of two strategies in Setit-Humera for which 800 hectare was selected as a representative farm indicated high rates of return for both assumed levels of production. The strategies compared were the existing labor intensive technology to more machine intensive technology. The returns to the labor intensive technology were lower than for the machine intensive technology, due to additional economies facilitated by the higher level of mechanization. Yet this was achieved at the expense of a lower level of employment. The Tendaho case evaluated mechanization on large-scale commercial plantations. Two strategies were considered here. Strategy I was based on the assumption that the plantations produce and sell raw cotton. Strategy II assumed the cotton was ginned before selling. In this case, returns to Strategy II were found to be higher than those for Strategy I, and also more labor will be employed. Green fully tested the financial analysis of the four cases but gave a little interest to the economic analysis. Green's thesis did not draw national policy conclusions.

Ahmad (1972) investigated the economic and social impacts of tractor mechanization in the Punjab Province of Pakistan. He analyzed the influence of mechanization on cropping intensities, yields, cropping pattern and rate of return on investment. The social aspects include influence of mechanization on employment, tenurial relationships and farming structure. Ahmad used secondary data and a cross-

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section survey of 50 farmers in three districts of the Punjab Province. He used a linear programming model to analyze the data. Ahmad showed that government programs can cause price distortions that result in the misallocation of resources. Ahmad's linear programming model showed that the incentive to tractorization was very great. Farms with tubewells got higher returns to mechanization such that the financial rate of return was 46 percent while without tubewells it was only 3 percent. The increase in returns with tubewells was due to the increased cropping intensities which can be reached. He concluded that for farmers with tubewells, mechanization is profitable even when all price distortions were removed. Ahmad found that tractor farms had relatively less family labor but more hired labor per acre compared to bullock farms. Tractorization also caused tenant ejection and an increase in landholdings of the tractor owners. As policy implication for his research, Ahmad recommended encouragement of threshers instead of tractors in areas without tubewells. In areas where tubewells existed, he suggested a policy that will increase the foreign exchange savings, improve off-farm linkages and reduce tenant displacement. Ahmad sees technical change as critical to agricultural modernization and it should be considered as a bundle of inputs, rather than as a single input, e.g., tractors only.

Clayton (1973) studied the impact of mechanization on employment in Uganda, Kenya and Tanzania. Clayton attempted

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to assess the income and employment impact of various mechanization programs in these three countries. He concluded that mechanization programs should not be encouraged in Uganda because they had proved to be uneconomic and labor-displacing. He suggested that the government should not subsidize farm machinery and argued that there was no indication that tractorization has raised over-all agriculture or labor productivity. Clayton claimed that ". . . the indications are that mechanization has decreased the demand for labor and is thus an employment destroyer."

Clayton found that in Kenya mechanization was financially viable for large farms, but considering the social cost and benefits of mechanization, it was undesirable for both large and small farms. Clayton estimated that tractorization absorbed 80 employed persons per 1,000 hectares, compared with over 1,000 on peasant small holdings. Clayton advocated mechanization on family farms in the coffee/tea, pyrethrum/coffee and coffee ecological zones, particularly when these are near towns or it is physically suitable to plow with a tractor. In Tanzania, Clayton suggested that tractor cultivation was uneconomic, although he presented no data to support that conclusion. Finally, he approved the government policy to encourage ox plow cultivation and considered the continuous increase in the number of ox plows purchased as an indication of its profitability.

Abercombie (1973) reviewed the mechanization situation in Latin America and its impact on employment. He characterized Latin American countries as having a high unemployment rate, and in the agricultural sector, underemployment was more serious than open unemployment. Abercombie, using data for Colombia, noted that the impact of tractors on employment varied with farm size. He estimated that on the average, as many as 19 workers could be displaced per tractor for farms in the 50 to 199 cultivated hectares range. For farms with over 200 cultivated hectares, however, the substitution ratio dropped to 2-3 workers per hectare. For Colombia, he estimated the introduction of one tractor resulted in an annual reduction of average labor requirements for major field crops of 5-7 man-years. This compared with 4.1 man-years in Chile and 6-8 man-years in Guatemala. The reduction in Chile was less than the other two countries because of the higher proportion of irrigated crops and greater use of animal power. His estimates were based on estimated labor requirement rather than actual figures. Abercombie estimated that the employment in off-farm employment due to agricultural machinery manufacture, distribution, maintenance and repairs for eleven Latin American Free Trade Association (LAFTA) countries in 1968 to be less than 150,000. Although these jobs were at a much higher productivity and income level than the agricultural jobs, they only represented 0.2 percent of total employment and about 0.5 percent of the

number of persons employed in agriculture. Using data from Brazil and Argentina, Abercombie estimated that an investment of up to US $20,000 was required to create one job in tractor manufacturing which would produce two to five tractors each year. The problem here was that each tractor had the potential to reduce farm employment by five man-years during each year of operation. The labor displaced differed substantially from crop to crop and also a greater displacement occured at the early stages of mechanization -- just the opposite from Dawlaty's findings in Afghanistan. Abercombie stated that most agricultural machinery in Latin America is owned by large-scale private farmers. They chose mechanization because it was profitable and convenient for them due to the distortions in factor prices which enabled them to borrow capital at less than its opportunity cost to society. Abercombie recommended that the governments of Latin America stop policies which encouraged more mechanization and instead follow selective mechanization policies to ensure employment opportunities for their growing labor forces.

Gostch (1973) in his study of mechanization in Pakistan concluded that government subsidies biased the private profitability of technology in a socially undesirable direction. In addition, institutional conditions would lead to the same results -- even if resources were valued at their opportunity costs. In Punjab Province, which is ecologically suitable for mechanization, he estimated that

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over five tractor horsepower per 100 cropped acres were available in central Punjab. This concentration was primarily related to the significance of irrigation, as nearly 75 percent of privately owned tractors were located on farms that had tubewells. The second reason was related to the farm sizes. Gostch concluded that tractorization in Pakistan was following a familiar pattern with the larger farmers adapting first. Government policies provided numerous incentives to mechanize. He suggested a policy which would reduce the divergence between net social cost and net private benefits by pricing capital at its opportunity cost. In addition, institutional changes would decrease the incentives to mechanize. Gostch did not see these as ways to improve the income distribution or increase employment, but they may lead to continued agricultural growth and a slow rise in farm wages sufficient to give the masses at least a nominal participation in the Green Revolution. Gostch reached the conclusion that the social net benefits from mechanization were negative. He also argued that if there were any benefits from mechanization, large landlords and urban consumers received them while the tenants and the landless were the adversely affected group.

Gemmil and Eicher (1973) reviewed mechanization research in Asia, Africa and South America and divided these into short-term static studies, medium-term dynamic studies, and long-term perspective studies. The short-term studies mostly included cost-benefit analyses concerned with one

locality and tended to focus on a particular machine. The medium-term studies are the less common of the three types and tended to be carried out at the regional level. The long-term studies were usually carried out to explain the historical process of mechanization. Eicher and Gemmil observed that government programs and policies mechanization can be divided into short-, medium-, and long-term. Researchers have generally concentrated on short-and long-term policy questions. They noted that researchers have often reached unjustified regional and national conclusions from studies in limited geographical areas. A drawback in many studies of farm mechanization was their failure to pursue specific policy questions. They believed that the question of mechanization is an empirical one and should not be solved by rules of thumb, and that the most acceptable mechanization policy would involve a compromise between alternative goals such as food production, export crop production, employment, and income distribution.

Merril (1975) reviewed a large number of mechanization studies in developing countries. He thought the farmers decision to substitute machinery for labor or animals depended on the relative prices of inputs or changes in the production function that increased the marginal productivity of machinery. His review showed that there is no way to prove or disprove general claims such as mechanization increases agricultural output and employment. From the review of the studies, he concluded that when mechanization

replaces animal power it results in a reduction in labor inputs. The degree to which the labor input will be reduced depends on the crops in question, the farm size, the extent, and type of mechanization. Mechanization in its early stages may be associated with a slight increase in cropping intensity, crop yields, and type of crops grown. Merril thought that unless there were government policies to prevent it, mechanization may result in an increase in land holdings and tenants displacements. His review of the studies indicated that the non-agricultural employment generated by mechanization replaced only a small part of those displaced by mechanization. He concluded that while mechanization of agriculture is a continuous and inevitable process in economic development, its speed and direction can be altered by public policies and programs.

Merril recommended that governments should not subsidize mechanization in a way that benefits large farmers, but it should support the development of agricultural machinery which can be used by small farmers and to a large extent be produced locally. He viewed mechanization as a part of modern agriculture which includes new yield increasing biological and chemical technologies.

Stavis (1978) made a detailed analysis of how China faced the political and social dimensions of mechanization. He discussed how China, through conscious policies, pursued mechanization programs that contributed to greater food production, equitable food distribution and significant job

enrichment. Chinese leadership used mechanization to accomplish the broader goals of social transformation. Stavis showed how mechanization policies developed in China and how the socio-political context shaped agricultural mechanization. Of significant importance is the fact that China has no seasonal internal migration and mechanization is needed to break the labor bottlenecks which resulted from increased multiple cropping. Another consideration was the conscious policy to improve the rural living standards and make it more equal to urban conditions. Mechanization was also used to free labor for other jobs, soil reclaimation, irrigation projects, etc. Finally, mechanization was used as a means to strengthen the economic foundations of large-scale collective agriculture.

Stavis saw that the striking aspect of agricultural mechanization in China was that its benefits are shared widely throughout the community of collectively owned institutions. This is one dimension in which China is different from many other countries. A dominant feature of China's mechanization program was a concentration on small-scale, labor-intensive agriculture.

Binswanger (1978) reviewed over 20 empirical studies on the economics of tractors in the Indian sub-continent and compared their reported results. Most of the studies reviewed were cross-sectional comparisons of various types of bullock operated farms with tractor operated farms. Other studies have compiled data for tractor farms only and have

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judged the impact of tractorization on the basis of before and after comparisons. Cropping intensity was the first performance measure considered. In areas where few opportunities exist for area expansion, the effect of additional power on cropping intensity is often regarded as a major potential benefit. However, the studies taken together give little support to the hypothesis that tractors are an important factor in crop intensification. When considering the yield effect of tractorization, out of 118 cases there were only five or six instances in which larger yield differences remain in the absence of equally large differences in fertilizers used. In all, the studies failed to provide much evidence for the yield increasing effect of tractorization. Another essential gain of mechanization which was considered was timeliness. No conclusive evidence was reached when all the studies were considered. Also, overall the studies did not show strong evidence of cropping pattern shifts. With respect to the effect of mechanization on labor displacement, Binswanger's review showed that as long as the wage rates remained low, there was little reason to expect tractors to gain a comparative advantage in labor intensive operations. The basic conclusions reached by Binswanger was that the tractor studies surveyed failed to provide convincing evidence for substantial increases in intensity, yields, timeliness and gross returns due to tractor use. Likewise, the evidence on labor displacement was far from conclusive.

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Disney and Elbashir (1984) analized the technical and economic performance of tractors and harvestors in the Sudan's irrigated Gizera Scheme and Gedanef mechanized rainfed farms. Their analysis sought to determine the employment effect and technical and economic efficiencies of mechanization. Their results showed that all inputs used in both areas had positive and significant marginal productives. They concluded that labor use was excessive, given the level of real wages used in their analysis. Their cost-benefit analysis gave a higher rates of return to tractors than combine harvestors.

Disney and Elbashir proposed policy recommendation which were in contrast to the recommeendations of the 1976 International Labor Office (ILO) mission to the Sudan. While the ILO mission argued for a reduction in the pace of mechanization, Disney and Elbashir contended that the social returns on imported agricultural machinery justified mechanization in the irrigated and rainfed sub-sector. They concluded that mechanization of agriculture in Sudan was justified in terms of both technical and economic efficiency analysis.

Binswanger and Pingali (1984) studied the evolution of farming systems and agricultural technology in sub-Saharan Africa. Using data from ten countries in the region, they studied the relation between the population densities and external markets with changes in farming systems, land-use pattern and institutions. They concluded that as population

densities increase, agricultural production intensify and the agricultural system become more responsive to labor inputs, purchased inputs, and investments in land - - such as irrigation. The increased population density lead to cultivation of relatively hard to work soils and so the farming system switch from the use of hand hoe to animal drawn implements and later to tractors. In sub-Saharan Africa chemical fertilizers was not commonly used, although it is usually associated with agricultural intensification, because long term soil fertility was maintained through periodic fallowing of land.

As the population density increases, land acquisition change from communal ownership to more narrowly defined group and ultimately to clearly defined private property rights. With these changes in land tenure and farming system, the institutions also change in form and functions.

Binswanger (1985) provided a conceptual frame to measure the benefits from agricultural innovations in land abundant areas of sub-Saharan Africa and the implication of that on agricultural research in the area. He concluded that under low population densities and at low technology levels the benefits of yield increasing technology are confined to the reduction in labor use associated with the area savings made possible by the yield increase. The higher the preexisting level of purchased inputs and machinery use, the more valuable is the yield increasing technology. The benefits, and probability of adopting labor saving

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technologies increase as the wage rate increase. He also concluded that in land abundant areas, the benefits of land quality enhancing innovations are independent of the value of land. The quality enhancing innovations that require labor are more widely adopted where labor is cheap.

Binswanger argued that, under land abundance, biological research has less opportunity to be adopted, because its benefits will be difficult to measure. In Thailand with an open land frontier, irrigation projects failed because of the limited demand for these types of innovations. The implication of this in the context of land abundant sub-Saharan Africa, is that yield increasing technologies may not be always appropriate. The limited research personnel and resources should concentrate on a limited number of problems. Research in sub-Saharan Africa, as Binswanger contends, should be targeted to improving the grain quality, pest resistance and drought tolerance of crop varieties. It is also important not to emphasize labor intensive cultural practices to raise yields, because in land abundant areas there is a very low demand for labor intensive practices. He concluded by saying that the emphasis on yield increase that most agricultural specialists from developed countries and Asia bring to Africa is counter productive in projects as well as in research.

In summary, this review of mechanization studies indicates that different conclusions have been reached with

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regard to the impact of mechanization on employment, financial profitability and output. The differences in conclusion are expected from the different forms of mechanization considered, crops under question and difference in macro policies, land tenure, water supply and farm sizes.

The consequences of changing farm power for agricultural and rural people have not always been beneficial. The effect of government policies on mechanization was documented by most of the studies. A wide variety of factors affect the decision taken by farmers to use, or not to use, farm machinery, but government policies have a great impact on that decision. Farm mechanization can be viewed as a continuous adjustment process involving people and government policies.

From the review of the studies, it is clear that the influences of mechanization on output or employment will depend on the type of machines used and the operations performed. In addition, it is also clear from the review that mechanization studies should follow a more dynamic setting by considering more than one crop and more than one operation to determine the influence of mechanization on employment or output. Conclusions from mechanization studies are usually limited to the area of the study due to differences between regions in regard to the many variables considered such as irrigation, topography, weather, and population density. The farmer's decision on whether to use

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more machine power or hired is a complex process that does not only involve the price of inputs and output, but a series of factors including land tenure arrangement, irrigation system, infrastructure, the farmer level of education, crops and crops varieties, availability of inputs, etc. Also the review of the studies showed the number of labor displaced by machines is due to a number of factors including the crop under investigations, method of irrigation, soil type, and farm size. Some studies suggests that there is a relation between the choice of technology and the land/man ratio, the market for inputs and output, and land use pattern and institution. This makes the policy implications of most of these studies geared to the short term or medium term. As the factors and environment change overtime, new evaluation of the situation and new policy prescriptions may be relevant.

The review of the studies also showed that usually the benefits and cost of an alternative production technology are not equally distributed. The political environment has a profound effect on the distribution of the benefits and cost. On the other hand, in countries where there is community control over the factors of production (e.g. China), the results suggests that the benefits and costs are universally shared.

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1.4 Need For The Study

Sudan, as is the case in many developing countries, has a history of economic planning. Since independence the government launched three economic development plans: the Ten Years Plan (1960/61 -1970/71), the Five Year Plan (1970/71 - 1974/75), and the Six Years Plan (1977/78 - 1982/83). The common theme of these plans was the dominance of the agricultural sector. All the development plans stressed the expansion in agricultural production to reach self-sufficiency in food crops and increase exports earnings.

In the early 1970's Sudan was reported in the world news as the "Bread-basket" of the Middle East. Sudan, with its vast agricultural potential coupled with oil producing Arab countries' capital, was thought to be a perfect combination to supply the food needs of the Middle East. A development programme based on a bread-basket strategy was initiated, with capital from oil producing Arab Countries providing the major source of investment capital. During the first half of the 1970's the government pursued a policy of expanding cultivated areas under the irrigated and rainfed sub-sectors. Due to declining yields in all agricultural sub-sectors during the second half of 1970's, the government decide to concentrate on rehabilitating the already cultivated areas rather than expanding the area in production.

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In the mechanized sub-sector the government policy was to continue the expansion of private sector farms (1000 - 1500 feddans) and also to allot large areas to national and foreign investors. The objective of this policy was to produce enough sorghum - the major staple - to meet domestic consumption, and also export an increasing surplus.

Mechanized rainfed farming is currently the most dynamic sub-sector in Sudanese agriculture, in terms of its rapid area expansion. Mechanized rainfed crop production in the Central Clay Plains was promoted by the government because of both its contribution to the domestic food supply -- sorghum being the main staple diet -- and its potential as a source of badly needed foreign exchange.[1] Also the sub-sector was credited with bringing vast sparsely populated plains under crop production (ILO, 1976).

The Mechanized Farming Corporation (MFC) officials and the World Bank, the main international donor to MFC, believe that there is a seasonal labor shortage, especially during harvest time.[2] To relieve the harvesting bottleneck, combine harvesting of sorghum, which can easily be widely adopted, is seen as a viable technical option. The MFC is also

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[1] In both the five year (1970/71 - 1974/75) and the six year (1977/78 - 1982/83) there was an emphasis on expansion of the MCPRS. It was credited with saving the country in the early 1970's, when drought struck the Sahelian zone (see Ministry of Agriculture, Food and Natural Resources, "Six Years Development Plan Agricultural Sector, 1977/78 - 1982/83," p. 6-7).

[2] IBRD, "Appraisal of Second Mechanized Farming Project, Sudan," IBRD, 1972.

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pursuing active adaptive research through its own organs, and with the collaboration of the National Research Council (NCR) to introduce herbicides and combine harvesting of sorghum and sesame in the MCPRS.[1] The government through its polices of overvaluing the local currency, cheap credit, and low import duties on machinery, fuel and spare parts is creating an incentive for farmers to use more capital intensive technologies. Finally the government is actively promoting the combine harvesting of sorghum which is the major crop under the Mechanized Crop Production Schemes (MCPRS).[2]

Recently, concern has been raised that the government policies of cheap credit and subsidized imported inputs are subsidizing rich farmers, misallocating valuable and needed resources, and enabling inefficient farmers to stay in business (Bateson, 1983; and Kursany, 1984).

To date, there is a serious lack of micro economic data to study and evaluate the financial and economic viability of mechanized rainfed farming. Secondly, there is a need to evaluate the financial viability of the different cultural operations (harvesting) that can be adopted by farmers.

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[1] MFC, "Task Force Report," Khartoum, Sudan, January 1984.

[2] The Minister of Agriculture in an interview with "El Sahafa" daily newspaper (9/14/1983) was quoted as saying, "we will pursue to mechanize harvest sorghum and sesame grown under rainfed agriculture."

Thirdly, it is necessary to look at the MCPRS from the point of view of the society, to see whether the country as a whole is benefiting or whether their schemes are a means of subsidizing rich farmers.

This study attempts to provide some understanding of the economics of the MCPRS system, to help identify appropriate policies concerning future development of the MCPRS in the Damazine area, and relate that to the development of the country's food strategy.

1.5 Objectives of the Study

This study will attempt to meet the following objectives:

1.) To describe the mechanized crop production rainfed schemes (MCPRS) in the Damazine.

2.) To evaluate the financial viability of the mechanized crop production rainfed schemes in the Damazine and measure the effects of adopting full mechanization of sorghum harvest on farm income and employment.

3.) To identify and measure the economic viability of fully mechanized harvested sorghum vs. partially mechanized sorghum in the Damazine mechanized crop production rainfed schemes.

4.) To identify the benefits and costs of alternative policy prescription for the future development of the mechanized crop production rainfed schemes.

1.6 Organization of the Study

Chapter 2 presents a descriptive profile of the study area's physical characteristic and the farming policy environment. Chapter 3 provides a descriptive background to the study, including the historical development of the mechanized rainfed schemes and a discussion of the farming system in the Damazine area.

Chapter 4 provides the description of the structure of the linear programming model used in the study. Chapter 5 includes an evaluation of the basic model, the results, and the sensitivity analysis.

Chapter 6 contains the financial analysis of the farm enterprise budgets when sorghum harvesting is partially and fully mechanized. The second part of the chapter discusses the economic costs and benefits of sorghum production when harvesting is partially and fully mechanized. Finally, Chapter 7 discusses policy implications of the findings.

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CHAPTER 2

PHYSICAL CHARACTERISTICS AND POLICY ENVIRONMENT FOR THE MECHANIZED CROP PRODUCTION RAINFED SCHEMES IN THE DAMAZINE

2.1 Physical Characteristics of The Area

The Damazine mechanized crop production rainfed schemes (MCPRS) lie in the Blue Nile Province, which is a part of the Central Region of Sudan. The MCPRS area lies between latitudes 32° 00', and 34° 40' north and longitudes 11° 50', and 13° 15' east (Figure 2.1). The study area lies to the west of the Blue Nile River and includes approximately 720 sq. km.

2.1.1 Topography and Soils

The area is part of the Sudan Central Clay Plains which extend from east to west across the country. The land scape of this area is flat with very gently undulations. Most of the area is approximately 600 m above sea level. The flat plains have a gentle slope of 0.5-1.0 percent (Abdelkarim, 1976) with a few isolated high rock outcrops, which are locally known as "Jebels."

The soils are montmorillonitic clays transported from the Ethiopian Plateau by the Blue Nile (Tothil, 1964). The underlying rocks are precambrian basement complex and have no influence on the top soil. The isolated mountains are

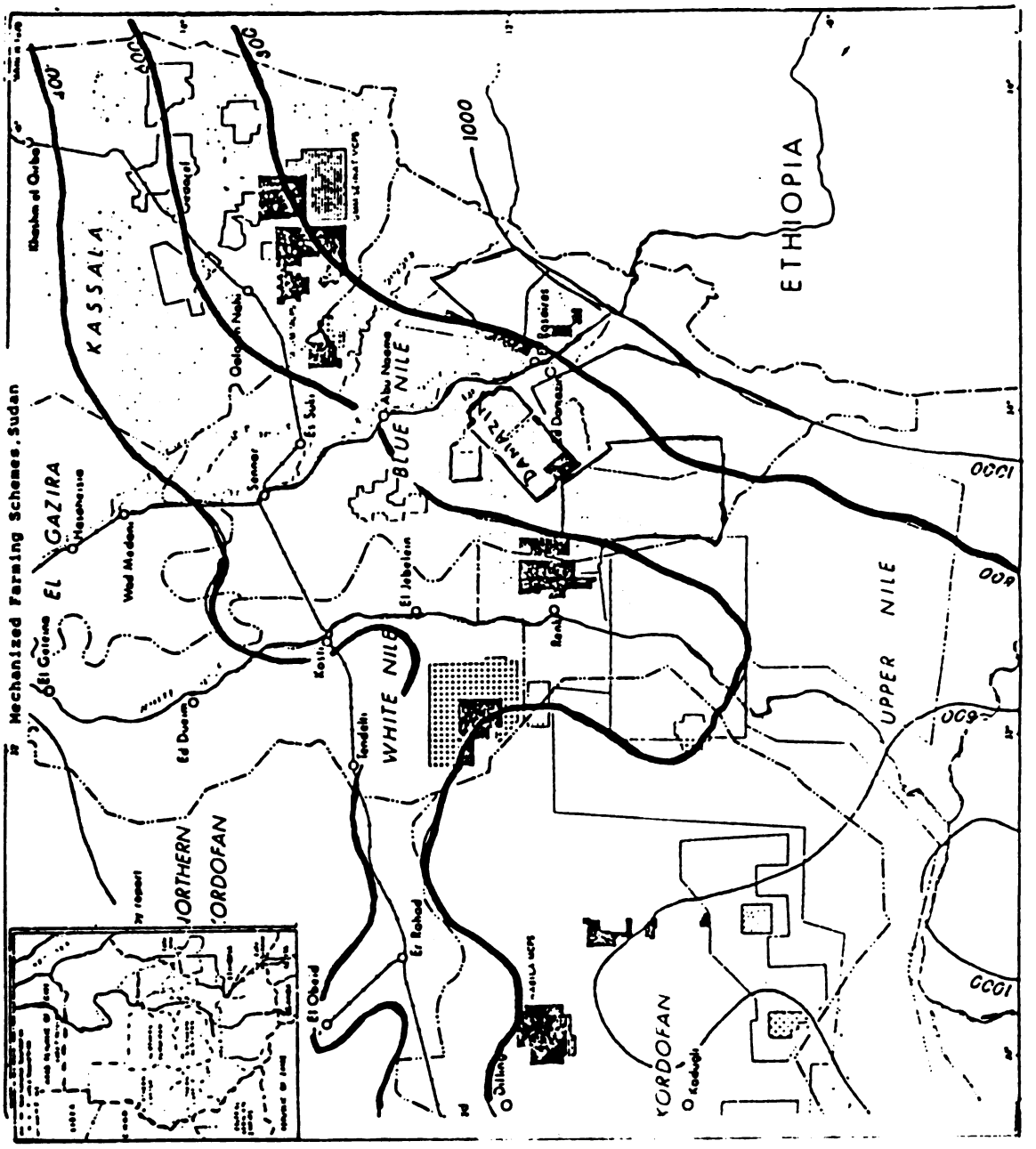

FIGURE 2.1 Mechanized Farming Schemes, Sudan

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granitic outcrops with narrow gently sloping pediment, and shallow profiles influenced by slow weathering. The area is mostly dominated by cracking clays (Dawoud, 1971). The soils are alluvial in origin with a clay content of 70-80 percent. They have a well developed self-mulching surface layer. They swell when wet and shrink when dry, resulting in deep wide cracks. Finally the soils are very sticky and plastic when wet.

2.1.2 Climate

The study area lies within the semi-arid zone. The area rainfall is associated with the West African air mass that picks up moisture in the South Atlantic. The rainfall pattern is unimodel. Rainfall occurs between May and October, with the highest precipitation during the July and August. Annual average rainfall for the Damazine area is shown in Figure 2.2. The Damazine area lies within the 600-800 mm rainfall isohyeles which run in a southwest-northeast direction (Figure 2.1). The amount and distribution of rainfall is very critical in determining the cropped area and the amount of output produced. Rainfall is also critical in determining the number of days available to complete agricultural operations (Mohamed, 1978). The fact that the soil gets sticky and plastic as its moisture content increases, make it impossible to work the fields until 1-2 days after heavy rains.

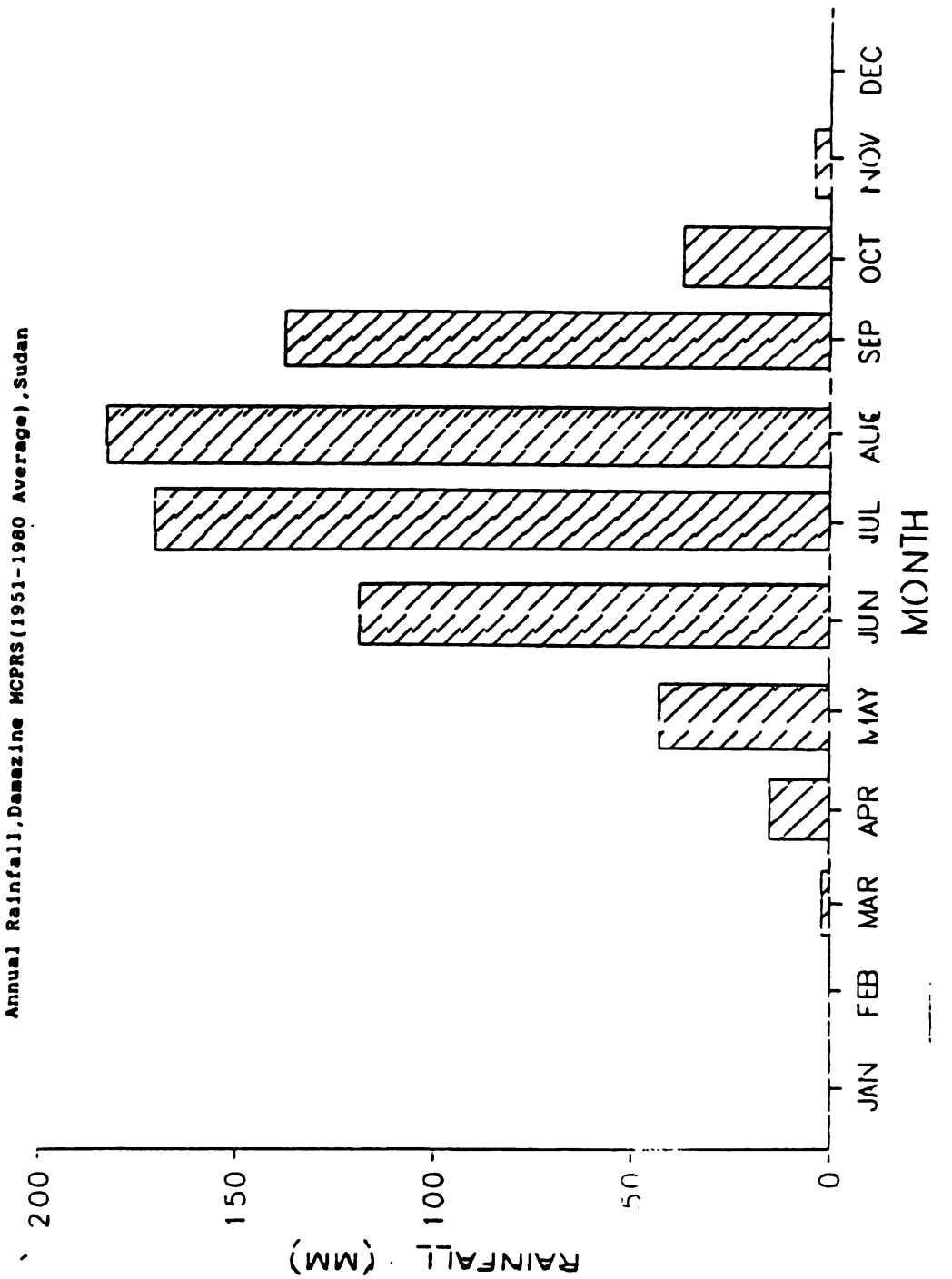
The daily mean temperature ranges from 30 to 40 ^{o}C (86 - 104 ^{o}F). April is the hottest month, with a mean temperature

FIGURE 2.2

Annual Rainfall, Damazine MCFRS (1951-1980 Average), Sudan

FIGURE 2.2

Annual Rainfall,Damazine MCPRS(1951-1980 Average),Sudan



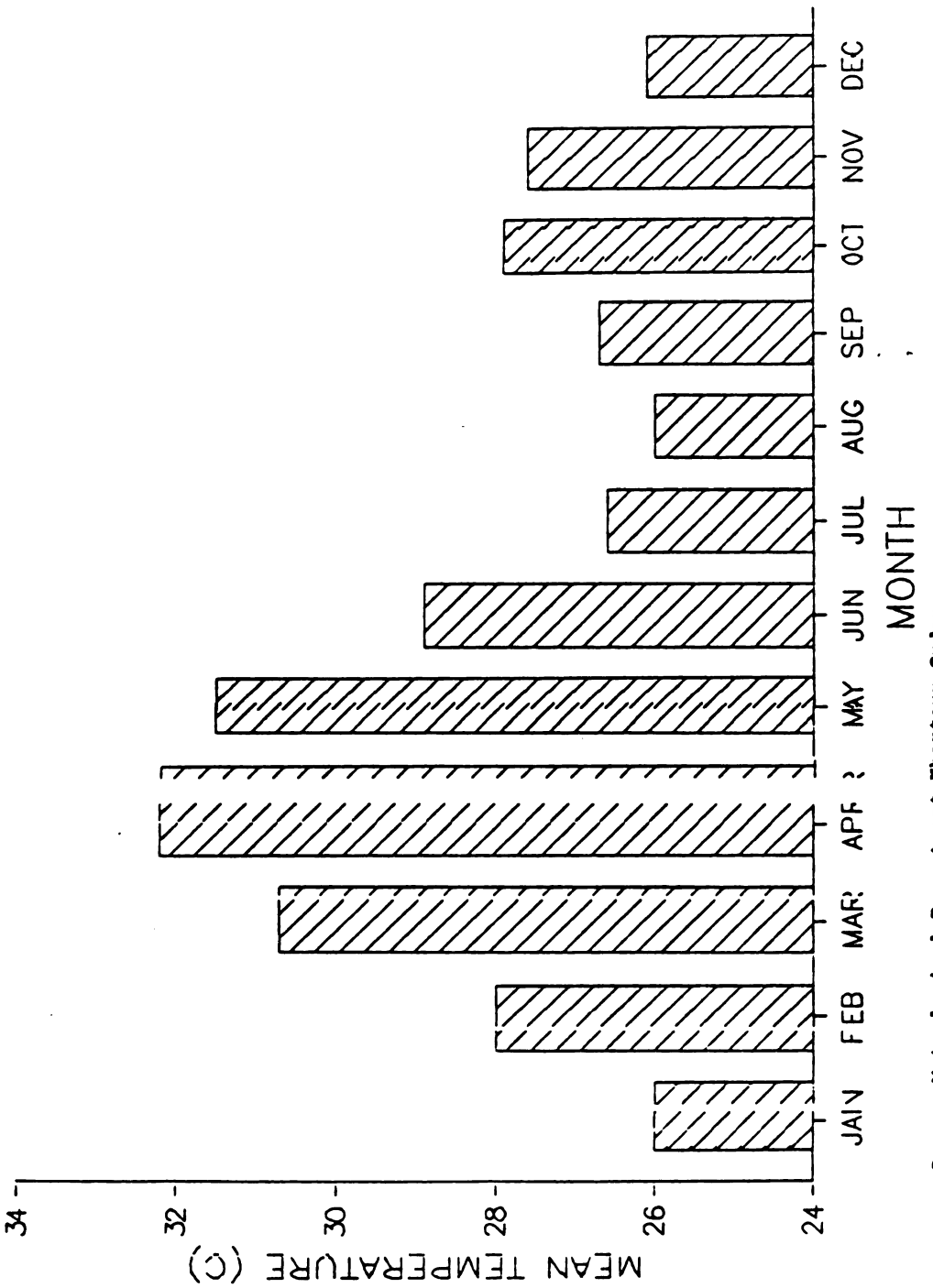
Source:Metrological Department,Khartoum,Sudan.

FIGURE 2.3

Rainfall MCPRS(1951-1980 Average), Sudan

FIGURE 2.3

Mean Temperature, Damazine MCPRS (1951-1980 Average), Sudan



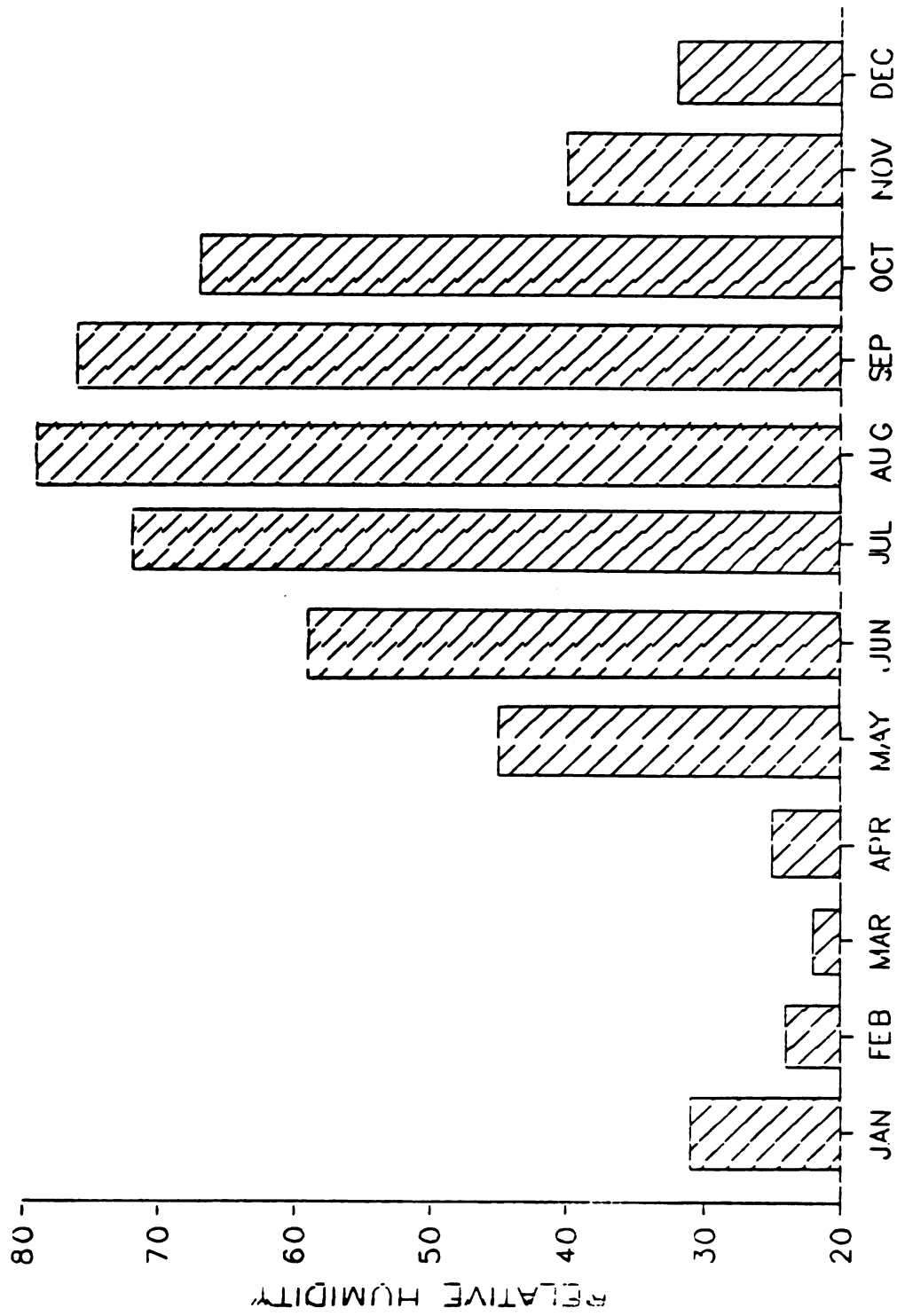
Source: Metrological Department, Khartoum, Sudan.

FIGURE 2.4

Relative Humidity, Damazine MCPRS (1966-1980 Average), Sudan

FIGURE 2:4

Relative Humidity, Damazine MCPRS (1966-1980 Average), Sudan



Source: Metrological Department, Khartoum, Sudan.

of 32.2 °C (90 °F), and January is the coolest month, with a mean temperature of 26.0 °C (79 °F).[1] (Figure 2.3). The relative humidity rises to 70 percent during the rainy season and drops to around 20-30 percent during the dry season (Figure 2.4).

2.1.3 Vegetation

The Damazine mechanized rainfed farms lie within the low rainfall woodland Savannah (Harrison and Jackson, 1958). The dominant types of trees in the area are the Acacia's; Acacia Seyal, A. tishula, A. complylacanth, A. bulanities, and A. senegal (Gum Arabic). These Acacia's alternate with grasses and other trees such as Lannea fruticosa, Gardina species, Lanchocarpus Laxiflorus, Combretum hartmannianum, and Albizzia species.

There are a wide variety of grasses in the area. The most common annual grasses are Sorghum purpureasericem, Cymbopogon nervatus, Hyperhenia pseudocymbaria, Hibiscus species, and Sehima ischacemoides.

2.1.4 Domestic Water Supply

In general, water is scarce in the Central Clay Plains, except around streams and rivers. The shortage of underground water is due to the lack of a basement complex. (Shazali and Abdel Magid, 1972). The resulting shortage of domestic water is cited as one of the handicaps to the

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[1] Sudan Metrological Department, "Climatological Normals, 1951-1980," Khartoum, Sudan.

development of the Central Clay Plains.[1]

In the Damazine MCPRS area, as in other parts of the Central Clay Plains, surface water disappears completely by the beginning of harvest (October/November) and does not reappear again until about the end of June at the beginning of the next rainy season. The general method of providing domestic water for permanent settlements around the foot of the mountains is to dig water reservoirs ("hafirs") that are fed from natural drainage. The farmers in the MCPRS dig small reservoirs to store rain water.[2] The large scale movement of nomadic livestock herds at the beginning and the end of the rainy season puts an additional strain on drinking water supplies. These herds are also a serious threat to the crops grown along the route to water supplies inside the farms.

The farmers' "hafirs" usually dry out by the end of the rainy season. When this occurs, farmers have to transport drinking water for farm laborers from the nearest village "hafirs." In low rainfall years, farmers may be restricted from taking water from this source. Under such conditions, farmers may be forced to go to the Blue Nile River to obtain

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[1] J. H. K. Jefferson, "Hafirs or Development by Surface Water Supplies in the Anglo-Egyptian Sudan," Tropical Agriculture, Vol. 31, pp. 95-108.

[2] Water reservoirs are locally known as "Hafirs." They are dug in depressed areas to catch rainfall run-off. Usually a "hafir" has dimensions of about 20x20x4 m. Water is taken from the "hafir" and distributed to casual field labor, using tractor pulled trailers.

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drinking water. The shortage of drinking water can have a pronounced effect on the costs of production, especially in low rainfall years, and/or in times of gas-oil shortages. This is because the water is hauled using a trailer pulled by a tractor or sometimes in tanker trucks.

2.2 The Policy Environment

In Sudan the government emphasizes the need to increase both domestic food supplies, and agricultural exports as the key to economic growth.[1] This strategy calls for horizontal and vertical expansion in the agricultural sector. Farm mechanization is seen as one of the important vehicles to increase agricultural production for domestic and export markets (Mohammed, 1982). The country is relatively sparsely populated, with a low man/land ratio (FAO, 1973). Thus, mechanization is seen as a way to substitute machinery for manpower in a country where animal power is not widely used.

In mechanized rainfed agriculture, the MFC is working to create conditions for full mechanization of all crops grown, in response to a perceived increasing shortage of seasonal labor (ILO, 1976). The World Bank, the main foreign donor to the MFC, also supports MFC policies of increased

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[1] Democratic Republic of The Sudan, Ministry of National Planning, The Six Year Plan for Economic and Social Development 1977/78-1982/83, (Khartoum: D.R. of The Sudan), p. 47-72, (in Arabic).

mechanization in the mechanized crop production rainfed schemes.[1] The speed of adoption of available mechanical technology is influenced by the economic factor scarcities, and macro-economic policies, such as the interest rate. Mechanization could be directly promoted through subsidies, or indirectly through cheap credit policies, overvalued exchange rates, special tax and tariff treatments (Binswanger, 1984).

2.2.1 Machinery Import Policy

Sudan imports all its motor-driven farm machinery from abroad. The country has experienced a continuous trade deficit most of the period since independence in 1956 (Table 2.1). Several times during this period, restrictions have been imposed on many imported commodities. Yet, the importation of agricultural inputs has never been restricted or curtailed. Importers of farm machinery need only to present a certificate from the Agricultural Engineering Administration of the Ministry of Agriculture and Irrigation showing that the particular machine is suitable to work under Sudanese conditions. As a result, many different kinds and makes of machinery have been imported, making the importation of spare parts and maintenance of machinery a major problem (Simpson and Simpson, 1983).

Also, Sudan's currency has been overvalued during most of the period since independence (Table 2.2). The

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[1] IBRD. "Appraisal of Second Mechanized Farm Project, Sudan," (Washington, April 6, 1972), pp. ii, iii.

TABLE 2.1

Balance of Payments (1970-1982),Sudan.

YEAR	EXPORTS	IMPORTS	BALANCE
	In Million Sudanse Pounds(LS)-a		
1970	103.91	100.12	3.79
1971	114.37	115.44	-1.07
1972	124.35	117.91	6.44
1973	152.19	101.85	.34
1974	122.01	247.49	-125.48
1975	153.47	359.88	-207.41
1976	193.01	341.39	-148.38
1977	230.18	376.49	-146.31
1978	202.34	449.46	-247.12
1979	232.67	477.32	-244.65
1980	271.34	788.19	-516.85
1981	370.01	866.71	-496.69
1982	483.11	1213.79	-730.68

Source:Bank of Sudan,"Economic and Financial Survey," BOS,Khartoum,Sudan,1982.

a-In 1984 the Official Exchange Rate LS 1.3 =US $ 1.00

TABLE 2.2

Overvaluation of the Exchange Rate in the Sudan
[1970-1980]

Year	Nominal (LS/$)-c	Real-a (LS/$)	Overvaluation-b (%)
1970	.348	.522	50
1971	.348	.496	42.5
1972	.348	.516	48.3
1973	.348	.496	42.5
1974	.348	.506	45.4
1975	.348	.558	60.3
1976	.348	.562	61.5
1977	.348	.607	74.4
1978			
Pre-June	.348	.64	83.9
Post-June	.4	.64	60
1979			
Pre-Sept.	.4	.31	82
Post-Sept	.4	.731	46.2
1980	.5	.819	63.8

Source: Sigma One Corporation,Raleigh,N.Carolina,1982.

a-The 1972 black market rate from Pick's Currency Index (LS .516= US$ 1.00) was assumed to be the real exchange rate. Real rates for the remaining years were calculated using the Consumer Price Index for Sudan(1975=100),CPIs, the IBRD world inflation index(1975=100),CPIw,and the following formula:

$$E_r = E_i \frac{CPIs}{CPIs} \frac{CPIw}{CPIw}$$

where E_r is the real exchange rate in year r.

b- Overvaluation $= \frac{E_i - E_r}{E_r} 100$ where E_r is the nominal exchange rate in year r.

c- LS = Sudanse Pound = 100 Piasters; $ = US$.

governments exchange rate policy has permitted the importation of agricultural machinery at the official exchange rate. Since 1969, the Agricultural Bank of Sudan (ABS) has been the major importer of farm machinery (Table 2.3). The Bank, as a government agency, has obtain foreign exchange both at the official exchange rates and through international donors. Most of the Banks agricultural imports have been allocated to the MCPRS farmers.[1]

2.2.2 Taxation and Subsidies

Whatever the implicit objective of the tax structure, it provides an incentive to distort resource allocation. The signaling power of taxes and subsidies are likely to exert an increasing influence on the choice of resources. In Sudan taxes make up a very important part of government resources, providing at least 80 percent of the central government's revenue since the mid-1970s (Sigma One Corporation, 1982). These include import, export and local taxes.

Import Taxes: In Sudan there are three major types of import duties. The import tax, additional tax, and the defense tax. The combined levies on imports account for about 50 percent of the total tax revenue. The import tax consist of 25 different ad valorem rates, and 16 specific rates accounting for about 40 percent of all tax revenues (Economic Survey, 1984). The import tax ranges from as low as 6.5 percent to more than 600 percent (Table 2.4). The

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[1] Agricultural Bank of Sudan, records.

TABLE 2.3

Total Tractor Importation of the Agricultural Bank of Sudan, Compared to Total Sudan's Importations [1969-1979]

Year	Total Importation		%
	(Sudan)	(ABS)	(ABS Share)
1969	1200	850	70
1970	1350	0	0
1971	740	568	76
1972	1300	1000	76
1973	900	0	0
1974	1630	1387	85
1975	1530	0	0
1976	1240	1000	80
1977	1722	500	29
1978	972	0	0
1979	711	0	0
Total	13115	5305	40

Source: Agricultural Bank of Sudan,Khartoum,Sudan,1983.

TABLE 2.4

Import Tax Rates on Selected Items,1969-1974,Sudan-a

Item	1969	1971	1972	1973	1974
Selected Food Stuffs					
Wheat	14.4	18.1	25.1	6.3	6.5
Sugar	35.8	36.2	36.2	34.6	53.5
Tea	49.6	44.4	32.3	50.6	29.1
Coffee	101.7	75.4	71.8	36.2	29.1
Cigarettes	604.2	634.2	774.3	639.8	670.6
Rubber	48.4	33.2	64.3	30.9	35.4
Iron and Steel	40.3	41.3	35.5	30.9	31.3
Machinary					
Electric	59.9	57.3	35.8	51.3	44.1
Non-Electric	21.2	33.1	25.7	23.1	20.4
Cars	67.1	113.2	75.7	80.3	122.2
Trucks	66.2	61.9	81.8	46.1	38.3
Textiles	61.6	45.5	40.2	37.5	41.3

Sources: Shanker N.A.,"Incentives for Resource Allocation: A Case Study of Sudan," World Bank Staff Working Paper No. 367,Washington,1979.

a-The Import Tax is Calculated Against the C.I.f Value.

additional tax is 13 percent and the defense tax is 15 percent. The custom duties are calculated on the CIF (cost, freight, insurance) price converted to Sudanese Pounds (LS). The rainfed sub-sectors, unlike the irrigated sub-sector, uses few imported inputs - - mainly machinery, spare parts, fuel, and jute sacks. Agricultural machinery, seeds and insecticides were exempted from import tax in 1976.

Export Taxes: There are two types of export taxes - - the export and the development tax. The export tax is calculated on ad valorem rates, which range from 0-15 percent. The development tax is 5 percent and is imposed on all exports. Sorghum is subject to both taxes, while sesame is exempted from the export tax.

Local Taxes: In Sudan the local governments has the power to impose local taxes. The most common local taxes on agricultural products are known as "usher and gibana." They are usually imposed as a percent of the price per unit sold. Typically, the price is based on a base year price, determined by the local authority and this price is changed as commodity price fluctuate. The "usher" tax is 10 percent of the value and "gibana" is 12 percent. The combined tax is usually between 10 and 15 percent of the actual price of the crop (Sigma One Corporation, 1982). In the Blue Nile Province, the tax rates in 1983/84 were LS. 1.50 per sack of sorghum and 3.70 per sack of sesame.[1] The local taxes on

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[1] Damazine Rural Council.

crops should be paid before the crop is transported off the farm. The farmers are supposed to pay the local taxes and obtain passes to transport their crops. Local governments have installed check points along the major roads, but some farmers evade the taxes by avoiding the check points. Farmers also can use the tax pass to transport more than the quantity for which the pass was originally given. The check point are usually manned by low paid guards, which open the doors to corruption.

2.2.3 Credit: Agriculture Bank of The Sudan

The Agricultural Bank of Sudan (ABS) is the major source of formal agricultural credit. The ABS provides short, medium and long term loans for qualified individuals. The requirements vary according to the duration and use for which the loan is taken, and the type of farm (rainfed or irrigated).

For the mechanized rainfed sub-sector, short term loans mature in 15 month and are intended to cover 70 percent of the variable cost of the activity for which it is intended. The costs are determined by the ABS regional offices (Table 2.5 and 2.6). Acceptable collateral required for securing short terms loan may include land, building, crops to be harvested or in stores, implements, bonds and shares, and guarantees by government, public institutions, autonomous agencies or cooperatives. Tables 2.5 and 2.6 clearly show that the cost estimates of agricultural activities is left to the discretion of the ABS branches managers.

TABLE 2.5

Agricultural Bank of Sudan: Estimated Cost of Land Preparation and Planting in MCPRS, Season 1983/84, Sudan

(In Sudanse Pounds)-a

Item	Branch				
	Gadaref	Dilling	Renk	Kosti	Damazine
Maintenance	1	1	1	1	1
Fuel	2	2	2	1.6	1.6
Food	1	.85	.85	.8	.8
Salaries	1.1	1.35	1.35	.9	.9
Weeding(cash)	2.5	2.1	2	2.3	2.3
Total	7.2	7.3	7.2	6.6	6.6

Source: Agricultural Bank of Sudan.

a- One Sudanse Pound (LS)= 100 Piasters.

TABLE 2.6

Agricultural Bank of Sudan:Estimated Cost of Sorghum Harvesting in MCPRS,Season 1983/84,Sudan

Item	Branch				
	Gedaref	Dilling	Renk	Kosti	Damazine
	LS/Sack[a]				
Cutting & Piling	2.3	2	2	2	1.5
Threshing	1.2	1.25	1.25	1.25	1.25
Sacks	1.03	1.5	1.5	1.5	1.5
Transportation	1.7	1.25	1	1.25	1.25
Total	6.53	6	5.75	6	5.5

Source: Agricultural Bank of the Sudan,"The Agricultural Bank of the Sudan Role in Granting Loans for Sorghum Production in the Sudan," The Second National Economic Conference,Khartoum,Sudan,1984.(In Arabic).

a- LS=One Sudanse Pound=100 Piasters.
One Sack of Sorghum=90 Kg.

Medium term loans, provides for purchasing capital items like farm machinery, mature in 5 years. The ABS give medium term loans in kind (i.e., machinery). Formerly, the loan covered 70 percent of the cost of the machine, but it was raised to 80 percent of the total cost in 1983.[1] Acceptable collateral to secure medium term loans includes immovable assets, credit letters from commercial banks, shares and bonds, and guarantees of the government and public corporations. Collateral for medium term loans should have a value equal to at least 130 percent of the loan. For rainfed agricultural there is no long term loans.

The interest rate on ABS loans has only been changed three times since the Bank started its lending activities in 1959 (Table 2.7). While the nominal interest rate, at least after 1981, is reasonable high; inflation has significantly reduced the interest rate to a negative level. The most conservative estimates put the inflation at 30 percent per year. (Zaki, 1983). Consequently, the ABS credit subsidy to MCPRS farmers may significantly increase profitability of the MCPRS farmers (Bateson, 1984).

The MCPRS are the principal recipients of government credit subsidies in the rainfed sub-sector. The traditional farmers in the rainfed areas do not receive any ABS credit as they do not qualify for credit according to the ABS's set rules.

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[1] ABS, Khartoum, Sudan.

2.2.4 Agricultural Research and Extension

The Agricultural Research Corporation (ARC) is the government agency responsible for agricultural research in the country. Sudan has a relatively long history of agricultural research compared to many African coutries. Research on irrigated crops - - cotton - - started in the 1920's. Research on rainfed crops started in the late 1950's.

The rainfed research station is located in the northern part of the Damazine mechanized rainfed area. The research is done on sorghum, sesame and a variety of other crops. The research on sorghum is concentrated on yield increasing and breeding combinable varieties. While a number of combinable varieties were released, mechanized crop production schemes farmers have not widely adopted them due to their low quality and poor drought tolerance. This situation also occurred in land abundant. Thailand where chemical and biological yield increasing technologies have not been widely adopted, because additional land can be put under crops.

The Mechanized Farming Corporation (MFC) is now financing adaptive research experiments which is being carried by ARC. The MFC through its own organs or the ARC does not carried out any research to determine the economic of crop production under the mechanized rainfed condition. Consequently, the program to introduce alternative sorghum harvesting technologies has not been evaluated financial or

economically.

One of the major functions of the MFC is to provide extension services to the farmers. Up to the late 1980's the MFC had no any form of extension programs or even information that could be passed to the farmers. The state farms which were run by the MFC and were supposed to be demonstration sites were financially a losing venture, partly due to lack of inputs at proper times. Recently the MFC established an extension department which started working in the Gedaref area. The department still lacks a trained staff and clear recommendations to offer to the farmers.

2.3 Selection of The Study Area

The research objectives will be address through a study of the Damazine MCPRS, Blue Nile Province. There were five main reasons for choosing this area.

1. The MCPRS are the fastest growing sub-sector within the agricultural sector. Approximately six million feddans are under this mode of production which only started in 1945. The Damazine area is second only to the Gedaref area, in terms of total area developed, but in the near future the Damazine has the potential to be the largest area under mechanized rainfed crop production.

2. The Damazine area has recently been the focus of large-scale private investment (20,000 feddans and more).

Some of these investments are joint venture between local and foreign investors.

3. Kenana Agricultural Research Station, which was initially established to generate new technology for rainfed agriculture, is in the Damazine. In addition, the country's only rainfed seed propagation scheme (Tozi) is in the Damazine.

4. The location of the Damazine (Map 2) may make it possible to generalize some of the study findings to other mechanized rainfall areas. This is due to the fact that its soils and rainfall are similar to both the Gedaref area to the east and the Renk area which border the Damazine on the west.

5. The author has personal experience with the Damazine MCPRS area, having worked as the manager of a 200,000 feddans government farm in the area between 1975-76.

2.4 Data Sources and the Analysis Methods Used[1]

Data Collection: Primary and secondary data were collected for the study. The primary data collection activities were carried in three complementary phases.

The first phase took place during March and April, 1983. This phase served three objectives: developing the

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[1] See Appendix A for detailed count of the data collection and research methods.

TABLE 2.7

Agricultural Bank of Sudan Interest Rates for Farmers,1959-1983,Sudan.

Date	Type of Loan	
	Short Term %	Medium Term %
1959 to 1966	6	8
1967 to 1980	7	9
1981 to Date	14	14

Source:Ahamed H.A.A.,"Agricultural Finance and Credit in the Sudan,"Department of Rural Economy,Faculty of Agriculture,University of Khartoum,Sudan,1983

sampling frame, studying the records of the MFC regional office in the Damazine, and visits to the study area. Using the MFC list of farmers as a sampling frame, approximately a 12 percent random sample (75 farmers) was selected from the total number of farmers (N=709). The second phase of data collection was carried out during June and July, 1983. A questionnaire was administered to obtain background information about the farmers and their farming conditions. Data on agricultural activities, technologies used, sources of inputs, credit, farm machinery, and government policies that affected the farmers' decisions were collected. The third phase of primary data collection was done during January and February, 1984. During this period a second questionnaire was administered to obtain input/output coefficients required to develop a linear programming model covering the 1983/84 cropping season.

In addition to the primary data secondary data was collected during the period, March 1983 to March 1984. Sources of secondary data collected included: feasibility studies for the MCPRS in the Central Clay Plains, records of privately owned companies in the Damazine, MFC records and reports, Agricultural Bank of Sudan records and reports, Ministry of Agriculture studies and reports, local government reports, and the records and publications of many other government agencies and departments.

The Analysis: After collecting the data and checking it in the field, it was taken to Khartoum - the capital city of

Sudan. There, the Ministry of Agriculture and Irrigation, Department of Agricultural Economics and Statistics microcomputer was used to load the data onto floppy disks. The disks were brought to Michigan State University, East Lansing for analysis.

The data collected is first used to describe the history and present operation of the mechanized rainfed schemes and the policy environment under which the system functions. The second objective of the study is met through the application of linear programming (LP). LP was used to evaluate income and employment consequences of alternative harvesting technologies - - partially and fully mechanized sorghum harvesting. The third objective is met through the use of enterprise budgeting to determine the financial viability of the MCPRS under both present condition and if fully mechanized harvesting of sorghum is pursued. Finally, budgeting techniques are used to determine the economic viability of the alternative sorghum harvesting technologies for MCPRS in the Damazine. The results from all the analytical techniques will be used in the final analysis to formulate policy recommendations and suggestions for future research.

CHAPTER 3

THE MECHANIZED CROP PRODUCTION RAINFED SCHEMES (MCPRS) OF THE DAMAZINE

3.1 Historical Background of the MCPRS in the Sudan

The development of mechanized rainfed agriculture in the Central Clay Plains of the Sudan can be divided into four phases. The criteria for identifying each phase includes (1) the type and rate of development, (2) production relations, and (3) the degree of government involvement and control. This criteria was established by Osman and Abdel Magid (1972), who also described the first three phases of MCPRS development. Their criteria have been extend by this author to identify a fourth phase.

Phase One (1944-1954): Mechanized farming in the Sudan started in 1944 as a government sponsored activity on 1,200 feddans in the eastern part of the country. The main objective of this venture was to supply the British troops in East and North Africa with food during wartime food shortages. The government initiated a sorghum production project using a tractor drawn single-row disc for land preparation and planting. The experience of the first two seasons showed it was not feasible to produce sorghum under complete mechanization of all the agricultural operations,

as labor was needed for weeding and harvesting. To meet this labor demand, share croppers were introduced and each was allocated 28 feddans. Under this arrangement, the government completed land preparation and planting mechanically and the cultivator completed the remaining operations manually. At harvest the crop was shared equally. In 1949/50 some notables and merchants were given up to 240 feddans and the government provided custom hire machinery services to these farmers. The area cropped reached 31,000 feddans by 1954. Development during this phase was confined to the Gedaref area in eastern Sudan.

Phase Two (1955-1968): In 1952 a working party was established by the government to evaluate the past experience of the mechanized farming project and to suggest policies for future development. As a result of their recommendations, the government made a number of decisions. The report advised the government to abandon direct state participation in crop production and concentrate on providing infrastructure and information to the private sector. Subsequently, pilot farms were established in several locations in the Gedaref area to study the problems of mechanized rainfed farming. In 1956 new areas were opened in the Blue Nile Province (now known as the Damazine Mechanized Crop Production Rainfed Schemes). In these schemes, individual allotments were increased to 1,000 feddan and leased for eight years.

Phase Three (1968-1978): All of the developments in the

first two phases were in the northern parts of the Central Clay Plains. These areas were developed first because of their light tree cover, which make it easier and cheaper to put the land into crop production. As these lands were exhausted, the new areas for expansion were in the high rainfall, high tree density southern sections of the area. The cost of bringing these areas into production become increasingly expensive. Consequently, the government stepped in with a program aimed at providing farmers with farm machinery and credit. To do this, the government established in 1968 the Mechanized Farming Corporation (MFC) to administer the whole mechanized rainfed sub-sector. Its responsibilities, as defined in the 1975 Act were to: (1) survey, demarcate and allocate land for mechanized farming; (2) assist private investors; (3) manage state farms; (4) promote research; (5) provide credit; and (6) provide services such as, extension and workshops for machinery maintenance.

When the MFC was established there were, 1,410,000 feddans already under production in Kassala, Blue Nile, and Upper Nile Provinces. The first plan executed by MFC covered a five year period (1970/71-1974/75) during which 2.7 million feddans were developed. The area developed was divided into three categories:

(1) private sector - self financed 1.7 million feddans;

(2) private sector - World Bank financed 600,000 feddans;

(3) public sector - State farms 400,000 feddans.

Phase Four - (1979 to present): The fourth phase is characterized by three developments. First, the government allotted about two million feddans to large scale private sector investors. The area allotted ranges from 5,000 to 500,000 feddans, but companies with areas over 20,000 feddans are not under the jurisdiction of the MFC. A new department in the Ministry of Agriculture, the Agricultural Investment Promotion Administration, was created to oversee companies with 20,000 feddans and over. In addition, special tax breaks and import duty exemptions were given to these companies under the "Agricultural Development and Investment Act of 1976."[1] Some of these companies were joint venture between Sudanese and foreign investors. For example, about 250,000 feddans was allotted to the Sudanese-Egyption Integration Agricultural Company, which is owned jointly between the Sudanese and Egyption governments, but run solely on a commercial basis.

A second important development was the MFC's decision to abandon its state farms, as the government found that state run farms in the mechanized rainfed sub-sector were unprofitable (MFC Task Force Report, 1984). The same recommendations, regarding the role of the government in the

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[1] Ministry of Agricultural and Natural Resources, "Agricultural Development and Investment Promotion Act of 1976," Khartoum, Sudan, (in Arabic).

development of the MCPRS, that were reached by the Government Working Party on mechanized rainfed farming in 1952 were again repeated by the Task Force formed to revise the role of the MFC. The recommendations called for the government to concentrate on providing services and information to farmers and to abandon any direct involvement in commercial crop production.

The third important development which characterize this phase was the decision by the MFC to legalize the selling of schemes titles by farmers. While this new policy has not yet been evaluated, some argue that it will increase the concentration of land in the hands of rich farmers who already operate more than one farm.

3.2 The Development of the Damazine Area

Mechanized crop production rainfed farming was introduced into the Damazine area in 1957, where 100,000 feddans were demarcated and alloted to farmers (Simpson, 1978). In the following year, 158,000 feddans were added. In the third year of development, another 198,000 feddans were alloted (Table 3.1). This expansion was not preceeded by any kind of feasibility studies. After a period of slow development, 299,000 feddans were allotted on the eastern side of the Blue NIle River. Unlike early development of MCPRS in the Gedaref area, the government did not play an active role in direct crop production in the Damazine area -

TABLE 3.1

Damazine MCPRS Area Development by Year (1957-1980),Sudan.

Year	Area	Cumulativ
	---Feddans('000)---	
1957	100	100
1958	158	258
1959	198	456
1967	26	482
1968	299	781
1971	409	1190
1975	202	1392
1976	22	1414
1978	200	1614
1980	52	1666
Total	1666	

Source: Mechanized Farming Corporation, Damazine Regional Office Records.

- except for a 2,000 feddans demonstration farm established in 1958.

In 1971 the government established a new policy which advocated direct government involvement in crop production in the mechanized rainfed areas. The main objectives stated for this policy were: (1) to stablize sorghum prices by building a reserve stock of sorghum; and (2) to establish the government as a leading innovator by demonstrating modern crop production systems. A state farm of 200,000 feddans was established in the Damazine in 1971. During the same period, 409,000 feddans were alloted to the private sector.

Between 1975 and 1980 another 476,000 feddans were allotted to the private sector. Unlike the development in the other regions, specifically Gedaref and Habila area, there was no foreign aid used for private farms development. A two million dollars loan was given by the Kuwait government to develop the state farm in the Damazine area.[1]

In 1977 more than 2 million feddans was allocated to large companies.[2] About 500,000 feddans of this land is already developed. Another dramatic development was the government decision in 1984 to abolish the government owned state farm and sell it to the Arab Authority for

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[1] MFC records.

[2] These companies are national and joint venture investments between Sudanese public or private sector and Arabic public and private investors.

Agricultural Development. Recent estimates by the MFC estimated the area with a potential for mechanized farming in the Damazine at between two and three million feddans.

3.3 The Farming System

This researcher's survey of 73 farmers in the MCPRS of the Damazine during 1983/84 season showed that all of the farmers were males and 93 percent of those interviewed were 40 years of age or older. Of the farmers interviewed, 95 percent had another income source beside farming. Analysis of the farmers' educational achievement shows that 54 percent had an equivalent of 6 years of schooling, 21 percent had 9 years of schooling, 19 percent were illiterate, 4 percent had a university degree, and 2 percent had a high school diploma. The educational level of the farmers surveyed was far higher than for the general population of the country.[1]

The survey shows that 75 percent of those farmers with another income source beside farming were merchants. Affan (1978), who studied the Habila MCPRS, Southern Kordofan Province, found that 88 percent of the farmers had a non-farming income source, and only 12 percent of the respondents gave farming as their sole occupation.

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[1] World Bank, "Annual Report, 1984," Washington, DC, 1984.

Typically the farm owner appoints a farm manager, locally known as the "wakeel," to carry on day-to-day farming decisions. While the survey showed that 90 percent of the farmers had "wakeels", the level of farm owner supervision varied between the farmers. Fifty eight percent of the farms surveyed were totally managed by the "wakeels," 42 percent of the owners said they were involved in running their farms, and only 10 percent of those interviewed said they managed their own farms. In addition, 4 percent of the farms' owners said they spent the whole season on their farm, 6 percent said they did not visit their farm, 20 percent said they spend 60 days or less on their farm, and 60 percent said they spent between 60 to 100 days on their farm during the 1983/84 cropping season.

Over 70 percent of the farms were deserted during the period between the end of harvest and the beginning of the new season. While none of the farms surveyed had permanent building, each farm had 4-8 grass huts for accommodation and storage during the cropping season.

3.3.1 The Land Tenure

Most of the land in Sudan is state owned, governed by the Land Settlement and Registration Ordinance of 1925. The government's policy is to retain land title and grant leases for the purposes and uses permitted by the law. In each province the Land Allotment Board is responsible for the allotment of rural land for the uses authorized by the regulations. In the case of the MCPRS, the MFC Board has to

approve Land Allotment Boards decisions before the leases can be granted to eligible individuals. The criteria for eligibility to MCPRS, as described by the MFC, require that the applicant (1) has or can obtain necessary agricultural machinery (2) has sufficient agricultural knowledge, experience, managerial ability and time to manage the farm, and (3) has sufficient capital to finance the farm.

The selected applicants are granted 25 year leases. The size of the leased farm can be 1,000, 1,500, or 2,000 feddans, depending on the location and year of allotment. Farms surveyed for this study had an average size of 1,500 feddans. Before signing the lease, individuals had to pay a LS. 1,500.00 development fees.[1] In addition, farmers pay an annual land rent. In the early 1940's, the rent was LS. 0.01 per feddan and was raised to LS. 0.05 per feddan during the 1960's. In 1978 it was raised to LS. 0.10 per feddan and raised again to LS. 0.25 per feddan in 1982. In March 1983 the land rent was raised to LS. 1.00 per feddan.[2]

The lease contract between the MFC and the farmer, upon allotment of the farm, details the relation between the two parties. The MFC requires that farmers cultivate the land according to MFC regulations.[3] The contract specifies that

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[1] One Sudanese Pound (LS.) is equal to 100 piasters.

[2] Actually, the MFC announced it was raising the land rent to LS. 2.00 per feddan, but due to pressure put on the government by the MFC Farmers' Union, the MFC was ordered to roll back its land rent to LS. 1.00 per feddan.

[3] Mechanized Farming Corporation, "Lease Contract for a Mechanized Scheme," MFC, Khartoum, Sudan, (in Arabic).

farmers must reside in their farms during the farming season, follow the rotation and guidelines set by MFC, and that at least one-third of the land in the farm is fallowed each year. Failure to comply with the lease conditions, or breaking any of the MFC regulations, can lead to the farmer's eviction without any compensation. Although MFC has the legal power to evict farmers for noncompliance with its regulations or failure to satisfy the terms of the lease, in actual fact farmers were only evicted if they failed to pay land rent. Although the farmers interviewed acknowledged signing the lease with MFC and understood its contents, all said they had not been questioned by MFC officials about their farming practices. MFC officials contend that a shortage of qualified manpower and transportation facilities prevents them for continuously monitoring the farming practices by the leases.

3.3.2 The Dominant Cropping Pattern

While the area is technically suitable for a wide variety of crops, only three crops are grown in the Damazine MCPRS[1] - - two cereals (sorghum and millet) and an oil crop (sesame). Sorghum has been planted in the Damazine MCPRS since it was started in 1957. In contrast, millet is a new crop in the area. Some farmers started to grow millet in the

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[1] Kennana Research Station studies in the area have shown that a number of crops can be commercially raised. These include maize, safflower, sunflower, soybean and cotton. Of these, only cotton is raised by large companies and on the state farm.

late 1970's, believing that it could restore fertility, command a higher price, and compete well with weeds. Of the 73 farmers interviewed, 27 percent said they were considering growing millet in the future. Of these farmers, 56 percent cited the fact that it restores soil fertility, 24 percent said because it commands a better market price, and 12 percent cited the belief that it suppresses weeds. Yet, Mahmond,[1] contends that there is no scientific basis to suggest that millet restore fertility (personal conversation).

Sorghum is the dominant crop, followed by sesame. The survey of 73 farmers in the Damazine MCPRS showed that approximately 85 percent of the total sample area was under sorghum, 15 percent was under sesame, and about 3 percent was under millet. The MFC records for all the Damazine MCPRS indicated that in 1983/84 season, 82 percent of the area was under sorghum and 18 percent was under sesame.[2]

3.3.3 Tree Clearance

Tree and bush clearance is required before crop production is possible. There are two modes of tree clearance - manual and partially mechanized. Partially mechanized tree clearing is done in two operations. First,

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1 Professor Mahmoud A. Mahmoud now works as a consultant to the MFC, on temporary release from the National Research Council. He was the head of the Kennana Research Station for a number of years.

2 Mechanized Farming Corporation Damazine regional office.

the tree are up-rooted using a heavy crawler tractor. The second operation, chopping and burning the trees, is done by seasonal labor. Formerly, the MFC custom hired its heavy crawler tractors (D7's and D8's) to farmers. Two crawler tractors would pull a ten ton chain across the area to be cleared, up-rooting the trees. Subsequently, laborers chopped the trees and burned the remains. In the early 1970's, farmers lost interest in this mode of tree clearance because they felt the mechanical operation left an uneven surface.

Manual tree clearance is now the only method used. The farm (1,500 feddans) is divided into 60 feddan squares (500 m by 500 m) which are locally know as "Marbu." A gang of 4-8 casual laborers is contracted to clear a "Marbu." The contract includes cutting the trees, destumping and burning the remains. The farmer pay the laborers the cash amount agreed upon in the contract, in addition to supplying them with raw food and water during their work period.[1] Tree cost of cleaning trees varies, depending on the tree cover density, type and age of the trees. Information this researcher collected suggests that the tree clearance costs an average of LS. 16.00 per feddan.

The MFC regulations require that farmers leave as wind breaks 10 m wide uncleared strip of trees every 500 m,

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[1] The labors are given raw food materials and they do the cooking themselves. The food materials given consist of sorghum flour, dry salted fish and/or wet salted fish, dried okra, onion, cooking oil, salt and pepper.

running east-west across the 2 by 3 Km farm. Also, the regulations require that gum arabic trees (Acacia sp.) and trees in low lying areas should not be removed. Field observations during the survey indicated that farmers in the area disregard these regulations and clear the whole farm area. Some observers believe that massive tree clearance in the MCPRS affects the micro climate of the area, with the recent decrease in rainfall cited as evidence (Kursany, 1984). The practice of massive tree clearance is also considered harmful to the environment, and it may contributed to wind and water erosion (Khider et. al., 1975).

3.3.4 Land Preparation and Planting

The mechanized crop production system utilizes wheel-tractors (70-75 horse power) and single-row disc-harrows with a seed box attachment loaded on top. Although the system is known as "mechanized farming," the only fully mechanized operations are land preparation and planting. The single-row disc-harrow has been used for land preparation and planting since mechanized crop production started in the mid-1940's. The disc-harrows used have a width that ranges between 3-4 meters, with 24-32 relatively low concavity discs which are 45-60 cm in diameters.

Land preparation is carried out after sufficient rain has fallen to germinate the weeds seeds and soften the soil. The first discing is usually done around mid-June. A second discing, sometimes necessary when the weeds population is

high, is usually carried out shortly after the first discing. The crops are sown with the second discing, unless a second discing was necessary before sowing the crops. In such a situation, planing is done with the third discing. The number of discings required depends on many factors, including the degree of weeds infestation, availability of gas oil, financial ability of the farmer, the rainfall situation and the crop sowing date.

While farmers usually plow no deeper than 15 cm, it is not known whether this is sufficient for the crops to utilize available soil moisture in the most efficient way (ILO, 1976). Khadir et. al. (1975) contends that the use of the single-row disc-harrow as a tillage and weed control implement results in poor seed bed preparation.

Planting usually start in late June.[1] Timeliness of planting is very critical in achieving adequate crops, with sesame more sensitive to sowing dates than sorghum (Mahmoud, undated). Sesame is sown first and is seldom planted after mid-July. Immediately after sesame is planted, farmers start sowing sorghum. Kenana Research Station recommends that sorghum be sown between late-June and mid-July. In practice, some farmers continue to sow sorghum until late August or even early September. Simpson (1978) contends that farmers delay planting to build up soil moisture, which reduces the

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[1] Kenana Research Stations "Technical Agricultural Papers" National Research Council, Undated.

time available for land preparation and planting. When soil conditions permits, land preparation and sowing are carried out in two shifts - a day shift and a night shift.

None of the farmers surveyed used chemical fertilizers or herbicides. The only chemical fertilizer use is AlderX T for seed dressing. The survey conducted during the 1983/84 season revealed that of the 73 farmers interviewed, only 3 percent used improved seeds.[1] Thirty-one percent of the farmers used seeds produced by other farmers and 65 percent used their own seeds.

3.3.5 Weeding

Two to three weeks after the crop emerges, the fields are generally manually weeded two times. In some cases, a third weeding is carried out. Mohamed (1982) hypothesized the factors that determine the number and timing of weeding include the previous season's crop management, current season, rainfall, timing of land preparation and planting, availability of labor and/or operating capital, crop establishment level, and anticipated returns from the operation.

Weeding is carried out by gangs of 3-7 casual labors who work on a per area contract basis. The contract is usually based on 60 feddans area ("Marbu"). The work is carried out using shafted hand hoes. The labors work from

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[1] Improved seeds refers to the seeds produced by the Plant Propagation and Certification Department of the Ministry of Agriculture.

sunrise to dawn, putting in about 10 hours of work. The contract include cash expenses plus feeding and drinking water supplied by the farmer during the period of the work. The cost of weeding varies depending on the crop, area, weeds type and density, and rainfall quantity and distribution. Kenana Research Station recommends that weeding be carried out in the first six weeks after planting. Farmers sometimes weed later to insure a clean crop stand to attract harvest labor, especially for sesame.

3.3.6 Harvest

Sorghum and sesame are harvested in two separate activities. Sesame is harvested first, starting in early October. It take 90-100 days to mature, depending on the variety and weather conditions. The harvest timing is very critical because if the crop is harvested prematurely, the seeds can not be released from the pods. On the other hand, if the crop is left to dry the pods will open during harvesting and the seeds will be lost. Sesame is cut when the pods turn yellow, bound into bundles and the bundles are stacked in an upright-position against each other in clusters of 400 bundles, known as "hila."[1] Cutting sesame takes 10-15 days, and the crop is left to dry before shaking it to release the seeds.

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[1] A "hila" is the local name used for a collection of 400 bundles of sesame plants. The bundles are tied firmly and each is about 45-60 cm. in diameter.

The casual laborers used to cut the sesame crop are paid according to the number of "hila's" they cut. The survey showed that the average laborer can cut 1.5 "hilas" par day. On the average, there were seven "hilas" per feddan. Casual labor are given raw food materials and water during the work period. Unlike sesame cutting, threshing of the sesame seed pods is contracted on the basis of a final payment per full sacks of sesame seeds.[1] Sesame threshing is done by casual labor who works in groups of 2-3 individuals. The laborers hold the crop bundles upside down over a 2 by 3 meters cloth and shake them. After shaking the seeds out of the pods, they use sieves to separate the trash from the seeds. The clean crop is then put into jute sacks.

Sorghum harvesting is usually carried out after the sesame harvested is completed. Sorghum harvesting was partially mechanized in all the 73 farms surveyed. Sorghum is harvested by gangs of casual labor contracted to cut the sorghum heads heads and pile them into heaps. Usually 2-4 heaps are made per 60 feddan area. The casual labor are paid in cash and also provided with raw food and drinking water. The cost of cutting sorghum heads is a function of the time of the contract, the variety of sorghum, and the reputation of the farmer in honoring contracts with casual labor. After the sorghum heads are piled into heaps, they are threshed using a privately owned stationary combine harvestor. The farmer pays the combine operator on a per sack basis.

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[1] On the average, a sack of sesame weigh 75-80 Kgs.

3.3.7 Farm Labor

Farmers in the MCPRS hire both permanent and seasonal labor. The permanent labor includes a farm manager and a farm guard.[1] They are paid on a monthly basis and are provided raw food and drinking water. Beside their salary, the permanent labor is given an incentive, in the form of grain sorghum, at the end of the season.

Seasonal labor is of two types, skilled and unskilled. The skilled typically includes two tractor drivers and two assistant tractor drivers. Those are hired for two months for land preparation and planting the crops. They work in alternate shifts, one team during the day and the other at night. On the average, drivers are paid LS. 80.00 per month and the assistant drivers LS. 40.00 per month - - plus food, water and tea. One driver and his assistant are kept for the whole cropping season to transport food, water, crops and farm laborers.

Seasonal unskilled labor is hired to carry manual agricultural operations, including weeding, harvesting, and the transportation of crops.[2] This labor come mostly from outside the Damazine MCPRS (Table 3.2). The survey showed that the majority of the seasonal labor came from the Blue Nile Province itself. The majority of the seasonal labor

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[1] The farm manager is locally known ad the "Wakeel" and the farm guard is known as the "Gafier."

[2] Seasonal unskilled labor is also hired for tree clearance, but this is done only once when the farm is first established.

that now reside in the Damazine MCPRS actually migrated to the area after mechanized crop productions started. The survey showed that all the labor that work in the farms surveyed are adult males. This reflect the difficulty of the work and the environmental conditions under which they work. For example, the average working day is 8-10 hours, depending on the time of the season and the crop.

Manual seasonal labor is paid in cash and kind. The cash payment is on a per area basis, except for sesame threshing for which labor is paid per sack of seeds. The in-kind payment is in the form of raw food and drinking water. After the end of the rainy season (October/November), drinking water costs rise tremendously because it has to be hauled from permanent or semi-permanent water sources in nearby villages or sometimes from the Blue Nile River.

TABLE 3.2

Seasonal Hired Labor:Paticipation % According to Place of Permenant Residence, Damazine MCPRS, Season 1983/84,Sudan

Place of Residence	Farming Activities		
	Weeding (%)	Harvest	
		Sesame (%)	Sorghum (%)
Damazine Area	46	20	36
Southern Blue Nile	24	35	34
Western Sudan	16	26	8
Southern Sudan	9	14	20
Other Parts of Sudan	3	3	a
Ethiopia	2	2	2

Source : Survey Data

a = Less than 1 % .

CHAPTER 4

THE STRUCTURE OF THE LINEAR PROGRAMMING MODEL FOR THE DAMAZINE MCPRS

4.1 Introduction

The preceding chapters described the Damazine MCPRS and the policy environment under which they operate. This chapter describes the linear programming model used to predict employment and income consequences of alternative sorghum harvesting technologies. The discussion includes assumptions of the model, the mathematical specifications, the objective function, the activity sets and the constraints structure.

The wide application of linear programming to analyze small farmers enterprises in Africa has been critized as being too naive by assuming these farmers are profit maximizers. In contrast to the small traditional farmers generaly considered when studying African agriculture, this study involves large farmers - with 1,500 farms - who we can reasonably assume are profit maximizers. Also, the linear programming allows the rapid evaluation of alternative technologies given the required resource levels. Unlike budgeting techniques, linear programming can help to directly identify the optimum farm plans within the constraints of available resources.

4.2 Assumptions of Linear Programming

Linear Programming (LP) is one of the mathematical tools that can be used by managers to evaluate alternative objectives of their firms, subject to the resource restrictions under which they operate. Management objectives can vary, depending on the nature of the investment, the risk preference of management, the environment under which the enterprise works, and management goals.

Linear programming is a mathematical structure, involving specific mathematical assumptions that can be solved using a standard algorithm (e.g., the simplex method). LP formulations and assumptions have been discussed widely in the literature. Five of these assumptions are reviewed briefly below.

4.2.1 Proportionality

This means that for any given decision variable, the contribution that any activity makes to the objective function, or a constraint, is a linear function of the weight attached to the activity. For example, if N units of an input are necessary to produce one unit of output, then 2N units of that input will be needed to produce two unit of output. This implies a constant return to scale relationship for the entire production range.

4.2.2 Additivity

This means that the total contribution of any restriction is the sum of the individual contributions. It

is assumed that there are no interactions between activities. If there are (N_1, N_2, N_3 . . . N_i) activities using resource B, then the amount of the resource used is equal to the sum of corresponding input quantities generated by each separate activity.

4.2.3 Divisibility

This means that the activity units can be divided into any fraction, such that non-integer values can appear in the solution. Results are often rounded off to the nearest integer to overcome this limitation or integer programming is used.

4.2.4 Determinism

This means that all parameters in the model are known with certainty. The input/output coefficients, the resource levels, prices, etc. are assumed to be known with perfect knowledge.

4.2.5 Non-Negativity

This means that the levels of all activities, resource levels, and outputs are greater than or equal to zero.

When assumptions 1 through 4 are violated, other programming models can be used such as mixed integer programming, integer programming, chance constraint programming, N stage Linear programming, separable programming models or quadratic programming.

4.3 Mathematical and Schematic Representation of the Damazine MCPRS/LP Model

The objective of the model is to maximize

$$Z = \sum_{j=1}^{n} e_j x_j \quad (j = 1, 2 \ldots n)$$

subject to the constraints

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad (i = 1,2 \ldots m)$$

and $x_i \geq 0$

Where;

Z = The net revenue to be maximized.

c_j = The marginal contribution of the jth activity.

x_j = The decision or activity variable.

a_{ij} = The input/output coefficient of the jth resource, i.e., how much of the jth resource is required for each activity.

b_i = A given amount of resource i available.

n = The number of activities in the model.

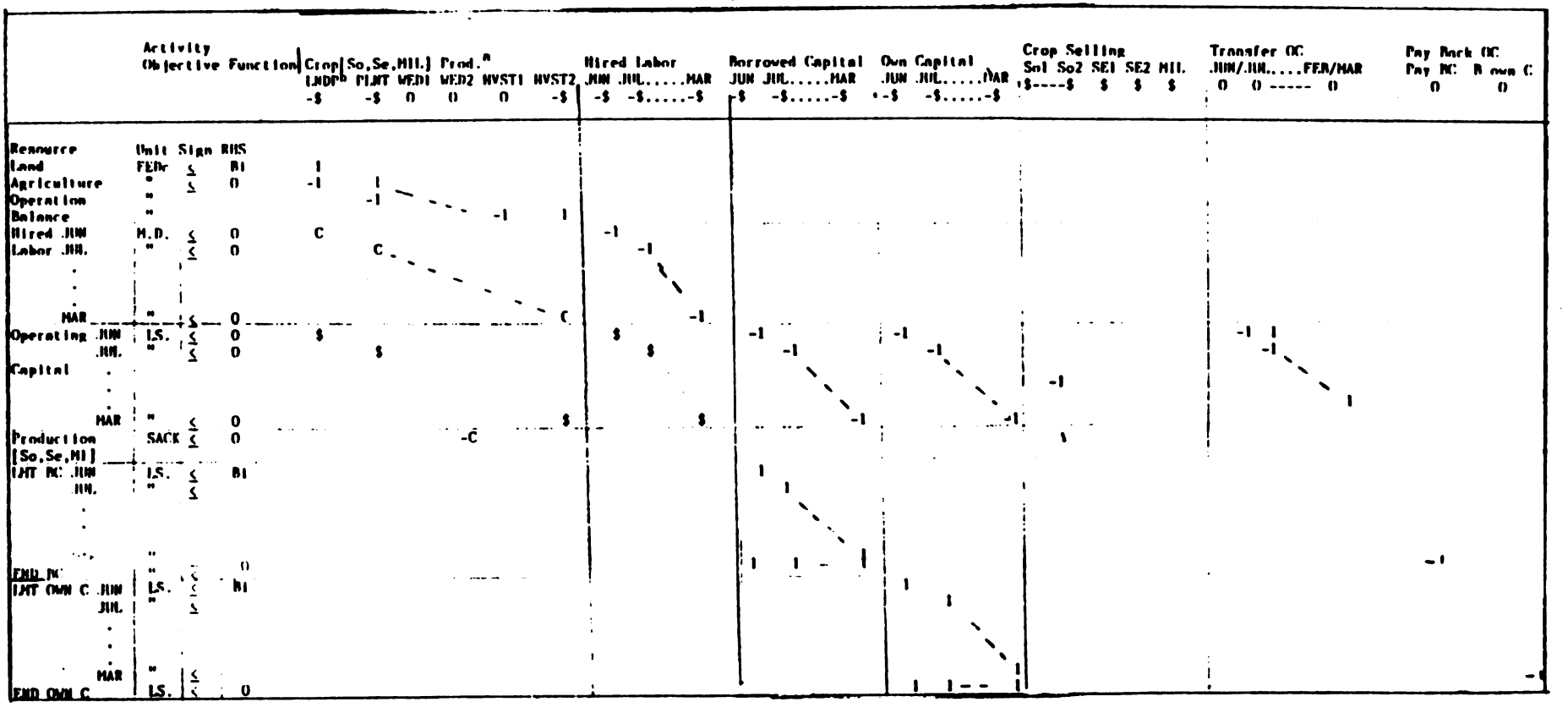
m = The number of resource restrictions in the model.

For a mathematical formulation of LP models in matrix notation, see Heady and Candler (1973).

The schematic representation of the model is given in Figure 4.1

FIGURE 4.1

Schematic Representation of Damazine MCPRS Basic LP Model



Abbreviations:

LNDP = Land Preparation
PLNT = Planting
WED1 = First Weeding
WED2 = Second Weeding
HVST1 = First Harvest
HVST2 = Second Harvest
RHS = Right Hand Side
FD = Feddan = 1.038 Acres
MD = Man-day
LS = Sudanse Pound = 100 Piasters

SO = Sorghum
SE = Sesame
MIL = Millet

$ = Monetry Value
C = Cofficient Not = 0
Bi = Level of the Resource in Model RHS

4.4 Description of the LP Model

4.4.1 The objective Function

A number of objectives have been specified for farmers. Most of the LP analysis of African agriculture (DeWilde, 1967; Lipton, 1968; Norman, 1973) has dealt with peasant farmers. Shultz (1964) and Hoper (1965) contend that the peasant farmers are profit maximizers. On the other hand, DeWilde (1967) and Lipton (1968) argue that for peasant farmers, the most important consideration is food security. Charlick (1974) suggests that peasant farmers may have objectives other than profit maximization.

The farmers considered in this study are by no means small peasant farmers as their farms are, on the average, 1,500 feddans.[1] Their farming objective is strictly commercial, although they may have other objectives such as improving their social status. Risk may play an important role in modifying the farmers' objectives due to the risky nature of their farming situation which is dependent on variable rainfall. The model assumes the farmer's objective is to maximize net revenue to fixed assets (equity capital), subject to the technical constraints of the production function; and the level of available resources. The net revenue is estimated per feddan of the mixture of field

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[1] One feddan = 4,200 sq. meters = 0.42 Hectare = 1.038 acres

crops (i.e., more than one crop in one farm). Expenses encompass all cash costs, including labor, raw materials, overhead and interest on borrowed capital.

4.4.2 Activities in the Model

Activities in the Damazine MCPRS LP Model include: crop production, labor hiring, capital borrowing, farmers own capital, crop selling, capital transfer, and capital repayment.

4.4.2.1 Crop Production Activities

The Damazine MCPRS farmers grow three crops in pure stands - - sorghum, sesame and millet. The activity choices for crop production are defined in Table 4.1 through 4.4. Two alternative ways of growing sorghum and sesame are shown - early and late growing. Early crops give higher yield than late crops, but late planted crops require fewer man-days during weeding. This may be because land preparation is carried out after most of the weeds have germinated, so most of the weeds are removed by discing during land preparation and planting.

The six activities specified for each crop enterprise are land preparation, planting, two weeding activities (first and second weedings) and two crop harvesting activities. The first crop harvesting activity represents cutting and the second theshing. The six activities for each crop produced are forced together in sequential order, to insure that all activities are performed for the crop selected by the LP model.

TABLE 4.1

Partially Mechanized Harvested Sorghum Activities ;
Damazine MCPRS,Season 1983/84, Sudan.

Objective Function (CJ's)		Early Sorghum						Late Sorghum						SIGN	RHS
		LNDP	PLNT	WED1	WED2	HVST1	HVST2	LNDP	PLNT	WED1	WED2	HVST1	HVST2		
		-5.46	-5.46	0	0	0	-18.15	-5.46	-5.46	0	0	0	-16.95		
Resource (Bi)	Unit														
LAND	FD	1						1						≤	1500
	FD	-1	1											≤	0
	FD		-1	1										≤	0
	FD			-1	1									≤	0
	FD				-1	1								≤	0
	FD					-1	1							≤	0
	FD							-1	1					≤	0
	FD								-1	1				≤	0
	FD									-1	1			≤	0
	FD										-1	1		≤	0
	FD											-1	1	≤	0
Hired Labor														≤	0
June	MD	.25						.25						≤	0
July	MD		.25						.25					≤	0
August	MD			1.06						1				≤	0
Septembe	MD			1.06	1.33					1	1.08			≤	0
October	MD				1.33						1.08			≤	0
November	MD													≤	0
December	MD					1.6								≤	0
January	MD					1.6						1.6		≤	0
February	MD						.35					1.6		≤	0
March	MD												.35	≤	0
Operating Capital														≤	0
June	LS	5.46						5.46						≤	0
July	LS		5.46						5.46					≤	0
August	LS													≤	0
Septembe	LS													≤	0
October	LS													≤	0
November	LS													≤	0
December	LS													≤	0
January	LS						18.15							≤	0
February	LS													≤	0
March	LS												16.95	≤	0
Qu. E.So.	Sack						-3.36							≤	0
Qu. L.So.	sack												-3.06	≤	0

Source: Survey Data
Abbreviations:

LNDP = Land Preparation
PLNT = Planting
WED1 = First Weeding
WED2 = Second Weeding
HVST1 = First Harvest
HVST2 = Second Harvest
RHS = Right Hand Side
FD = Feddan = 1.038 Acres
MD = Man-day
LS = Sudanese Pound = 100 Piastres

SO = Sorghum
SE = Sesame
MIL = Millet

Qu E.So= Quantity of Early Sorghum
Qu.L.So= Quantity of Late sorghum

TABLE 4.2

Sesame Production Activities, Damazine MCPRS, Season 1983/84, Sudan

		Early Sesame						Late Sesame						SIGN	RHS
Objective Function (CJ's)		LNDP	PLNT	WED1	WED2	HVST1	HVST2	LNDP	PLNT	WED1	WED2	HVST1	HVST2		
		-5.46	-5.66	0	0	0	-10	-5.46	-5.66	0	0	0	-8		
Resource (Bi)	Unit														
LAND	FD	1						1						$	1500
	FD	-1	1											$	0
	FD		-1	1										$	0
	FD			-1	1									$	0
	FD				-1	1								$	0
	FD					-1	1							$	0
	FD							-1	1					$	0
	FD								-1	1				$	0
	FD									-1	1			$	0
	FD										-1	1		$	0
	FD											-1	1	$	0
														$	0
Hired Labor															
June	MD	.25						.25						$	0
July	MD		.25						.25					$	0
August	MD			2.8	1.45					2.6	1.4			$	0
Septembe	MD				1.45						1.4			$	0
October	MD					4.7						4.7		$	0
November	MD						1.4						1.4	$	0
December	MD						.25						.25	$	0
January	MD													$	0
February	MD													$	0
March	MD													$	0
Operating Capital															
June	LS	5.46						5.46						$	0
July	LS		5.66						5.66					$	0
August	LS													$	0
Septembe	LS													$	0
October	LS						10						8	$	0
November	LS													$	0
December	LS													$	0
January	LS													$	0
February	LS													$	0
March	LS													$	0
Qu.E.Se	Sack						-1.6							<=	0
Qu.L.Se	Sack												-1.28	<=	0

Source: Survey Data

Abbreviations:

LNDP = Land Preparation
PLNT = Planting
WED1 = First Weeding
WED2 = Second Weeding
HVST1 = First Harvest
HVST2 = Second Harvest
RHS = Right Hand Side
FD = Feddan = 1.038 Acres
MD = Man-day
LS = Sudanese Pound = 100 Piastres
Qu.E.Se= Quantity of Early Sesame
Qu.L.Se= Quantity of Late Sesame

TABLE 4.3

Pearl Millet Crop Production and Crop Selling Activities,
Damazine MCPRS,Season 1983/84, Sudan.

		Millet						Crop Selling					SIGN	RHS
Objective Function (Cj's)		LNDP_a	PLNT	WED1	WED2	HVST1	HVST2	E.SO	L.SO	E.SE	L.SE	MIL		
Resource (Bi)	Unit													
LAND	FD	1											≤	150
	FD	-1	1										≤	0
	FD		-1	1									≤	0
	FD			-1	1								≤	0
	FD				-1	1							≤	0
	FD					-1	1						≤	0
Hired Labor														
June	MD	.25											≤	0
July	MD		.25										≤	0
August	MD			1.13									≤	0
Septembe	MD			1.13	1.4								≤	0
October	MD				1.4								≤	0
November	MD												≤	0
December	MD					3.4							≤	0
January	MD						.35						≤	0
February	MD												≤	0
March	MD												≤	0
Operating Capital														
June	LS	5.46											≤	0
July	LS		5.66										≤	0
August	LS												≤	0
Septembe	LS												≤	0
October	LS												≤	0
November	LS									-43	-43		≤	0
December	LS												≤	0
January	LS						10	-18.8				-29	≤	0
February	LS												≤	0
March	LS								-19.2				≤	0
Qu. E.So.	Sack						1.32						≤	0

Source:Survey Data
Abbreviations:

LNDP = Land Preparation
PLNT = Planting
WED1 = First Weeding
WED2 = Second Weeding
HVST1 = First Harvest
HVST2 = Second Harvest
RHS = Right Hand Side
FD = Feddan = 1.038 Acres
MD = Man-day
LS = Sudanese Pound = 100 Piastres
SO = Sorghum
SE = Sesame
MIL = Millet
Qu.MIL = Quantity of Millet

TABLE 4.4

Fully Mechanized Harvested Sorghum Activities ,
Damazine MCPRS,Season 1983/84, Sudan.

Objective Function (Cj's)		Early Sorghum						Late Sorghum						SIGN	RHS
		LNDP	PLNT	WED1	WED2	HVST1	HVST2	LNDP	PLNT	WED1	WED2	HVST1	HVST2		
		-5.46	45.46	0	0	0	-27	-5.46	-5.46	0	0	0	-24.9		
Resource (Bi)	Unit														
LAND	FD	1						1							1500
	FD	-1	1												0
	FD		-1	1											0
	FD			-1	1										0
	FD				-1	1									0
	FD					-1	1								0
	FD							-1	1						0
	FD								-1	1					0
	FD									-1	1				0
	FD										-1	1			0
	FD											-1	1		0
Hired Labor															
June	MD	.25						.25							0
July	MD		.25						.25						0
August	MD			1.06						1					0
Septembe	MD			1.06	1.33					1	1.08				0
October	MD				1.33						1.08				0
November	MD														0
December	MD														0
January	MD						.35								0
February	MD												.35		0
March	MD														0
Operating Capital															
June	LS	5.46						5.46							0
July	LS		5.46						5.46						0
August	LS														0
Septembe	LS														0
October	LS														0
November	LS														0
December	LS														0
January	LS						27								0
February	LS														0
March	LS												24.9		0
Qu. E.So.	Sack						-3.36								0
Qu. L.So.	sack												-3.06		0

Source:Survey Data

Abbreviations:

LNDP = Land Preparation
PLNT = Planting
WED1 = First Weeding
WED2 = Second Weeding
HVST1 = First Harvest
HVST2 = Second Harvest
RHS = Right Hand Side
FD = Feddan = 1.038 Acres
MD = Man-day
LS = Sudanse Pound = 100 Piastere
Qu E.So= Quantity of Early Sorghum
Qu.L.So= Quantity of Late sorghum

For sorghum, two alternative technologies are considered. In the basic MCPRS model, only partially mechanized sorghum harvesting is included. Subsequently, the model is extended to include fully mechanized harvesting, as shown in Table 4.4.

The input/output coefficients in Tables 4.1-4.4 represent the amounts of input required per unit of activity. They specify how the magnitude of a resource constraint would change with an increase of one unit of each activity in the model. The coefficients representing a decrease in the magnitude of a constraint carry positive signs, while those coefficients indicating an increase in the magnitude of a constraint have negative signs. The input/output coefficients of crop production activities are derived from the survey data of 69 farmers in the Damazine MCPRS. The activity unit or the crop production area that each unit of activity represents, is one feddan (See Appendix A for data collection details).

4.4.2.2 Labor Hiring Activities

Farmers in the study area are totally dependent on hired labor. The labor hiring activities cover the whole cropping season from June to March (Table 4.5). The activity units are man-days (equivalent to eight hours of field work). The survey showed that all the labor employed were adult males. While no constraint was put on the amount of labor the farmer can hire, the availability of hired labor is partly constrained by the availability of operating

TABLE 4.5
Hired Labor Activities, Damazine MCPRS, Season 1983/84, Sudan.

Objective Function (Cj's)			Hired Labor											
			JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Sign	RHS
			-5.66	-5.66	-2.21	-2.21	-3.27	-2.56	-2.56	-2.56	-2.56	-2.56		
Resource (Bi)		Unit												
Hired Labor														
	JUN	MD	-1										≤	0
	JUL	MD		-1									≤	0
	AUG	MD			-1								≤	0
	SEP	MD				-1							≤	0
	OCT	MD					-1						≤	0
	NOV	MD						-1					≤	0
	DEC	MD							-1				≤	0
	JAN	MD								-1			≤	0
	FEB	MD									-1		≤	0
	MAR	MD										-1	≤	0
Operating Capital														
	JUN	LS	5.66										≤	0
	JUL	LS		5.66									≤	0
	AUG	LS			2.21								≤	0
	SEP	LS				2.21							≤	0
	OCT	LS					3.27						≤	0
	NOV	LS						2.56					≤	0
	DEC	LS							2.56				≤	0
	JAN	LS								2.56			≤	0
	FEB	LS									2.56		≤	0
	MAR	LS										2.56	≤	0

Source : Survey Data

Abbreviations:

RHS = Right Hand Side
FD = Feddan = 1.038 Acres
MD = Man-day
LS = Sudanese Pound = 100 Piasters

capital and the availability of drinking water. Ten (one per month) hired labor activities are incorporated in the model, covering the June to March cropping season.

Labor is hired per unit of land (usually per 60 feddans) and remunerated both in cash and in-kind in the form of raw food and drinking water. For convenience, in-kind amounts have been translated into cash values (Mohamed, 1982). An average monthly wage rate was estimated by combining the value of the cash and in-kind payments. The labor hiring activities have positive coefficients, indicating that one unit of hired labor is used by the model per activity. The hired labor wage rate is positive in the operating capital row, indicating that a one unit increase in hired labor will decrease operating capital by the amount of the wage rate. Thus, the extent to which hired labor can be used is limited by the availability of operating capital and drinking water.

Labor hiring activities (c_j's) have negative values which are equal to the average estimated wage rate in the particular month. This means each unit of labor that is hired reduces the objective function by the amount of the daily wage rate. For June and July, the wage rate was higher than for the rest of the period because it represents the wage rate for the tractor drives. During October when sesame was harvested, the wage rate was also above the average wage rate during the season. This was because sesame harvest demands a high labor requirement (4.7 man-day/feddan) and

during a short period of time (see, Chapter 3).

4.4.2.3 Capital Borrowing Activities

Capital borrowing activities are shown in Table 4.6. The Agricultural Bank of Sudan (ABS) is a specialized public institution which supplies qualified farmers with credit for land preparation, planting, weeding and harvesting. Credit was given in several installments during the cropping season. The model includes monthly capital borrowing activities to cover the times when capital was borrowed. These activities have negative coefficients in the operating capital rows to indicate the use of borrowed capital and positive coefficients in the limit in the borrowed capital rows to indicate a decrease in borrowed capital by the amount used by the model.

The objective function (c_j's) for borrowed capital are negative, indicating a decrease in the objective function by the interest rate paid on capital. As the Agricultural Bank of Sudan charges 14 percent interest, the objective function for capital borrowing activities is entered as -.14.

4.4.2.4 Farmer Own Capital Activities

Farmers in the study area use their own capital to augment borrowed capital. Farmers' own capital activities are represented in Table 4.7. The structure of the coefficient for own capital is similar to that of borrowed capital. As described in Chapter 3, most of the owners are merchant farmers who have the opportunity to invest their own capital in commerce rather than agriculture. For this

TABLE 4.6
Borrowed Capital Activities

Objective Function (Cj's)		JUN -.14	AUG -.14	SEP -.14	OCT -.14	NOV -.14	DEC -.14	Repay 0	Sign	RHS
Resource (Bi)	Unit									
Operating Capital										
JUN	LS	-1							≤	0
AUG	LS		-1						≤	0
SEP	LS			-1					≤	0
OCT	LS				-1				≤	0
NOV	LS					-1			≤	0
DEC	LS						-1	1	≤	0
Limit Operating Capital										
JUN	LS	1							≤	4200
AUG	LS		1						≤	2300
SEP	LS			1					≤	12000
OCT	LS				1				≤	4000
NOV	LS					1			≤	4000
DEC	LS						1		≤	1000
End Operating Capital	LS	1	1	1	1	1	1	-1	≤	0

Source: Survey Data

Abbreviations:

RHS = Right Hand Side
LS = Sudanse Pound = 100 Piasters

TABLE 4.7

Farmers' Own Caital Activities,Damazine MCPRS,Season 1983/84,Sudan

Objective Function (Cj's)			JUN -.21	JUL -.2	AUG -.19	SEP -.18	OCT -.16	NOV -.14	DEC -.12	JAN -.11	FEB -.09	MAR -.07	Repay	Sign	RHS
Resource (Bi)		Unit													
Operating Capital															
	JUN	LS	-1											≤	0
	JUL	LS		-1										≤	0
	AUG	LS			-1									≤	0
	SEP	LS				-1								≤	0
	OCT	LS					-1							≤	0
	NOV	LS						-1						≤	0
	DEC	LS							-1					≤	0
	JAN	LS								-1				≤	0
	FEB	LS									-1			≤	0
	MAR	LS										-1	1	≤	0
Limit	Own Caoital	LS	1	1	1	1	1	1	1	1	1	1	-1	≤	20000

Source:Survey Data

Abbreviations:

RHS = Right Hand Side

LS = Sudanse Pound = 100 Piasters

reason, the interest rate that commercial banks charge to their most preferred customers (21 percent) is taken as the opportunity cost of using own capital. This assumption is reasonable, given the high inflation rate in the economy.[1]

The objective function (c_j's) for own capital activities is negative, indicating a decrease in the objective function by the interest rate (i.e., 21 percent).

To guard against the high inflation rate, farmers hedge in farm machinery (mainly tractors and discs harrows) and acquire more land in both the demarcated or undemarcated areas. This is made possible by the ADB policy which permits farmers to obtain machinery loans (in-kind) as long as they have repaid previous machinery loans. The survey showed that more than 20 percent of the farmers owned more than one tractor. The illegal expansion of production to undemarcated land is pervasive. The Mechanized Farming Corporation records showed there were 1.7 million feddans in the Damazine which were unofficially cultivated (i.e., undemarcated and unallotted). Simpson and Simpson (1978) suggested that most of these unofficially cultivated areas were run by farmers who also had officially allotted farms.

4.4.2.5 Crop Selling Activities

The LP model allows all crops produced to be sold. The five initial crop selling activities are early sorghum, late

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[1] A conservative estimates put the inflation rate at 30 percent (see Zaki, 1983).

sorghum, early sesame, late sesame, and pearl millet (Table 4.3). Two additional crop selling activities were added when a combine harvesting option for early and late sorghum was considered. The model assumes that all selling is done at harvest and that there is no storage. Prices are those observed during the survey. Sorghum sold during March commands a higher price than sorghum sold during December. This is because by March, all roads outside the production area are accessable so the crop can be easily transported to other consumption areas. In contrast, the traditional farmers harvest during December, making the supply higher than the local market demand.

The selling activities units are one sack and prices are average prices received by farmers in the area in 1983/84. The objective function coefficients are positive because selling adds to the value of the objective function. The selling price coefficients appear negative against the operating capital rows because crop selling adds to the operating capital.

4.4.2.6 Transfer Activities

Table 4.8 represents operating capital transfer activities which are used to pass surplus operating capital from one month to another during the cropping season. The transfer activities have a zero value in the objective function, and negative and positive values against the operating capital rows to transfer any capital surplus to the next month. The capital transfer activities are followed

TABLE 4.8
Operating Capital Transfer Activities

Objective Function (Cj's)		JUN/JUL	JUL/AUG	AUG/SEP	SEP/OCT	OCT/NOV	NOV/DEC	DEC/JAN	JAN/FEB	FEB/MAR	Sign	RHS
		0	0	0	0	0	0	0	0	0		
Resource (Bi)	Unit											
Operating Capital												
JUN	LS	1									≤	0
JUL	LS	-1	1								≤	0
AUG	LS		-1	1							≤	0
SEP	LS			-1	1						≤	0
OCT	LS				-1	1					≤	0
NOV	LS					-1	1				≤	0
DEC	LS						-1	1			≤	0
JAN	LS							-1	1		≤	0
FEB	LS								-1	1	≤	0
MAR	LS									-1	≤	0

Source: Survey Data

Abbreviations:
RHS = Right Hand Side
LS = Sudanse Pound = 100 Piasters

by two activities, one for the repayment of borrowed capital and a second for the repayment of own capital.

4.4.3 Restrictions of the Model

The following section discusses the structure of the constraints imposed on the LP model. The Damazine MCPRS operates under a number of constraints, including land, hired labor, operating capital, agricultural operating balance restrictions and non-negativity constraints.

4.4.3.1 Land Restrictions

The total land available for cultivation is limited by the size of the farm allotted to each farmer. The average farm size is 1,500 feddans. No provision is made in the model for renting or buying more land. The MFC requires that one-third of the land be left fallow, but the survey found that farmers ignore this restriction. Consequently, this MFC imposed institutional constraint on land use was relaxed in the sensitivity analysis. The LP model includes an option for farmers to sell or buy land. Land is assumed to be homogeneous in quality and the row unit for land is one feddan.

4.4.3.2 Labor Constraints

The LP model imposes no restrictions on the amount of hired labor. The row unit for hired labor is one man-day. The amount of labor that can be hired is constrained by the amount of operating capital available for this activity.

4.4.3.3 Operating Capital Constraints

As emphasized earlier in this chapter, there are two

sources of operating capital, - - credit obtained from the ABS and the farmers' own capital.

1 - Borrowed Capital.

The ABS provides credit in three installments to MCPRS farmers for land preparation and planting, weeding and harvest (Table 4.6).

2 - Farmer's Own Capital

Borrowed capital is augmented by the farmers' own capital. It is always difficult to specify the farmers' own capital constraints (Etuk, 1979; Amani, 1981; Mohamed, 1982), due to the difficulty of obtaining data on the amount of operating capital actually available. In this study, the average estimated amount of farmers' own capital is used.

The operating capital constraints are specified on a monthly basis. Transfer activities are used to pass surplus capital from one month to the next during the cropping season.

4.4.3.4 Drinking Water Constraint

Drinking water availability is a major determinant of the number of casual laborers that a farmer can keep on the farm during any one period. Access to drinking water becomes a critical problem after the end of the rainy season in October. The survey showed that a laborer needs about three gallons of water per day.[1] On the basis of the farmers best

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[1] Simpson and Simpson (1978) estimated that the daily drinking water needs of a laborer in the Gedaref area was 2.5 gallons per day.

estimates, the maximum number of laborers for which a farmer can provide drinking water is approximately 4,500 man-day of labor per month.

4.4.3.5 Non-Negativity Constraints

An assumption of LP Models is that none of the activities included in the model operate at negative levels.

CHAPTER 5

RESULTS OF LINEAR PROGRAMMING ANALYSIS

Chapter 4 described the structure of the Linear Programming Model for the Damazine MCPRS. In this chapter, the results of LP analysis are presented. The analysis focuses on changes in farm income, crop area, and resource use and the marginal productivity of resources. These results identify the optimum combination of input resources that give the highest output value for every input combination. However, the "optimum" obtained assumes farmers have perfect knowledge of both the resource and product market situation (Day, 1974). Even with this limitation, the LP model results - - when compared to actually observed data - - highlight the existing level of resource efficiency among the Damazine MCPRS farmers.

The first optimum, or base plan, is estimated with the existing levels of technology and resources. Then, coefficients reflecting the introduction of new technology (combine harvested sorghum) are introduced to determine the optimum plan under this new technology. The base model and the modified model under the new sorghum harvesting technology are then compared. In each case analysis provides information on the value of the objective function; The optimum enterprise combination; resources used and their

respective marginal value product; non-optimal activities; and the cost of forcing non-optimal activities into the optimal solution.

5.1 Cropping Pattern - Basic Solution

Table 5.1 presents the characteristics of the optimum farm plan under the existing (partially mechanized) sorghum harvesting technology, together with the results obtained from the 1983/84 farm survey. The value of the objective function, in terms of net cash income, is LS. 7,178. The objective function value does not take into account costs that are considered fixed to the farm, such as machinery depreciation.

The LP results shows the dominance of sorghum and are consistant with the survey results (Table 5.1). In the optimal plans the total sorghum area was 5.6 percent greater than indicated by the survey . However, while under the optimal plan the late sorghum area was 16 percent less than the actual late sorghum area, the area in early sorghum was 35 percent greater than the actually planted area estimated by the survey. In contrast, in the optimal plan, the total area under sesame (16.5 percent of the total area) was comparable to the actual area under sesame (17.3 percent). Yet, under the optimum plan no late sesame was produced - reflecting the high profitability of early sesame, compared to late sesame.

TABLE 5.1

Comparison of the Linear Programming and Survey Results,Damazine MCPRS,Season 1983/84,Sudan.

Item	Activity Level			
	Model Results		Survey Results	
	Feddans_a	%	Feddans	%
Early Sorghum	527	35	345	23
Late Sorghum	726	48	859	57
Early Sesame	247	17	162	11
Late Sesame	0	0	80	5
Pearl Millet	0	0	54	4
Total	1500	100	1500	100
Gross Farm Income	LS._b 95827		89677	

Source:LP Model and Survey of 69 Farms Conducted Season 1983/84.

a- Feddan = 1.038 Acres = .42 Hectares = 4200 Square Meters.
b- LS. = Symbol for Sudanse Pound = 100 Piasters.

Some of the crops grown by the farmers in the Damazine MCPRS were not included in the optimum plan. While pearl millet was not included in the optimum, farmers actually planted an average of 54 feddans (3.6 percent of the total farm land). Its exclusion from the optimum reflects the fact that under the existing output and resource prices, it was not competitive enough to be included in the income maximizing plan. The cost of forcing one unit of land (i.e., one feddan) of millet into the optimum solution was LS. 11.95. This indicates how much the objective function would be reduced if one additional feddan of millet is forced into the optimum plan.

5.1.1 Resource Use

Levels of resource use of the Damazine MCPRS are shown in Table 5.2. The entire 1,500 feddans of land available to the farmers is used in the optimum solution - - equal to the actual cropped area estimated from the survey data. Total hired labor used in the optimum plan is 13,664 man-days, for an average of nine man-days per feddan of crop. The total own capital used is LS. 20,000, for an average of LS. 29.73 per feddan. This does not include the capital generated and used by the enterprise during the cropping season (i.e., the revenues from early sesame were later used for the harvest of sorghum).

5.1.2 Marginal Value Products of Resources

The shadow price or marginal value product (MVP) of a disposable activity is the increase in the value of total

TABLE 5.2

Optimum Plan Resource Use Under Existing Technology, Damazine MCPRS, Season 1983/84, Sudan.

Resource	Unit	Resource Level
Hired Labor		
June	Man-day	375
July	Man-day	375
August	Man-day	2335
September	Man-day	3127
October	Man-day	2598
November	Man-day	346
December	Man-day	905
January	Man-day	2004
February	Man-day	1345
March	Man-day	245
Operating Capital		
Borrowed	LS-a	24600
Owen	LS	20000

Source:LP Model

a- LS = Sudanse Pound = 100 Piasters.

output that can be obtained from the use of an additional unit of the resource, all other inputs held constant. The latter condition is not met in the linear programming framework, because production coefficients for the activities are assumed to be in a fixed ratio to one another. Beneke and Winterboer (1971) contend that the interpretation of the shadow prices of the disposable activities as their marginal value products is not consistent with the precise definition of marginal value product. Despite this, the shadow prices of the disposable activities are good approximations that provide information as to the most likely resources that, if made more available, will increase the value of the objective function. The MVP of a resource is constant over a specific range, until other resources become limiting. At that point, another solution becomes optimal and the MVP of the resources changes.

The MVPs indicate the productivity of resources to the enterprise or the increase in total farm income that can be obtained by utilizing an additional scarce unit of the resource. The MVP's are zero for slack resources and positive for the limiting factors (constraint resources). The more limiting the resource, the higher its MVP. It is profitable to acquire an additional unit of a resource if its MVP is greater than its acquisition price (i.e., its marginal factor cost or MFC). Thus, it is profitable to acquire resources up to the point where their MVP's equal

their MFC's. At this point, the maximum net income is obtained.

Table 5.3 shows the MVP for the Damazine MCPRS, under the existing level of technology and resources. The MVP for land is LS. 1.70, reflecting that the objective function will increase by LS. 1.70 for every additional feddan of land cropped. Expansion of land beyond the available amount is profitable, if the MFC of land is less than or equal to LS. 1.70. Since farmers pay the Mechanized Farming Corporation a land rent of LS. 1.00 per feddan, land use can be expanded until the MVP of land is equal to the MFC. This may partly explain why farmers ignore the MFC rotation regulations and risk eviction (if the Mechanized Farming Corporation laws were enforced) by putting their total farm land into crop production.

Hired labor is a limiting factor in production during the entire June to March cropping season (Table 5.3). The MVP's on hired labor for each month correspond very closely to the peak periods in farm activities. First, MVP's are highest during land preparation and planting (June/July) and the weeding period (August/September). Second, the MVP of hired labor is higher during October than during August/September, reflecting the higher demand for labor during the sesame cutting period when labor requirements are highest and timeliness most critical. Third, at the beginning of the sorghum harvest the MVP is higher than towards the end of the harvesting period. Finally, during

TABLE 5.3

Shadow Prices for Resources Used Under Existing Sorghum Harvesting Technology, Damazine MCPRS,Season 1983/84,Sudan.-a

Month	Hired Labor (Man-day)	Operating Capital (LS.)
June	7.21	.29
July	7.21	.29
August	2.81	.29
September	2.81	.29
October	4.16	.29
November	3.26	.29
December	2.68	.06
January	2.68	.06
February	2.56	0
March	2.56	0

Source : LP Model

a-The Shadow Price of Land = LS 1.7.

the end of the sorghum harvest (February/March), the hired labor MVP equals the wage rate (i.e., MFC of hired labor), indicating an optimum level of resource use. These results indicate that farmers can afford to pay higher than the prevailing wage rate for hired labor through the June to January period.

The marginal value product of operating capital is 0.29 from June through November. During this period the MVP of operating capital is higher than the MFC of the farmer's own capital, which is .21. Hence, farm income could be increased if more operating capital were available and no other resource was limiting. The MVP's on operating capital abruptly drop to 0.06 in December and January and then falls to zero in February and March. These low MVP's are probably explained by the fact that the enterprise starts to generate its own capital by November when sesame is sold, and again in January when the early sorghum crop is sold. An important implication is that for farmers to effectively use credit, it must be provided earlier in the first half of the cropping season.

5.2 Sensitivity of the Base Model to Changing Some Critical Assumptions

This section investigates the influence of enforcing the MFC fallow requirement, and the impact of yield and price increase on the profitability of the farm enterprise.

5.2.1 The Effect of Enforcing the Mechanized Farming Corporation Fallow Requirement

As discussed in Chapter 4, the Mechanized Farming Corporation requires farmers to fallow one-third of their leased land each season. The survey showed that farmers ignore this regulation entirely and the base run LP analysis showed that maximum net returns are achieved when the total available land (1,500 feddans) is cropped. The objective of this section is to estimate the effects of constraining the available land to 1,000 feddans as required by MFC regulations. The results of the analysis are shown in Tables 5.4 and 5.5.

5.2.1.1 Cropping Pattern

The first noticeable impact of imposing a land constraint is that late sorghum drops out of the optimum plan. Second, the area under early sesame increases to 279 feddans, which represents 28 percent of the total cropped area, compared to only 16.5 percent when all the land is cropped. Finally, the objective function declined to LS. 5,393, a difference of LS. 1,773 compared to when all the land is cropped. These result show that an increase of less than 100 sacks in total production of early sorghum will off-set the difference in the objective function between the 1,500 feddans cropped farm and the 1,000 feddans cropped farm. Consequently, a slight increase in productivity (yield) would make it possible to obtain the same returns from a 1,000 feddans as from a 1,500 feddan farm at existing yield levels.

TABLE 5.4

Optimum Enterprise Combination: Basic Model VS. the Model With MFC Fallow Requirement, Damazine MCPRS, Season 1983/84,Sudan.

Crop	Basic model		Model With MFC Requirement	
	Feddans	%	Feddans	%
Early sorghum	527	35	721	72
Late Sorghum	726	48	0	0
Early Sesame	247	17	279	18
Late Sesame	0	0	0	0
Pearl Millet	0	0	0	0
Total	1500	100	1000	100
Value of the Objective Function (LS.)-a	7177		5393	

Source: LP Model

a- LS = Sudanse Pound = 100 Piasters.

TABLE 5.5

Comparsion of the Marginal Value Product of Resources: Basic Model VS. Model With MFC Fallow Requirement, Damazine MCPRS, Season 1983/84, Sudan.

Resource	Unit-a	Marginal Value Product	
		Model With MFC Requirement	Basic Model
Land	FD	4.93	1.7
Hired Labor			
June	MD	6.58	7.21
July	MD	6.58	7.21
August	MD	2.67	2.81
September	MD	2.52	2.81
October	MD	3.72	4.16
November	MD	2.92	3.26
December	MD	2.59	2.61
January	MD	2.59	2.69
February	MD	2.56	2.56
March	MD	2.61	2.56
Operating Capital			
June	LS	.22	.29
July	LS	.21	.29
August	LS	20	.29
September	LS	14	.29
October	LS	14	.29
November	LS	.14	.29
December	LS	.01	.06
January	LS	.01	.06
February	LS	0	0
March	LS	0	0

Source: LP Model

a_ FD= Feddan; MD= Man-day ; LS= Sudanse Pound =100 Piasters.

5.2.1.2 Marginal Value Product of Resources

When only two-thirds of the farm is cropped (Table 5.5) the marginal value product for land is LS. 4.93. The marginal value product of hired labor was worth less under the model with the land constrained at 1,000 feddans than in the base model. This can be explained by the fact that there is less demand for labor when the cultivated land is constrained at 1,000 feddans. The same explanation can be given for the decrease in the MVP's for the operating capital.

5.2.2 Yield and Price Changes

5.2.2.1 Yield Increase of 25 Percent

The impact of increasing crop yields by 25 percent is shown in Table 5.6. The objective of this experiment is to determine the effect of introducing yield increasing technology (e.g., improved crop varieties or improved cultural practices) on net farms income. This analysis assumes that yields do not significantly affect the labor and capital need for different cropping activities. While this assumption is not totally correct, the results of the experiment do indicate the effect of an increase in the crop yields.

A 25 percent increase in crop yields more than doubles net returns. While there is no change in the cropping pattern, minor changes occur in the crop areas. First, while the area under early sorghum and late sorghum increases by 1.2 and 1.7 percent respectively, the area in early sesame

TABLE 5.6

Sensitivity Analysis on Basic Model: Level of Activities and Resource Use if Crop Yields Increased by 25%, Damazine MCPRS, Season 1983/84, Sudan.

Item	Unit	Basic Model	Crop Yields Up 25%	Change (%)
Objective Function	LS-b	7177	24139	241
Crop				
Early Sorghum	FD-c	527	533	1.2
Late Sorghum	FD	726	738	1.7
Early Sesame	FD	247	228	-7.6
Late Sesame	FD	0	0	0
Pearl Millet	FD	0	0	0
Hired Labor				
June	MD-d	375	375	0
July	MD	375	375	0
August	MD	2335	2274	-1.6
September	MD	3127	3141	a
October	MD	2597	2534	-2.4
November	MD	346	319	-7.8
December	MD	904	910	a
January	MD	2004	2034	1.5
February	MD	1345	1367	1.6
March	MD	254	258	1.6
Total		13662	13587	

Source: LP Model

a = Less than 1 %.
b- LS = Sudanse Pound = 100 Piasters.
c- FD = 1.038 Acres = 4200 sq.m.
d- MD = Man-day.

decreases by 7.6 percent. Second, total hired labor requirements decreased by 75 man-days, representing a reduction of about 0.5 percent. Third, monthly hired labor decreases slightly in the first half of the cropping season and increased slightly in the later part of the season. These changes reflect the decrease in the amount of land under sesame. There is no change in the operating capital requirement, as the capital requirement for hired labor remained about thee same.

5.2.2.2 Price Increase of 25 Percent

The food shortage of 1984/85 increased the cereal crops prices in the Sudan drastically. The price of sorghum was reported to be five times the price of the previous season. The effect of price changes due to the drought is a short run phenomena that is not expected to continue. Without the drought effect, prices of food crop were observed to have an increasing trend. In the short run this trend is expected to continue. The following analysis assumes a 25 percent increase in all crop prices so that the impact of such a price change can be evaluated.

The impact of increasing all crop prices by 25 percent, compared to the output price used in the basic model, is examined below. In this analysis the crop yields are assumed to be at the level reported in the survey conducted during the 1983/84 season. Also, it is assumed that input prices remain constant, while crop prices are increased by 25 percent.

The total area under crops and the crop patterns remained the same as in the basic optimum plan (see Table 5.7), but the area under each crop changes. First, the area under early sorghum increases by nearly 30 percent over the basic model. Second, the area under late sorghum decreased by almost 21 percent, while early sesame decreases by 3.4 percent. On the other hand, although the total man-days of hired labor remains about the same as in the basic model, the monthly hired labor requirement change - - reflecting the monthly differences in hired labor requirements of the crops. Finally, the operating capital requirement remained the same as in the basic model because total labor - the main cost item - remained about the same.

Increasing all crop prices by 25 percent increases net cash income increase by more than three fold. The net income of the farm was LS. 30778.

5.3 The Effect of the New Sorghum Harvesting Technology

The previous part of this chapter presented an analysis of the existing production practices. This part of the analysis evaluates the impact of introducing fully mechanized sorghum harvesting under two sorghum production alternatives (early and late sorghum). Assumptions about the input-output coefficients, prices, resource levels, and crop yields remain the same for all activities not affected by the sorghum harvesting technology. In contrast, the input-

TABLE 5.7

Sensitivity Analysis on Base Model:Level of Activities and Resource Use if Crop Prices Increase by 25%, Damazine MCPRS, Season 1983/84, Sudan.

Item	Unit	Basic Model	Crop Prices Up 25%	Change (%)
Objective Function	LS-b	7177	30778	334
Crop				
Early Sorghum	FD-c	527	684	30
Late Sorghum	FD	726	577	21
Early Sesame	FD	247	239	3.4
Late Sesame	FD	0	0	0
Pearl Millet	FD	0	0	0
Hired Labor				
June	MD-d	375	375	0
July	MD	375	375	0
August	MD	2335	2317	a
September	MD	3127	3181	1.7
October	MD	2597	2608	a
November	MD	346	334	-3.4
December	MD	904	1154	27.6
January	MD	2004	2017	a
February	MD	1345	1162	-13.6
March	MD	254	201	-20.8
Total		13662	13724	

Source: LP Model

a = Less than 1 %.
b- LS = Sudanse Pound = 100 Piasters.
c- Fd = Feddan = 1.038 Acres = 4200 sq. m.
d- MD = Man-day.

output coefficients for the new technology differ from those of partially mechanized of sorghum harvesting. This is very critical, since the validity of the inferences drawn concerning the effects of the new technology depends on the extent to which differences in input-output coefficients reflects differences between the sorghum harvesting technologies.

The impact of the new technology is derived by comparing the optimum farm organization under the new technology with the optimum farm organization under the basic model, as presented in Table 5.8.

The net income generated under the new technology is LS. 9,221, about 30 percent above net income produced with the existing technology. This indicates a potential increase in net income to farmers who adopt fully mechanized sorghum harvesting. Two changes occur in the optimum plan, indicating that early sorghum and sesame are the most competitive enterprises under the new technology. First, there is a 120 percent increase in the land under early sorghum, and late sorghum drops from the optimum plan. In addition, the sesame area increases by 37 percent. Thus, the introduction of the new harvesting technology reduces the diversity of the cropping pattern.

5.3.1 Resource Use

Farmers plant 1,500 feddans (Table 5.9) under both the existing and the new sorghum harvesting technology. In contrast, under the new technology, 10,729 man-days of hired

TABLE 5.8

Comparsion of the Optimum Organization: Base Model VS. New Technology Model, Damazine MCPRS, Season 1983/84,Sudan.

Item	Base Model	New Technology	Change
	Feddan-a	Feddan	%
Crop			
Early Sorghum	527	1161	120
Late Sorghum	726	0	-100
Early Sesame	247	339	37
Late Sesame	0	0	0
Pearl Millet	0	0	0
Objective Function (LS)-b	7177	9221	30

Source : LP Model
a- Feddan = 1.038 Acres = 4200 sq. m.
b- LS = Sudanse Pound = 100 Piasters.

TABLE 5.9

Resource Use: The Base Model VS. the New Technlogy Model, Damazine MCPRS ,Season 1983/84, Sudan.

Item	Unit	Base Model	New Technology Model	Change %
Land	FD-a	1500	1500	0
Hired Labor				
June	MD-b	375	375	0
July	MD	375	375	0
August	MD	2335	2672	14
September	MD	3127	3265	4
October	MD	2597	3071	18
November	MD	346	475	37
December	MD	904	491	-46
January	MD	2004	0	-100
February	MD	1345	0	-100
March	MD	254	0	-100
	Total	13662	10724	
Operating Capital	LS-c	44600	43860	-3

Source: LP Model
a- FD = Feddan = 1.038 Acres = 4200 sq. m.
b- MD = Man-day.
c- LS = Sudanse Pound = 100 Piasters.

labor are required, compared to 13,662 man-days under the existing harvesting technology. This represents a reduction of 22 percent in hired labor requirements. Finally, the new technology uses a total of LS. 43,860 of operating capital, about two percent below the amount of operating capital required by the existing sorghum harvesting method.

5.3.2 The Marginal Value Products (MVP)

The marginal value products of resources used under the new versus the existing sorghum harvesting technology are compared in Table 5.10. The MVP of land under the new technology is LS. 5.64, more than twice the MVP of land under existing technology. Thus, with the new technology under the given resources levels and input/output coefficients, an additional unit of land would increase the net income by LS. 5.64 (i.e., objective function).

During July to January, the marginal value product of hired labor is lower under the new technology than the existing technology. Under both technologies, the marginal value products of hired labor is higher than the average wage rate - indicating that hired labor is limiting during this period. Yet, due to increased labor requirements under the existing technology, the marginal value product of hired labor is higher under the existing technology than the new technology. Under the existing sorghum harvesting technology farmers need to pay higher wage rates to attract hired labor than under the new technology. This indicates that more operating capital is needed under the existing technology

TABLE 5.10

Comparsion of the Marginal Value Product of Resources: Basic Model VS. Model With New Technology, Damazine MCPRS Season 1983/84, Sudan.

Resource	Unit	Marginal Value Product	
		New Technology	Basic Model
Land	FD-a	5.54	1.7
Hired Labor			
June	MD-b	6.91	7.21
July	MD	6.91	7.21
August	MD	2.71	2.81
September	MD	2.52	2.81
October	MD	3.73	4.16
November	MD	2.56	3.26
December	MD	2.56	2.68
January	MD	2.56	2.68
February	MD	2.56	2.56
March	MD	2.56	2.56
Operating Capital			
June	LS-c	.22	.29
July	LS	.22	.29
August	LS	.22	.29
September	LS	.14	.29
October	LS	.14	.29
November	LS	.14	.29
December	LS	0	.06
January	LS	0	.06
February	LS	0	0
March	LS	0	0

Source : LP Model
a- FD = Feddan = 1.038 Acres = 4200 sq. m.
b- MD = Man-day.
c- LS = Sudanse Pound = 100 Piasters.

than the new technology. Towards the end of the cropping season, the marginal value product of hired labor is equal to the wage rate, indicating less demand for hired labor during the last two months of the season under both technologies than in the previous part of the season.

Operating capital is limiting under the existing technology from June to January, while it is limiting under the new technology from June to October. Even from June to October, the operating capital is more limiting under the existing technology than under the new technology. This is because more operating capital is needed to cover the cost of the higher levels of hired labor under the existing technology than the new technology. The marginal value product of operating capital abruptly drops to zero in November. This is because less operating capital is needed, due to both the reduction in hired labor and the generation of capital by the enterprise itself through the selling of the early sesame crop.

5.4 Sensitivity Analysis of the Model Under the New Sorghum Harvesting Technology

To see how the optimum plan under the new technology would change if some of the basic assumptions of the model are modified, two assumptions are considered. First, what will happen if all crop yields are increased by 25 percent. Second, a 25 percent increase in only sorghum yield is considered.

5.4.1 A 25 Percent Increase in Yields of All Crops

The result of increasing crop yields by 25 percent is shown in Table 5.11. The objective of this experiment is to determine the activity levels and resources used if yields are increased by 25 percent. It is assumed that the changes in yields do not significantly affect the labor and capital need for different cropping activities.[1]

First, increasing all crop yield increases net returns 38 percent, compared to when the crops is produced under the existing technology. Second, the cropping pattern changes drastically under the new technology. The early sorghum area increases by 118 percent, late sorghum drops from the optimum plan, and early sesame increased by 49 percent (Table 5.12). Third, total hired labor decreased from 13,587 man-days under the existing technology with a 25 percent yield increase to 10,724 man-days under the new technology with a 25 percent increase in crop yield. This amount to a 21 percent decrease in hired labor use. Also, borrowed capital use decreases by three percent (Table 5.12). All the farmers' own capital is used because under the optimum plan with new technology and a 25 percent increase in crop yields, sufficient borrowed capital is available in the beginning of the cropping season.

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[1] Input/output coefficients were assumed to be constant over the range to which the new level of yield are reached.

TABLE 5.11

Employment Effect of the New Technology (Fully Mechanized Harvested Sorghum), Damazine MCPRS,Season 1983/84, Sudan.

Item	Base Model (Man-day)	New Technology (Man-day)	Change (%)
Total Hired Labor	13662	10724	-22
Hired Labor/Feddan	9	7	-22

Source: LP Model

TABLE 5.12

Sensitivity Analysis : Base VS. New Technology Model, Level of Activities and Resource Use if Crop Yields Increase by 25%, Damazine MCPRS, Season 1983/84, Sudan.

Item	Unit	Basic Model	New Technology Model	Change (%)
Objective Function	LS-a	24138	33387	38
Crop				
Early Sorghum	FD-b	523	1161	118
Late Sorghum	FD	738	0	-100
Early Sesame	FD	228	339	49
Late Sesame	FD	0	0	0
Pearl Millet	FD	0	0	0
Hired Labor				
June	MD-c	375	375	0
July	MD	375	375	0
August	MD	2374	2672	18
September	MD	3141	3265	39
October	MD	2534	3071	21
November	MD	319	475	48
December	MD	910	491	46
January	MD	2034	0	-100
February	MD	1367	0	-100
March	MD	258	0	-100
Total		13687	10724	

Source: LP Model

a- LS = Sudanse Pound = 100 Piasters.
b- FD = Feddan = 1.038 Acres.
c- MD = Man-day

5.4.2 A 25 Percent Increase in Sorghum Yield

In this experiment, a 25 percent increase in sorghum yield is assumed, with other crop yields remaining the same. Sorghum is the major crop in the area and extensive research has been conducted in the past decade to improve its yield.[1] The objective is to see the effect of increasing sorghum yield on the cropping pattern, net cash income, and employment of hired labor.

From Table 5.13 it is clear that with a 25 percent increase in sorghum yield, only sorghum is produced under the new technology. This reduces the objective function by about two percent and reduces the amount of operating capital used by 12 percent - - when compared to the situation where all crop yields increase by 25 percent. Hired labor is reduced by 22 percent below the optimum plan under the new technology with all crop yields increased by 25 percent. Hired labor use declines by more than 40 percent below the optimum plan under the new technology with sorghum yield increased by 25 percent - - compared to the base plan under the existing technology (Table 5.1).

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[1] A hybrid variety of sorghum was developed by the National Council of Research, and commercial production is being considered. It was reported that the hybrid sorghum can produce up to the equivalent of more than 25 sacks per feddan (See, Eicher, 1985).

TABLE 5.13

Sensitivity Analysis on the New Technology Model: Level of Activities and Resource Use if All Crop Yields Increased 25% VS. Only Sorghum Yield Increased 25%, Damazine MCPRS,Season 1983/84, Sudan.

Item	Unit	All Crop Yield by 25%	Sorghum Yield by 25%	Change (%)
Objective Function	LS-a	33387	32881	-2
Crop				
Early Sorghum	FD-b	1161	1500	29
Late Sorghum	FD	0	0	0
Early Sesame	FD	339	0	-100
Late Sesame	FD	0	0	0
Pearl Millet	FD	0	0	0
Total Hired Labor	MD-c	10724	8445	-22
Operating Capital	LS	43860	38584	-12

Source: LP Model

a- LS = Sudanse Pound = 100 Piasters.
b- FD = Feddan = 1.038 Acres = 4200 sq. m.
c- MD = Man-day.

5.5 Employment Effects of the New Technology

The effect of mechanization on employment varies with the package of mechanization used, as has been shown in the literature review in Chapter 1. The last section of this study shows two important impacts. First, mechanizing one operation of one crop can affect the cropping pattern and the farms total demand for labor. When sorghum was combine harvested, the aggregate employment per farm decreases by 22 percent and the labor demand for sorghum decreases by about 40 percent. Thus, as the area under sorghum increases, the number of hired labor man-days required per farm decreases. Second, as the total demand for hired labor decreases, the wage rate decreases as farmers find it less profitable to hire labor at the same wage rate as when the sorghum harvest is partially mechanized.

This combine effect of a lower demand for labor and a lower wage rate reduces the total income obtained by hired labor when mechanization is adopted. There is a reduction of a total of nearly 3,000 man-days of hired labor per farm when the sorghum harvest is fully mechanized. The principal reason for the reduced labor demand is the decrease in the labor required for harvesting sorghum - which was partly off-set by the increase in the sesame area, with its higher labor intensity. If we assume that on the average the same sorghum harvesting technology is adopted throughout the Damazine area, the total loss in seasonal hired labor will

amount to a loss of 2.7 million man-days. This translates to a loss of about LS. 5.26 million of income to the seasonal hired labor in the Damazine area alone (the average wage rate is LS. 2.56 per man-day, see Chapter 4).

5.6 Summary

The empirical findings presented in this chapter indicate that under prevailing conditions in the MCPRS it is most profitable for farmers - - in the short run - - to put their total farm under crops, rather than to follow the MFC regulations of leaving one-third of the farm fallow. The findings also indicate that farmers are acting rationally when they put about 80 percent of their farms under sorghum. Yet, there are indications that in the long run, continuous cropping deterioration soil fertility and, consequently, decreases crop yields (Simpson and Simpson, 1978).

Forcing the MFC fallow requirements into the base solution reduces net revenue due to a decrease in the area cropped, but this can be off-set by slight increases in crop yields. This suggests that adopting better cultural practices (Mohamed, 1978) or improved crop varieties can improve the farm income and assure long run use of resources.

Pearl millet, which was recently introduced in the area, was found not competitive with the existing crop options - under the existing conditions.

The introduction of combine harvesting of sorghum increases farm income by 30 percent. With the introduction of combine harvesting of sorghum, the cropping pattern becomes less diversified and hired labor use per feddan decreased by about 40 percent for sorghum and by about 22 percent per feddan for the total cropped area. This loss amount to more than 3,000 man-days per farm. A slight increase in crop yields under the existing production technology may more than off-set the increase in farm income due to the introduction of the new technology and at the same time increase the total hired labor requirement.

CHAPTER 6

A FINANCIAL AND ECONOMIC ANALYSIS

There are two major objectives of this chapter. The first is to estimate the private costs and benefits of the MCPRS under the partially mechanized and fully mechanized sorghum harvesting technologies. The second is to estimate the economic costs and benefits of the MCPRS under both sorghum harvesting technologies.

6.1 Distinction Between Financial and Economic Analysis

Financial analysis is concerned with enterprise viability as assessed from the viewpoint of the individual owner or participant (Brown, 1982). In financial analysis the main objective is to find whether a particular enterprise under given production conditions is viable in strictly monetary terms. In valuing inputs and outputs, the actual price received or paid by the enterprise are used.

In this study inputs are valued at the average unit price paid by farmers. Outputs are valued at the average unit price received by farmers for each crop during the 1983/84 cropping season.

Economic analysis of an enterprise, on the other hand,

reflects its profitability from the viewpoint of society as a whole. Brown (1978) defined profitability in this context as the capacity of the project to maximize the efficient use of a nations resources in producing national income. In an economy with no factor price distortions, prevailing market prices for inputs and output factors of production, are equal to the real economic costs. However, in Sudan factor price distortions exist because of various subsidies, tariffs, import and export duties, taxes, and an over-valued exchange rate (see Chapter 2).

Economic analysis differs from financial analysis in two important respects. First, economic analysis is concerned with how real resources are used. This means the analysis focuses on the opportunity costs of the resources rather than their monetary values.[1] Second, in economic analysis, resources are valued at their opportunity costs, which may differ from their market prices. Therefore, in the transition from the financial analysis to the economic analysis, adjustments are made to exclude transfer payments, loan receipts, and debt service; and to remove distortions in prices of foreign exchange of inputs and outputs.

In Sudan, farmers in the MCPRS face factor price distortion on selected inputs (e.g. credit) and an over-

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[1] Opportunity cost is defined as the maximum net returns that are sacrificed because the resource is not employed in its next most profitable alternative (Harsh, 1981).

valued exchange rate (an implicit subsidy). The factor price distortions increases the demand for artificially cheap imported capital resources. This encourages formers to adopt production technologies which are more capital intensive than they would otherwise use if factors of production are priced at their real economic costs.

6.2 Financial Analysis of the Damazine MCPRS

First, it is necessary to quantify the financial costs and returns of crops under the two alternative sorghum harvesting technologies. The linear programming results which were reported in previous chapters were used to derive the crop enterprise budgets. The budgets for crops raised under the existing technology will be referred to as crops produced under System 1, and those produced under the new technology, full mechanization of sorghum harvesting, will be referred to as produced under System 2.

The crop budgets are important as they help to explain the relative contribution of each enterprise to the farm as a whole. In addition, they help to identify the profitability of each crop, compare the efficiency of resource use by each crop, and derive financial returns to selected factors of production.

The budgets were organized in two categories, non-labor costs and labor costs. Labor costs covered the part of the budget associated with the seasonal hired labor expenditure.

The non-labor costs includes costs of materials, items, and operating costs other than hired labor.

6.2.1 Derivation of Input-Output Coefficient

For each crop enterprise the resource quantities and costs were estimated on a per feddan basis for each field activity. Costs of each crop enterprise were divided into the different cultural practices (i.e., land clearance, land preparation, planting, weeding and harvesting) and a general category was included for activities which are not attached to one specific cultural activity. The output values are the product of crop yields and their prices. Prices used are average farm gate prices received by farmers at the time of harvest.

6.2.2 The Costs of Land Clearance

Land clearance is essential before cropping activities can start (see Chapter 3). The land is cleared once in the life span of a farm, although a few shrubs and small trees may grow and need removal from time to time. As there was no tree clearance observed on the surveyed farms, information about the cost of tree clearance was collected from both the MFC regional office in the Damazine, and some farmers outside the surveyed farms. Land clearance is done by manual labor. The average cost of tree clearance was spread over a 15 year period and included in the budgets on a per feddan basis.

6.3 System 1: Crop Production System Under Partial Mechanization of Sorghum Harvest

Three crops were produced under this system; early sorghum, late sorghum and early sesame.

6.3.1 Crop Enterprise Budgets in System 1

Financial budgets representing the costs and returns to the three enterprises raised under System 1, derived from the 1983/84 cropping season survey, are shown in Tables 6.1.1 - 6.1.3. The area planted to early sorghum, late sorghum and early sesame represents 35 percent, 48 percent, and 16 percent of the farm, respectively. The mean labor utilization for the three crops was 12.1, 8.8, and 8.2 man-days per feddan for early sesame, early sorghum, and late sorghum, respectively. On the average, the labor requirement for sesame was 40 percent higher than for sorghum. The average expenditure per feddan for hired labor was LS. 33.38, LS. 22.13 and LS. 20.76 for early sesame, early sorghum and late sorghum, respectively. On the average, the labor expenditure on sesame was more than 50 percent higher than sorghum. This reflects the high labor requirement for sesame and also, the high wage rate for labor during the sesame harvest. Hired seasonal labor costs represent 64 percent of the total cost of early sesame, while on the average it was 40 percent for early and late sorghum. While about 57 percent of hired labor costs for sesame was for harvesting. only about 40 percent of hired labor expenditure for sorghum was for harvesting.

TABLE 6.1.1

Early Sorghum Costs and Returns Under System 1,
(527 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity	Operating Costs							
Item	Non-Labor Costs				Labor Costs			
	Unit	Rate Per FD.	Total Units	Cost Per Unit	Total Cost LS.	Man-day Per	Total	Wage	Total
Land Clearance	FD-a	1.00	527	1.10	580	.00	.00	.00	.00
Land Preparation									
Tractor	HR-b	.25	132	13.84	1823	.16	84	5.56	469
Planting									
Tractor	HR.	.25	132	13.84	1823	.16	84	5.56	469
Seeds	KG.	1.40	738	.25	184	.00	.00	.00	.00
Weeding									
First	FD.	.00	.00	.00	.00	2.12	1117	2.21	2469
Second	FD.	.00	.00	.00	.00	2.66	1402	2.21	3098
Harvesting									
Cutting	FD.	.00	.00	.00	.00	3.20	1686	2.56	4317
Machine Thresh	Sack	3.36	1771	1.50	2656	.35	184	2.56	472
Other									
Land Rent	LS-c	1.00	527	1.00	527	.00	.00	.00	.00
Farm Trans-d	LS.	1.00	527	1.65	877	.09	47	5.56	264
Crop Trans	Sack	3.36	1771	1.00	1771	.08	42	2.56	108
Sacks	Sack	3.36	1771	1.50	2656	.00	.00	.00	.00
	Total				12894	8.82	4648		11656

SPURCE: Survey Data

a- FD = Feddan = 1.038 Acres = 4200 sq. m
b- HR = Hour.
c- LS = Sudanse Pound =100 Piasters.
d- Trans = Transportation.

TABLE 6.1.2

Late Sorghum Costs and Retuns Under System 1,
(725.7 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity: Operating Costs									
Item	Non Labor Costs				Labor Costs				
	Unit	Rate PER FD-a	Total Units	Cost Per Unit	Total Cost LS-b	Man-day Per FD.	Man-day Total	Wage Rate	Total Cost LS.
Land Clearance	FD.	1	725.7	1.1	798.3	0	0	0	0
Land Preparation									
Tractor	HR.-c	.25	181.4	13.84	2511.	.16	116.1	5.56	645.6
Planting									
Tractor	HR.	.25	181.4	13.84	2511.	.16	116.1	5.56	645.6
Seed	KG.	1.6	1161.	.25	290.3	0	0	0	0
Weeding									
First	FD	0	0	0	0	2	1451.	2.21	3208.
Second	FD	0	0	0	0	2.16	1568.	2.21	3464.
Harvesting									
Cutting	FD	0	0	0	0	3.2	2322.	2.56	5945.
Threshing	Sack	3.06	2221.	1.5	3331.	.35	254.0	2.56	650.2
Other									
Land Rent	LS.	1	725.7	1	725.7	0	0	0	0
Taxes	LS.	3.06	2221.	1.85	4108.	0	0	0	0
Farm Trans-d	LS.	1	725.7	1.95	1415.	.09	65.31	5.56	363.1
Crop Trans	LS.	3.06	2221.	1	2221.	.08	58.06	2.56	148.6
Sacks	Sack	3.06	2221.	1.5	3331.	0	0	0	0
	Total				21242	8.2	5951.		15070

Source:Survey Data

a- FD = Feddan =1.038 Acres.
b- LS = Sudanse Pound =100 Piasters.
c- HR = Hour.
d- Trans = Transportation.

TABLE 6.1.3

Early Sesame Costs and Returns Under System 1,
(247 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity	Operating Costs								
Item	Non Labor Costs					Labor Costs			
	Unit	Rate Per FD-a	Total Units	Cost Per Unit	Total Cost LS-b	Man-day Per FD.	Man-day Total	Wage Rate	Total Cost LS.
Land Clearance	FD.	1.00	247	1.10	272	0	0	0	0
Land Preparation									
Tractor	HR.	.25	62	13.84	855	.16	40	5.56	220
Planting									
Tractor	HR.	.25	62	13.84	855	.16	40	5.56	220
Seeds	KG.	1.10	272	.60	163	0	0	0	0
Weeding									
First	FD.	0	0	0	0	2.80	692	2.21	1528
Second	FD.	0	0	0	0	2.90	716	2.21	1583
Harvesting									
Cutting	FD.	0	0	0	0	4.50	1112	3.27	3635
Threshing	FD.	0	0	0	0	1.40	346	2.56	885
Other									
Land Rent	LS.	1.00	247	1.00	247	0	0	0	0
Taxes	LS.	1.60	395	4.35	1719	0	0	0	0
Farm Trans-d	LS.	1.00	247	1.65	408	.09	22	5.56	124
Crop Trans	LS.	1.60	395	1.00	395	.10	25	2.56	63
Sacks	Sack	1.60	395	1.50	593	0	0	0	0
	Total				5506	12.11	2991		8258

Source: Survey Data

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanse Pound = 100 Piasters.
c- HR = Hour.
d- Trans = Transportation.

More than 90 percent of all labor used for these crops was for weeding and harvesting. This was due to the fact that land preparation and planting is done mechanically (see Chapter 3).

These results are particularly important as hired unskilled labor represents the major source of labor for these farms. There was no involvement of family labor in these farms other than the owner. Thus, the high dependence on hired unskilled labor clearly indicates the importance of these farms as a source of employment.

The non-labor expenditure per feddan was LS. 30.67 for early sorghum, and LS. 22.79 for early sesame (Table 6.1.1 - 6.1.3). Local taxes on corps represents the single major non-labor cost for the three crops. The local taxes represent 37, 20 and 19 percent of the non-labor costs of sesame, early and late sorghum, respectively.

The seed rates observed for all the crops were different from the recommended rates by Abu Naama Research Station.[1] The seed rate farmers use for sesame (1.4 kg./feddan) is about 80 percent of the recommended seed rate. In the case of sorghum, the seed rate used by farmers (1.5 kg./feddan) is 75 percent of the recommended seed rate.

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[1] Abu Naama Research Station is part of the National Research Corporation. It serves the rainfed mechanized agricultural area and is located in the Damazine area.

6.3.2 Comparison and Appraisal of the Crop Enterprises in System 1

This section compares the financial costs and returns of the crops produced under System 1. A summary of the general characteristics, financial situation, and the performance measures is provided in Table 6.1.4. Five measures of performance were computed for each crop to identify the crop with the highest financial returns.

Gross Output[1]

Sesame gave the highest gross income (LS. 68.80/feddan), followed by early sorghum (LS. 63.16/feddan), and late sorghum (LS. 58.60/feddan). The results reflect the high per unit sesame price, although sesame yields were only one half sorghum yields.

Net Income[2]

Sesame also gave the highest net income per feddan. The net income per feddan for the three crops was LS. 10.51, LS. 10.36, and LS. 8.56 for early sesame, early sorghum and late sorghum, respectively.

Hired Labor Income

Hired labor represents the major single cost item for all of the three crops. The total income per farm to hired labor was LS. 15071, LS. 11666, and LS. 8950 for late sorghum, early sorghum and early sesame, respectively. The

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1 Gross Output, in monetary terms, is calculated by multiplying the total area devoted to the crop by the average yield times the average price received (Brown, 1978).

2 Net income of each enterprise is calculated by subtracting the total costs from the gross income.

TABLE 6.1.4

System 1:Comparative Analysis of the Crops Enterprises
Damazine MCPRS, Season 1983/84,Sudan.

Criteria	Unit	Crops		
		Early Sorghum	Late Sorghum	Early Sesame
General Characterisics				
Plot Size	FD-a	527	726	247
Average Yield	Sack/FD	3.36	3.06	1.6
Total Production	Sack	1771	2221	396
Average Price	LS/Sack	18.80	19.15	43
Financial Summary				
Gross Income	LS-b	33290	42525.	17014.
Operating Capital				
Hired Labor	LS.	11666	15071	8950
Non Labor Costs	LS.	16166	21243	5465
Capital Opportunity cost	LS.	1606	2107	828
Cost of permenant Labor	LS.	949	1306	594
Performance Measures				
Net Income				
Per Total Area	LS.	5458	6211	2599
Per Feddan	LS.	10.36	8.56	10.51
Hired Labor INcome				
Per Total Labor	LS.	11666	15071	8950
Per Man-day	LS.	2.51	2.53	2.99
Return to Management & Permenant Labor				
Per Total Area	LS.	3852	4104	1771
Per Feddan	LS.	7.31	5.66	7.16
Return to Management				
Per Total Area	LS.	2903	2797.8	1178
Per Feddan	LS.	5.51	3.86	4.76
Per Man-day	LS.	16.13	15.54	6.54

Source:Computed FromTable 6.1.1-6.1.3.

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanse Pound = 100 Piasters.

income of hired labor per feddan was LS. 2.99, LS. 2.53, and LS. 2.50 for sesame, late sorghum and early sorghum. The income of hired labor for early and late sorghum was approximately equal, indicating their similar hired labor requirements. The income of hired labor was 19 percent higher for sesame than for sorghum.

Return to Management and Permanent Labor

On mechanized crop production farms, the only permanent labor is the farm supervisor and the farm guard. Hence, the permanent labor is part of the farm management. By separating the permanent labor and management, we can compute the return to the farm owner's time and effort in running his farm. In computing return to management and permanent labor, a value must be assigned to operating capital. Normally, operating capital is treated as an input without any opportunity cost in the accounting period. But, since farmers use their own capital and borrowed capital to finance the farm activities, and this money was tied up during the season, it is a capital expenditure which has an opportunity cost. The Agricultural Bank of Sudan charges farmers a 14 percent interest rate for agricultural credit. This was used as the opportunity cost for operating capital.

The total return to management and permanent labor was LS. 4104, LS. 3852, and LS. 1771 for late sorghum, early sorghum and sesame, respectively. The return to management

and permanent labor per feddan was higher for early sorghum (LS. 7.31) followed by early sesame (LS. 7.16) and late sorghum (LS. 5.66), respectively.

Return to Management

To compute the returns to management, the cost of permanent labor was subtracted from the returns to management and permanent labor. The total return to management was highest for early sorghum (LS. 2903) followed by late sorghum (LS. 2798) and sesame (LS. 1771). In contrast, on a per feddan basis, returns were higher for early sorghum (LS. 5.51) followed by early sesame (LS. 4.76), and late sorghum (LS. 3.86).

The returns to management, calculated per man-day spent, were highest for early sorghum (LS. 16.13/feddan), followed by late sorghum (LS. 15.54/feddan) and early sesame (LS. 6.54/feddan). On the average, returns to management were about 50 percent higher for sorghum than for sesame. This reflects the high management and supervision required for sesame, especially during harvest time.

6.4 System 2: Crop Production System Under Full Mechanization of Sorghum Harvesting

Early sorghum and early sesame were produced when the sorghum harvest was fully mechanized.

6.4.1 Crop Enterprise Budgets in System 2

Costs and returns to early sorghum and early sesame enterprises are shown in Tables 6.2.1 and 6.2.2. There was

TABLE 6.2.1

Early Sorghum Costs and Returns Under System 2,
(1161 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity / Item	Operating Costs								
	Non Labor Costs					Labor Costs			
	Unit	Rate Per FD-a	Total Units	Cost Per Units	Total Cost LS-b	Man-day Per FD.	Man-day Total	Wage Rate	Total Cost
Land Clearance	FD.	1.00	1161	1.10	1277	0	0	0	0
Land Preparation									
Tractor	HR-c	.25	290	13.84	4017	.16	186	5.56	1033
Planting									
Tractor	HR.	.25	290	13.84	4017	.16	186	5.56	1033
Seed	KG.	1.40	1625	.25	406	0	0	0	0
Weeding									
First	FD.	0	0	0	0	2.12	2461	2.21	5440
Second	FD.	0	0	0	0	2.66	3088	2.21	6825
Harvesting									
Combine	LS.	3.36	3901	3.50	13653	.35	406	2.56	1040
Other									
Land Rent	LS.	1.00	1161	1.00	1161	0	0	0	0
Taxes	LS.	3.36	3901	1.85	7217	0	0	0	0
Farm Trans-d	LS.	1.00	1161	2.13	2473	.09	104	5.56	581
Crop Trans	LS.	3.36	3901	1.00	3901	.08	93	2.56	238
Sacks	Sack	3.36	3901	1.50	5851	0	0	0	0
	Total				43374	5.82	6525		16189

Source: Survey Data

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanse Pound = 100 Piasters.
c- HR = Hour.
d- Trans = Transportation.

TABLE 6.2.2

Early Sesame Costs and Returns Under System 2, (339 Feddans), Damazine MCPRS, Season 1983/83, Sudan.

Item	Operating Costs								
	Non Labor				Labor				
	Unit	Rate	Total Cost	Total	Man-day Per FD-a	Man-day Total	Wage Rate	Total Cost LS-b	
Land Clearance	FD.	1.00	339	1.10	373	0	0	0	0
Land Preparation									
Tractor	HR.	.25	85	13.84	1173	.16	54	5.56	302
Planting									
Tractor	HR.	.25	85	13.84	1173	.16	54	5.56	302
Seeds	KG.	1.10	373	.43	160	0	0	0	0
Weeding									
First	FD.	0	0	0	0	2.80	949	2.21	2098
Second	FD.	0	0	0	0	2.90	983	2.21	2173
Harvesting									
Cutting	FD.	0	0	0	0	4.50	1526	3.27	4988
Threshing	FD.	0	0	0	0	1.40	475	2.56	1215
Other									
Land	LS.	1.00	339	1.00	339	0	0	0	0
Taxes	LS.	1.60	542	4.35	2359	0	0	0	0
Farm Tran-c	LS.	1.00	339	1.65	559	.09	31	5.56	170
Crop Tran	LS.	1.60	542	1.00	542	.10	34	2.56	87
Sacks	Sack	1.60	542	1.50	814	0	0	0	0
	Total				[illegible]	12.11	4105		[illegible]

Source: Survey Data.

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanse Pound = 100 Piasters.
c- Tran = Transportation

77 percent of the total farm area (1161 feddans) under early sorghum, and 23 percent (339 feddans) under early sesame. Under System 2, the area under early sorghum was more than twice that of early sorghum produced under System 1. Also, late sorghum was eliminated from the farm plan under System 2. Finally, the area under sesame was 37 percent higher under System 2 than under System 1.

Average labor use per feddan for early sorghum under System 2 (5.62 man-days) was 36 percent higher than that of early sorghum under System 1 (8.8 man-days), due to the full mechanization of harvesting. In contrast, for sesame there was no difference in labor requirements between Systems, as there was no change in the sesame production technology.

There was a noticeable change in the cost of hired labor and non-labor inputs for early sorghum produced under System 1 compared to System 2. While non-labor inputs represented only 58 percent of the production costs of early sorghum under System 1, they represented 73 percent of the early sorghum production costs under System 2. This change was largely due to both the reduction in labor requirements and the increase in machine cost for sorghum harvest under System 2. The cost of combine harvesting sorghum System 1 was 16 percent of the total non-labor costs, while it increased to 31 percent of the total non-labor costs under System 2. The mean expenditure per feddan for early sorghum under both systems was very close, LS. 52.8, and LS. 51.8 for early sorghum under System 1 and System 2, respectively.

The only other cost for which the early sorghum produced under both systems was different was the cost of field transportation. Collection of combine harvested sorghum sacks from the field under System 2 cost more than stationary threshed sorghum under System 1.

6.4.2 Comparison and Appraisal of the Crops Enterprises in System 2

The purpose of this section is to compare the financial costs and returns to the crops produced under System 2. A summary of the general characteristics, financial situation, and the performance measures is provided in Table 6.2.3.

Gross Income

The gross income for early sorghum was LS. 73,338 and LS. 23,321 for early sesame. The higher gross income for early sorghum reflects the fact that three-fourths of the farm was under sorghum.

Net Income

Sorghum gave both a higher total net income (LS. 13,201) than sesame (LS. 4514.2) and a higher per feddan net income (LS. 13.32 Vs. LS. 10.58). The net returns to sorghum per feddan were 7 percent higher than that of sesame.

Hired Labor Income

The total income of hired labor were greater for early sorghum (LS. 16,182) than for early sesame (LS. 12, 219). In contrast, income of hired labor per feddan were higher for sesame (LS. 2.99) than for early sorghum (LS. 2.48). In part, the high income of hired labor from sesame reflect its higher labor requirements. Sesame requires more than twice

TABLE 6.2.3

System 2: Comparative Analysis of the Crop Enterprises
Damazine MCPRS,Season 1983/84,Sudan.

Criteria	Unit	Crops	
		Early Sorghum	Early Sesame
General Characteristics			
Plot Size	FD-a	1161	339
Average Yield	Sack/FD	3.36	1.6
Total Production	Sack	3901	542
Average Price	LS/Sack	18.8	43
Financial Summary			
Gross Income	LS-b	73338.	23323
Operating Capital			
Hired Labor	LS.	16182	12219
Non Labor Costs	LS.	43955	7517
Capital Opportunity Cost	LS.	3614	1113
Cost of Permenant Labor	LS.	2090	610
Performance Measures			
Net Income			
Per Total Area	LS.	13201	3587
Per Feddan	LS.	11.37	10.58
Hired Labor Income			
Per Total Labor	LS.	16182	12219
Per Man-day	LS.	2.48	2.98
Return to Management & Permenant Labor			
Per Total Area	LS.	9587	2474
Per Feddan	LS.	8.26	7.30
Return to Management			
Per Total Area	LS.	7498	1864.2
Per Feddan	LS.	6.46	5.50
Per Man-day	LS.	41.65	10.36

Source:Computed From Table 6.2.1 and 6.2.2.

a- FD = Feddan = 1.038 Acres .
b- LS = Sudanse Pound = 100 Piasters.

the labor required for early sorghum under System 2 (Tables 6.2.1 and 6.2.2).

Returns to Management and Permanent Labor

The total returns to management and permanent labor were higher for early sorghum (LS. 9587) than for early sesame (LS. 2474). Also, the returns to management and permanent labor per feddan were 13 percent higher for early sorghum (LS. 8.26/feddan) than for sesame (LS. 7.30/feddan).

Returns to Management

As we did in the computation of returns to management under System 1, the returns to permanent labor were subtracted from the returns to management and permanent labor. The total return to management was LS. 7498 and LS. 1864 for early sorghum and sesame, respectively. The return to management on a per feddan basis was 17 percent higher (LS. 6.46/feddan) than for sesame (LS. 5.50/feddan). The performance measures discussed above all confirm the advantage of fully machine harvested sorghum on a per feddan basis over sesame. The returns per man-day to management was about four times greater for early sorghum (LS. 41.65/man-days) than for sesame (LS. 10.36/man-day).

6.5 Comparative Financial Analysis of Two Production Systems

The purpose of this section is to compare the financial returns to the whole farm under System 1 and System 2. In the second part of the section, only sorghum produced under

the two systems will be compared. Five measures of performance have been computed for each system and the results analyzed to identify the system with the highest returns.

Two production systems were studied. In System 1 sorghum harvesting is partially mechanized (i.e. machine threshing). In System 2 sorghum harvesting is fully mechanized. Table 6.3.1 summarizes the general characteristics, costs and returns, as well as measures of performance for the two production systems. The analysis focuses on the private profitability of the whole farm enterprise. The performance measures were based on average costs and returns during the 1983/84 season.

Under both systems the total farm area (1500 feddans) is cropped. System 2 uses 2,967 man-days less hired labor than System 1. This is a reduction of about 22 percent of the total manpower used. This reduction in labor required was probably due to the decrease in labor needed for sorghum harvesting. The increase in sesame area from 247 feddans under System 1 to 339 feddans under System 2 increased the use of hired labor, but not enough to compensate for the loss of hired labor due to the mechanization of sorghum harvesting.

Net Income

System 2 produced about an 18 percent higher net cash income (LS. 17,715) than System 1 (LS. 14,964). Net cash income per feddan was 15 percent higher for System 2 (LS.

TABLE 6.3.1

Comparative Analysis of System 1 and System 2 Whole Farm Enterprises, Damazine MCPRS, Season 1983/84, Sudan.

Criteria	Unit	Cropping System	
		System One	System Two
General Characteristics			
Farm Size	FD-a	1500	1500
Total Production	Sack	4387	4443
Total Man-days	Man-day	13588	11621
Financial Summary			
Gross Income	LS-b	92829	96661
Operating Costs			
Hired Labor	LS.	34991	27498
Non Labor Costs	LS.	42874	51448
Capital Opportunity Cost	LS.	4541	4726
Cost of Permenant Labor	LS.	2700	2700
Performance Measures			
Net Income			
Per Total Area	LS.	14964	17715
Per Feddan	LS.	9.98	11.81
Hired labor Income			
Per Total Labor	LS.	3499	27498
Per Feddan	LS.	2.58	2.37
Return to Mangement & Permenant Labor			
Per Total Area	LS.	10423	12989
Per Feddan	LS.	6.95	8.66
Return to Management			
Per Total Area	LS.	7723.4	10289
Per Feddan	LS.	5.15	6.86
Per Man-day	LS.	21.49	28.58

Source: Computed from Tables 6.1.4 and 6.2.3

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanese Pound = 100 Piasters.

11.81) than for System 1 (LS. 9.98). This was due to the increase in the area under early sorghum and sesame, and also the reduced cost for sorghum harvesting under System 2.

Hired Labor Income

Under System 1 seasonal hired labor earned LS. 34,991 per farm on the average. The total amount of income that the hired labor realized under System 2 was LS. 27,948. The reduction in labor earnings when farmers move from System 1 to System 2 was LS. 7,493, or a reduction of 21 percent. The per feddan income of hired labor was comparable; LS. 2.57 and 2.58 under System 1 and System 2, respectively.

Return to Management and Permanent Labor

To compute the returns to management and permanent hired labor, an opportunity cost (interest rate of 14 percent) was assigned to operating capital. The operating capital was taken as an expenditure farmers carried until harvest. Because crops are sold at harvest, capital used to finance harvest was assumed to have a zero opportunity cost.

The total returns to management and permanent labor were higher for System 2 (LS. 12,989) than for System 1 (LS. 10,423). The returns to management and permanent labor was 27 percent higher for the farm under System 2 than under System 1 (Table 6.3.1).

6.6 Comparative Financial Analysis of Sorghum Production with Partial and Full Mechanization of Harvesting

In this section, the discussion will focus on the financial costs and returns to the sorghum crops produced under partially versus fully mechanized harvesting. Five measures of financial efficiency have been computed for sorghum produced under each system. For partially mechanized sorghum, early and late sorghum crops were raised (see Table 6.1.4). The average input-output relationships for each enterprise were used to represent sorghum produced under System 1.

The results of this section will be carried further to determine the economic costs and returns of sorghum produced under the conditions of partial mechanization or full mechanization of harvesting. In the case of partial mechanization, the crop heads are cut by manual labor and collected into big heaps, then threshed using a stationary combine harvestor. The full mechanization of sorghum harvesting refers to the direct harvesting of the crop using a combine harvestor.

Net Income

Although the total area under sorghum was greater under System 1 (1253 feddans), still the net income from sorghum was 13 percent less than under System 2 (1161 feddans). (Table 6.4.1). On a per feddan basis, the net income of LS. 11.37 for fully mechanized sorghum was 22 percent higher than the net returns of LS. 9.32 for partially mechanized

TABLE 6.4.1

Comparative Analysis of Partailly and Fully Machine Harvested Sorghum,Damzine MCPRS,Season 1983/83,Sudan.

Criteria	Unit	Machine Harvesting	
		Partial	Full
General characteristics			
Area	FD-a	1253	1161
Average Yield	Sack/FD	3.21	3.36
Total Production	Sack	4021	3901
Average Price	LS/Sack	18.98	18.8
Financial Summary			
Gross Income	LS-b	75815	73338
Operating Costs			
Hired Labor	LS.	26737	16182
Non Labor Costs	LS.	37409	43955
Capital Opportunity Cost	LS.	4641	4517
Cost of Permenant Labor	LS.	1804	1671
Performance Measures			
Net income			
Per Total Area	LS.	11669	13201
Per Feddan	LS.	9.32	11.37
Hired Labor Income			
Per Total Labor	LS.	26737	16182
Per Man-day	LS.	2.52	2.48
Return to Management & permenant Labor			
Per Total Area	LS.	7028	8684
Per Feddan	LS.	5.61	7.47
Rerturn to Management			
Per Total Area	LS.	4723	6595
per Feddan	LS.	3.81	5.68
Per Man-day	LS.	26.52	36.64

Source:Computed From Tables 6.1.1,6.1.2,and 6.2.1.

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanse Pound = 100 Piaste

sorghum. This indicates that sorghum produced with full mechanization of harvesting is more profitable to the individual farm than when partially mechanized.

Hired Labor Income

The total earning of hired labor was 39 percent higher for partially machine harvested sorghum (LS. 26,737) than for fully mechanized harvested sorghum (LS. 16,182). But, the income of hired labor on a per feddan basis was comparable under both system, at LS. 2.52 and LS. 2.48 for System 2 and System 1 respectively.

Return to Management and Permanent Labor

In computing the returns to management and permanent labor, the cost of operating capital was first subtracted from the net returns. The total returns to management and permanent labor were higher for sorghum produced with full mechanization (LS. 8,684) then when partially mechanized (LS. 7,028). The returns per feddan to management and permanent labor of sorghum produced with full mechanization were 33 percent higher (LS. 7.47) than for partially mechanized harvested sorghum (LS. 5.61).

Returns to Management

Returns to management were also higher for fully mechanized sorghum (LS. 6,595) than for partially mechanized sorghum (LS. 4,773). The fact that more partially mechanized sorghum was produced explains part of the reduced returns to management. On a per feddan basis, management realized an approximately 50 percent higher income from fully mechanized

over partially mechanized harvested sorghum. The returns per man-day of management (LS. 36.64/man-day) were 38 percent higher than for partially mechanized sorghum (LS. 26.52/man-day).

6.7 Economic Analysis of Partially Mechanized Vs. Fully Mechanized Sorghum Harvested

This section presents the economic costs and returns to the two sorghum harvesting technologies in the absence of imperfections in factor and product markets. Sorghum is the most important crop in the MCPRS in terms of both area and total returns. Here, the economics of partially and fully mechanized harvested sorghum will be considered.

In economic analysis real resource costs to society are considered. Three adjustments are necessary to convert financial costs and returns to reflect their real costs to the society. The first step in adjusting financial prices to economic values is to eliminate items such as direct transfer payments, such as taxes, tariffs, and import duties. These items do not represent use of real resources, but only the transfer of claims to real resources from one individual in the society to another. The second step in adjusting financial prices to reflect economic values is to adjust for distortion of traded goods. Traded goods are commodities that can be exported, imported or substitute for imports. The CIF (cost, freight, insurance) is generally used if traded goods are imported, and the FOB (free on

board) price is normally used if traded goods are exported. To convert CIF prices or the FOB price to domestic real prices, the real exchange rate (e.g., shadow exchange rate) is used. The third step is to adjust for the distortions in the price of non-traded goods or items not imported or exported because the are bulky or highly perishable (Gittinger, 1979). The opportunity cost of producing traded goods is used to reflect their real cost to the society.

6.7.1 Adjusting Prices for Economic Analysis

Farmers in the Damazine pay a subsidized price for all imported inputs, land and credit they use, as shown in Table 6.5. For some of these items farmers receive an explicit subsidy. For imported items (tractors, combines and sacks) farmers get an implicit subsidy due to the overvalued official exchange rate. When the overvalued exchange rate is taken into account, the total subsidy for imported capital items, tractors and combine, was 42 and 40 percent, respectively, of the economic price. For jute sacks the implicit subsidy was 50 percent. The private land rent reflects the undistorted market opportunity cost of land. The MFC charges farmers LS. 1.00 per feddan, while the private rental value of one feddan in the area is LS. 2.50 per feddan. The subsidy on land rent amounts to 150 percent.

6.7.1.1 Determining the Value of Foreign Exchange

The foreign exchange rate expresses the number of units of the local currency that can be exchanged for one unit of

TABLE 6.5

Subsidized and Unsubsidized Costs of Selected Agricultural Activities,Damazine MCPRS,Season 1983/84,Sudan.

Item	Unit	Costs		Subsidy Level (%)
		Subsidized	Unsubsidized	
Land Preparation-a				
Tractor	FD.	3.63	5.41	49
Planting				
Tractor	FD.	3.63	5.41	49
Mechanical Harvesting-b				
Threshering	FD.	3.40	5.25	54
Combine Harvesting	FD.	8.50	13.12	54
Sacks-c	SACK	1.50	2.54	69
Land Rent-d	FD.	1.00	2.50	150

Source:Computed From Survey Data.

a- Tractor Financial and Economic Costs See Tables C.1.1 and C.1.2, Appendix C.
b- Combine Harvestor Financial and Economic Costs See Tables C.2.1 and C.2.2 ,Appendix C.
c- Financial and Economic Costs of Sacks See Table C.3.1,Appendix C.
d- Mechanized Farming Corporation Records.
e- FD = Feddan = 1.038 Acres.
f- LS = Sudanse Pound (Shadow Exchane Rate LS 2.20=US$ 1.00).

another currency (Brown, 1979). Here, the distinction is made by the official exchange rate (OER) and the shadow exchange rate (SER). The official exchange rate is the rate established by the government and is used in the financial analysis. A major problem in adjusting the financial account to reflect real economic values is determining the real value (shadow price) of foreign exchange, which reflects a more reliable estimated of how much the local currencies can be exchanged for in foreign currencies.

During the period of June, 1983 to March, 1984, the official exchange rate for Sudan was LS. 1.30 = US $1.00 (Zaki, 1983; Winch, 1984). Bateson and Sidhu (1984) estimated the shadow exchange rate for Sudan to be LS. 2.20 = US $1.00. The SER of LS. 2.20 = US $1.00 was the rate used in this study for valuing the exchange rate. All agricultural inputs were imported on the basis of the official exchange rate of LS. 1.30 = US $1.00. The SER was used to adjust the financial account into economic values. The SER adequately reflects real resource flow and is an accurate indicator to the opportunity cost of foreign exchange.

6.7.1.2 Import Parity Price of Sorghum

The world price is used to evaluate the profitability of sorghum in the Damazine MCPRS, since part of Sudan's sorghum production is exported and there is a potential for increased exports.[1]

The farm gate import parity price of sorghum produced

in the Damazine MCPRS is LS. 22.00 per sack (Table 6.6). This is equivalent to an increase of 17 percent and 16 percent over the price actually received by farmers for fully and partially mechanized sorghum. Thus, farmers in the area received less than the world market price of sorghum when the exchange rate is valued at its shadow price (LS. 2.20 = US $1.00).

6.7.1.3 Calculating the Economic Costs of Sorghum Production[2]

In the analysis of economic costs and returns to partially and fully mechanized harvested sorghum, the enterprise budgets were derived using the economic prices of factors of production in the following manner:

Non-Labor Costs:

Non-labor costs were derived using the unsubsidized prices shown in Table 6.5. Local taxes on crops were removed for the economic analysis as they are transfer payments and do not represent the use of real resources (Brown, 1982).

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[1] About 300,000 tons of sorghum (about 15 percent of the total production) is exported annually, mainly as animal feed, and the income generated from sorghum export accounts for 15 percent of the total exports in 1979/80 (Ahamed and Salam, 1983).

[2] See Appendix B for the actual compulation of the unsubsidized factors costs of producing sorghum under System 1 and System 2.

TABLE 6.6

Damazine MCPRS,Economic Farm Gate Price of Sorghum, Season 1983/84,Sudan.

Item	Value LS/MT
FOB at Port Sudan(LS/MT)_a	363
Less Port Charges_b	5
Less Handling Costs-c	18
Less Land Transport-d	77
Less Marketing Costs-e	20
Less Unloading Costs-f	3
Farm Gate Price-g	239

Source: Adapted From William M.Bateson ,"Considerations on the Use of Foriegn Conversion Formulas for Dura Exoprts,"Khartoum ,Sudan(Unpublished Report).

a_FOB Port Sudan priceof US$ 165/MT. Converted to LS> by the of LS 2.20 = US $ 1.00
b_Port charges of 1.5 percent of FOB price
c_Handling costs estimated at LS. 18.00/MT.
d_In land transportation estimated at LS. .09/MT-Km (Damaine Sudan approximatety 700 Km.)
e_Marketing cost estimated at LS. 20.00/MT.
f_Unloading costs at the farm estimated at LS. 3.30/MT.
g_One Metric Ton = 11 sacks of sorghum (i_e price/sack =LS.

Hired Labor Costs:

The major labor source for the MCPRS was seasonal hired labor. The financial cost of hired labor were valued at the existing wage rate, since the government's minimum wage regulation does not apply to rural unskilled labor.[1] As the wage rate in the area was determined by market supply and demand forces, the seasonal wage rate reflects the opportunity cost (MVP) of hired labor.

Opportunity Cost of Borrowed Capital:

In economic analysis, capital costs are estimated using the opportunity cost of capital in the country. The Agricultural Bank of Sudan (ABS) provides credit to farmers at 14 percent, far below the yearly inflation rate of 30 percent (Zaki, 1983). This means that the capital resources are not only priced to reflect their opportunity cost, but that farmers pay a negative interest rate of 16 percent.

In this study, the inflation rate was used as the opportunity cost of borrowed capital in the economic analysis. In a capital scarce country like Sudan, the opportunity cost of capital might be higher than the inflation. Choosing the inflation rate as the opportunity cost of capital, assumes that farmers pay a zero real interest rate on borrowed capital.

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[1] The minimum urban wage rate is LS. 38 per month.

6.7.2 A Comparative Economic Analysis of Partially Vs Fully Mechanized Harvested Sorghum

From society's point of view, fully mechanized sorghum harvesting produced economic losses, while partially mechanized harvesting produced economic profit (Table 6.7). When all real resource costs used in sorghum production are taken into account (Table 6.5), fully mechanized sorghum gives economic losses of LS. 16,368 per farm. This reflects an economic loss of LS. 14.00 per feddan of combine harvested sorghum. Partially mechanized sorghum produced a economic profit of LS. 11,582 per farm, or LS. 9.25 per feddan.

The economic cost of producing one sack of sorghum (90 kg./sack) is LS. 26,4 which is 18 percent higher than its parity price in the Damazine area (Table 6.6). The cost of producing one sack of partially mechanized sorghum (LS. 19/sack) is 14 percent lower than the parity price of sorghum.

The results show that it is 37 percent cheaper, economically, to produce one sack of sorghum under partial than under full mechanization of harvesting. These results show that, from the perspective of the national economy, it is still profitable to produce sorghum in the Damazine MCPRS with partial mechanization, even when all the factors of production are priced at their ecinomic values.

TABLE 6.7

Comparative Economic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,Damazine MCPRS, Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-c	87811	85784
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	6435	5962
Planting	LS.	6910	6002
Machine Harvesting	LS.	7982	46284
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	18389	18045
Operating Capital	LS.	12000	12000
Total Economic Costs	LS.	79829	105752
Economic Loss or Benefit	LS.	7982	-19968

Source:Computed From Survey Data.

a- Computed from Table B.1.1 and B.1.2,Appendix B.
b- Computed From Table B.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

6.7.3 Comparison of Financial and Economic Costs of Fully and Partially Mechanized Harvested Sorghum

The financial and economic costs of producing sorghum under full and partial mechanization are summarized in Table 6.8. When harvesting is fully mechanized, the economic cost per metric ton of sorghum is 68 percent greater than the financial cost. With partial mechanization of sorghum, the economic cost of producing one metric ton is 19 percent greater than the financial cost.

The economic cost of sorghum production in the Damazine MCPRS is higher than the financial cost because the implicit and explicit production subsidies (Table 6.5) were not included in the financial analysis. In addition, full mechanization of sorghum, which involves more capital than partial mechanization , is economically more costly than the latter because of the high level of subsidies involved. In contrast, partial mechanization is financially more costly than sorghum harvested under full mechanization due to lower subsidies to the former. Fully mechanized harvested mechanized sorghum, while financially the latter is four percent more costly than the former.

6.7.4 Sensitivity of the Economic Analysis Results to Changing Interest Rate and Exchange Rate Assumptions

6.7.4.1 Changing the Interest Rate Assumptions

In the previous economic analysis of the two alternative sorghum harvesting technologies, an interest equal to the inflation rate (30%) was assumed. In this section three interest rates, which reflect positive real

TABLE 6.8

Financial VS. Economic Costs of Production of Fully and Partially Machine Harvested Sorghum,Damazine MCPRS,Season 1983/84,Sudan.

Production System	Financial (LS/MT)-a	Economic (LS/MT)	Subsidy Level-b
Fully Mechanized	170_c	288_d	69
Partially Mechanized	176_e	209_f	19

Source:Computed.

a- LS/MT = Sudanse Pounds Per Metric Ton.
b- Subsidy Level=(Unsubsidized Price-Subsidized Price)/Subsidized*100.
c- Computed From Table 6.2.3.
d- Computed From Table C.2.1,Appendix B.
e- Computed From Table 6.4.1.
f- Computed From Table C.1.1 and C.1.2,Appendix C.

interest rates are used (Table 6.9.1 - 6.9.3).

First, a 35 percent (i.e. + 5% real interest rate) is assumed. At this rate, the net income of partially mechanized sorghum is reduced by 25 percent, while that of fully mechanized sorghum is reduced by 10 percent (Table 6.9.1). Second, when a 40 percent interest rate (i.e. + 10% real interest rate) is assumed, the economic profit of partially mechanized sorghum decrease by about 50 percent. In control, for the fully mechanized sorghum enterprise, economic losses increased by about 20 percent (Table 6.9.2).

At a 50 percent interest rate (i.e. + 20% real interest rate),net income for the fully mechanized sorghum enterprise decreased by 42 percent, while the partially mechanized sorghum enterprise just breaks even. In summary, the partially mechanized sorghum enterprise will breaks even until the interest rate is 50 percent (i.e. + 20% real interest).

6.7.4.2 Changing the Exchange Rate Assumption

Three exchange rates,all higher than the SER used in the economic analysis, are evaluated. First, a SER of LS. 2.50 = US $1.00 is assumed. Under this assumption economic profits of partially mechanized sorghum increased by about 50 percent. For the fully mechanized sorghum enterprise, economic losses declined by 31 percent. Compared to when a SER of LS. 2.20 = US $1.00 is used (Table 6.10.1).

Second, when the SER is raised to LS. 2.80 = US $1.00 the economic profits of partially mechanized sorghum

TABLE 6.9.1

Sensitivity Analysis:Economic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,With 35% Interest Rate on Credit, Damazine MCPRS,Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-c	87811	85784
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	6435	5962
Planting	LS.	6910	6002
Machine Harvesting	LS.	7982	46284
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	18389	18045
Operating Capital	LS.	14000	14000
Total Economic Costs	LS.	81829	107752
Economic Loss or Benefit	LS.	5982	-21968

Source:Computed From Survey Data.

a- Computed from Table B.1.1 and B.1.2,Appendix B.
b- Computed From Table B.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

TABLE 6.3.2

Sensitivity Analysis:Economic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,With 40% Interest Rate on Credit, Damazine Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-c	87811	85784
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	6435	5962
Planting	LS.	6910	6002
Machine Harvesting	LS.	7982	46284
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	18389	18045
Operating Capital	LS.	16000	16000
Total Economic Costs	LS.	83829	109752
Economic Loss or Benefit	LS.	3982	-23968

Source:Computed From Survey Data.

a- Computed from Table B.1.1 and B.1.2,Appendix B.
b- Computed From Table B.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

TABLE 6.9.3

Sensitivity Analysis:Economic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,With 50% Interest Rate on Credit, Damazine MCPRS,Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-c	87811	85784
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	6435	5962
Planting	LS.	6910	6002
Machine Harvesting	LS.	7982	46284
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	18389	18045
Operating Capital	LS.	20000	20000
Total Economic Costs	LS.	87829	113752
Economic Loss or Benefit	LS.	-18	-27968

Source:Computed From Survey Data.

a- Computed from Table B.1.1 and B.1.2,Appendix B.
b- Computed From Table B.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

TABLE 6.10.1

Sensitivity Analysis:Eonomic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,With SER of LS 2.50 =US$ 1.00, Damazine MCPRS,Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-c	103799	101425
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	7281	6745
Planting	LS.	7755	7151
Machine Harvesting	LS.	13456	52601
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	19547	19176
Operating Capital	LS.	12000	12000
Total Economic Costs	LS.	88453	115132
Economic Loss or Benefit	LS.	15346	-13707

Source:Computed From Survey Data.

a- Computed from Table 8.1.1 and 8.1.2,Appendix B.
b- Computed From Table 8.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

increased by more than 60 percent and the economic losses of fully mechanized sorghum were reduced by more than 50 percent (Table 6.10.2).

Finally, when the SER is set at LS. 3.00 = US $1.00, fully mechanized sorghum shows economic profits and the economic profits of partially mechanized sorghum increased by about four fold (6.10.3).

In summary, the exchange rate level can drastically effect the profitability of the alternative sorghum harvesting technologies in the MCPRS. During the 1984/85 food crisis in the Sudan, it was reported that the free market exchange rate exceeded LS. 3.50 = US $1.00. At such a high level, all other assumed constant, both sorghum producing technologies are profitable. Yet, as the exchange rate increases, the margin of economic profit of the partially mechanized sorghum over the fully mechanized sorghum increases.

6.8 Summary

The first purpose of this chapter is to determine the financial profitability of farming in the Damazine MCPRS under partially and fully mechanized sorghum harvesting. The second purpose is to determine the economic costs and returns to sorghum produced under the alternative of fully versus partially mechanized harvesting.

The financial analysis showed that in System 1 - -

TABLE 6.10.2

Sensitivity Analysis:Eonomic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,With SER of LS 2.80 =US$ 1.00, Damazine MCPRS,Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-d	122164	119369
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	8156	7555
Planting	LS.	8630	7961
Machine Harvesting	LS.	24124	58918
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	20663	20268
Operating Capital	LS.	12000	12000
Total Economic Costs	LS.	101687	124161
Economic Loss or Benefit	LS.	20477	-4792

Source:Computed From Survey Data.

a- Computed from Table B.1.1 and B.1.2,Appendix B.
b- Computed From Table B.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

TABLE 6.10.3

Sensitivity Analysis:Eonomic Analysis of Partially VS. Fully Mechanized Harvested Sorghum,With SER of LS 3.00 =US$ 1.00, Damazine MCPRS,Season 1983/84,Sudan.

Item	Unit	Sorghum Machine Harvesting	
		Partially-a	Fully-b
Total Area		1253	1161
Gross Economic Benefits	LS-c	87811	85784
Economic Resource Costs			
Non Labor			
Land Clearance	LS.	1378	1277
Land Preparation	LS.	6435	5962
Planting	LS.	6910	6002
Machine Harvesting	LS.	7982	46284
Labor			
Pre-Harvest	LS.	14831	14324
Harvest	LS.	11905	1858
Other	LS.	18389	18045
Operating Capital	LS.	12000	12000
Total Economic Costs	LS.	79829	105752
Economic Loss or Benefit	LS.	382	-19968

Source:Computed From Survey Data.

a- Computed from Table B.1.1 and B.1.2,Appendix B.
b- Computed From Table B.2.1,Appendix B.
c- LS = Sudanse Pound = 100 Piasters.

where sorghum harvesting was partially mechanized - - sesame generated the highest net cash income per feddan (LS. 10.51/feddan), followed by early sorghum (LS. 10.36/feddan) and late sorghum (LS. 8.56/feddan) as shown in Tables 6.1.1 - 6.1.3). Also, sesame gave the highest return per man-day to hired seasonal labor (LS 2.76), compared to early and late sorghum (LS 2.56). Among the three crop enterprises in System 1, sesame had the highest cost of production per unit of output. The production costs per sack were LS. 36.43, LS. 15.72, and LS. 12.53 for sesame, early sorghum and late sorghum, respectively.

In System 2 - - where sorghum harvesting was fully mechanized - - the financial analysis revealed that sorghum generates a higher total net income (LS. 13,201) than sesame (LS. 4,514). On a per feddan basis, the net return to sorghum is 7 percent higher than for sesame (Tables 6.2.1 and 6.2.2). The return per man-day to hired labor is LS. 2.99 for sesame and LS. 2.48 for early sorghum. Finally it, is twice as expensive to produce one sack of sesame (LS. 35) as one sack of fully mechanized harvested sorghum (LS. 15.42).

Comparison of the financial analysis of the two production systems reveled that under System 2, the farm, gives an 18 percent higher net return to the farm owner. System 2 requires 22 percent less hired seasonal labor and gives less income to hired labor (Table 6.3.1). Sorghum produced under full mechanization gives a higher total

return and a higher return per feddan than sorghum produced with partial mechanization of harvesting (Table 6.4.1). All the enterprises give a positive return in the financial analysis. When sorghum harvesting was fully mechanized, the total returns to the whole farm were higher than the case of partial mechanization of sorghum harvesting. The seasonal hired labor number of man-day and total returns were less for both the whole farm and the sorghum enterprise when the sorghum harvest was fully mechanized than when partially mechanized.

Economic analysis of sorghum produced under System 1 and System 2, required that the financial account were adjusted to remove all subsidies to the factors of production. The imported inputs were highly subsidized due to overvalued local currency (Table 6.5). Of the domestic factors of production, the land rent subsidy amounted to 150 percent of the land rent. When inflation was considered, the interest rate on credit was found to be negative (-16 percent).

The economic analysis of fully mechanized versus partially mechanized harvested sorghum shows that the partial mechanization system is the least costly production alternative. Economically, producing one unit of sorghum under full mechanization cost 37 percent more than when partially mechanized harvesting technology is used (Table 6.8). When sorghum harvesting was fully mechanized the social loss was LS. 16,388 per farm. In contrast, when

sorghum was partially machine harvested the social net gain was LS. 11,581 (Table 6.7). The economic cost of producing one metric ton of fully mechanized harvested sorghum was 38 percent higher than the financial cost of producing it, while the economic cost of producing a ton of partially mechanized sorghum was only 19 percent higher than the financial costs.

The production of sorghum with partial mechanization of harvesting was both privately and socially profitable under the existing conditions of the Damazine MCPRS.

CHAPTER 7

SUMMARY, POLICY IMPLICATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 Summary

Sudan, a country with an area of one million square miles and a population of 21 million and large land reserves, is paradoxically unable to feed itself. Most of its land reserves lie in the Central Clay Plains, where a sub-sector of mechanized rainfed farming has developed over the last forty years. Today, the area under mechanized rainfed farming represents about 37 percent of the total cultivated area in the country. The schemes were praised for saving the country from the famine which spread through the Sahelian zone of sub-Saharan Africa during the 1970's.

The mechanized crop production schemes play a vital role in the Sudanese economy and a major role in food production. The importance of the MCPRS is clearly demonstrated by their 82 percent contribution to national sorghum output - - the major staple cereal in the country. The MCPRS, established across the central part of Sudan, represent a viable food production system which is located strategically for easy distribution.

The government's policy is to increase both domestic

food supplies and agricultural exports as the key to the country's economic growth. There is a perceived shortage of labor and now the government is adopting a policy of encouraging more mechanization in the agricultural sector. Also, mechanization is seen as the means of modernizing agriculture (ILO, 1976). Implicit and explicit policy incentive signals are given for increasing the level of mechanization. The explicit policies include the ABS credit policies, which provide loans in-kind for machinery purchase. The over valued local currency acts as an implicit incentive for adoption of intensive capital goods like machinery and petroleum products.

In early 1970's the Sudanese government advocated a policy of self-sufficiency in many agricultural products. Sudan, the largest country in Africa with about one-third of its land suitable for agricultural uses was called the "bread basket" of the Middle East. With only ten percent of the land being actually cultivated, there exists a great potential for further area expansion. Most of this agricultural potential lies in the Central Clay Plains rainfed areas. The MFC estimates that 60 million feddans are suitable for mechanized rainfed farming - - ten times the area now under mechanized crop production (MFC, Task Force, 1984).

In the light of the present food crisis in the country and the influx of starving Ethiopian refugees, there is an urgent need for strengthening and expanding the food system.

The mechanized rainfed agriculture has played the major role in the food system of the country for the last three decades and will continue to play the leading role in the foreseeable future. Because the mechanized rainfed sub-sector is entirely dominated by private investment, it should have the flexibility to grow in response to government policies and changes in the farming conditions.

The objective of this study is to investigate and measure the effect of the government policy on the financial viability of the Mechanized Crop Production Rainfed Schemes (MCPRS) in the Damazine area, and to measure the employment and income effect of partial and full mechanization of sorghum harvesting. The study evaluated the financial and economic costs and returns to the sorghum enterprises under partial and full mechanization of harvesting.

The Damazine MCPRS in the central region, was chosen as the area for the study because it is both the fastest growing area within the MCPRS, and has the largest potential area for future development.

While sorghum is the dominant crop (over 80 percent of the area) in the existing cropping system, sesame and millet are also raised. The production system is built on a wheel tractor (70-75 HP) with a single row disc as the only land preparation and planting implement. Weeding is done manually as is the harvesting of sesame. The dominant practice for sorghum harvesting is cutting the crop heads and piling them

into heaps for stationary threshing. The farmers neither use fertilizer nor follow the recommended crop rotation.

The data that provided the empirical base for the study was obtained from primary and secondary sources. The primary data was obtained from the survey of 73 farmers in the Damazine area during the 1983/84 season. The secondary data for the study consisted of published and unpublished government agencies reports and studies, and feasibility studies of MCPRS and big private companies in the Damazine area.

Static linear programming is used for analyzing the income and employment consequences of the existing production system (System 1) under which sorghum is partially mechanized and the alternative system (System 2) under which sorghum harvesting is fully mechanized. The structure of the linear programming model is described in Chapter IV. The model is used to generate optimum farm plans and measure the marginal value product (MVP) of the resources used. A comparative analysis of these optimum farm plans is used to measure the consequences of the new sorghum harvesting technology on farming and employment.

Farm budgets are also developed for the crop enterprises under the two systems, as a tool to measure the relative contribution of each enterprise and to compare the financial profitability of the two systems. The financial costs and returns of partially and fully mechanized harvested sorghum were adjusted to reflect the opportunity

cost of resources. Financial prices were adjusted by first removing the transfer payments and then adjusting the distortion in traded and non-traded items. The results of the economic analysis of sorghum harvesting under partial and full mechanization are compared to evaluate their profitability to the national economy.

The results of LP analysis indicated that the introduction of combine sorghum harvesting increased net farm income by 30 percent. Efficiency of resources used, measured by the net returns to the farmer, were also increased by the introduction of the new technology. Millet, which was recently introduced in the area, was not competitive with the existing crops under the prevailing conditions, regardless of harvesting system.

The optimal cropping pattern under the new sorghum harvesting technology was less diversified. With the introduction of combine harvesting, hired labor use per feddan decreased by 40 percent for the sorghum crop and the labor use per feddan for the whole farm decreased by 22 percent. The hired labor loss amounted to more than 3000 man-days per farm.

The new sorghum harvesting technology also decreased the need for operating capital by three percent. The cropping season was two months shorter when the new technology was adopted because late sorghum dropped out of the optimal solution. Yet, the decrease in the length of the cropping season did not affect the cropping intensity, as

the system was dependent on the rainy season which extends from June to November.

The results of the LP analysis also indicated that under the existing level of land rent, farmers were acting rationally as short-run profit maximizers when they ignored the MFC fallow requirement. The MVP of land was about five times the land rent (LS. 1.00/feddan) when only two-thirds of the farm was under crops, while it was about twice the land rent when all the land was under crops.

Financial analysis is used to determine the financial viability of the crop enterprises under partially (System 1) and fully mechanized sorghum harvesting (System 2). The financial analysis of the two production systems indicated that all the enterprises under the two systems gave positive net returns.

Financial analysis of the two production systems showed that System 2 gave an 18 percent higher return to management than System 1. Under System 2 sorghum gave higher net returns on 8 percent less cultivated area, than in System 1.

Full mechanization of sorghum reduced seasonal hired labor demand and total income for both the whole farm and sorghum enterprises.

An economic analysis of sorghum produced under partial and full mechanization indicated that farmers in the MCPRS received government subsidies through an overvalued exchange rate, subsidized credit and low land rent. The subsidy levels ranged from 150 percent for land rent to 40 percent

for combine harvesting. Fully mechanized harvested sorghum was more highly subsidized than the partially mechanized enterprise due to the higher intensity of capital used in the former. Economic analysis showed that fully mechanized sorghum generated a net loss per farm of LS. 16,368 when all the subsidies were accounted for, while the partially mechanized sorghum gave a net return of LS. 11,582 - - even when all the subsidies were removed. These results indicated that the financial profitability of the MCPRS - - even with low yields on soils exhausted through continuous cropping, and low husbandry levels - - was largely due to the high level of subsidies farmers received. Farmers who produced sorghum under partial mechanization of harvesting received 19 percent of their net income in the form of subsidies, while the subsidy share of net income for fully mechanized harvested sorghum amounted to 68 percent. Producing one unit of sorghum under full mechanization costs 37 percent more than when the harvest was partially mechanized. In summary, while sorghum produced with full mechanization gave higher financial returns than when partially mechanized, the former generated economic losses and the latter gave positive economic returns.

7.2 Policy Implications

In the light of the results of the analysis presented in the preceding chapters and the background laid for the

study, some policy implications of the study are discussed below.

7.2.1 Developing a Food Strategy

A national food strategy must take into account factors such as food consumption, nutrition, food production, rural employment, and food prices (Mellor, 1984). Timmer (1981) set four objectives for a national food strategy, 1) efficient growth in the food and agricultural sector; 2) improved income distribution, through rural employment creation; 3) provision of basic nutritional needs for the entire population; and 4) adequate food security to ensure against bad years.

A food strategy is needed that can ensure the continuous role of the mechanized rainfed schemes in meeting Sudan's food needs and also extend their potential for producing food exports. To achieve this, several problems associated with the mechanized rainfed farming must be addressed.

First, the sub-sector is characterized by low and declining yields. This is due to the farmers behaving as short-run profit maximizers and ignoring the long-run impact of their current cropping practices on soil fertility. Low land rent and the availability to new land on the frontiere tend to encourage exploitive use of the cheap land resource.

There is a need to develop an improved farming system that encourages permanent land cultivation and provides an incentive for farmers to settle in the vicinity of their

holdings. This could include the provision of such infrastructure as all weather roads, drinking water supplies and other services and amenities. Better roads would improve the communication between the farms and the outside world, and - - by so doing - - reduce the cost of obtaining inputs and make it easier to reach nearby towns in case of emergency. Finally, roads will facilitate the dissemination of better farming practices. In addition to infrastructure, there is a need to introduce improved farming practices that increase output, maintain soil fertility, and increase profits. This may be achieved through the introduction of new crops which can improve the soil fertility, such as legumes. In addition, farmers now use low quality crop seeds with low yield potential. New hybrid sorghum should be tested in the schemes to evaluate claims that these varieties can double yield - - even at the existing level of farming practices.

Second, the domestic macro policy conditions need to be revised to create an environment for food system development. Of critical importance is the fiscal and monetary policy. Slowing the chronic escalating inflation needs immediate attention. In addition, there is a need to reduce the high budget deficit and worsening foreign debt situation. Unless these problems are addressed, it will be difficult to guide development effectively.

Another major component of macro-policy relates to the exchange rate. The overvalued local currency distort the

macro prices for labor, land and capital. Under the present situation, imports appear cheaper and consequently increase the demand for foreign exchange. Also, the overvalued currency decreases the potential for earning foreign exchange, by making domestic products more expensive for foreign consumers.

7.2.2 Farm Employment

Sudan has a high land/man ratio. This is particularly true for the Central Clay Plains, where population densities are low. Seasonal labor migrate from other parts of the country to work in the mechanized schemes. An ILO study (1976) which reviewed the political and economic situation in Sudan advocated a reduction in the pace of mechanization. In contrast to the ILO study, Disney and Elbashir (1983) contend that the social return on imported agricultural machinery still justifies mechanization.

In this study, factor prices were adjusted to reflect their opportunity cost. The economic profitability of a selected capital intensive operation (fully mechanized harvested sorghum) was found to be negative. In contrast, harvesting with less capital intensive technology (partially mechanized sorghum) gave positive returns. In addition, full mechanization of sorghum harvesting reduce the labor requirement per farm by 22 percent, compared to partial mechanization. In a land abundant country like Sudan, the employment effect of new technologies must be considered in the short run and also in a longer-run prospect. In the

Central Clay Plains, as in the rest of the country, there is the possibility of bringing millions of feddans under cultivation. Hence, labor displacement is not a high priority issue. In contrast, the present food crisis in Sudan and neighboring countries indicate the need to put more areas in the Central Clay Plain under food production.

The important question is whether to use the country's meager capital resources to buy tractors which extend the frontier or to buy additional combine harvesters for existing areas so the sorghum crop can be combine harvested. Combine harvesting has little impact on yield, but has a major labor displacing impact. Currently the ABS lends to the MCPRS to finance tractors, does not lend farmers capital to purchase combines. An important policy recommendation is for this policy to continue. This will allocate capital toward expanding the cultivation frontier and generating employment, and away from simply labor displacing mechanization.

Analysis in this study was based on 1983/84 cropping season. The food shortage and the famine which struck the country in 1984, due to the drought and the influx of refugees from neighboring countries, has greatly affected the relative factor prices. The price of sorghum was reported to have increased more than fivefold. In financial terms the mechanized rainfed farmers may have enjoyed high profits during this period. For the sake of the analysis of the MCPRS, this can be considered as a short-run phenomenon

with a minimal long-run effect. At the same time, the current food crisis has alerted policy makers and planners in Sudan to the importance of the mechanized sub-sector in the food system of the country.

7.2.3 Credit and Taxation Policy

Two major policy issues are the tax system now in use and the price of ABS credit. Farmers now pay taxes ("usher" and "gibana") levied per unit of produce. This system punishes the highly productive farmer. There is a strong case for assessing these taxes on a per feddan basis. This would change them from being a variable to a fixed costs and raise the farmers marginal return from additional sales. Also, by enacting a per feddan tax, the local government could reduce the cost of collecting taxes by eliminating the roadblock guards and also ensure a predictable amount of revenue.

Farmers in the MCPRS receive credit from the ABS at a subsidized rate, in a country where capital is a major constraint. At the same time the continually increasing inflation rate makes the real interest rate negative. The government should adopt a policy which values capital to reflect its opportunity cost. The lending rate should be increased. In addition the ABS could act as both a saving and lending institution. Providing an opportunity for saving at a reasonable rate of return may encourage farmers to save more. This is a very important policy as it will enable the bank to extend credit to more farmers and also give the

farmers an opportunity to realize a reasonable return on their saving.

7.2.4 Agricultural Research and Extension

Sudan has a long tradition in research on export crops - - mainly irrigated cotton. In the late 1950's research on rainfed crops started, directed mostly on increasing yields and breeding for combinable varieties of sorghum. As research on rainfed crops in the Central Clay Plain has a history of less than thirty years if is still in its developmental phase.

Given the research systems limited financial and manpower resources, there is need for research to be better targeted to find appropriate solutions to Sudans most urgent problems. For example, experience from other land abundant countries indicates that the widely promoted fertilizer based yield increasing technologies are often not widely adopted due to the existance of a land frontiere. An agenda for research in the Central Clay Plains need to be set which addresses the following issues.

First, there is a need to breed varieties that are drought tolerant and of higher taste quality. The recent dought that hit the region demonstrated a significant need to intensify breeding for drought tolerant varieties. The fact that previously released sorghum varieties foro the mechanized rainfed schemes were not widely adopted due to low taste quality, indicates the importance of this breeding objective.

A second research priority is to identify improved cultural practices for the mechanized rainfed schemes. A number of researchers contend that the single row disc now being used for land preparation and planting is not suitable. Together with machinery research, there is a need to research appropriate contour farming and soil conservation practices. Currently, farms in the area are set on a 2X3 Km grid, and little attention is paid to plowing on the contour lines an oversight that significantly increases soil erosion.

The third research need is to develop a viable rotation that includes leguminous crops to maintain soil fertility. The farmers now ignore the fallow requirement set by the MFC because it does not benefit them financially and increases the weed population in the following season. Soybeans, safflower and sunflower have all been tried in the area and there is strong evidence that they can be profitably included in the crop rotation.

Finally, the survey indicated a complete lack of extension services. Farmers are unaware of existing research results or the benefits that might result if they followed the research recommendations. Thus, there is an urgent need to build an extension system that is responsive to the needs of the farmers and effective in disseminating research results.

Both fact that the farms are layed out in 2x3 km. grid and that the farming activities are mostly carried out by

farm managers rather than the actual lease holders, require a special extension approach. The fact that large farmers are involved may make it possible to establish a unique private-public sector initiative. The MCPRS farmers could finance the establishment of strategically located demonstration sites, staffed with qualified personnel that would provide advice and demonstrate better means of farming. The government could provide the sites and the farmers could hire the staff to run the centers. In this way the extension staff will be more responsive to the farmers needs, and the service would not put an additional burden on the government's already strained resources.

7.3 Suggestions for Further Economic Research

Although this study is based on micro data from the Damazine area for only the 1983/84 crop production year, it demonstrated the potential for improving the MCPRS system through careful policy analysis.

Attention should be given to a larger study which covers the four mechanized rainfed areas and which can generate detailed data over more than one cropping season. Results would be useful in developing long-range policies for the sub-sector.

There is a need for interdisciplinary research aimed at assessing the profitability of introducing new crops, especially legumes, and establishing rotation that can both

increase productivity and ensure proper conservation of soil fertility.

Finally, there exist few studies on the marketing and marketing infrastructure for sorghum. In some parts of the country shortages are usually reported, but in other regions crops are deteriorating under improper storage because of a lack of transportation or market information. Hence, there is a need to study the feasibility of an information network, and strategically located storage facilities. Linked to this study, there is a need to evaluate the foreign export market potential for sorghum, both in neighboring countries and also in Southern Europe.

APPENDICES

APPENDIX A

RESEARCH METHODS

APPENDIX A

RESEARCH METHODS

The purpose of this section is to describe the data collection procedures and methods. The data collection for the study took place during the 1983/84 cropping season.

Data Collection

Primary and secondary data were collected for this study. The primary data collection activities were divided into three phases. Each phase served certain objectives and purposes. The phases were integrated and complementary to each other.

Phase I: This phase took place during March/April period. It served three purposes; developing the sampling frame, studying of MFC regional office at the Damazine records, and as an exploratory period to the study ares, the farmers, and the government institutions.

Records of the Mechanized Farming Corporation (MFC) regional office in the Damazine area were used to collect information about the historical development and the present status of the Damazine Mechanized Crop Production Rainfed Schemes. Information about areas allotted to private individuals, large private corporations and state farms. The information collected includes; cropped areas, production, and price of crops in the area. Data on infrastructure,

weather, and the problems of the area as perceived by governmental agencies and the farmers union.

Development of the sampling frames: The Damazine MCPRS comprises two main areas, east and west of the Blue Nile River. The eastern area (Dinder area), which represents less than 10 percent, of the farmers, was not included in the study because of its remoteness from the major area west of the Blue Nile.

MFC keeps records of the farm owners, their farm sizes, estimates of their cropped areas and production each year. From the MFC records it was found that the total number of farms west of the Blue Nile was 953 farms (approximately 1.5 million feddans)[1] of which 172 farms were allotted to cooperatives. The cooperatives were excluded from the study because the information collected from the MFC records showed that cooperative farms were either deserted or rented to individuals, and those which were still in business had a membership from outside the area and could not easily be located.[2] The information collected from the MFC records, farmers unions, and some individual farmers, showed that the farmers in the area adopt similar farming practices.

A random sample of 10 percent was chosen from the

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[1] One feddan = 1.038 acres = 0.42 Hectare = 4200 sq. meters.

[2] Those cooperative farms still in business during the 1983/ 84 season were run by cooperatives from the Northern Province.

farmers list. Seventy-three farms were selected for the data collection.

Ideally, the sample size should be determined by the degree of precision required. However, prior estimates were needed to enable the use of a statistical procedure that gives the required sample size. Such information was not available. Another problem associated with determining the cost, which would increase as the sample size increased. The objective of any sample size is cost minimization with the highest degree of precision possible. This means that, at least, the sample size should minimize the following errors:

a - sampling errors,

b - variation in yield, crop mixture, cultural practices, etc.

As a trade off, a sample of 73 farmers, which represents 10 percent of the total population of the study, was selected. Two questionnaires were developed for the study.

Phase II: This took place during June/July, 1983. The information collected and the arrangements made during the first phase helped to solve many logistical problems that were encountered during this phase. The questionnaire developed and tested for this phase was used to collect information on the policy issues and the conditions under which the system operates. The main areas of investigations included in the questionnaire is summarized below:

a. General Information - Information about the farmers age, education level, permanent residence and family composition.

Also, information was collected on time devoted to farming during the different cultural practices time.

b. Crop Production Information - Information was collected on the farm sizes, historical data about areas cropped and the production obtained, information about rotations fallowed and crop varieties grown.

c. Production Technology Information - Information about alternative technologies used for crop production, including land preparation, planting, weeding and harvesting.

d. Sources of Credit Information - This includes information about short and medium term credit, amounts, and names of lending institutions. Information about collateral required and interest rate charged.

e. Information about Labor - This includes information about labor utilization and availability for the different cultural practices.

f. Machinery, Spare Parts and Fuel Information - This includes information on availability, sources and quantities used.

g. Marketing Information - This includes information on different crop prices, time of sale, and place of sale. Also, it includes historical information about crop prices.

h. Government Policies Information - This includes information about policies the government implements and their effect on the farmers decisions.

i. Farmers Constraints Information - This includes information about the constraints that the farmers face.

This is neither an inclusive list of the variables included in the questionnaire, nor is it arranged in any form of ordering.

Phase III: This was carried out during January and February of 1984. The researcher, helped by three interviewers, spent five weeks in the study area to administer the second questionnaire. Out of the 73 farmers interviewed during the first round, 69 farmers were reinterviewed during the second round. The first two phases helped in designing and administering the second questionnaire.

The questionnaire was pre-tested and the interviewers trained before administering the second questionnaire.

The second questionnaire was designed to include information on:

a. Cultural Practices - Information on different operations carried out, their time, machinery used and labor in man-days. Also, information about the cost of food, fuel and drinking water during these operations.

b. Labor Information - This includes information on labor use, availability, wages, and locality.

c. Information about Machinery - This information includes time machinery spent in each activity, machinery hired in and out, cost of spare parts, insurance and taxes for different machinery used.

d. Information about 1983/84 Cropping Season Credit - This includes information about lending institutions, activities for which loans were taken, amount, and interest rate

charged.

e. Information Marketing and Marketing Strategies.

f. Information about farm buildings and other items used for food and water; their cost, life span, and maintenance costs.

Training and Supervision of the Interviewers

Three graduates, who are members of the Planning and Agricultural Economics Administration, Ministry of Agriculture and Irrigation (MOAI), joined in the data collection period of the second survey. They were first introduced to the research problem, and the objective of the study was clearly explained to them.

They were trained intensively for three days in Khartoum on the questionnaire filling and the interview procedure. The first two days in the field were also used for further office and field training. They accompanied researchers on field trips and did actual interviews, which were later discussed thoroughly before they started interviewing the farmers.

During the data collection period, the researcher reviewed all the questionnaire filled by the interviewer day by day. The researcher also attended some of the interviews. Some farmers were revisited to check on the information obtained from them.

Pre-Testing of the Questionnaires

After the development of the first questionnaire, it was discussed with the staff of MOAI, and USAID in Khartoum. Then a revised version of the questionnaire was tested in Khartoum with MCPRS farmers who came to MFC Headquarters during that period. After that the questionnaire was written in a final draft.

The same previous steps were done for the second questionnaire except the pre-testing, which was done in the field. The researcher went to the Damazine during late November to pre-test the second questionnaire. The final draft of the second questionnaire was written in Khartoum during December, 1983.

Data Coding and Data Entry

After finishing the first survey the raw data was carried to Khartoum. In Khartoum, the data was coded and put on floppy discs using the Planning and Agricultural Economics Administration of MOAI North-star micro-computer.

During the second survey data was coded in the field. The coded data was bought to Khartoum and put on floppy discs. Data was verified and checked after it was entered. The verified checked data will be carried to Michigan State University, Eas Lansing, for the analysis using the university main frame computer.

The Analytical Procedure[1]

Descriptive statistics (e.g. means, frequency, etc.) were used to describe the system. They would be used to meet the first objective of the study. Linear programming was used to evaluate income and employment consequences of the different alternative technologies. There are four main cultural practices done in MCPRS. These are land preparation, planting, weeding and harvest. Weeding and harvesting are the most labor consuming operations. They also represent the highest money spending items.[2] There are two alternative technologies available to the farm for harvesting sorghum. These technologies are either practiced now in the area on a wide scale or on a limited scale. Farmers harvest sorghum either by cutting the crop heads menually and then threshi it using a combine harvestor or by directly combine harvesting it by a combine.

Farm budgets were used to test the financial and economic profitability of the system.

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[1] Explained in more detail in the main text.

[2] Mohamed, El Tayeb; "Modes of Agricultural Production in Nuba Mountains," Unpublished M.Sc. thesis, University of Khartoum, 1979.

APPENDIX B

ECONOMIC COSTS OF SORGHUM PRODUCTION

TABLE B.1.1

Early Sorghum Economic Costs and Retuns With Partial Machine Harvesting,(527 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity	Operating Costs								
Item	Non-Labor Costs					Labor Costs			
	Units	Rate Per FD.	Total Units	Cost Per Unit	Total Cost LS.	Man-day Per FD	Man-day Total	Wage Rate	Total Cost
Land Clearance	FD.	1.00	527	1.10	580	.00	.00	.00	.00
Land Preparation									
Tractor	HR.	.25	132	20.55	2707	.16	84	5.56	469
Planting									
Tractor	HR.	.25	132	20.55	2707	.16	84	5.56	469
Seeds	KG.	1.40	738	.25	184	.00	.00	.00	.00
Weeding									
First	FD.	.00	.00	.00	.00	2.12	1117	2.21	2469
Second	FD.	.00	.00	.00	.00	2.66	1402	2.21	3098
Harvesting									
Cutting	FD.	.00	.00	.00	.00	3.20	1686	2.56	4317
Machine Thresh	Sack	3.36	1771	2.00	3541	.35	184	2.56	472
Other									
Land Rent	LS.	1.00	527	2.50	1318	.00	.00	.00	.00
Farm Trans-d	LS.	1.00	527	1.65	870	.09	47	5.56	264
Crop Trans	Sack	3.36	1771	1.00	1771	.08	42	2.56	108
Sacks	Sack	3.36	1771	2.25	3984	.00	.00	.00	.00
Total					17662	8.62	4648		11666

Source: Survey Data

a- FD = Feddan = 1.038 Acres = 4200 sq. m.
b- HR = Hour.
c- LS = Sudanse Pound =100 Piasters.
d- Trans = Transportation.

TABLE B.1.2

Late Sorghum Economic Costs and Returns With Partial Machine Harvesting,(725.7 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity Costs									
Item	Non Labor Costs					Labor Costs			
	Unit	Rate PER FD-a	Total Units	Cost Per Unit	Total Cost LS-b	Man-day Per FD.	Total	Wage Rate	Total Cost LS.
Land Clearance	FD.	1.00	726	1.10	798	0	0	0	0
Land Preparation									
Tractor	HR-c	.25	181	20.55	3728	.16	116	5.56	646
Planting									
Tractor	HR.	.25	181	20.55	3728	.16	116	5.56	646
Seed	KG.	1.60	1161	.25	290	0	0	0	0
Weeding									
First	FD	0	0	0		2.00	1451	2.21	3208
Second	FD	0	0	0		2.16	1568	2.21	3464
Harvesting									
Cutting	FD	0	0	0		3.20	2322	2.56	5945
Machine Threshing	Sack	3.06	2221	2.00	4441	.35	254	2.56	650
Other									
Land Rent	LS.	1.00	726	2.50	1814	0	0	0	0
Farm Trans-d	LS.	1.00	726	1.95	1415	.09	65	5.56	363
Crop Trans	LS.	3.06	2221	1.00	2221	.08	58	2.56	149
Sacks	Sack	3.06	2221	2.25	4998	0	0	0	0
	Total				23433	3.20	5951		15070

SOURCE : SURVEY DATA.

a- FD = Feddan =1.038 Acres.
b- LS = Sudanse Pound =100 Piasters.
c- HR = Hour.
d- Trans = Transportation.

TABLE 8.2.1

Early Sorghum Economic Costs and Returns Under System 2, (1161 Feddans),Damazine MCPRS,Season 1983/84,Sudan.

Activity	Operating Costs								
Item	Non Labor Costs					Labor Costs			
	Unit	Rate Per FD-a	Total Units	Cost Per Units	Total Cost LS-b	Man-day Per FD.	Man-day Total	Wage Rate	Total Cost
Land Clearance	FD.	1.00	1161	1.10	1277	0	0	0	0
Land Preparation									
Tractor	HR-c	.25	290	20.55	5965	.16	186	5.56	1033
Planting									
Tractor	HR.	.25	290	20.55	5965	.16	186	5.56	1033
Seed	KG.	1.40	1625	.25	406	0	0	0	0
Weeding									
First	FD.	0	0	0	0	2.12	2461	2.21	5440
Second	FD.	0	0	0	0	2.66	3088	2.21	6825
Harvesting									
Combine	LS.	3.36	3901	11.87	46304	.35	406	2.56	1040
Other									
Land Rent	LS.	1.00	1161	1.00	1161	0	0	0	0
Farm Trans	LS.	1.00	1161	2.13	2473	.09	104	5.56	581
Crop Trans	LS.	3.36	3901	1.00	3901	.08	93	2.56	238
Sacks	Sack	3.36	3901	2.25	8777	0	0	0	0
	Total				76229	5.62	6525		16189

Source: Survey Data

a- FD = Feddan = 1.038 Acres.
b- LS = Sudanse Pound = 100 Piasters.
c- HR = Hour.

APPENDIX C

ESTIMATED COSTS OF FARM MACHINARY AND JUTE SACKS

TABLE C.1.1

Estimated Costs of a 75 H.P. Tractor and a Disc Harrow, Damazine MCPRS,Season 1983/84,Sudan.

Estimated Owing Costs a 75 Wheel Tractor	
Owing Costs	LS.
Purchase Price	22000
Plus,Interest 14 % on 70 % of Purchase Price	2156
Plus,Repairs (At 40 % of Purchase Price)	8800
Plus,Insurance	880
Total Owing Costs Of Tractor	33836
Tractor Operating Costs Per Hour	
Fuel (2 GAL/HR)	5.34
Engine Oil and Grease (40 % of Fuel Costs)	2.14
Total Operating Costs (Not Including Drivers Cost)	7.48
Estimated Cost of a Single Row Disc Harrow	
Owing Costs	
Purchase Price	14000
Plus,Interest at 14 % on 70 % of Purchase Price	1372
Plus,Repairs Costs	2800
Total Costs	18172
Owing and Operating a Tractor With a Disc Harrow	
Total Costs Per Hour	14.91
Total Costs Per Feddan	3.73

Source:Computed From Survey Data.

a- Assumptions

Anticipated Life = 7000 Hours.
The Tractor Works 1000 Hours Per Year.
There is No Salvage Value at the End of the 7th Year.
Tractor Works 4 Feddans Per Hours.

TABLE C.1.2

Estimated Economic Costs of a 75 H.P. Tractor and a Disc Harrow Damazine MCPRS,Season 1983/84,Sudan.

Estimated Real Owing Costs a 75 Wheel Tractor	
Real Owing Costs	LS.
CIF Price at Port Sudan	33710
Plus,Port Charges-b	506
Plus,Dealer's Costs	5132
Plus,Repairs-c	21641
Total Real Owing Costs	60989
Tractor Real Operating Costs Per Hour	
Fuel (2 GAL/HR)	6.14
Engine Oil and Grease (40 % of Fuel Costs)-e	2.46
Total Operating Costs (Not Including Drivers Cost)	8.60
Estimated Real Cost of a Single Row Disc Harrow	
Real Owing Costs	
CIF Price at Port Sudan	16445
Plus,Port Charges	247
Plus,Dealer's Costs	2504
Plus,Repairs Costs	2879
Real Owing Costs	22075
Real Owing and Operating Costs of a Tractor With a Disc Harrow	
Total Real Costs Per Hour	20.46
Total Real Costs Per Feddan	5.12

Source:Computed From Survey Data.

a- Assumptions
- Shadow Exchange Rate of LS 2.20 US$ 1.00.
- Anticipated Life = 7000 Hours.
- The Tractor Works 1000 Hours Per Year.
- There is No Salvage Value at the End of the 7th Year.
- Tractor Works 4 Feddans Per Hours.

b- Port Charges at 1.5 % of FOB Price.

c- At 55 % of Purchase Price.

TABLE C.2.1

Estimated Costs of Operating a 105 H.P. Combine Harvestor,Damazine MCPRS,Season 1983/84,Sudan-a

	LS.
Owing Costs	
Purchase Price	75000
Repairs Costs	41250
Insurance(at 4 % of Purchase Price)	3000
Total Owing costs	119250
Operating Costs Per Hour	
Fuel(2.5 Gal/HR)	6.68
Engine and Grease(40 % of Fuel Costs)	2.67
Cost of Drivers	.84
Total Operating Costs Per Hour	10.19
Summary	
Owing Costs Per Hour	23.85
Operating Costs Per Hour	10.19
Total Costs Per Hour	34.04
Total Costs Per Feddan	8.51

Source: Computed From the Survey Data.

a- Assumptions
Anticipated Life of Combine 5000 Hours.
Combine Works 800 Hours Per Season.
There is No Salvage Value at the end of the Life Span.
The Combine Works Four Feddans Per Hour.

TABLE C.2.2

Estimated Economic Costs of Operating a 105 H.P. Combine Harvestor,Damazine MCPRS,Season 1983/84,Sudan-a

Real Owing Costs	LS.
CIF Price at Port Sudan	101538
Port harges	1523
Dealer's Costs	15459
Repairs Costs	65186
Total Owing costs	183706
Real Operating Costs Per Hour	
Fuel(2.5 Gal/HR)	7.08
Engine and Grease(40 % of Fuel Costs)	2.83
Cost of Drivers	.84
Total Operating Costs Per Hour	10.75
Summary	
Owing Costs Per Hour	36.741
Operating Costs Per Hour	10.75
Total Costs Per Hour	47.49
Total Costs Per Feddan	11.87

Source: Computed From the Survey Data.

a- Assumptions

Anticipated Life of Combine 5000 Hours.
Combine Works 800 Hours Per Season.
There is No Salvage Value at the end of the Life Span.
The Combine Works Four Feddans Per Hour.
The Shadow Exchange Rate LS 2.20 = US $ 1.00.

TABLE C.3.1

Economic Costs of Jute Sacks,Damazine MCPRS, Season 1983/84,Sudan-a

	LS.
CIF PORT Sudan	492.80
Port Charges (1.5 % CIF Price)	7.39
Dealer's Costs	125.05
Internal Transportation	50.00
Total Costs Per Bale	675.24
Cost Per Sack (1 Bale = 300 Sacks)	2.25

Source:Computed From Agricultural Bank Of Sudan Records.

a- Assumption
Exchange rate of LS 2.20 = US $ 1.00.

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