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Risk Management in the Rain-fed Sector of Sudan: Case Study, Gedaref Area Eastern Sudan

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Preface

This study is a part of a series of analysis of the economic development and social problems in developing countries, carried out at the University of Giessen within the DAAD program "Agricultural Economics and Related Sciences". The underlying empirical research work, including a six month field study was done during the period 2001-2006 and has led to a PhD degree for the author.

The Study aims mainly to analyze the rain-fed mechanized farming system of Eastern Sudan under uncertainty with special reference to yield and price instability. The research work results show that business and financial risks can have serious implications for farmer's decisions and farm income variability. However, farmers could be more risk-efficient and earn more income by adopting more diversified farming systems and by applying the recommended improved practices.

For the editors: Siegfried Bauer, University of Giessen, Germany

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Abbreviations

ABS: Agricultural Bank of Sudan
BRAC: Breakeven Risk Aversion Coefficient
CDF: Cumulative Distribution Function
CE: Certainty Equivalent
EMV: Expected Money Value
FAO: Food and Agriculture Organization of the United Nations
FLIPSIM: Farm Level Income and Policy Simulator
FSD: First-Degree Stochastic Dominance
IMF: International Monetary Fund
NPV: Net Present Value
PDF: Probability Density Function
TYESP: The Three-Year Economic Salvation Program
SD: Sudanese Dinar (Currency)
SEU: Subjective Expected Utility
SDRF: Stochastic Dominance with Respect to Function
SSD: Second–Degree Stochastic Dominance

1 INTRODUCTION

1.1 Introduction

Risk and uncertainty are unavoidable in agriculture due to the imperfect nature of the agricultural decisions attributed by the changes that take place between the time the decisions were made and the time the outcome of these decisions are known.

In developing countries where farming is particularly weather-dependent, farmers face substantial risk of farm income fluctuations originated mainly from yield and price uncertainties. Therefore, risk considerations in these areas are more important especially for poor farmers. Moreover, increased income risk is considered itself a loss of welfare to risk-averse farmers. It might make modern crop technology less attractive to farmers and hence decelerate agricultural development.

In the study area of Gedaref in eastern Sudan which is a main supplier of food crops and a large contributor to export earnings in the country, agriculture is typically characterized by a high degree of instability. The agricultural production in this area is associated with a high degree of uncertainty arising from a variety of factors among which, dependence of agriculture on unpredictable events like weather, unexpected prices changes and unexpected changes in governmental policies. The prevailing risk and uncertainty in the study area are clearly reflected on farmer’s behaviour. They often prefer farm plans that provide a satisfactory level of security even if this means scarifying income on average. At the same time farmers restrict themselves to the established technologies rather than venturing into new ones.

Despite the increasing importance of risk analysis and risk management in agriculture, the available literature indicated that, until quite recently, considerations of risk were rarely incorporated into farm planning. Instead, farmers were assumed to behave in a risk neutral, profit maximizing way. However, the emergence of utility theory together with the recent advances in computer software and hardware have made application of the methods of risk analysis simpler and quicker than before, bringing them within the scope of farmers, farm advisors and agricultural policy analysts (HARDAKER et al, 1997).

Therefore, studying and analysing the uncertainty faced by the rain-fed mechanized farming in Sudan particularly Gedaref area and its implications in agrarian development is of great importance, and hence represent a major objective in this study.

1.2 Problem Statement

Although the soil and rainfall in Sudan's vertisols are suited for a variety of crops such as sesame, cotton, sunflower and millet, the mechanized rain-fed sub-sector is essentially a sorghum monoculture system with occasional fallow periods. Since 1980, the area under sorghum averaged 87% of total crop area. Only 12% was allocated to sesame and 1% for other crops (AHMED, 1994).

This extensive system uses mechanized plowing and planting, one or two hand weedings and hand harvesting with mechanical threshing. Traditional local cultivars without mineral fertilizers application or other improved agronomic practices characterizes the system, even though technical advancement on improved varieties, use of chemicals and use of more efficient machinery have been achieved by research centers in Sudan since the early eighties. The immediate consequence of this extensive production technology predominant in the mechanized rain-fed sector is the low land productivity. Sorghum yields have been low and declining mainly due to the decline in soil fertility (SALIH, 1993). With declining soil fertility and an erratic and variable rainfall, there has been an increasing variability in output over time. The coefficient of variation of output increased from 14% during the 1970s to 65% during the 1980s (AHMED, 1994). Therefore, there is an urgent need of introducing and promoting intensive agriculture specially Gedaref area which is a leading production area in this sub-sector.

On the other hand, the output prices in the study area of Gedaref are observed to be very low especially during harvest time. This is mainly the consequence of farmers' inability to store their products for long as they have to pay labor wages and repay their loans. As a result, farmers are obliged to deliver their produce directly after harvest to the market, creating a surplus which in turn leads to a sharp decrease in output prices. Moreover, the marketing system in the region functions in the face of large fluctuations in output, major problems of transport, lack of information on market opportunities and possible market barriers resulting from weak macroeconomic and sectoral policies. These problems caused prices of commodities to fluctuate over time causing a considerable source of risk to farmers. Besides production risk due to the great variability in yield, and market risk resulting from the fluctuating product prices over years and within the season, perceived financial risk is also important in the study area. This is because of the fact that farmers mostly depend on borrowed funds to finance their agricultural operations and hence exposing to financial risk due to leverage.

One other aspect to be considered is that the government of Sudan puts great emphasis on the irrigated sub-sector because it is believed to be the engine of political and economic stability and development. Therefore, a broad spectrum of incentives (modern input supply, credit and extension services…etc.) is allocated to this sector (MEPD, 2003) while the rain-fed sub-sector, despite its great importance; is neglected in terms of development funds allocation and also in terms of other public expenditures e.g. for infrastructure and services. This clearly suggests that the role of this sub-sector has been undermined by the government over the last decades and consequently, this farming system experienced negative growth rates during the 1990's. The area of crops harvested decline by 2.4% per annum and yield declined even more (5.1% per annum) (IDRIS, 2004).

LIPTON (1968) quoted in EGZIABHER (1994), views farmers as individuals maximizing utility. Their risk aversion dominates over profit maximization in deciding which crops to produce and how to produce them. For business survival, therefore, the farmer must seek a plan that increases economic security and by which he maximizes his utility. A subsequent crop failure in large scale farming could result in bankruptcy, so it is safer to grow relatively low yielding crops by well-tried methods than diverting resources to a new technology with a higher expected yield but with a higher risk of failure. Accordingly, inefficient decisions are the outcome of risk aversion, policies that reduce yield and income variability should encourage the farmers to raise their productivity and hence their farm income.

Based on the above information, it can be concluded that it is the insufficient resource base, lack of incentives, low level of technology used, lack of infrastructure and services, together with the presence of high degree of business and financial risk, which have caused the low and variable productivity and producer prices prevailing in the area. As a result, low farm income and financial difficulties are common among farmers and hence considerable numbers of them have left the business.

Agricultural productivity and hence farm income, therefore, must be stabilized and increased in order to provide adequate supply of food and raw materials for industry and export so as to increase the welfare of the society both at the regional and national levels. This can be achieved by the use of improved technology, more diversification in farm enterprises as well as more efficient allocation of resources on farms. Definitely, price and non-price measures that stimulate agricultural efficiency and productivity equally deserve exclusive attention.

To accomplish development and growth in mechanized rain-fed sector of eastern Sudan, first the farming system needs to be analyzed and studied. For farmers to stay profitable where farming is more commercial than subsistence, some alternatives are possible and available in the area. First, the low productivity and hence farm income can be improved through application of the new technology recommended by research centers in the area for the main crops sorghum and sesame, while farm income can be increased through more efficient use of the available resources. Secondly, to manage risk, diversification by introducing animals and setting a part of the farm land aside for growing trees are proposed.

In summary, this study will present an empirical approach to analyze mechanized rain-fed large scale farming of Gedaref area of eastern Sudan under uncertainty. The research work aims, first, to examine the potential of the farming system in generating sufficient farm income in the long run that guarantee the survival of the business through the risk-efficient strategy under both traditional and improved cultural practices. Second the analysis will examine the impact that new technology may have on farm income and on its variability. Moreover, the study of the large scale mechanized rain-fed sector and its implications for agricultural development is very helpful for planners and policy makers. And finally, the apparent limitations on comprehensive studies that consider risk analysis and risk management in this sub-sector; provide another incentive to conduct the current research.

1.3 Objectives of the Study

The over all objective of this study is to investigate means to undertake development in the mechanized rain-fed sub-sector through analyzing the system under uncertainty and hence make suggestions for possible interventions in the sight of the results gained. The specific objectives of the study are:

1. To analyze the existing farming system with emphasis on production methods and level of technology used; resources endowment and allocation and the main problems and constraints.

2. To identify sources of uncertainty which affect the performance of the mechanized farming system in eastern Sudan.

3. To determine the risk-efficient production strategy or strategies in the system under both traditional and improved cultural practices in producing field crops.

4. To evaluate different levels of financial structure in the mechanized large scale farming, and their influence on the existing risk.

1.4 Hypothesis

The major following hypothesis will be tested:

1. High intensity farming system increases farm income but adds income variability.

2. Introduction of livestock and forest activities to the farming system reduces the level of risk involved and insures sustainability of the system.

3. Higher levels of leverage increase return to equity capital but increases financial risk in large-scale farming.

1.5 Organization of the Study

The following chapter reviews briefly the Sudanese economy, its structure, growth rates, policies and development strategies with special emphasis on the agricultural sector. Chapter three, first sheds some light on the mechanized rain-fed sub-sector in Sudan in general, and then gives a specific account of the case study region. Chapter four describes the data requirement and sampling procedures. It also sketches some socio-economic characteristics of the sample farmers and summarizes the main characteristics of the region under study. In chapter five a detailed description of the theoretical aspects of the analytical methods is presented. Then the empirical part of the different analytical approaches used to answer the research questions is illustrated. In chapter six costs and returns and profitability analysis of the different enterprises adopted in the study area are discussed. Chapter seven clears up the results and discussion of the stochastic budgeting and stochastic efficiency analysis for the different production strategies under consideration and the last chapter brings out the summary, conclusions and some recommendations derived from the research results.

2 ECONOMY AND AGRICULTURAL DEVELOPMENT IN SUDAN

The aim of this chapter is to review the Sudanese economy in general and the agricultural sector in particular, and to see if there have been any reputable changes over the last two decades. The chapter also highlights some factors that have affected either positively or negatively the development of the economy in general and the agricultural sector in particular.

2.1 General Background

With an area of 2.5 million squared kilometres, Sudan is the largest country in Africa and the ninth largest country in the world (figure 2.1). Its vast area includes stretches of tropical forests, marshlands, mountains in southern and central parts to savannah, stone sand deserts and mountains in the north, east, and west. The Nile with its fertile banks runs throughout the country, connecting its various parts.

Sudan's population in 2001 was estimated at 31.7 million based on the last population survey from 1993, which estimated the urban population at 30 percent and the rural population at about 70 percent (including nomadic groups). The population growth rate is 2.7. Most of the country is sparsely populated because of the arid conditions and the substantial rural–urban migration in recent years (IMF, 1999). According to 1993 national census the population density per square kilometres is estimated to be 10.2 persons. This figure, however, can be a misleading indicator if the population distribution is not considered. In Sudan, a great deal of land is desert, desert-like, or simply non-arable. Therefore, when land area is limited to that which has some potential arability, population density would increase to 31.4 persons/km^2, and go as high as 370 persons/km^2 when considering land presently cultivated (MEPD, 2003). The beginning of the civil war in 1983 together with the severe drought of 1984, which has mainly hit western Sudan and the famine as a result of that, have led to a substantial change in the demographic distribution. Large numbers of population moved into towns (mainly Khartoum the capital) and the irrigated and rain-fed areas of central and eastern Sudan (IMF, 2002). With regard to land use in Sudan, the total arable land is estimated at 202 million feddans (85 million hectares), the grazing area is estimated at 92 million feddans (39 million hectares), while forests occupy some 152 million feddans (64 million hectares) (ABDALLA et. al, 2001).

Figure 2.1: Sudan location

Source: Institute of Geography, JLU

2.2 Structure of the Sudanese Economy

Sudan like most developing countries has an economy widely based on agriculture and raw material production. Table (2.1) presents the structure of the GDP in Sudan through the period 1986-2003. The table shows that, agriculture continues to be the most important production sector compared to the other components of the economy (services and industry). Statistics of 2003 indicate that agriculture alone contributed about 45.6% of the GDP while services and industry sectors contributed about 30.2 and 24.2% respectively. In the past, agriculture was also found to be the largest contributor to the GDP in Sudan. For example, at time of Sudan independence in 1956, agriculture accounted about 60% of total GDP, whereas industry accounted for 5% and services about 35% (WORLD BANK, 2003).

The agricultural sector of Sudan comprises three major crop production systems besides livestock and forest production. In this sector the production of traditional crops such as cotton and gum arabic have declined, while livestock maintaining its dominant position accounting for about half of the GDP from agriculture.

Recently, an increase in the industrial sector is noticed in the urban areas. The main industrial activities of Sudan include manufacturing, construction, mining and electricity and water. The manufacturing sector includes large scale investments such as in sugar, oil refinery and cement, as well as in medium and small scale private enterprises, mainly food processing, pharmaceutics and transport. As it can be seen from table (2.1), the share of industry in GDP declined continually from the mid 1980s to the mid 1990s. The share of industry in total GDP accounted to 14% during the period 1996 to 2000, and increased to 24.2% in 2003. The importance of the industrial sector lies largely in its potential contribution, based on the present under utilized capacity. The sector is also a valuable source of employment and income for many Sudanese.

The relative share of the services sector in total GDP declined from 48.6% in the mid of nineties to 30.2% in 2003. This sector consists of sub sectors that have evolved in different magnitudes. Transport, communications, hotels and restaurants have been among the fastest growing sub-sectors during the period 1998- 2003. These have likely grown in response to the increased demand for services from the emerging oil and oil related industries.

Table 2.1: Structure of the GDP[1], Sudan, 1986-2003

Year	Agriculture %	Industry %	Services %
1986-90	40.2	11.6	48.2
1991-95	38.8	10.5	48.6
1996-00	40.5	14.0	42.5
2001	40.6	22.8	31.6
2002	46	23.1	30.9
2003	45.6	24.2	30.2

Source: World Bank 2003, Bank of Sudan 2003

2.3 Growth Trends of Sudan Economy

The growth of GDP during 1990-2003 improved as compared to the situation of 1980s. The growth rates of GDP in 1991/92, 1992/93 and 1994/95 were 11.3, 12.3 and 7.3% respectively. According to the national accounts, GDP growth rate averaged 3.8% per annum during 1990-1995, and 6.2% per annum during the period 1996-2003 (table, 2.2). The corresponding average annual growth rate of per capita income was 4%. This result implied a positive annual average growth in real per capita GDP. This improvement was affected mainly by a recovery of the agricultural production. The agriculture GDP grew remarkably by about 32% in 1992 and by 26% in 1993 and the average agriculture GDP growth amounted to about 9.5% from 1990 to 2003. From this, one can conclude that, the accelerated GDP growth of the 1990s coincided with high and relatively stable agricultural production. While a number of factors explain the noticeable increase of agricultural output, the most important single factor is the weather. Northern and central Sudan enjoyed relatively drought–free conditions. Agricultural production was also stimulated by economic reforms that removed price and marketing controls and stimulated exports at the beginning of the 1990s. Incentives were further strengthened by removal of most agricultural taxes by 2001.

The industry sector has also contributed to the recent economic growth. Between 1998 and 2003 the industrial sector grew by about 15% on average annually. The intensification of economic reforms took place at the same time that oil and oil-related industries were built up. In 1996, construction on the 1610 km oil pipe line

[1] GDP at constant prices of 1981/82

started, refineries were built, and oil production came on the stream in 1999. These recent developments increased the role of industrial sector in GDP growth. On the other hand, the growth of the service sector remains unremarkable. The average rate of growth in this sector during the period 1990-1997 was about 2% and had increased to 2.9% during the period 1998-2003.

From the previous information it can be concluded that the main reasons behind the recent positive growth of the Sudanese economy during 1990s are three factors; first the favourite weather conditions, second the economic reforms which took place in the early 1990s, and finally, exploitation and exportation of oil.

Table 2.2: The Real Growth in the Economic Sectors, Sudan, 1990-2003

Years	GDP	Agriculture	Industry	Services
1990	0.3	-3.7	-5.9	3.5
1991	0.4	-4.4	15	0.2
1992	11.3	31.5	8.5	1.5
1993	12.7	26.4	15.6	2.1
1994	7.3	13.1	0.9	4.9
1995	4.5	9.3	-7.4	7.4
1996	4.7	9.7	7.2	-1
1997	6.1	12.3	10.6	-2.5
1998	6	8.3	5.7	3.1
1999	6	8.5	11.4	0.4
2000	8.3	0.7	46.5	1.6
2001	6.4	4.7	13.3	4.2
2002	6.5	7.3	8.1	4.0
2003	6.1	5.3	10.6	4.0

Source: Ministry of Finance and National Economy, 2003

Despite the apparently good performance of the Sudanese economy, the relationship between growth, distribution and poverty indicates that poverty has increased in the 1990's. As a result, Sudan is classified by the international institutions (IMF and the WORLD BANK) as one of the poorest countries in the world, with low per capita income (estimated annual average at US$ 395 in 2001), and a disappointingly low level of domestic savings and investment (about 9.7% and 15.3% of GDP respectively during the 1990s), weak social indicators and persistent structural distortions and institutional weaknesses in the economy. Sudan is also heavily indebted to external creditors with a debt of US$ 22.4 billion as of end 1998 (of which US$ 19.3 billion was in arrears). The high level of arrears and the poor political relations with many creditors and donors have resulted in a near drying up of international aid and credit, further exacerbating the domestic economic difficulties (IMF, 1999). However, the following constraints have been summarized to be most important in delaying economic development in Sudan, these include: poor infrastructure, insufficient technological generation and dissemination, a low level of human resource development and accelerating environmental degradation. The capacity for easing these constraints is continually undermined by the combined effects of war and drought as well as weak development policies and strategies.

2.4 Structure of Exports and Imports

2.4.1 Sudan Exports

Before 1999 Sudan export was dominated by agricultural commodities. The main traditional export commodities are cotton, sesame, gum arabic, ground nut, sorghum and livestock. At that time, the country experienced many difficulties in earning adequate foreign exchange and faced chronic trade deficit. Total exports during 1980s fluctuated between US$ 333 million and US$ 721 million, while imports increased significantly during the mid-1980s. The deficit in balance of payment is about US$ one billion in 1980/81. It was narrowed due to heavily restricted import measures to about US$ 0.5 billion in 1988/89 (MOHAMED, 1999).

During the 1990s, exports volumes grew in line with overall GDP. Exports of agricultural commodities grew at an average rate of about 11% during 1991-2000. The impact of export volume growth was, however, offset by the declining world commodity market in Asian countries in 1997. The prices of the Sudanese main traditional exports experienced a downward trend between 1996 and 2001. The prices of cotton fell 10% per year on average while the prices of sorghum declined at an average annual rate of 2.2% during 1996-2001. In the relatively longer term (1990-2001), the prices of cotton and sorghum fell at an average annual rate of 11.3 and 3% respectively and the prices of groundnut and sesame are also declined. Thus, despite export volume growth, non-oil export earnings fell during 1996-2001 (World Bank, 2003).

Oil exports rose from zero in 1998 to US$ 267 million in 1999, accounting for 35% of total exports. In 2000, oil earned about US$ 1.4 billion, accounting for 80% from total exports. After more than 20 years of consecutive trade deficits, a surplus was registered in 2000 (figure 2.2). In 2003 the share of oil in total exports accounted for 77% of GDP, while cotton, sesame and livestock shares were 4, 4 and 3% respectively (figure 2.3). The main Sudan export partners in 2002 are Asian countries mainly China, India and Japan (73.7%), Arabian countries (15.9%), European countries (7.9%), USA (0.1 %) and other countries (2.5%) (MFNE, 2002).

2.4.2 Sudan Imports

Since the mid 1990s, merchandize imports have risen faster than exports. The main imports in 2003 as illustrated by figure (2.4) include: manufactured goods (26%), machinery and equipment (25%), food (14%), transport equipments (14%), chemicals (8%), and petroleum (5%). The composition of imports change initially as agricultural production improved. Food imports mainly wheat and flour, fell from 18% of total imports to 14% during 1994-1998, while the import of manufactured goods rose from 29 to 41% during the same period (MOHAMED 1999). By 2003, food imports stood at around 14% of total imports. Imports of crude oil and associated products declined dramatically following the start of oil production and expansion of domestic oil-refining capacity. The share of oil from total imports fell from 13% in 1999 to 5% in 2003 (figure 2.4). Main import partners of Sudan are the Arabian countries (34.5%), some Asian countries mainly China (18.7%), European Union countries (15.9%) and East Europe (3.1%) (MFNE, 2002).

During the nineties Sudan also intensified its efforts to build closer international relations with trading partners. A number of bilateral trade agreements have been concluded within the Common Market for Eastern and Southern Africa (COMESA). Also efforts to become member of the World Trade Organization (WTO) have been renewed by revitalizing its earlier request from 1994.

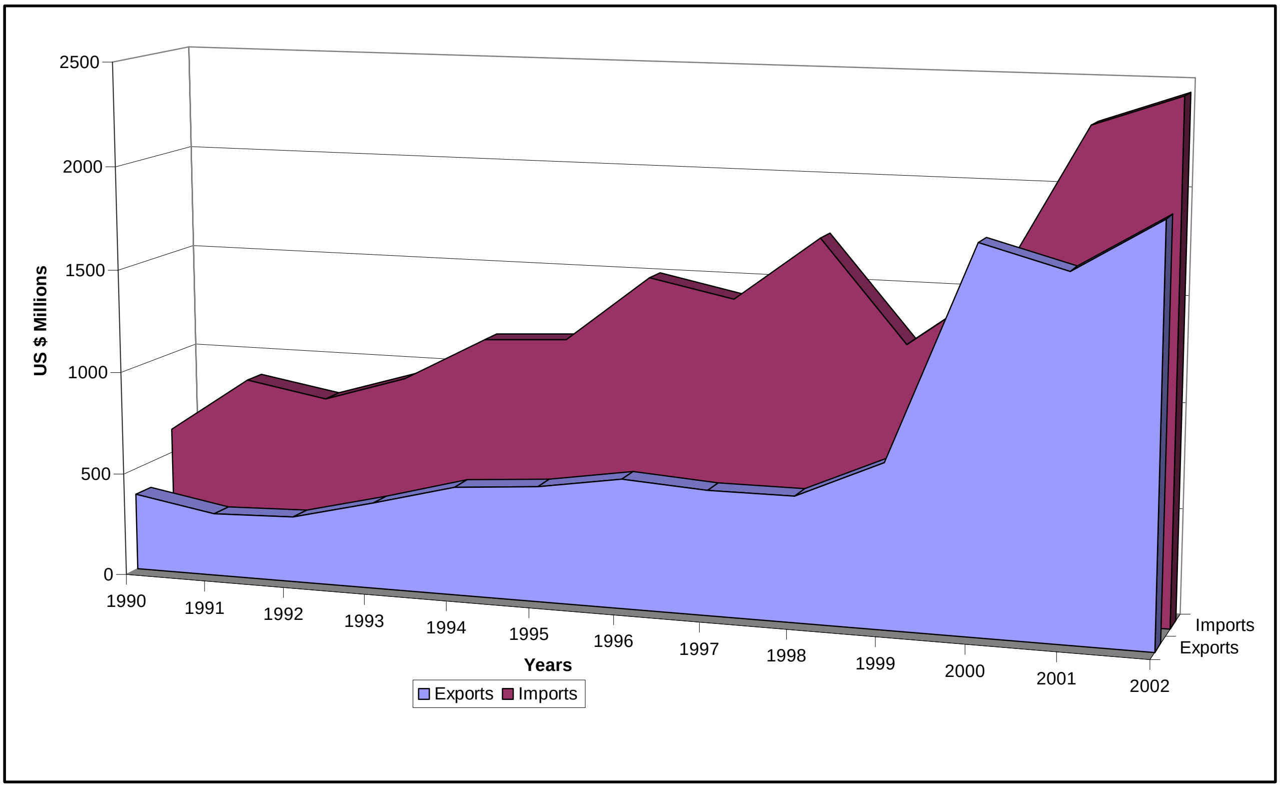

Figure 2.2: Value of Total Exports and Imports, Sudan, 1990-2002

Source: Ministry of Finance and National Economy, various issues

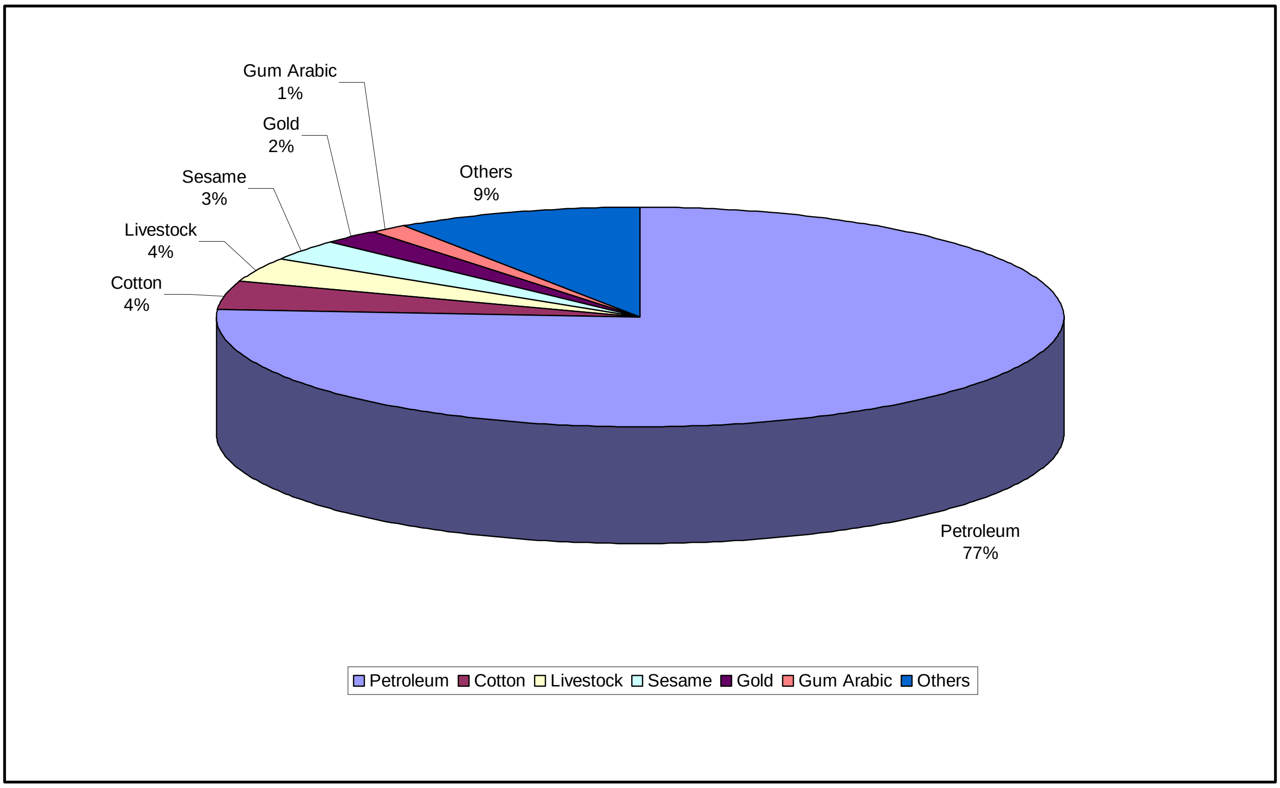

Figure 2.3: Structure of the Exports, Sudan, 2003

Source: Bank of Sudan, 2003

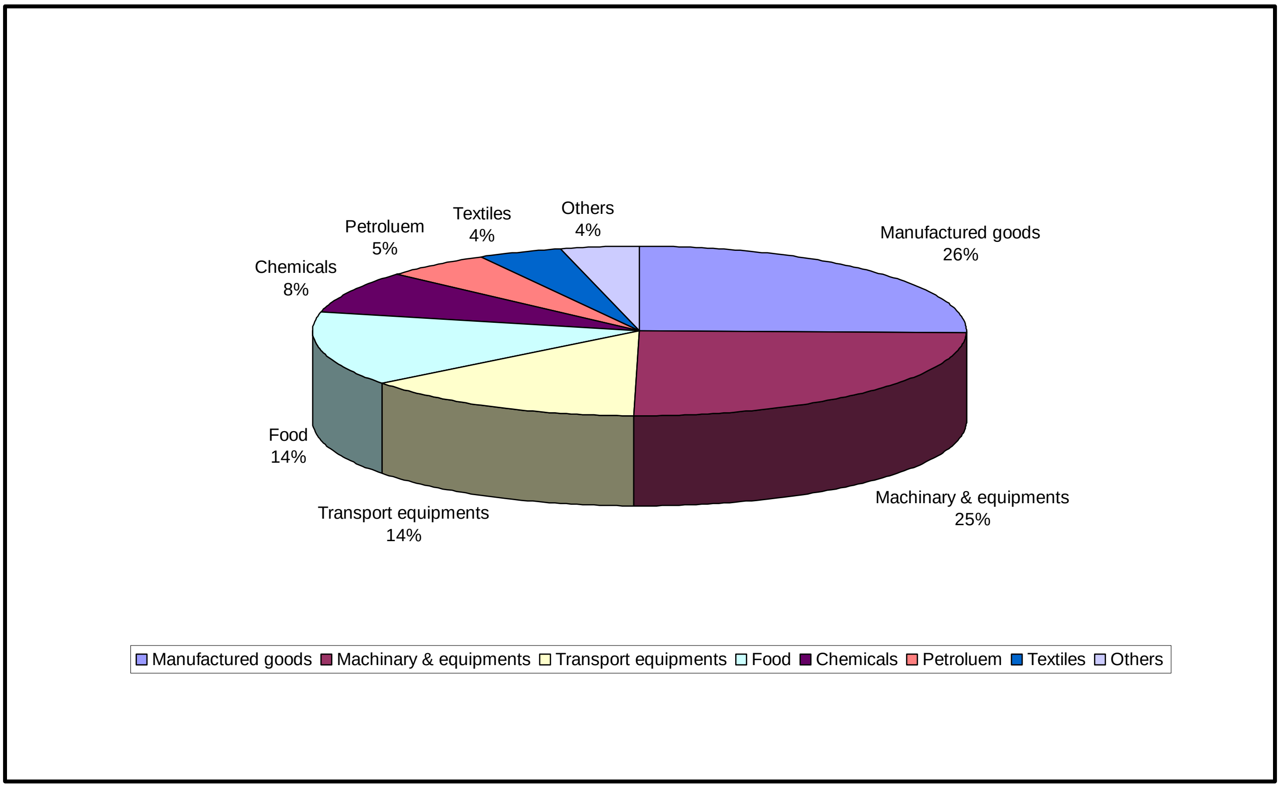

Figure 2.4: Structure of the Imports, Sudan, 2003

Source: Bank of Sudan 2003

2.5 Economic Policies and Development Plans

Economic policy is one of the major factors that have affected the performance and growth of the Sudanese economy. The agricultural sector is prominent in the economic policies, both because it is the major productive sector and because it is the object of myriad policy interventions. Therefore, high priority was given to the agricultural sector in all development plans launched since the Sudan achieved its political independence in 1956. These plans included the Ten-Year plan (1960-1970), the Five-Year plan (1970-1975), the Amended Five-Year Plan (1970-1977), the Six-Year Plan (1977-1982), the First-Three Year Public Investment Program (1979-1982), the Third Three-Year Public Investment Program (1982-1985), the Four-Year Salvation, Recovery and Development Program (1988-1992), and The three-Year National Salvation Program (1990-1993). The later is unprecedented and has major changes in the structure of the Sudanese economy, therefore, some details about it are explained below.

2.5.1 The Three-Year Economic Salvation Program (TYESP), (1990-1993)

The three-year was chosen as a medium-term for the TYESP. This time span considered to be sufficient to stop the deterioration in the economy and to put a base for a sound recovery that would take the economy back onto a path of sustained growth and financial stability (MAHRAN, 1995). The general objectives of the program were:

1. Revitalization of the Sudanese economy through reallocation of resources towards production.
2. Enhancement of the role of the private sector, whether national or foreign, to play a more active role in achieving the objectives of the program and to reorient financial, economic and institutional structures with a view to creating an environment more conductive to private sector participation.
3. Maintenance of social balance by protecting the poor during the adjustment period.

The main measures used to achieve these objectives include:

(i) Removal of government intervention monopoly in the areas of agriculture, industrial production, domestic marketing, and economic services.

(ii) Unifying the foreign exchange rate and freeing the circulation and use of foreign exchange by commercial banks, firms and individuals.

(iii) Lifting price controls and regulations to allow market forces to interact.

(iv) Taking institutional and legal reforms including laws governing taxation, custom duties, prices and industrial relations, with a view to facilitating and enhancing efficiency in resource allocation.
(v) Reducing export taxes to 5% for all exports and to 10% for cotton and gum arabic.
(vi) Removing subsidies on goods and services provided by Agricultural Public Corporations, most important of which are fertilizers, insecticides, land and water.

This program put more emphasis on agriculture as a leading sector in the economy. Thus, exports were to be enhanced through an immediate and complete liberalization of export prices. This was to be supported by the removal of bank credit ceilings to agriculture, abolition of marketing monopolies of all agricultural commodities (MAHRAN, 1995, and ELAMIN et al, 1997). This economic reform program was described by the World Bank as successful and unusual, because it restored macro economic stability, revived economic growth and resulted in increasing GDP per capita. It was unusual in the sense that reforms were pursued without external financing or technical assistance.

2.6 The Agricultural Sector of Sudan

Agriculture is the dominant sector of the Sudanese economy. The background information given should clearly show that the social and economic growth of Sudan depends to a great extent on the performance of the agricultural sector. In addition to generating directly about two-fifths of GDP, agriculture also drives activity in the industry and service sectors such as transportation, agro-industries, and commerce, which account for a large part of the rest of the economy. Even more importantly, 80 percent of the labor force is employed in agricultural and related activities, and the performance of agriculture is the main determinant of year-to-year changes in poverty levels and the food security of the population. Finally, agriculture is the source of virtually all of the Sudan’s exports (before oil extraction in1999) (table, 2.3) and therefore, it is a key determinant of balance of payments developments.

The agricultural resource base covers several agro-economic zones that include forests, farmland, arable cropland and grazing land for livestock as well as fisheries in the Nile basin and in the Red Sea. The currently cropped area is about 41 million feddan[2] (17 million hectares) which account to about 20 percent of the potential arable land. The arable land within the isohyets 400-800 mm (the rain-

[2] One feddan is approximately one acre and 0.42 hectares.

fed zone) is estimated at 59 million feddans (25 million hectares), of which 35 million feddans (15 million hectares) are currently utilized either traditionally (21 million feddan) or mechanized (14 million feddans). The relatively light infertile soils and the limited availability of water are, however, serious constraints to agricultural production in most areas. Rainfall varies from near zero in the extreme northwest to 1,600 mm per year in the temperate and rich forest zones in the south. About half of Sudan is susceptible to periodic severe droughts that often span two years (WORLD BANK, 2003).

Table 2.3: Composition of Sudan Exports (%), 1998 – 2002

Year / Product	1998	1999	2000	2001	2002
Crude oil	0.0	35.4	74.6	81.0	77.5
Agriculture	73.4	51.8	20.2	14.0	17.9
Manufactured goods	17.8	4.5	1.8	1.7	1.3
Mining goods	7.7	7.7	2.8	2.7	2.7
Others	1.1	0.6	0.6	0.6	0.6

Source: Ministry of Finance and National Economy, 2002

2.6.1 The Structure of the Sudanese Agriculture

Sudan has three distinct farming systems, these are: irrigated, mechanized rain-fed and traditional rain-fed sub-sectors. The irrigated agriculture accounted for an average of about 21% of the value of total agricultural production between 1991 and 1999; mechanized rain-fed agriculture accounted for 6.3%; and traditional rain-fed agriculture 12.5% (table 2.4). Pastoralism (predominantly livestock production in the traditional rain-fed areas) has always been classified as a separate farming system, even though it is integrated with other farming systems, particularly with traditional rain-fed farming. From 1991 to 1999, the average value of livestock production accounted for about 47% of the total value of agricultural production (table 2.4).

Table 2.4: GDP Shares for Different Sub-sectors within Agriculture in Sudan, 1991 – 1999

Item	Share of GDP within agriculture (%)
Irrigated crops	21.1
Rain fed semi-mechanized crop	6.3
Rain fed traditional crops	12.5
Minor crops	1.2
By-products	5.9
Total	47.0
Livestock	46.9
Forestry	4.8
Fisheries	1.3
Total	100.0

Source: World Bank, 2003

2.6.1.1 The Irrigated Sub-Sector

Irrigated farming has been one of the pillars of agricultural development strategy. Historically, it has been a major source of foreign exchange earnings. There are between four and five million feddans of land suitable for irrigation (MEPD, 2003). This sector is dominated by large national schemes like Gezira, New Halfa, Rahad and Sugar schemes. Tenancy sizes in the irrigated schemes range from 10 to 40 feddans. The main crops grown under irrigation include: cotton, sugarcane, sorghum, groundnuts, wheat, legumes, fruits, vegetables, and irrigated fodder. The sub-sector contributes 100% of the wheat and sugar, about 99% of the cotton, 52% of the groundnut, and 25% of the sorghum produced in Sudan (ABDALLA et al, 2001).

2.6.1.2 The Mechanized Rain-fed Sub-Sector

This system is concentrated in Gadaref, Blue Nile, Upper Nile, White Nile, Sinnar, and Southern Kordofan states. Annual area covered is on average about 14 million feddans (6 million hectares), with average holdings size of 1000 feddans. The main crops grown in this sector are sorghum and sesame. Mechanized farming accounts for about 65% of the sorghum, 53% of the sesame, 5% of the millet, and almost 100% of sunflower produced in Sudan. Historically, this sub-sector has been a source of sorghum exports as well as meeting internal needs particularly in urban areas (MEPD, 2003).

2.6.1.3 The Traditional Rain-fed Sub-Sector

This system includes nomadic, transhumance (moving with livestock and growing short-maturity subsistence crops), and sedentary agriculture which also includes a significant number of livestock. Although there is some rain-fed traditional farming in every state, the system is most prevalent in the States of Kordofan , Darfur, Sinnar, and the Blue and White Niles. The total cropped area in this system varies from 12 to 21 million feddan (5-9 million hectares) which varies annually with variation in rainfall. Crops grown are sorghum, sesame and cotton in clay soils, millets and groundnuts in sandy soils; the sector is also a major producer of gum Arabic and livestock. Out of the country's total production, this sector contributes 90% of the millet, 48% of groundnuts, 28% of the sesame, 11% of the sorghum, and almost all of the gum arabic (ABDALLA et al, 2001**).**

2.6.1.4 Livestock

Livestock is prevalent in the traditional rain-fed farming system throughout the country where they are raised under nomadic and transhumance systems. Sudan is considered as one of the most important countries in the Arab and African worlds in the field of animal wealth. Livestock is the second most important sub-sector within the agricultural sector in Sudan. It comprises about 47% of the agricultural GDP for the period 1990/91-1998/99; this contribution is increasing over the years implying the increasing importance of this sub-sector. With the second largest herd in Africa, next in size to that of Ethiopia, and close proximity to large and expanding markets, Sudan should enjoy a comparative advantage in both production and exports of livestock (ELAMIN cited in IMF 1999). There exists also substantial scope to enhance the price of Sudanese livestock products by improving the currently poor quality through improved processing methods. Livestock in Sudan also provide an important capital asset and they are a risk management tool for pastoralists and farmers in times of drought. In general the productivity of livestock production in Sudan, like productivity of crop production, has been extremely low (WORLD BANK, 2003**).**

2.6.1.5 Forests

Forests in Sudan occupy an area of about 64 million hectares, about 26% of the country's area. The forests reserve has a large potential economic value. It can provide the basis for a sustainable timber industry, wildlife tourism and other forest products. Currently, forest resources are used mainly for gum Arabic production and subsistence needs. Although more than 80% of the rural population depends on forest products, forestry accounts for less than 5% of the agricultural GDP (ABDALLA, et al, 2001 and WORLD BANK, 2003**)**.

To sum up, the contribution of the different agricultural sub-sectors to the country's GDP during the period 1990/91-1998/99 was as follows: irrigated crops and livestock were the leading sub-sectors contributing respectively 5.7% and 11% of average GDP. The contribution of the traditional and mechanized rain-fed farming and forestry was 3.8, 3.2, and 3% respectively during the same period (ABDALLA, et al 2001). Within the agricultural sector, crops and forests account for 51.8% of the gross value of product and livestock products account for the remaining balance (48.2% including fisheries) (table 2.4).

2.6.2 Performance of the Agricultural Sector

Given its dominant role, the performance of the Sudanese economy can be gauged on the performance of the agricultural sector. The share of agriculture in total GDP was estimated at 37% during the early 1980s. As agriculture declined between the mid-1980s and the early 1990s, its share of total GDP fell to 28%, but recovered to about 45.6% by the year 2003. The difference in GDP growth from agriculture between 1980s and 1990s was remarkable. From 1981/1982 to 1990/1991 the growth in GDP from agriculture was only 0.6% annually, whereas, during the successive 10 years, average annual growth rate reached 10.8% (WORLD BANK, 2003). In more details, the growth rate of the agricultural sector has noticeably decreased from 7.3% in 2002 to 5.2% in 2003 (table 2.5). The decline in the growth rate was attributed to the decline in the growth rate of the traditional sub-sector from 37.3% in 2002 to -4.9% in 2003, this in spite of an increase in the growth rate of the irrigated agriculture from 0.3% in 2002 to 4.3% in 2003, and the increase in the growth rate in the mechanized rain fed agriculture from 27.1% to 78.2% in 2003 (BANK of SUDAN, 2003).

The agricultural growth rate, achieved during the 1990s, reflected a recovery from the decline in the 1980s that was mainly the results of serious droughts and the government's interventionist policies, which reduced incentives for farmers to increase production. However, the specific actions which are responsible for the improvement of agriculture during the 1990s included the elimination of the fixed and overvalued exchange rate that imposed implicit taxes on agricultural exports, and curbing the power of commodity boards that had undermined production incentives through price and marketing controls as well as heavy marketing charges. Moreover, the removal of state agricultural taxes in March 2001 further improved production incentives. In conclusion, the recovery of agriculture was not the result of a major technological transformation of the sector; rather it was a return to earlier levels of output. Nevertheless, it confirms the agricultural sector as the most important source of sustainable growth in the Sudanese economy despite the sharp increase in the production and export of oil (WORLD BANK, 2003 and IDRIS, 2004).

Table 2.5: Growth Rates (%) of Agriculture and Agricultural Sub-sectors, 2000-2003, Sudan

Year	Total agriculture	Irrigated sub-sector	Mechanized sub-sector	Traditional sub-sector	Livestock sub-sector	Forests sub-sector
2000	0.7	7.6	-55.7	-0.6	5.6	5.0
2001	4.7	12.3	5.4	-12.0	6.0	5.0
2002	7.3	0.3	27.1	37.3	2.5	4.0
2003	5.2	4.3	78.2	-4.9	5.3	4.0

Source: Bank of Sudan, 2003

Sudan has huge agricultural potential in terms of arable land, pasture as well as water resources compared to many African countries. However, Sudan lies far behind most of the African countries in terms of agricultural growth and development. One of the basic problems of the agricultural sector of Sudan is the very low productivity. This is obvious from the fact that, about 80% of the labor force is engaged in agriculture and produce only about 40% of the GDP. The primary causes of this low productivity in agriculture, is that, the technology used is virtually traditional and the application of modern inputs has been extremely limited. The poor performance of agriculture has been also attributed to weak macroeconomic and sector policies, including market and price controls, deterioration of agriculture infrastructure and finally the incidence of drought (IMF, 2002).

2.6.3 Concluding Remarks

The information given above, clearly confirms that the agricultural sector is the engine of the sustainable growth of the Sudanese economy. In spite of the considerable extraction and exports of oil in the last few years, dependency on oil returns only is not enough to make substantial transformation in the economy of Sudan. Therefore, the enhancement of the other economic sectors particularly agriculture is of great importance. More attention should be given to the mechanized rain-fed sub-sector as a large and effective sub-sector which has considerable potential for building a national food stock and for generating foreign exchange through export sales. Efforts and policies should be directed to remove constraints and encourage foreign and domestic private investment which can substantially add to agricultural development and hence the development of the economy as a whole.

3 STUDY AREA

The purpose of this chapter is mainly to describe the study area i.e. Gedaref region of eastern Sudan, where the current study was conducted, in terms of its importance, geographical and climatic characteristics, demography, pattern of production and the on going research endeavors. In addition a historical overview of mechanized farming in Sudan is presented first in order to introduce the mechanized farming in Gedaref area.

3.1 Historical Overview of Mechanized Rain-fed Farming in Sudan

Mechanized farming began in Northern Gedaref in 1944 in response to the shortage of sorghum, the staple food grain for most Sudanese. The shortage was due to the increase in demand by the British armies during the Second World War in East and North Africa. This marked the first phase in development of mechanized farming in Sudan. The low annual rainfalls (600 to 700 mm) and the short rainy season (June to September) prevailing in the area retained only a light tree cover, which in turn, reduced the costs of land clearing. Subsequently, the areas for mechanized farming have rapidly developed (SIMPSON and SIMPSON, 1978).

During this stage, development continued through the establishment of government managed schemes where land was prepared through mechanical means assisted by manual labor from the towns. Due to the difficulties of mechanized crop production schemes as state farms, the system of participating cultivators was introduced in the 1948/49 season. In this system, land was to be plowed and sown by the scheme's management then weeded and harvested by the cultivators on a share cropping basis. However, the share-cropping system has not survived because of permanent settlement difficulties manifested by the seasonality of the production and the inadequacies of the requisite infrastructure (ADAM et. al, 1981). Until 1950, sorghum was the only crop grown, but in 1950 American short-staple cotton and local white-seeded sesame were introduced on small areas (SIMPSON and SIMPSON, 1978). In 1952/53, the total crop area expanded from the initial area of 12,000 to 29,000 feddan (5,000 to 12,600 hectares).

The second phase began in 1953 when the direct state participation was abandoned and instead 1,000 feddan's (420 hectares) holding were subleased to private tenants at a nominal rent. The private tenants were largely from merchants lived in towns and others entrepreneurs of Gedaref with both capital resources and management ability. Generally, the merchants lived in towns and hired farm managers to organize and implement the field operations. Once the concept of 1,000 feddan (420 hectares) was introduced, the area under cultivation in the Gedaref area expanded rapidly by 1959/60 passed one million feddan (420,000 hectares).

Mechanized farming then spread to other areas. In 1958/59, mechanized farming was introduced into the Dali/Mazmum and Damzine areas in the south east of Gedaref on the opposite side of the Blue Nile on 96,000 feddan (42,000 hectares) that expanded to 780,000 feddan (328,000 hectares) by 1968. In 1957/58 mechanized rain fed farming was also introduced in the Nuba Mountains area of Kordofan in Western Sudan. The rainfall in these areas is higher than at Gedaref but these areas are more remote from major markets.

Encouraged by the rapid spread of mechanized farming, the government has devoted attention to the possibilities of future expansion. Production and most of capital for expansion were seen emanating from the private sector, the role of state being the provision of roads and rural water supplies (SIMPSON and SIMPSON, 1976). Great emphasis was given to American short-staple cotton production for the recently established textile industry. The government also emphasized the introduction of sesame into the rotation with the objective of export diversification away from the over dependence on cotton exports from the irrigated zones.

The increased production of sesame and cotton was to be secured by adoption of a new rotation on mechanized farms; cotton-sorghum-sesame-fallow. The government, however, had little success in securing the desired expansion in cotton area at Gedaref. Cotton is a labor-intensive crop and the costs were not justified by the low yield levels normally attained. A major constraint was the shortage of drinking water during the operations of picking, collecting and burning of plant residues (January to March).

Sesame also was not successful in Gedaref. The crop is very sensitive to soil moisture conditions in its early stages and tends to die off when rainfall is either insufficient or excessive. Consequently, little progress was made with crop diversification especially in the Gedaref area where the farming system is predominantly sorghum monoculture with small area in sesame. The remedy for this problem was seen in the introduction of four-year fallow; to be implemented by leasing each tenant an extra one thousand feddan (420 hectares) holding so he could alternate a four year cropping period and a four year fallow between the two. The plan did not achieve its objectives, for two basic reasons. The new schemes were often a considerable distance away from the original holdings. Farmers were reluctant to operate a fallow system and find the capital to clear fresh land that they could not farm continuously. In fact, the system was already extensive without these additional constraints.

The third phase began in 1968, when the awareness of the problem of land deterioration, poor agricultural practices, low yields and unauthorized removal of the natural vegetation led the government to establish the Mechanized Farming Corporation (MFC). The MFC was entrusted with surveying and allocating land for mechanized farming, assisting of private investors, managing the state farms, promoting research, and providing of credit and other services. In practice, the MFC's activities were confined to the first two activities since the state farms had been abandoned in 1984 and the remaining activities are provided by other agencies.

When the MFC was established, there were 1,400,000 feddans (600,000 hectares) already under production in the Gedaref, Damazine and Rank areas. The first plan executed by the MFC covered a five year period (1970/71-74/75) during which an additional 2.689 million feddans (1.13 million hectares) were opened for mechanization. Sixty three percent of this development was self-financed by private sector, 22% financed by the World Bank for private farmers and 15% by state farms (SIMPSON and SIMPSON, 1976). Under this plan, mechanized farming was extended into South Gedaref and Habila in western Sudan. By 1988 mechanized farming in Sudan was practiced on 11.42 million feddans (4.8 million hectares). The current phase has undergone much transformation. Important among the modifications that characterized this phase is the decision by MFC to legalize the selling of the schemes licenses by farmers (IBNOUF, 1985). Some argued that it may increase the concentration of land in the hand of the few rich farmers who already operate multiple farms. Another development in this phase is the increased emphasis and attention given to importance of modernizing production practices and solving the resource mismanagement and low yield problems by technological change. The Agricultural Research Corporation (ARC) began to give more emphasis to rain-fed adaptive research and as a result several hybrids and new cultivars have been released since 1983. A new research station was established at Gedaref city to carry out applied research for the rain-fed area like developing new water retention technologies, improving chemical fertilizer use and designing optimum crop rotations (AHMED, 1994).

The expansion of mechanized agriculture in the Sudan has made a major contribution to its self-sufficiency in sorghum, except in years of severe drought; in many years the value of its sorghum exports may have more than paid for its cereal imports. Private capital has been utilized in the agricultural sector to much greater degree than before. Mechanized farming has also contributed modestly towards cash crop production but through sesame and very recently sunflower, rather than cotton. The price paid for this success has been the destruction of vast areas of savanna woodland and exhaustion of soils over large areas (DAVIES, 1991).

3.2 Relative Importance of the Gedaref Area

The mechanized rain-fed farms in the Gedaref area are the largest and the oldest in Sudan Since the early1960s, the contribution of Gedaref region in sorghum and sesame has been substantial in terms of crop area and output. Looking to table (3.1), one can conclude that Gedaref continued to cultivate almost half of the sorghum area in the mechanized rain-fed sub-sector and around 30% of total sorghum area in Sudan since the early sixties. Although most of Sudan's sesame is produced in the traditional rain-fed sub-sector, the Gedaref area grows 54% of total sesame area of the mechanized rain-fed sub-sector, which is 17% of the total sesame area in Sudan. Due to the development of the southern Gedaref in the 1970s, the relative area share of Gedaref in the seventies increased substantially as compared to the sixties. However, its large share in the mechanized crop began to decline during the eighties and nineties due to the recent expansion of mechanized farming in western Sudan and to the relative slow down of the area expansion as compared to 1970s' levels (table 3.1).

Table (3.2) shows the average contribution of the Gedaref area to sorghum and sesame output both in the mechanized rain-fed sub-sector and in the country as a whole during the period 1963-2001. This area produces 45% and 58% of the total rain-fed sorghum and sesame output respectively in the mechanized sub-sector. This is equivalent to 26% and 21% of the national output of the two crops. However, the data presented in table (3.1) and table (3.2) indicated that the share of Gedaref region in crop area is relatively larger than its output share especially for sorghum and throughout the period. This implies that crop yields in Gedaref area are relatively lower than in other areas. This also raises the concern, about the declining yield trends since almost half of the crop area in Gedaref is now more than half a century old and farming practices are extremely extensive.

Table 3.1 Gedaref Average Shares in the MRS and Sudan's Area of Sorghum and Sesame, 1963-2001

Period	Sorghum		Sesame	
	MRS*	Sudan	MRS*	Sudan
1963-72	0.44	0.29	0.81	0.16
1973-82	0.62	0.30	0.56	0.14
1983-92	0.46	0.30	0.44	0.17
1993-2001	0.41	0.27	0.34	0.21
1963-2001	0.48	0.29	0.54	0.17

Sources: Ahmed (1994) and Ministry of Agriculture and Forestry 2001

* MRS: Mechanized rain-fed sub-sector

Table 3.2: Gedaref Average Shares in the MRS and Sudan's Output of Sorghum and Sesame, 1963-2001

Period	Sorghum		Sesame	
	MRS*	Sudan	MRS*	Sudan
1963-72	0.35	0.25	0.84	0.14
1973-82	0.57	0.30	0.58	0.17
1983-92	0.44	0.27	0.50	0.25
1993-2001	0.45	0.22	0.38	0.28
1963-2001	0.45	0.26	0.58	0.21

Sources: Ahmed (1994) and Ministry of Agriculture and Forestry 2001

* MRS: Mechanized rain-fed sub-sector

3.3 General Features of the Study Area

The Gedaref state is located in eastern Sudan (figure 3.1), boarded by Kassala state to the north, Kahrtoum state to the northwest, Sinnar state to the south, Gezira state to the west and Eriteria to the east. The state covers a total area of 75,263 Km^2 (UN, 2003). It lies between latitude 12^o 45 N and 14^o 15 N and longitude 34^o E and 37^o E, its average altitude is 600 meters above the see level. Also, the region under consideration is about 490 km from the capital Khartoum and 770 km from Port Sudan city, the main sea port of Sudan. Thus the region's geographical position is favorable to domestic and foreign trade (OMER, 1989).

About one million people live in Gedaref area according to 1993 Population census, ninety percent of them are classified as farmers engaged in settled agriculture, either in traditional or large scale mechanized farming, the other 10% are engaged in semi-nomadic pastoralism. The average population density of Gedaref area was estimated at approximately 10 persons per square kilometer.

The area is generally divided into three agro-ecological zones on the basis of the amount of rainfall and main agricultural characteristics. The northern zone with rate of rainfall less than 500 mm; where animals especially sheep production is primarily practiced beside crop production, the central zone with rainfall range between 500 to 600 mm and the southern zone with rainfall range between 600 to 900 mm.

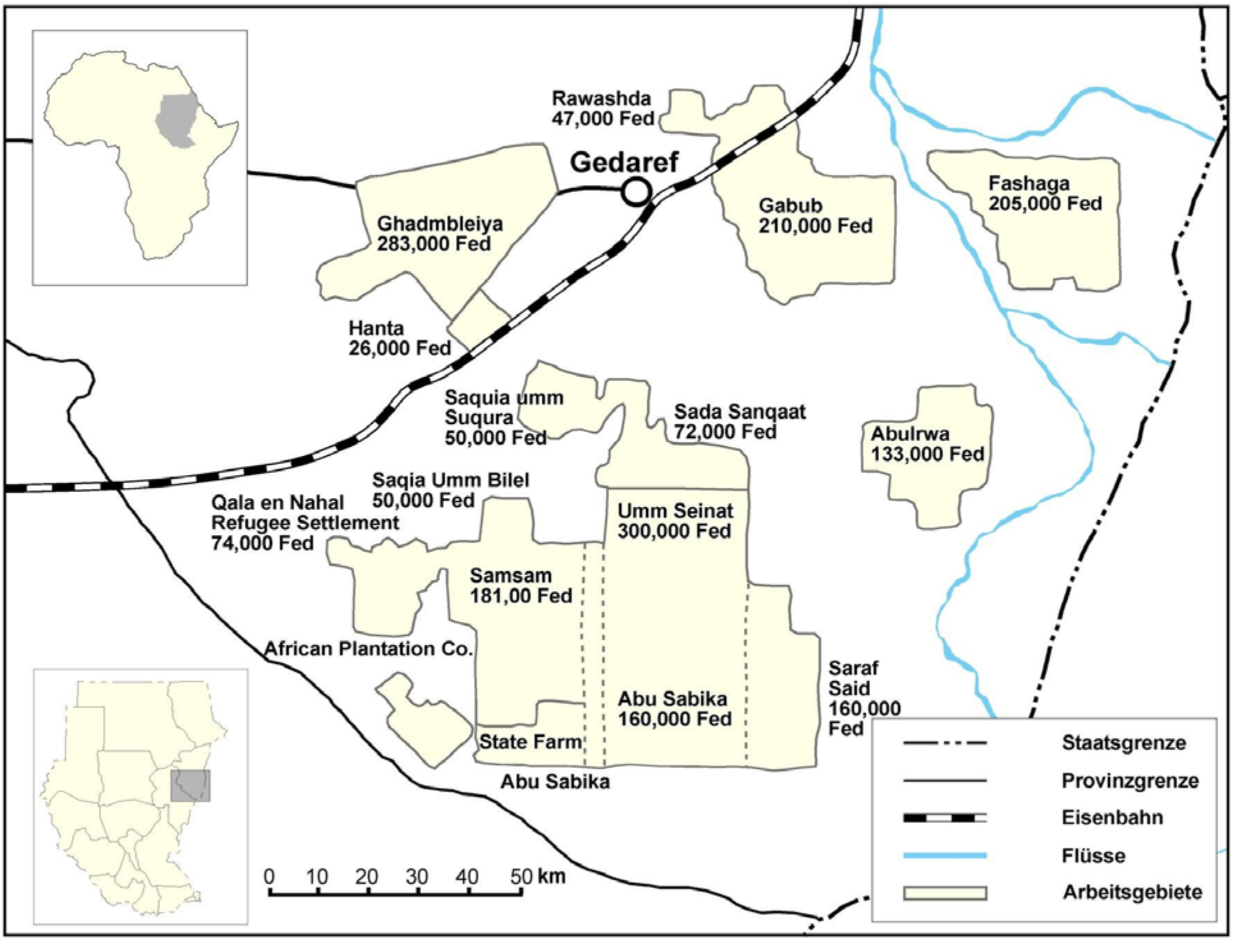

Figure 3.1: Gedaref Map

Source: Institute of Geography, JLU

3.3.1 Rainfall

Climate has always been a major concern; therefore, it is necessary here to briefly review the subject in relation to the study area. Since the agricultural production in the area is dependent mainly on weather, the link between occurrences of climatic fluctuations and the variability of crop yields, production and hence prices in the area need to be verified.

The Gedaref region is characterized by semi-arid climatic conditions where rainfall is erratic and concentrated in only few months of the year. The length of rainy season fluctuates around four months i.e. from June to September and the peak of rainfall is in August. The amount and distribution of rainfall in the study region varied greatly during the period 1982-2002 (figure 3.2). Rainfall varied from 400 mm to over 700 mm with an annual average of 591 mm and standard deviation of 102 mm during this period. According to the figure, 1999 received the highest amount of precipitation (750 mm) followed by the year 1989 (725 mm); and the lowest amount of rainfall was recorded in 1984 and 1986 (442 and

408 respectively), the years of drought, where crop production in the region plummeted to the lowest levels. Indeed, these variations affect the level of crop yields and hence comprise a major source of risk in the study area. Moreover, hazards of delays in rainfall commencement and subsequent poor rainfall distribution often necessitate re-planting and hence create additional cost of production. Rainfall is also considered as an important factor in determining the type and the variety of crops to be grown and the agricultural techniques to be used for optimum production.

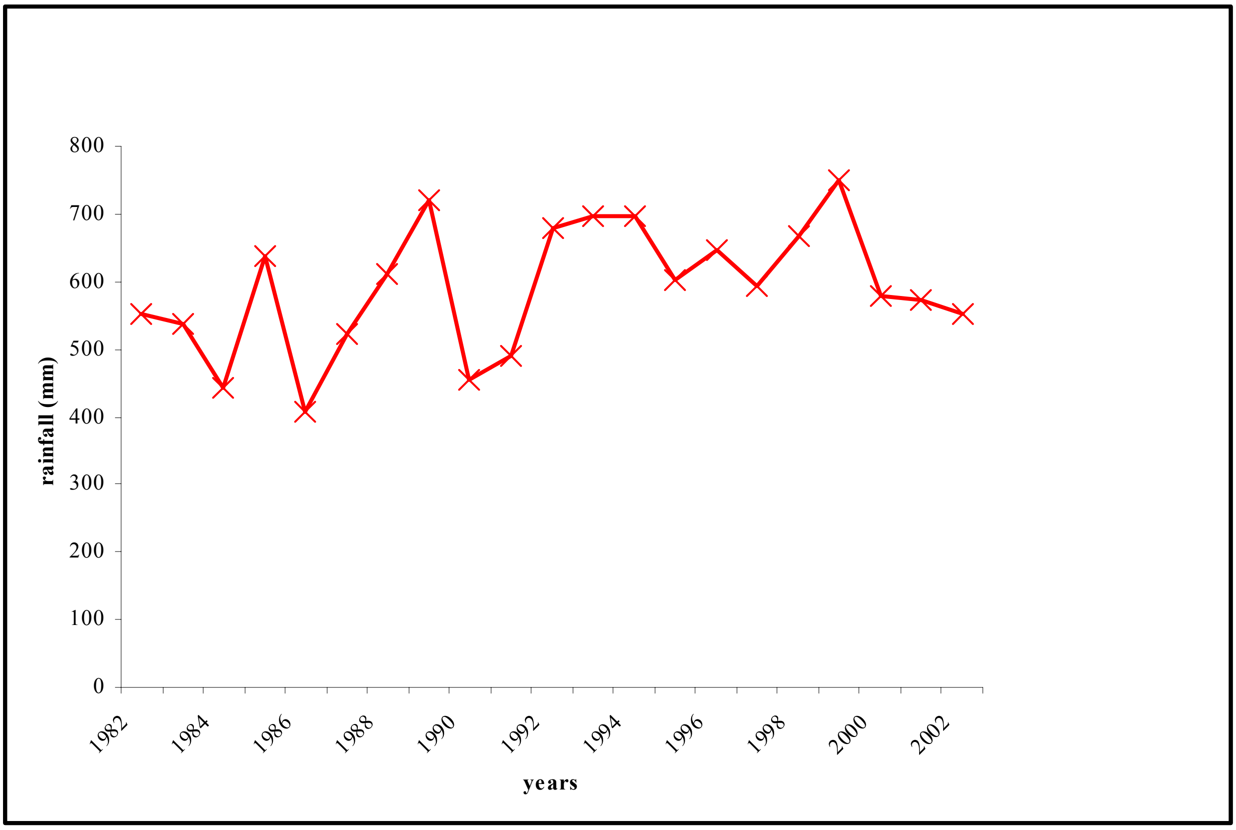

Figure 3.2: Average Annual Rainfall, Gedaref Region, 1982-2002

Source: MFC, various years

The seasonal distribution is equally as important as the amount of precipitation. Figure (3.3) illustrates the average rainfall and its distribution for specific different locations in the northern, central and southern zones of the study area during the period (1982-2002). The figure shows that the rainfall monthly average is higher in Doka town in the south followed by Gedaref city in the center and then Gadambalia town in the north. The average monthly rainfall in June at the beginning of the rainfall season; ranges from 66 mm at Gadambalia to 70 mm at Gedaref and 95 mm at Doka. At the peak of the rainfall season in August, rainfalls range from 176 mm at Gadambalia to 196 mm at Gedaref and 207 mm at

Doka. In September towards the end of the rainy season, the rainfalls range from 72 mm at Gadambalia to 83 mm at Gedaref and 105 mm at Doka.

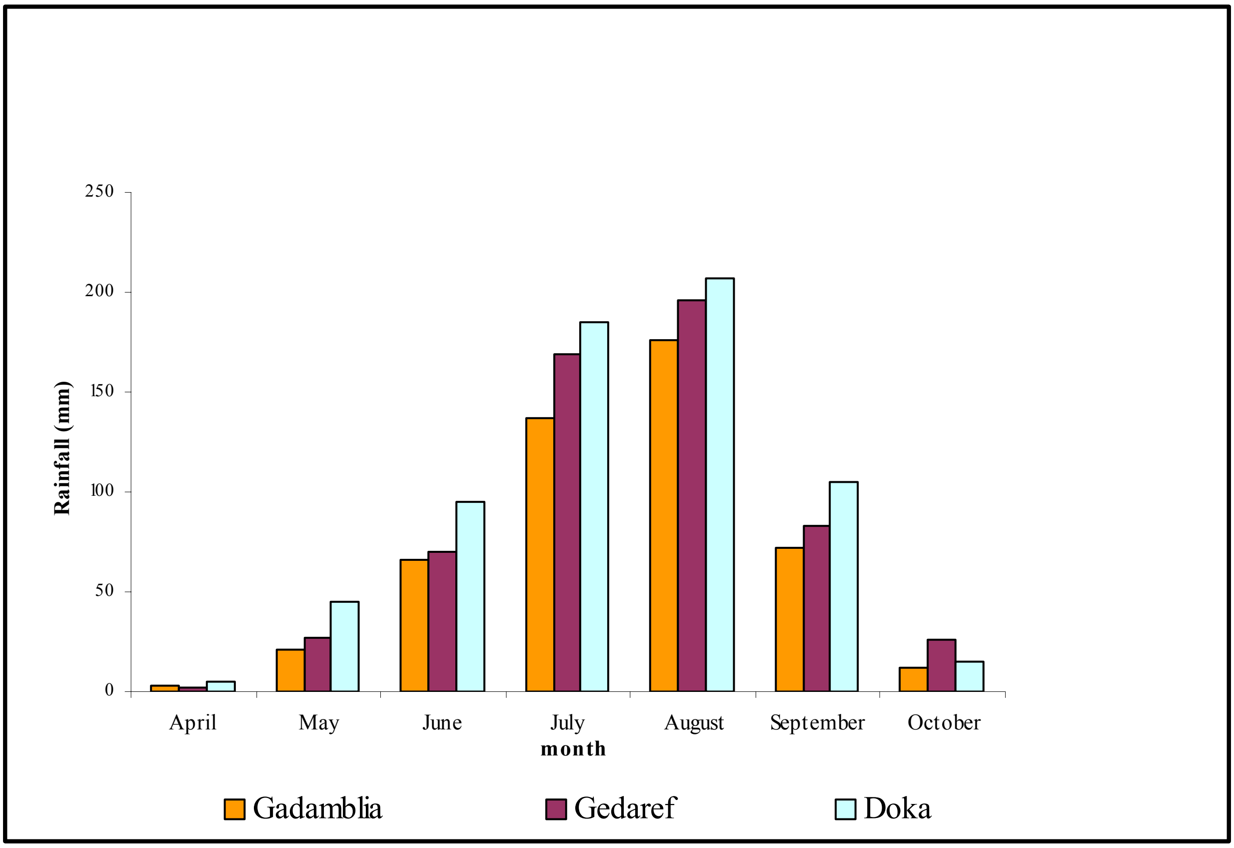

Figure 3.3: Monthly Rainfall in Different Locations of the Gedaref Region, 1982-2002

Source: MFC, various years

Although the total amount of precipitation during the rainy season may seem sufficient to meet the requirement of most crops, the high temperatures of the rainy months, together with a high percentage of light rainfalls events, substantially reduce the amount of effective rainfall (OMER, 1989). Since agriculture is practiced only under rain-fed conditions in this area, the timing and seasonal distribution of rainfall have greater influence on farmers' decision making process regarding agricultural production as it can be inadequate in amount and unreliable in its distribution. Such decisions involve risks, which calls for caution in timing and selection of production activities and management strategies.

3.3.2 Soils

The Gedaref area is characterized by a semi-arid climate which is related to soils having dark colors, a high clay content and strong vitriolic properties. The area includes a large, rather uniform, clay plain intersected by small valleys. The clay content is very high and generally 75% to 80%. The color of the soils is very dark grayish brown. The organic matter and nitrogen content of the soil are low but as there is no deficiency of other plant nutrients, the soils are moderately fertile. The water holding capacity of the soil material is very high. This, in combination with the deep penetration of water in the soil through the vertisolic cracks, causes the available water holding capacity of the soil to be very high. This high water holding capacity allows crops to grow on stored water during dry spells and long after the rainy season. The soils also have undesirable physical characteristics, such as a low permeability when wet, causing soils in water receiving sites to be waterlogged for certain periods during the rainy season. Also, the soils are difficult to cultivate as they are very hard when dry and very sticky and plastic when wet, causing the moisture range at which the soils can be cultivated to be very narrow. Thus, mechanization of the land preparation operation is critical to work in this narrow time frame. In fact, without mechanization, it would be impossible to develop these vast areas of vertisols.

3.4 Overview of the Farming System and Related Institutions in the Study Area

The Gedaref state has a unique farming system. It is formed as a result of the interactions between the agricultural activities and the supporting institutions that coevolved as a consequence of the existence of the agricultural economic activities. Describing the mechanized rain-fed farming system of the Gedaref can lead to a better understanding of the environment within which the farmers take their decisions and would provide precise diagnosis for the system problems which helps in better planning for the whole area.

3.4.1 Agricultural Activities

The predominant agricultural activities in the area include sorghum and sesame cultivation, livestock rearing and forestry.

3.4.1.1 Crop Production

3.4.1.1.1 Sorghum

Sorghum is a drought resistant crop with a very efficient, well-branched root system containing considerable amounts of silica that prevent the plant from collapsing in dry soils. Sorghum can also reduce its transpiration during periods of water shortage by rolling its leaves and by stomata closure; in these conditions, it can remain dormant while other crops perish, and when the rains resume it recovers rapidly. Sorghum needs at least 300-380 mm water during the growing period. It is one of a few crops that can withstand short periods of water logging; therefore it is popular on heavy clay soils. Bird damage is one of the main causes of crop loss in sorghum, and bird susceptible varieties may not be able to manage any yield at all. Insects and diseases are another major source of crop losses (ACLAND, 1971).

Throughout Sudan, sorghum is the major cereal crop and considered as main pillar of food security in the country providing about 60% of the quantity of the cereal consumed (KARIM, 2002). Sorghum production in 2001 in the mechanized rain-fed areas of the Gedaref represents 26% of the total production in Sudan and 45% of mechanized rain-fed sector (table 3.2). Table (3.3) gives information about the evolution of area, production and yield of sorghum in the mechanized rain-fed agriculture of the Geraref during the period 1990-2001. The information reflects large variability in the area where the maximum area cultivated is 5.297 million feddans in the year 1997 and the minimum area grown is 1.826 million feddans in 1993 with an average of 3.435 million feddans and standard deviation of 0.933 million feddans during this period. This large variability in area is attributed mainly to the amount and distribution of rainfalls; it is also influenced by the availability of credit and the prices of the previous season.

The production of sorghum in the Gedaref region reached its highest level of 1.215 million tons in the year 1999, while the lowest level of production of 0.183 million tons was recorded in 1991. The yield of sorghum is declining and varying considerably during this period. The average yield is 198 kg/feddan with standard deviation 67 kg/feddan. The highest level of yield attained is 314 kg/feddan in 1993, and the lowest was 100 kg/feddan in 1991. The continuous decline in the yield of sorghum can be seen in table (3.3) and reflects the present inadequate cultural practices and continuous cropping. In addition to weather conditions, yield is determined by the age of the farm; yield reaches its peak in the first two to four years then starts to decline until the seventh year and it stabilizes at the low levels achieved presently. It has been noticed that most farms in the area have passed their peak crop yields.

Table 3.3: Sorghum Area, Production and Yield, Gedaref, 1990-2001

Year	Total area (Million fed.)	Sorghum		Production (000) MT	Yield Kg/feddan
		Area (000) fed.	% from total		
1990	3.250	2.900	89.2	440	152
1991	2.126	1.826	85.9	183	100
1992	3.240	2.890	89.2	1,124	289
1993	4.450	3.735	83.9	1,173	314
1994	4.090	3.600	88.0	767	213
1995	4.886	4.259	87.2	916	215
1996	4.495	3.430	76.3	556	162
1997	6.222	5.297	85.1	1,145	216
1998	4.105	3.280	79.9	494	151
1999	5.133	4.509	87.8	1,215	270
2000	3.988	2.869	71.9	315	110
2001	3.591	2.625	73.1	495	188

Source: Ministry of Agriculture and Forestry, 2002

3.4.1.1.2 Sesame

Sesame is moderately drought resistant crop. A level of 380-510 mm of water by rainfall is needed during the growing season. Moist conditions are necessary during the early stages of growth. Most varieties of sesame are photoperiod sensitive. Sesame is very intolerant to water-logging but diseases seldom do serious damage (ACLAND, 1971).

Gedaref is the major supplier of sesame in Sudan during the last forty years. It represents about 21% and 58% of the total production in the Sudan and mechanized rain-fed sector respectively (table 3.2). The average share of sesame in total area in the Gedaref region during the period 1990-2001 is about 17% (table 3.4). However, it is observed from the data presented in the table, this share has increased considerably in the years 2000 and 2001 to reach around 30%. The increase has been mainly attributed to the increase of the world prices of sesame, which led farmers to expand its area at the expense of sorghum.

Table (3.4) shows information about the evolution of area, production and yield of sesame in the mechanized rain-fed of the Geraref during the period 1990-2001.

The information reflects large variability in the area where the maximum area cultivated reached 1.119 million feddans in the year 2000 while the minimum area grown was 0.3 million feddans in 1991. The average cultivated area during this period is 0.696 million feddans with a standard deviation of 0.287 million feddans. This large variability in area is mainly attributed to the sesame prices of the previous season; it is also influenced by the availability of credit and the amount and distribution of rainfall.

The production of sesame in the Gedaref region reached its peak in the year 1996 which is 0.119 million ton, while the lowest level of production was 0.27 million ton attained in 1991. The yield of sesame like sorghum is declining and varied considerably throughout this period. The average yield is 91 kg/feddan with standard deviation 16 kg/feddan. The highest level of yield attained is 117 kg/feddan in 1997, and the lowest was 70 kg/feddan in 2000. The decline in the yield of sesame also reflects the present inadequate cultural practices and continuous cropping.

Table 3.4: Sesame Area, Production and Yield, Gedaref, 1990-2001

Year	Total area (Million fed.)	Sesame		Production (000) MT	Yield Kg/fed.
		Area (000) fed.	% from total		
1990	3.250	0.350	10.8	32	90
1991	2.126	0.300	14.1	27	90
1992	3.240	0.350	10.8	31	90
1993	4.450	0.715	16.1	79	110
1994	4.090	0.490	12.0	39	70
1995	4.886	0.627	12.8	56	90
1996	4.495	1.065	23.7	119	112
1997	6.222	0.925	14.9	108	117
1998	4.105	0.825	20.1	86	101
1999	5.133	0.624	12.2	47	75
2000	3.988	1.119	28.1	78	70
2001	3.591	0.966	26.9	75	78

Source: Ministry of Agriculture and Forestry, 2002

3.4.1.2 Livestock Production

Table (3.5) shows livestock population in the Gedaref state. The total number of animals is estimated in 1999 to be 3,896,134 heads. Sheep herds comprise about 48% of the total animal number followed by goats 24%, cattle 24% and camels are about 4%. Livestock production is the second major economic activity in the state. The animals depend on natural pasture land throughout the year with the exception of the period April-June during which the state experiences deficits in animal feed. Pastoralism is subdivided into nomadic and settled or semi-settled traditional pastoralism. The first category specializing in camel, cattle, sheep and goats are nomadic throughout the year while in the second category, the young people look after the herds and their families remain behind, practicing rain-fed farming. However, the semi or settled pastoralists constitute the prime source of milk to the neighboring cities. In this farming system, livestock provides a mean for risk management during drought and crop failure period.

Table 3.5: Livestock Population in the Gedaref State (1999)

Type of livestock	Number	Percentage
Sheep	1,878,852	48.2
Camel	162,085	04.2
Cattle	917,921	23.6
Goats	938,276	24.0
Total	3,896,134	100

Source: UN, 2003

3.4.1.3 Forests Production

The Gedaref state is classified within the woodland savanna ecological division, which includes mixed type of vegetation composed of grass along with bushes and trees, which is the characteristic of the dry tropics with a monsoon rainfall confined to a few months, followed by a long hot dry season. The dominant tree in the region is the Acacia Senegal; its local name is Hashab. The tree is a hardy leguminous tree belonging to the genus Acacia. It is an arid-zone tree well-known as a multi-purpose species providing gum arabic, wood fuel, fodder and poles and improving the soil. Also, its contribution towards environmental protection and economic development in the Sudano-Sahelian region is significant. In this zone the Hashab tree is of vital importance to the permanent farming system. The major economic activity of the forest is the production of gum arabic from the Hashab tree. Gum arabic is the natural gummy exudates obtained by tapping the branches of the Hashab tree. The final use of the product is in the off shore pharmaceutical and cosmetic industries; so it is one of the key Sudanese export goods. The total area of forests in the Gedaref region is estimated at 1,600,000 feddans (672,268 hectares). The forests are registered and monitored by the forest management section of the Ministry of Agriculture. The Gedaref state average share was about 14% of the total production of gum arabic throughout the period 1970-1998 in the country (table 3.6).

It deserves here mentioning that the evolution and success of the mechanized rain-fed farming in the area is achieved on the expense of the forest and natural cover. Shifting rain-fed agriculture has been replaced by mechanized farming and the scale of land clearance has led to the degradation of the natural environment. The mechanized agriculture has been criticized severely for leading, first, to the destruction of the vegetation on a massive scale, second, to the exhaustion of land and third, to the abandoning of the fields. Thus, the greatest concern in this sub-sector is the uncontrolled removal of the natural vegetation for the purpose of farming resulting in environmental degradation. The recent farm plans which have the aim of arresting environmental deterioration and maintaining high levels of yields, have recommended the strategy of set aside 10% of the farmer's land for forest production.

Table 3.6: Gum Arabic Production by Region, Sudan, Average 1970-1998

Region	Production (MT)	Percentages
Kordofan	412,281	54.0
Darfur	146,277	19.2
Eastern (Gedaref)	103,584	13.6
Center	93,106	12.2
South	8,114	1.0
Total	869,975	100

Source: Ministry of Agriculture and Forests, 2000

3.4.2 Field Operations of Sorghum and Sesame Crops

The average farm area in Gedaref region is 1,000 feddan (420 hectares). Forty percent of owners of the area under the scheme are traders who make extensive use of hired managers. They rarely live on their scheme areas but appointe a foreman (*wakeel*) for day-to-day management. The *wakeel* and a couple of guards are usually the only resident employees. Two tractor drivers each with an assistant are needed for two months and about eighty seasonal laborers per farm unit are used for weeding and harvesting. The periods of these two operations are characterized by high scarcity of hired labor (SIMPSON, 1991). Figure (3.4) exhibits the timing and the operations of a typical farm in the mechanized rain-fed large scale farming. The cropping season starts as early as June after the first rain. By the onset of rainfall, first plowing is done to eradicate early weeds using wide-level disk. A second disking is carried between mid-June and mid-July during which, planting is completed. SIMPSON and SIMPSON (1978) estimated that it takes 14 working days of 20 hours to plough and plant the 1,000 feddans standard farm. Usually two weeding operations are done manually. The first is completed two to three weeks after crop emergence. The second weeding is carried out to control late season weeds.

Harvesting starts in early October for sesame, which is exclusively a manual operation. Sesame harvesting is very critical as any delay will lead to substantial crop losses due to shattering of mature pods, while premature pods are difficult to open during manual threshing. Sorghum harvesting usually starts in November by cutting the heads and collecting them in large piles. The heads are then threshed using stationary threshers or by using combined harvesters as stationary harvesters (AHMED, 1994)

This farming system, although called mechanized, it uses limited number of equipments; usually a four-wheeled tractor of about 65 or 75 hp fitted with a set of disc harrows and a seed box, and a vehicle for transport, usually a pickup van. Farmers have no permanent buildings, the usual arrangement is a collection of mud walled, thatched round traditional huts which provide a temporary camp during the cropping season i.e. June to January. In the remaining period, the machinery and stores are shifted and the farm is left deserted. The farms are isolated from the outside world, consequently men, machines, stores including food, tractor fuel and spare parts have to be moved to the land towards the end of the dry season.

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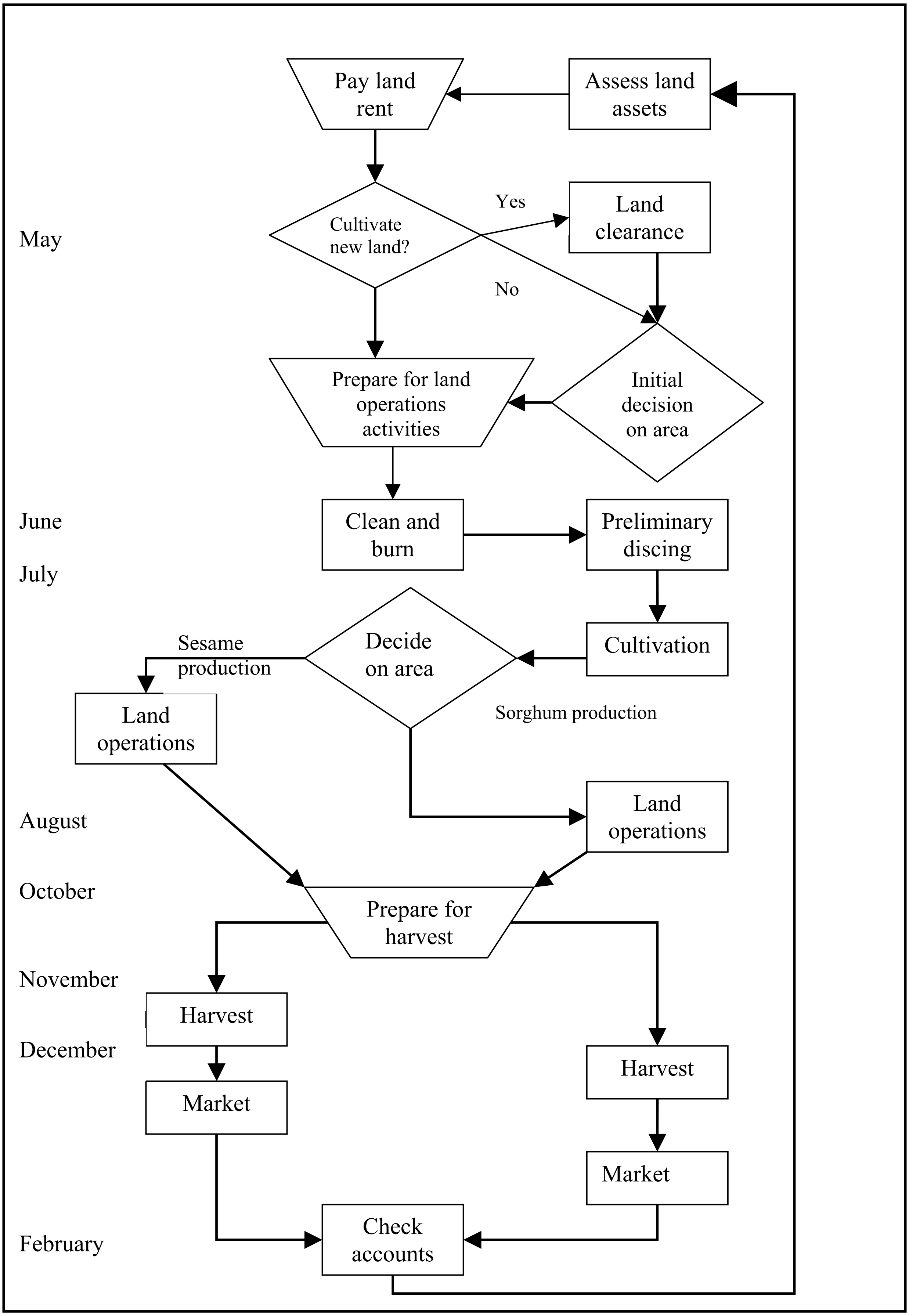

Figure 3.4: Flow Chart of Mechanized Farm Production Operations

3.4.3 Land Tenure

Before reaching the current arrangement of land tenure, the system has passed through many phases. At the beginning in 1943 when mechanized farming first started in Gadambalia north of Gedaref, the Gezira irrigated scheme was taken as a model with plots of 28 feddans plus four to five feddans for private cultivation allocated as tenancies. Government tractors cultivated the land, but tenants were responsible for all subsequent operations and the crop output was equally shared. It was not a success; tenants were blamed for neglecting their plots and the system was abandoned in 1953. In 1954 the department of Agricultural Economics of the Ministry of Agriculture noted the heavy losses on the government schemes and recommended their closure, leaving future development to the private owners. The size of the basic private farming unit was determined by the area which could be operated with single tractor. It was set at two kilometer square block of 952 feddans (400 hectares), subsequently often referred to as 1,000 feddans (SIMPSON, 1991).

Large blocks of land were demarcated and allocated by Provincial Land Boards mainly to individuals, but also to co-operatives and companies. Individuals were able to possess up to two blocks while the co-operatives and companies have up to eight blocks. Initially, Leases were annual, but were extended to eight and eventually twenty five years. In this connection it is relevant to refer to the phenomenon of illegal sub-leasing in the Gedaref state. Its extent and magnitude could not be officially known because sub-leasing is not allowed according to the conditions of the original lease. In order to carryout the sub-lease without violation of the contract, farmers make use of the article which permits the original lease holder to appoint a representative (the *wakee*l) to act on his behalf. Thus the sub-lessee poses as a representative but he runs the farm for his own benefit. A nominal rent is charged annually, it is still low in relation to output value.

3.4.4 Markets and Marketing Systems

The Gedaref is a major regional contributor to the national sorghum and sesame markets supply. All agricultural crops produced in the Gedaref area, specially in the large scale sub-sector are marketed through Gedaref auction, which is a well established and organized auction market located in the Gedaref city. It works as a regional assembly point for recording, taxing and selling the supply of sorghum, sesame and gum arabic. The storage capacity of the market's silos is about 100,000 ton with about annual storage cycle of 350,000 ton, while warehouses storage capacity is around 200,000 tons.

The market was established in 1945 in the south western part of the city. It started to get its importance since 1970s when a managerial body was appointed to administer the marketing of sesame, gum arabic, sorghum and cotton crops. According to the market regulations, the above mentioned crops are deprived from being traded outside the auction fences. The market administration is also committed to supervise some 22 rural assembly market centers in the Gedaref region. The ordinance of the market highlights the following goals:

(i) Organizing and maintaining the links between farmers and traders.

(ii) Enhancing the domestic marketing of the crops.

(iii) Facilitate the collection of taxes and fees levied on crops.

All crops delivered to market are auctioned. The auction market is frequented by traders, transport entrepreneurs, intermediate buyers, and well off farmers who have to deliver all their supplies of sorghum, sesame and gum arabic. Most of the harvest from mechanized schemes is marketed by the farmers who tend to be traders and transporters as well. Before being admitted to the auction procedure, private merchants and companies representatives have to prove possession of a certain amount of capital, provide a profit tax certification, a trade license, and a guarantee of a bank or of an important person of commercial life (OESTERDIEKHOF, 1991). Since sorghum is the major crop in the study area, some more detailed information about its marketing is given below.

The Gedaref market is the biggest sorghum market in the Sudan. The region also stands first as a surplus producing area for this crop. The surplus produce goes to other consuming areas either national or international (UN, 2003). The description of sorghum marketing channels provides a better understanding of how the marketing system of sorghum grains works. As the term implies, marketing channel defines the whole way the product moves from farmers, via assembly, storage and/or processing to the final consumer. Most of the harvest from mechanized schemes is marketed by the farmers themselves who tend to be traders and entrepreneurs in logistics at the same time. The output of sorghum is usually turned over on the official market (the Gedaref auction). Farmers who had loans from banks deliver part of their harvest to the bank in kind and the rest of their harvest goes to the Gedaref auction where it is sold to whole sellers or companies. Part of the sold produce goes to the Gedaref silos for sieving, storage and packing then exported mainly to Saudi Arabia, Egypt and Ethiopia. The other part is transported to the consumption centers in the country mainly the capital Khartoum.

Most of Sudan sorghum exports come from Gedaref area and the share of the other producing areas such as Blue Nile region depends on whether Gedaref alone can satisfy the export needs or not (HASSAN 1993, cited in HUSSIEN 2001). Sorghum is less controlled by the government than other cash crops. Only few instances of interference have taken place by the Agricultural Bank of Sudan (ABS) on behalf of the government. In most cases this interference is caused by a popular pressure from the farmers in sorghum surplus seasons or by urban consumers in deficit years. The sorghum marketing system witnessed changes at macro level during the 1990's including the adoption of price liberalization and Islamic modes of credit which are based on commodity title transfer. Through these credit modes, the banks sign contracts and own the future crop. This meant the explicit involvement of commercial banks and companies as participants in sorghum marketing (HUSSEIN, 2001).

3.4.5 Financial Institutions and Methods of Finance

Two main sources of credit are reported in the Gedaref area. The first are the formal sources which represent the state institutions such as the Agricultural Bank of Sudan (ABS) and the other commercial banks. The second are the informal sources, mainly what is locally called *Shail* system.

3.4.5.1 The Formal Credit

Formal credit provided by the financial institutions which compose of specialized banks such as Agricultural Bank of Sudan (ABS), and the commercial banks which dominate the sector in terms of deposits and lending.

3.4.5.1.1 The Agricultural Bank of Sudan (ABS)

The agricultural bank of Sudan (ABS) has been playing an effective role in both financing and marketing the agricultural production. It was the only formal agency specializing in farm credit prior 1990. The ABS was established by the Sudanese government, its objectives as stated by the Agricultural Bank Act (1957), are to support agriculture and identical accessory, ancillary or subsidiary activities by providing assistance in cash, kind, goods or services to persons who are primarily engaged in agriculture or its allied and subsidiary industries. Section four of the bank act states that the ABS is to promote agriculture by engaging in a wide variety of activities: extension of credit for agriculture and subsidiary services; purchasing and selling of agricultural inputs including the importation and customer's clearance of goods for its own clients and other parastatal bodies; purchases, storage and selling of crops; performing commercial banking activities such as acceptance of current and time deposits; and borrowing from foreign and local national institutions. With 90 branches, now ABS is the most geographically wide spread agricultural financial institution in the country. Previously, the bank was not engaged in deposit-taking and its lending capacity was determined by its capital and support by the central bank. The ABS provides loans to farmers in irrigated and rain-fed sectors (mechanized and traditional) according to Islamic modes, mainly *Salam* and *Murabaha* methods.

3.4.5.1.2 Financing Methods

Different types of financing methods are used by financial institutions in Sudan. The financial institutions follow the Islamic financial principles in achieving their transactions. The most common methods in financing agriculture are *Salam* and *Murabaha*.

3.4.5.1.2.1 The Salam

The *Salam* is a purchase contract with deferred delivery of goods and is mostly used in agricultural finance. Farmers receive cash advances on the promise of selling a certain amount of his future crop to the lender at an agreed price and time. The bank pays the farmer the full negotiated price of the contracted product (IMF, 1999). The loan is given in cash and the repayment is in kind. The amount of the repayment is tied, through a formula, to the market price of the crop at harvest.

The contract includes an item which works as an adjustment mechanism and known as price penalty avoidance and called locally *Ezalat Algubn*. In this item the two partners agreed to remove any sort of price penalty that might take place due to tangible price increments or decrements by more than one third of the contract price. In case of price increment the bank pays the difference more than one third and the client pays it in case of price decrement (HUSSEIN, 2001).
The main features of the *Salam* contract are:

1. It applies only to products whose availability on maturity date is normally assured and quality and quantity can be specified.
2. The banks pay the client the full negotiated price of the contracted goods (e.g. crops) when the contract is signed.
3. The seller is only obliged to deliver the promised products or the price he received from the bank if the product could not be delivered.
4. The contract can be sold to a third party only at par (IMF, 1999).

The system could offer an alternative to prohibitively high interest rates that would be necessary in the Sudan's high inflation economy and, therefore, reduces the farmers default risk (WORLD BANK, 1995). The *Salam* furnishes the farmer with liquid money and free hand in its utilization (ELHIRAIKA, 1991). The major disadvantage is the burden on the supplier of agricultural credit, where, the formula on which repayments are based apparently has not allowed the credit institutions to keep up with inflation and recover a positive real return (HUSSEIN, 2001).

3.4.5.1.2.2 The Murabaha

It is a purchase and resale contract with the resale price determined based on cost plus profit mark up. The bank purchases the goods ordered by the client and resell them to him at a higher price, usually on deferred payment basis. This method satisfies Islamic legal requirements since the lender takes physical possession of the goods being financed and the mark up is related to the length of the period over which the transaction is to be completed. This also means that the lender also subject to risk of potential loss might be caused by negligence and fraud. The main features of this contract are:

(i) The cost and the mark up must be known for the bank and for the client.
(ii) The bank must assume the ownership of the goods prior to reselling them to the client (bearing all the ownership risk in the interim).
(iii) The client's promise to buy the goods purchased on his order by the bank is binding.
(iv) No interest is levied for late payments but the bank could require collateral.
(v) The bank could not sell the Murabaha contract to a third party (IMF, 1999).

This form is used mainly to finance the purchases of input materials but it doesn't cover the cost of labor or the fixed cost.

3.4.5.2 The Informal Credit

The agrarian credit market in Sudan has a dual character in the sense that formal and informal lending and borrowing are carried out simultaneously. In the absence of institutional loans; farmers resort to the informal market to meet their financing needs. KEVANE (1993) pointed out that little institutional credit is available to satisfy farmer's production and marketing needs, and there is no access to consumer credit. Consequently farmers look for local merchants to satisfy their consumption and production credit needs. Although it means paying high interest rates, farmers continue to borrow from this source.

The most common informal method is called locally the *Shail*. It is described as leverage derived from the meaning of lifting the burden (money need) by the lender off the recipient shoulder. In the most common type of the *Shail*, money lender advances loan to farmers who pledge the delivery of a specific quantity of output equivalent to the value of the loan at the time of harvest. The *Shail* could be in cash or in kind, but repayment is usually in kind at lender-set prices that are significantly lower than harvest prices. Money lenders (merchants) who provide loans to farmers in the *Shail* mode, benefit from the method in two ways, at one hand lending money to farmers eases merchants job of accumulating sorghum at harvest time when they collect the loan in kind. On the other hand, farmers use part of the barrowed fund to buy their consumption goods from the merchants themselves. Some studies have calculated the interest rate of the *Shail* from the *Shail* contract price and actual harvest price, and in some cases the *Shail* interest reached about 726% (KEVANE, 1993).

3.4.6 Government Agricultural Development Policies

Government development policies towards the mechanized rain-fed sub-sector in the past attempted to encourage rapid and extensive development by subsidizing agricultural inputs. The low land rent, low interest rates, and low foreign exchange rates on machinery imports are good examples for government policy support. However, in the early 1990s the government began a policy liberalization regime to eliminate the above distortions. The foreign exchange rate is now determined in the free market and is now at or close to its real value. All commercial banks are now allowed to extend credit to eligible farmers at the prevailing cost based on the Islamic banking system. The equivalent interest rate is expected to be much higher than the rates that traditionally have been charged by the agricultural bank of Sudan (ABS). Since March 2001, for the first time, production taxes on agricultural products were abolished, which is expected to increase farmer's incentives.

3.5 Risk and Agriculture in the Study Area

It is stated in general that the types and severity of risks facing farmers in agriculture, vary with the farming system, environmental, technical and policy factors. In the mechanized large scale farming system of Gedaref area, three types of risks are predominant viz. production, market and financial risk.

The uncertain and uncontrollable factors affecting farming in the Gedaref region contribute to the magnitude of production risk. However, the main determinants of crop yields are weather, insects, diseases and indirectly, changes in national policies. The variations of physical output are attributed primarily to the weather conditions. Among the environmental factors, the point worth emphasizing is the untimely rains i.e. too much or too little rain at the wrong time. The time series data obtained from the mechanized farming corporation in Gedaref show a greater variability of yield for both sorghum and sesame during the period 1980/81 to 1999/2000 (figure 3.5). The yield variability for sorghum (CV=40%) is quite high compared to sesame (CV=24%) This implies that throughout the period, sesame is more stable but a downward trend of productivity prevails for both crops.

Market risk in the study region originates mainly from sorghum and sesame prices variability. The lack of information and the unstable market conditions besides the large fluctuations in output in Gedaref area and in other parts of the country contribute principally to this price variability. The time series data obtained from the Gedaref Crop Market for the period 1985/86-1999/2000 reflects this variability (figure 3.6). Both sorghum and sesame prices for the specified period showed greater variability and downward trends.

In the mechanized rain-fed farming system, agricultural production involves a large amount of capital investment; of which considerable amount is borrowed. The results of the field survey during the season 2003/2004 showed that 47% of the sampled farmers in the study area have used borrowed funds from formal institutions to finance their agricultural operations. Data from the Agricultural Bank of Sudan (the governmental body responsible for providing credits for large scale mechanized farmers) showed that 52.5% of farmers are unable to repay their credits in the year 2002. Also, the data revealed that the phenomenon of indebtedness has been prevailing since 1997 where its ratio reached 42.5% and it is increasing over time. The above mentioned information indicates the availability and importance of financial risk in the region that stems from the increasing trend of dependence on borrowed capital to finance agricultural operations in one hand and the inability to repay loans on the other hand.

From the above information it can be concluded that, in large scale mechanized farming of Gedaref; yields, price and financial risks are important and they have a considerable influence on farmers' decision making process therefore, they will be considered in this study. The variability of yield and prices and the attitude of farmers to this variability may be a significant determinant of their choice of production technologies and strategies.

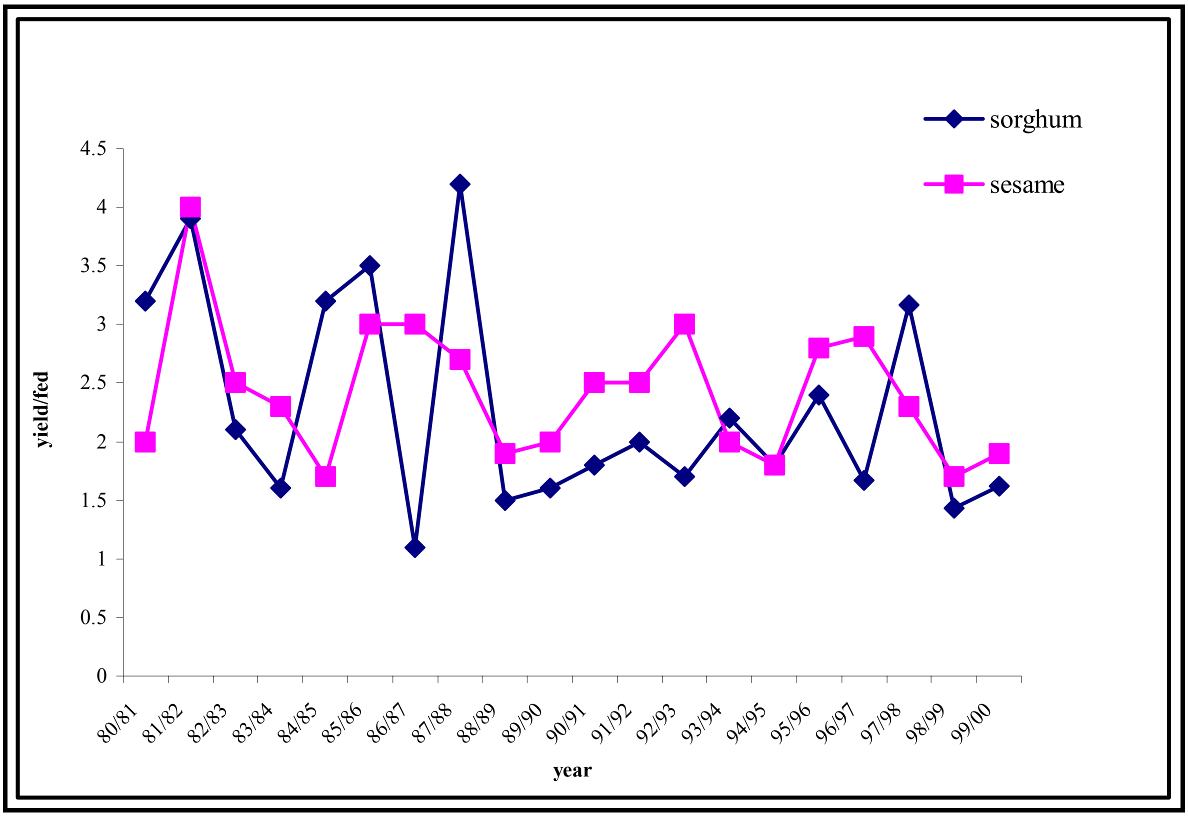

Figure 3.5: Yield Variability in the Gedaref Area, 1980-2000

Source: MFC, various years.

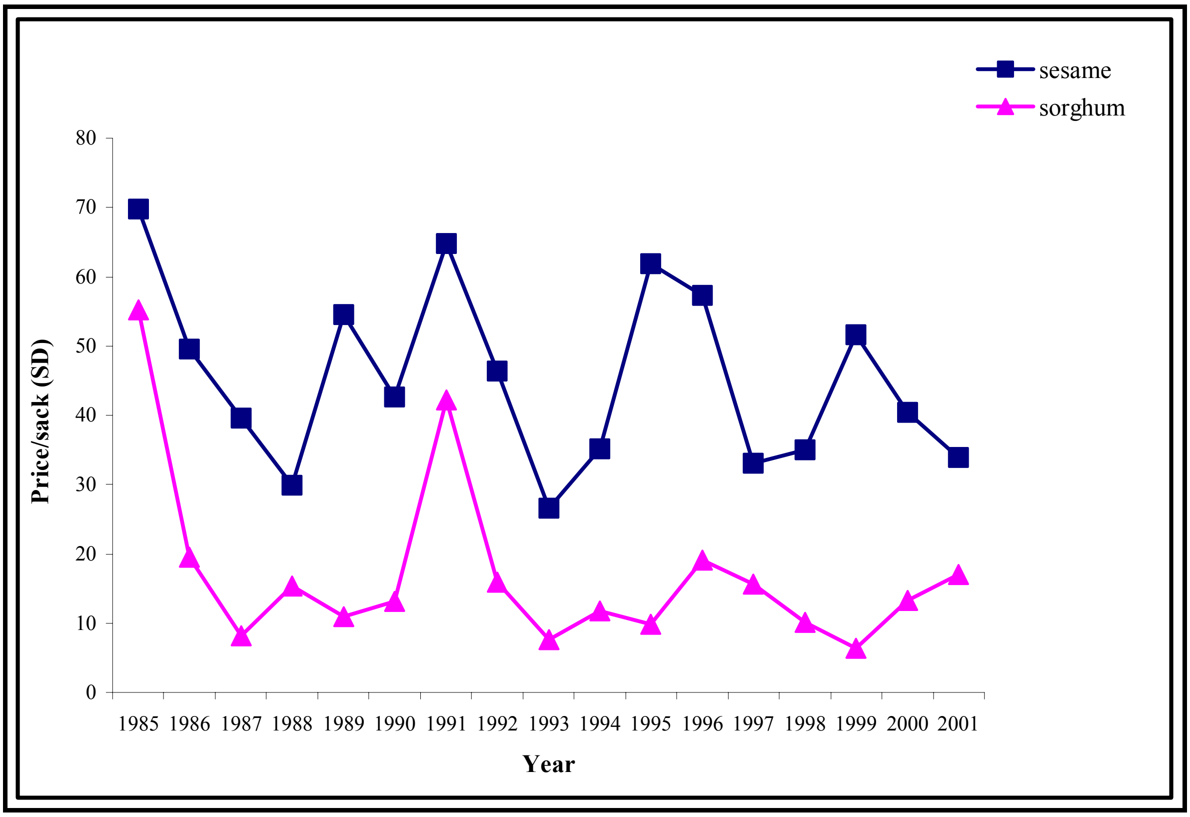

Figure 3.6: Sorghum and Sesame Prices in the Gedaref, 1985-2000

Source: Gedaref Crop Market, various years

3.6 The Sudanese-Canadian Mechanized Rain-fed Agricultural Project

In September 1979, a general agreement was signed between the governments of Canada and Sudan to establish a program of development co-operation, in conformity with the objectives of economic and social development of the government of Sudan. The agreement included the establishment of the Sudanese-Canadian rain-fed agricultural project in Gedaref area given the fact that mechanized farming in Sudan has considerable potential for building a national food stock and for generating foreign exchange through export sales (CANADIAN I.D.A. 1979 quoted in OMER 1989). The Canadian International Development Agency (CIDA) and the mechanized farming corporation (MFC) of Sudan were designated as the authorities responsible for the implementation of the project. The project is located approximately 160 km south of Gedaref and covers 10,000 feddans (4,200 hectares) (OMER 1989).

According to CANADIAN I.D.A. (1979), the objectives of the project is to demonstrate the successful application of new technology in a production oriented scheme that will provide the potential for expanded, intensified and stabilized agricultural output in the rain-fed area of Sudan by:

a. Identifying and strengthening the farming methods in the existing farming system.
b. Providing the required technology and equipments.
c. Providing agricultural training to private sector farmers.

The activities of the Sudanese-Canadian project involve introduction of large modern machinery to meet the following:

1. Demonstrating the magnitude of potential yield increase.
2. Demonstrating the possibility of reducing fuel and other costs associated with crop production.

Research activities of the project is intended to be an extension of the applied research done by the agricultural research corporation (ARC), universities and some agro-industries in the fields which are relevant to dryland farming and their application on a large scale using farm machinery. Factors such as varieties, dates of seeding, rates of seeding, seeding patterns and weed control were tested and analyzed in the project. An additional objective of the project is to provide extension and training program to other farms in the area. The extension program was restricted to field days which provide a forum for discussion between visitors and project staff. On the other hand, the training program is based on the concept of exchange of information between Canadian and Sudanese staff, with the purpose of developing individual skills in the field of agronomy, management and supervision and the operation, maintenance and repair of machinery.

4 DATA COLLECTION AND RESULTS OF THE FIELD SURVEY

This chapter outlines the results of the field survey and the building of the database. As a step to understand farmers' behavior and attitudes, this chapter includes descriptive analysis of the farmers' socio-economic characteristics, agricultural activities, land use, level of used technology, farmers' access to credit and farmers' storage capacity.

4.1 Data Collection

4.1.1 Primary Data

The primary data was obtained from sampled farmers in the Gedaref state by personal interviews for the cropping season 2003/2004. Although the rainfall varies from 900 mm in the south to 400 mm in the north of the region, informal surveys have shown no significant differences within the farming system regarding farmer's decisions on crop mix, yields and production. Therefore, a sample of 100 randomly selected farmers was used to represent the whole system. Following the advice of Agriculture Economics Unit (AEU) staff, the survey was conducted during the off-season period (February – June). During this period most farmers are marketing their crops in Gedaref city and have enough time to answer the interview's questions. The sample covers the three administrative areas of Gedaref state north, middle and south. The data were collected by enumerators from AEU who had previous experiences in conducting interviews; moreover, they are familiar with farmer's conditions and attitudes and had a good knowledge of the local farming conditions.

The questionnaire was aimed at gathering relevant information on social and economic aspects of farming in the research area (details are given in Appendix 4.1). First, it covered general information on farmers' social characteristics such as age, education level, experience in farming and involvement in other off-farm activities. Second, it solicited information on sources, methods of finance and the repayment period, as well as the types of accepted collateral. Third, it asked for a description of the land base and cropping activities. The amount of land devoted to each crop was obtained in order to estimate the share of land under major crops. The questionnaire did seek the details of the field activities, input use and production levels of the two major crops (sorghum and sesame) and information on crop rotation as well as adoption of the recommended technologies, and the major problems influencing technology application. Fourth, it collected information on livestock and livestock management as well as the major agricultural problems of the sample communities. Finally, the questionnaire included a section of open ended questions to compile the farmers' opinions on the problems they face regarding different aspects of the agricultural business and to understand the reasons behind their attitudes towards the recommended technologies and crop mix.

4.1.2 Secondary Data

The secondary data was collected to complement the information obtained from the sample farmers. The secondary data, obtained from different institutional sources was compiled ahead of the primary data collection to support the charting out of the latter. Published and unpublished materials were screened in order to draw maximum available data.

The source of secondary data includes the following institutions:

- Agricultural Bank of Sudan (ABS).
- Agricultural Research Corporation (ARC).
- Bank of Animal Wealth (BAW).
- Bank of Sudan (BOS).
- Central Bureau of Statistics.
- Farmers' Union.
- Gedaref Crops' Market. (Gedaref Auction).
- Mechanized Farming Corporation (MFC).
- Gedaref State Ministry of Agriculture and Animal Wealth.
- Federal Ministry of Agriculture and Animal Wealth.
- The Sudanese-Canadian Project in Sim-Sim area, Gedaref.

The information gathered include: Time series data of prices, production, productivity and area grown of sorghum and sesame, the contribution of the Gedaref area to the national production and exports, as well as time series prices of gum arabic and prices of different animals besides agro-climatic data. Also, the collected secondary data have provided information on the credit institutions and its financial policies, different methods of finance used and credit ceilings, consumer price indices, detailed costs of production of the main crops grown, on-farm research data on technology levels used and other recommendations.

4.1.3 Data Problems and Management

Some difficulties were faced during secondary and primary data collection process. Regarding secondary data, the data obtained from different sources are inconsistent and it is also recorded on average for the whole region without in depth details. With regard to primary data, the enumerators were faced with some problems in eliciting information from farmers as they were sensitive to questions related to their level of production and farm income. They are reluctant to give information about their off-farm income and the number of livestock as well. On the other hand, farmers have their own local scaling for production units; it might lead to misleading results if enumerators are not carefully converted the answers to the standard scale. Moreover, farmers do not keep records for their farms regarding the number of labor employed in the different operations. The methods of keeping records on area grown, area harvested, costs, production and yield are not regular, not systematic and only for a short time period.

4.2 Results of the Field Survey

In this study, some degree of homogeneity among the farming system domains is assumed based on the fact that the nature of farming among large scale farmers in the Gedaref does not differ from one another in terms of farm size, crops produced, level of technology used, methods of finance and the marketing procedure.

4.2.1 Farmer's Socio-Economic Characteristics

4.2.1.1 Age Structure

Age structure is one of the factors that are used to distinguish the farming systems. Table (4.1) shows the age structure of the sampled farmers. The average age of the sampled farmers is 46 years with standard deviation of 10 years. The average age structure discloses that most of the farmers (85%) are within the active age of (20-60) and about 15% are over 60 years. The survey also showed that the majority of the sampled farmers (81%) have spent more than ten years in the agricultural work with average experiences in agricultural work of about 20 years. Concerning farmer's age variable, it is often hypothesized that increasing age reduces the probability of adoption. Younger farmers tend to have better education and are often expected to be more willing to innovate (RANAIVOARISON, 2004).

Table 4.1: Farmers Age Structure, Gedaref Area, 2003/2004

Age Group	Percentage
20 – 40	21
41 – 50	41
51 – 60	23
> 60	15
Total	100

Source: Field survey

4.2.1.2 Education Levels

The survey showed that most of the farmers (97%) have attained some sort of education, the majority of them (85%) have joined the formal education institutions, and 37% of the sampled farmers have got a secondary or a university education (table 4.2). Since the farming in Gedaref area is considered as a type of business investment, the area during the 1980s attracted many investors from urban areas who attained some sort of education before they joined this farming activity. The level of farmers' education is relatively high if compared to conventional farmers in the irrigated farming of Gezira where the level of illiteracy amounted to 43% (ADAM, 1995).

Age composition and the level of education are indicators of the farmers' level of awareness and their abilities of taking decisions on how and what to produce, taking marketing decisions, approaching credit and market institutions, allocating their available resources, and adopting new agricultural technologies. In this case the high level of education would ease the process of extension in transferring knowledge and technology to the farmers. Moreover, it insures that the farmers are highly aware of their business environment, and they take their decisions on light of their accumulated knowledge, available resources and limiting constraints. The education level and the age of the farmers were proved to have a positive effect on planning horizon, which in turn influences farmer's decision to invest in the new technologies (FEDER and NORONHA, 1987). In addition, a higher level of education most probably allows farmers to better understand the modalities involved in the use of inputs and equipments. This allows them to evaluate the economic benefits of these factors and thus, to increase productivity (RANAIVOIRISON, 2004).

Table 4.2: Farmer's Level of Education, Gedaref Area, 2003/2004

Education Level	Percentage
Illiterate	3
Informal Education	12
Elementary Education	26
Intermediate Education	22
Secondary Education	26
High Education (University)	11
Total	100

Source: Field survey

4.2.2 Farming Activities

4.2.2.1 Crop Production

Table (4.3) demonstrates sorghum and sesame yields and areas according to farm sizes. Farms in this sub-sector are usually distributed in the unit size of one thousand feddans called locally 'schemes'. Accordingly, the principal farm size of one thousand feddans is obtained by 63% of the sample. Farmers in this farm size category have allotted 80% of the area for growing sorghum and 20% for growing sesame on an average. However, companies, cooperatives and some individuals may own more than one scheme and this explains the farm size category of more than one thousand feddans (34%) that appeared in the sample. As shown by the table, the average yield attained for sorghum is 201.3 kg/feddan (2.3 sack) with standard deviation of 96 kg (1.05 sack), while the average yield of sesame is 58.4 kg/feddan (1.25 kantar), with standard deviation of 52 Kg (1.16 kantar).

Table 4.3: Sorghum and Sesame Areas and Yields by Scheme Categories, Gedaref Area, 2003/2004

Area grown (feddan)	Farmers No.	Average sorghum area (%)	Sorghum yield (Kg/fed.)	Average sesame area (%)	Sesame Yield (Kg/fed.)
< 1000	3	64	265.3	22.1	116.9
1000	63	80	189.4	20	68.3
>1000 ≤ 2000	21	76.3	237.9	23.7	143.8
>2000 ≤ 3000	8	88.7	219.6	11.3	69.2
> 3000	5	82	146.4	10.3	43.1
Average	-	82	201.3	17.8	58.4

Source: Field survey

4.2.2.2 Livestock Production

Livestock production is the second major activity beside crop production in the Gedaref region. Farmers maintain an extensive system of raising their animals. Animals feed depends mainly on the natural pasture of the eastern region of Sudan. The herds spend the dry summer season (February-June) in the farmers' land where they graze crop residues of the previous crops mainly sorghum. During the rainy season and winter (July-January) when the farmer's land is occupied by crops, animal herds are sent to the pasture land in the neighboring region of Butana. Normally farmers raise a mixed herd of cattle, sheep, camel and goats, but sheep is by far the dominant in the herd. Table (4.4) shows that the largest average number of livestock is sheep (181 heads) among the sample farmers. About 47% of the total farmers in the sample owned livestock beside their traditional crop activities. This trend of keeping animals besides agricultural production is expected to increase in the future.

Table 4.4: Livestock Average Herd Size, Types and Breeds, Gedaref Area, 2003/2004

Type	Average No. of animals	Local race (%)	Cross breed (%)
Cattle	91	96.3	3.7
Sheep	181	100	0
Camel	60	100	0
Goats	32	100	0

Source: Field survey

The prevailing livestock are mainly local breeds. They are preferred by farmers as they are able to tolerate the harsh environment of the region, and ease in marketing them in the area. Most of the interviewed farmers explained that livestock helps them to repay their loans in case of bad seasons. Also, the returns from livestock activities are used to finance agricultural operations for field crops. It is evident that the risky production situation of farmers which has been created by the mono-cropping practice of growing sorghum and the uncertainty in productivity and prices has led the farmers to keep animals besides their traditional farming.

ANDERSON and DILLON (1992) argued that one general survival strategy of farmers facing climatic uncertainty is the mixing of crops and livestock activities. Mixed farming leads to more efficient use of labor on land resources and through synergistic use of intermediate joint products such as biologically fixed nitrogen and grazing of growing (and failed) crops and crop residues, the stability or relatively low variability of performance can be attained.

4.2.3 Off-farm Activities

The off-farm activities are of great importance in the large scale farming system of the Gedaref region in providing alternative income sources to the farmers when the agricultural activities fail. Although we could not quantify the income from off-farm activities due to the reasons stated before, we managed the information on the sources of the off-farm income. About 43% of the sampled farmers have off-farm activities besides their farm activities. Most of them (77%) involved in commercial work and 23% work as employees for the government.

4.2.4 Land Use

Table (4.5) shows farmers allocation of land among the different available activities. This table disclosed that sorghum is the dominant crop in terms of area since it was grown by all farmers in the sample. About 72% of the sampled farmers devoted more than 750 feddans of the scheme area for growing sorghum while none of them grew less than 250 feddans with this crop. Unlike sorghum, sesame is not grown by 27% of the sampled farmers in the last season, and 36% of them devoted less than 250 feddans to be grown with this crop. Thus, sorghum monoculture continues dominating the Gedaref farming system. These results confirm the statistics of the Ministry of Agriculture (2001) which showed that, over the period 1990-2000, eighty five percent of total crops area was under sorghum, while fourteen percent under sesame and one percent under other crops.

The farmers were asked in the questionnaire, why they limit sesame area. Most of them (88%) have mentioned high cost of labor as the main reason that limits their expansion in sesame area, while (12%) have resorted that to biological and climatic reasons. Some of the interviewed farmers explained that growing small areas by sesame is only for the purpose of using sesame returns to finance the cost of coincident farm operation particularly sorghum harvesting, as sesame is harvested and marketed earlier in October.

Table 4.5: Land Allocation, Gedaref Area, 2003/2004

Activity Area (Feddan)	Farmers percentage		
	Sorghum	Sesame	Fallow
0	0	27	93
> 0 ≤ 250	0	36	7
>250≤ 500	19	31	0
>500≤ 750	9	2	0
>750	72	4	0

Source: Field survey

AHMED (1994) outlined some of the reasons that are responsible for limiting the expansion on sesame production. First the crop is very sensitive to soil moisture conditions in its early stages and tends to die off when rainfall is either insufficient or excessive. Second, sesame production requires large numbers of labor particularly during harvest time. Sesame harvesting (cutting, stalks tying and threshing) is by hand which is quite labor intensive and hence acts as a constraint to the increase in the areas under this crop.

In spite of the recommendations of having fallow area in order to improve soil conditions, farmers in the study area are reluctant to apply it. The survey results show that only 7% of the farmers left a small part (less than 250 Feddans) as fallow. This is only, because they have no enough funds to cultivate the whole scheme area. Farmers also think that leaving some scheme area as fallow gives weeds a good chance to grow and to reproduce which means more efforts to get rid of them (two to three land preparation operations are needed) which in turn involves additional cost. Moreover, fallow could provide suitable environment for insects, birds and attracts other animals which can be harmful to the neighboring crops grown.

In 1997 a specific rotation was imposed by the Ministry of Agriculture with the aim of arresting the environmental deterioration and maintaining sustainable agriculture in the region. The rotation includes growing 50% of the land by sorghum, 25% by sesame and the rest 25% is under forest and fallow. It is also used by the agricultural bank as a pre-condition for providing agricultural loans for farmers. However, the recommended rotation is not adopted or applied by the farmers in the area.

4.2.5 Technology Adoption

New agricultural Technologies are usually provided to farmers in the study area through Agricultural Research Corporation and the Sudanese-Canadian project; both of them have administratively been working with the State Ministry of Agriculture. The recommended package of technology envisaged for a farm of 1,000 feddans size includes the following:

- Land preparation and sowing with 65-75 HP tractor and 12 ft wide level disc planter.
- Use of improved seed varieties.
- Application of chemical fertilizers, 9 kg nitrogen per feddan in form of urea.
- Application of the chemical herbicides 24D, about 0.4 litre per feddan.
- Application of the specified rotation, (at least 50% of the farm land devoted to sorghum and the other 50% divided between sesame and fallow).

The aim of the recommended technology package is to achieve high level of yields and at the same time to reserve soil fertility taking economic constraints into consideration. Farmers in the study area normally use 75 horsepower tractors and disc-planters which are the recommended types of machinery for a unit farm of thousand feddans. As indicated by the surveyed farmers and shown by table (4.3), about 82% of farm land on average was put under sorghum crop while the other 18% was grown by sesame which is in fact far from the recommended rotation. On the other hand, the practice of continuous cropping adopted by farmers in the study area has resulted in the loss of soil fertility which is becoming an increasingly limiting factor for crop productivity in the area. None of the sampled farmers (0%) have tried to improve soil fertility by using fertilizers (table 4.6). However, research results have generally shown positive responses to the application of Nitrogen and Phosphorus; it has been proved that 9 kg of nitrogen will give increase of 30-50% and 29-69% per feddan in output of sorghum and sesame respectively (FARAH and ALI, 2000). About 45% of the sampled farmers have mentioned that the high cost is the main reason for not applying fertilizers, 40% have no idea of how to apply and what are the expected gains from the application of fertilizers (table 4.7). The data from the sample indicated that farmers in general do not have adequate knowledge about fertilizer and intuitively feel that its use may not be profitable to them. The uncertainty added to the pay-off of fertilizer use is further complicated by anticipations of the occurrence of drought.

Table 4.6: Farmers Application of the Recommended Technology, Gedaref Area, 2003/2004

Item	Sorghum (%)	Sesame (%)
Improved seed varieties	20	18
Herbicides	9	9
Fertilizers	0	0
Rotation	0	0

Source: Field survey

The survey results showed that, only 9% of the sampled farmers have applied herbicides on their farms (table 4.6). The use of herbicides depends mainly on its cost; it is preferable only when its cost is less than the cost of manual weeding. Accordingly, about 60% of the farmers who did not apply herbicides in their farms have mentioned the high cost of herbicides as a main reason (table 4.7).

Farmers started to use herbicides in the last two years, and the market of herbicides is growing in the area. Moreover, prices of herbicides would be decreased if few more firms enter the market ensuring fair competition, and may accelerate the adoption process. On the other hand, the research results of the Sudanese Canadian Project showed that the use of herbicides is expected to completely replace manual labor of weeding which is a major constraint in this farming system. Consequently, considerable weeding cost will be eliminated.

Table 4.7: Problems Related to Fertilizer and Herbicides Application, Gedaref Area, 2003/2004

	Fertilizers		Herbicides	
Problem	**No. of Farmers**	**%**	**No. of farmers**	**%**
High cost	45	45	55	60
Not available	15	15	11	12
Lack of extension	40	40	25	28
Total	100	100	91	100

Source: Field survey

Apparently, because of the high cost connected with the implementation of such technological package coupled with likely hazards of inadequate rainfalls; farmers' tend to be risk-averse and may not intensify their inputs use. The same view was derived by HAZELL and NORTON (1986). They stated that due to risk-averse behavior, especially when the business requires large investments, farmers often prefer farm plans that provide a satisfactory level of security even if this means scarifying income on average. More secure plans may involve producing less of risky crops, diversifying into a number of enterprises, using established technologies rather than undertaking the new ones.

4.2.6 Farmers Access to Credit

Table (4.8) performs farmer's main sources of capital for running their farms. It shows that around 48% of the sampled farmers use their own savings which indicates economic sustainability of this farming system or the contribution of off-farm activities in financing the agriculture. On the other hand, it has been noticed that during the last few years, farmers who obtain loans from banks, have experienced severe indebtedness problems, rendering the credit from banks a non-preferable option to them. Farmers, who take loans from sources other than banks, represented only 5% of the sample. This category of farmers usually gets loans from local merchants or relatives, and the *shail* form is mainly used in this type of informal credit. It is obvious to the enumerators that farmers normally do not want to admit that they have used the *shail* form because of its inconsistency with the Islamic laws. However, having loans from other sources with the *shail* form is common or familiar among small farmers who have less than 500 feddans farm land. On the other hand, around 32% of the sampled farmers depend completely on the banks in financing their farms. Farmers who support their own capital with bank loans are 15%. This indicates that 47% of the total sampled farmers have loans from Banks. The loans could be acquired from the Sudanese Agricultural Bank or from one of the 14 other commercial banks spread in the Gedaref area. These banks working within the frame of the general policy set by the central bank (BOS) which implies the use of Islamic forms of *Salam* and *Murabaha* since 1990.

Table 4.8: Farmers Sources of Finance, Gedaref Area, 2003/2004

Source of Finance	**%**
Private	48
Banks	32
Mixed (Bank & private)	15
Informal (Shail)	5
Total	100

Source: Field survey

Up to 1991, commercial banks' advances to agriculture stood at less than one percent of their total advances. As a result of government initiatives to motivate the agriculture sector with the purpose of achieving food security and increasing agricultural exports, the number of banks branches in rural areas was more than doubled, and the ratio of farm credit rose to an average of 18% during the period 1990-1993. Moreover, the central Bank (BOS) has raised the commercial banks' ceiling for operation and non-operation credit to agriculture to 40% of their total advances (ELHIRAIKA, 1998).

Figure (4.1) shows the forms of finance adopted by the sampled farmers who have obtained their loans from official credit institutions. Both lending forms the *Salam* and the *Murabaha* are used by farmers and they are short term loans. The figure depicts that 70% of the farmers used the *Salam* form only, 15% used the

Murabaha form and the remaining 15% used both forms. The high percentage of *Salam* borrowers reflects the popularity of this form among farmers compared to *Murabaha*. This is because, *Salam* allowed covering the operational labor costs of weeding and harvesting which have a considerable share in the farm operating costs, while the *Murabaha* is limited to cover the cost of input materials (fuel, chemicals, empty sacks …etc.). Moreover, having loans in the *Salam* form; give the farmers an opportunity to repay their loans in kind, while the repayment of the *Murabaha* loans is restricted only to cash payments.

In the case of the *Salam*, farmers can obtain their loans at the beginning of the season in June, on condition that, the loans repayment should be at harvest time in December, that means farmers are restricted to a short repayment period of six months. Land is not accepted as collateral, since it is owned by the government and farmers has only the right of land use. Accordingly, most farmers provide their machineries (Tractor and accessories) or houses as collateral against their loans. Figure (4.2) shows that, 70% of farmers provided machinery, 16% offered houses, 6% provided personal pledge and 8% afforded private land (other than farm land) as collateral.

For the cropping season 2003/2004, the *Salam* price of sorghum was set in June at SD 2,500 per sack, while the actual average market price in December (the harvest time) is SD 2,842. This indicates that the bank has roughly charged the farmers an interest of 14%, and the Banks are expecting more benefits as prices increase. In the case of sesame the *Salam* price was set at SD 4,000 per Kantar, while harvest price averaged SD 6,809 which implies 55% as interest; (Penalty avoidance formula is usually used to alleviate price differences as explained in chapter 3). On the other hand, The *Murabaha* interest rate (called locally *Hamish Murabaha*) was determined at 12% for the year 2003.

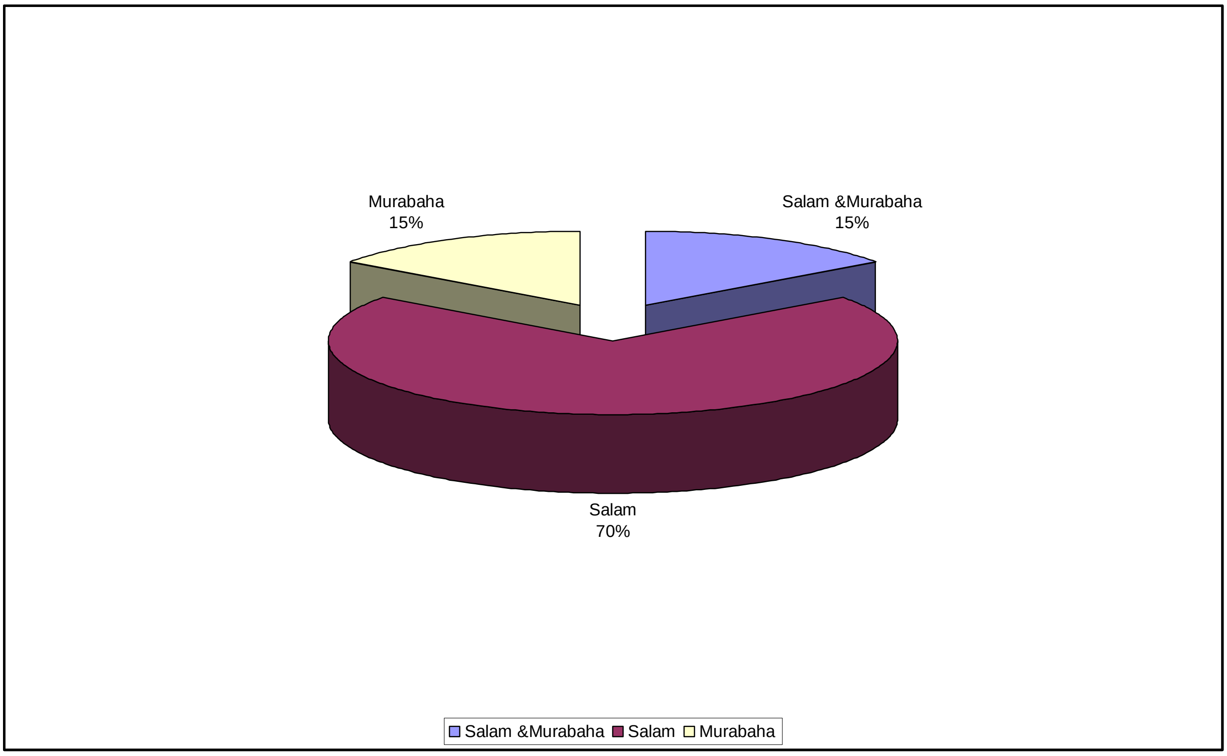

Figure 4.1: Forms of Finance, Gedaref Area, 2003

Source: Field survey

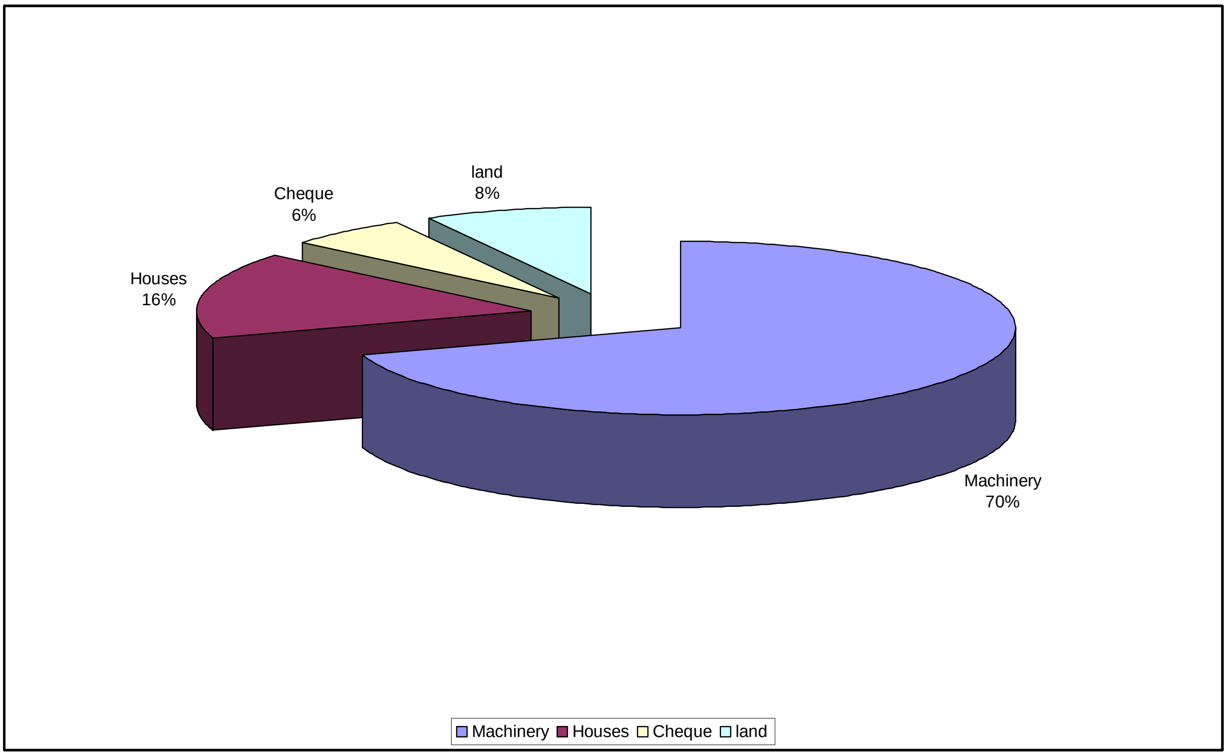

Figure 4.2: Type of Collateral, Gedaref Area, 2003

Source: Field survey

In the questionnaire, farmers who have loans from banks were asked about major financial problems they have faced. About 45% had mentioned the timeliness of the credit as a main problem, since farmers often face regular delays in the loans payments. Thirty four percent had mentioned the short time of repayment, while 21% had reported the complicated procedures of getting loans as the main problem.

STIGLITZ (1995) argued that sharecropping performs a role in sharing risks between landlords and tenants in the absence of insurance market. Therefore, we can conclude that the *Salam* reduces farmers' risk, as farmers produce for predetermined prices of output, however, the short repayment period of the *Salam* limits farmers storage capacity, in the sense that farmers has no chance to store considerable amount of their output to gain potential benefits of high prices later. Moreover, the *Salam* form provides an incentive to farmers to increase their output as the repayment is in kind i.e. farmers will try to raise the level of output beyond the contracted amount of produce to be delivered to the banks.

Medium-term loans are available to the farmers to buy the different types of machinery including tractors and their accessories, harvesters; water pumps, and chemical sprayer. The machinery purchase loans are provided through the *Murabaha* method with repayment period for more than one year, and interest (*Murabaha margin*) of 12% annually.

The high percentage of using formal credit (47%) and the low percentage of informal credit (5%) among farmers indicate that farmers prefer formal credit to the informal one and this is because of the high interest rate, the short repayment period and the higher risk involved in the informal credit.

4.2.7 Farmers' Storage Capacity

The storage facilities available to farmers are embodied in the storage warehouses of the main crop market (*Suoqe Elmahsol*) in Gedaref city which have storage capacity of 200,000 tons. Farmers can store in these warehouses for nominal fees. The market administration has provided this facility to farmers to increase their negotiation power. In case farmers are not satisfied by the prices prevailing in the market, they could be able to store at low cost waiting for better level of prices.

Sesame is normally harvested before sorghum, in October. Its harvesting period is short, this is basically, attributed to the small area planted with sesame (only 20% or less of the total farm land on average). Second, the harvest is prone to complete loss because of sesame short maturity period, thus the harvesting process should be completed as quickly as possible. It is noticed that sesame harvesting is the only farm operation that laborers have bargaining power over farmers and it is the most costly operation among other manual farm operations. Table (4.9) shows farmer's selling time of their crops after the harvesting process. About 62% of farmers who grow sesame have sold their crops within one month after harvest, 27% have stored their crops for two month and only 11% are able to store for more than two months. Clearly, sesame is sold in the market immediately after harvest. As stated by farmers, cash returns of sesame are used primarily to finance the harvesting of sorghum, the main crop, secondly to fulfill bank obligations and finally to pay other labor wages. Sorghum harvest starts in December and continues till February. Unlike sesame, sorghum heads can remain in the field after its maturity for longer period but bird attack is a potential threat. From the table, also the majority (67%) of sorghum growers has sold their crops immediately after harvest, and only few of them 10% could manage to store for longer time.

Apparently, farmers are obliged to sell their crops immediately after harvest. The reasons behind this behavior are summarized in three points. First, loan obligations, the different lending sources (formal and informal) reclaim their loans at harvest time; with a short repayment period of only six months on an average (Interlocking transactions between banks and farmers). Second, manual labor who demands their wages in cash also promised to be paid from harvest[3]. Third, in the case of sesame, its returns are needed to meet sorghum harvesting costs. The three above mentioned reasons are found together to limit farmer's storage capacity and deprive them from expected profits that could have been attained if farmers were in a better financial position. Other factors that found to affect farmers' decisions to store their produce are summarized mainly on farmer's liabilities, the information and speculations on prices and the level of production in other regions of Sudan.

[3] A common scene near the Gedaref crop market; is a truck full of sorghum and/or sesame sacks, at the same time full of laborers who are waiting for their wages to be paid from the crops sale.

Table 4.9: Farmers' Marketing Date from Harvest Time, Gedaref Area, 2003/2004

Crop / Date of Marketing	Sorghum		Sesame	
	Farmers No	%	Farmers No	%
Within one month	67	67	45	62
After two months	23	23	20	27
After more than two months	10	10	8	11
Total	100	100	73	100

Source: Field survey

Table (4.10) compares returns of one feddan of sorghum and one feddan of sesame at different times of the year, starting from harvest time. It was noticed in the year 2003/2004 farmers could gain higher returns as far as they store. Farmers will enjoy 12% and 24% higher returns than harvest time if they manage to store sorghum for three and six months respectively. On the other hand, sesame returns are as high as 46% and 55% from harvest time returns for the respective three and six month's storage periods.

Table 4.10: Sorghum and Sesame Returns at Different Storage Periods, Gedaref Area, 2003/2004

Crop / Storage Period	Sorghum Returns		Sesame Returns	
	SD/fed.	%	SD/fed.	%
No storage	7,705	100	14,958	100
Three months	8,625	112	21,858	146
Six months	9,545	124	23,286	155

Source: Field survey

4.2.8 Machinery Ownership

The mechanized rain-fed sub-sector takes this name as a distinction from the traditional rain-fed sub-sector. In the former system, machineries are used completely for land preparation and partially for crop harvesting while in the latter no machineries are used, instead, farm operations are carried out with traditional tools due to small size of farm lands representing higher fragmentation.

In the mechanized sub-sector, Land preparation and sowing are completely mechanized, as the average farm area is relatively large (one thousand feddans), while weeding is usually carried out manually for both sorghum and sesame. Recently, weeding with chemical herbicides is introduced using a sprayer attached to the tractor. On the other hand, harvesting of sesame is entirely carried out manually. Sorghum harvesting includes three operations; heads cutting, heads piling and threshing. The first two operations are done manually while threshing is done by mechanical harvesters. Accordingly, the main machineries used in the farm are tractors with disc-planter and harvesters. Other items such as Lorries, trucks and pumps are regarded as supportive equipments owned only by a small number of farmers.

The survey showed that about 75% of the sampled farmers have their own tractors and disc-planters; this means that the other 25% rent tractors to accomplish land preparations and planting. The mechanical part of sorghum harvesting is normally done on rental basis, because combine harvesters are very expensive (SD 10,000,000 on average). Therefore, farmers view obtaining a harvester only to accomplish a part of one operation (threshing) is economically not justifiable. However, combine harvester are owned only by large companies and co-operatives. Only a very few number of farmers own their own harvesters and they are usually from the small mobile type. It is estimated that on average the combined harvester produces 80 sacks of 90 kg per hour while the small mobile harvester produces 20 sacks per hour.

The machinery owned by farmers is the main farm assets, and also they are the major collateral for agricultural loans as depicted by figure (3.2). The average value of a new tractor and disc-planter together is about SD 6,000,000 (US$ 23,076), which is accepted normally by the banks as collateral for farmers' credits. There is a great possibility of machinery renting market in this sector, particularly for land preparation and sorghum harvesting, since most of the sampled farmers have rented harvesters to accomplish sorghum threshing and about 25% have rented tractors for land preparation and sowing operations.

4.3 Concluding Remarks

The presentation of the field survey results has emphasized the main features of the Mechanized Rain-fed large scale farming system of the Gedaref and farmer's attitudes and behavior regarding economical and environmental constraints. Farmers' degree of awareness is high because they have a good level of education and a fair experience in agriculture and hence they are capable of taking their agricultural decisions.

The mono-culture of sorghum in an extensive system is the dominant crop activity, although it involves different types of risks. The new technologies are not fully adopted by farmers because of their high cost and the high probability of loss under this farming system conditions, besides farmers lack of knowledge about these technologies due to the absence of effective extension services in the area. Farmers are forced to sell their crops in unsuitable time by the high cost of labor and interlocking transactions with the financial institutions.

5 METHODOLOGY

In this chapter the theoretical background of the decision making process under uncertainty is discussed. The stochastic simulation and stochastic efficiency analytical methods are presented, and then the estimation procedures for the empirical methodological approaches, which are used to test the study hypothesis, are explained.

5.1 Introduction

Before discussing the theoretical and empirical aspects of the methodological approaches used in this study, some introductory information on definitions, measurements and sources of risks are presented.

5.1.1 Definition of Risk

The terms risk and uncertainty can be defined in various ways. For example, HERMANN and KIRSCHKE (1985) defined uncertainty as the existence of one or more stochastic variables. In this case, they clarified that price uncertainty to mean the market price is not only determined by deterministic, but also by stochastic variables. On the other hand, HASSAN (1988) stated that the term uncertainty is used by some analysts in connection with instability, which can be a justified definition given the fact that uncertainty is considered as an outcome of instability. Thus, he defined instability as a state of deviation from a desirable norm or standard that makes it considerably uncertain to predict the future. Other authors also, like FLEISHER (1990) defined uncertainty as a situation in which the decision maker does not know the outcomes of every action when the decision is being made because at least one action has more than one possible outcome. Therefore, defining risk as the situation in which the resolution of uncertainty affects the well being of the firm or the decision maker, thereby involving the chance of gain or loss. The USDA (1996) defined uncertainty as a situation in which a person does not know for sure what will happen and risk as uncertainty that affects an individual's welfare, which is often associated with adversity or loss. Other groups of researchers like HARDAKER et al, (1997, 2004) defined uncertainty as imperfect knowledge and risk as uncertain consequences, particularly exposure to unfavorable consequences.

Given the diversity in definitions of risk and uncertainty, as demonstrated above, there is always an argument that although uncertainty is always there, risk may be absent. Thus risk is only present when the uncertain outcomes of a decision are regarded by the decision maker as significant i.e. when they affect the decision maker's well being.

Systematically dealing with risk in agriculture, whether for farmers, farm advisors or researchers is difficult. One reason for the difficulty is confusion and differences in opinions about what risk is, and how it can be measured. This term 'risk' can be used in several differing ways, which cause considerable confusion, especially when systematic efforts are made to measure and evaluate risk. Generally, three common definitions of risk are usually used, which include:

1. The chance of a bad outcome;
2. The variability of outcomes; and
3. Uncertainty of outcomes.

The different definitions of risk mentioned above are implications of different ways of measuring risk. Following HARDAKER (2000), risk is best formalized as uncertainty of outcomes and this approach, rather than the other two mentioned above, was the one mainly adopted for the present study.

5.1.2 Measurements of Risk

For each of the above three common definitions of risk, differing methods of risk measurements are applied. In his case, HARDAKER (2000) criticized the other two definitions of risk and their measurements. He instead suggested that the whole range of outcomes be it good or bad, together with their associated probabilities, need to be considered in order to have a careful evaluation of risk. MCCONNELL and DILLON (1997) evaluated the idea of depiction of risk by the entire probability distribution of outcomes. This view is some what different from every day usage of the term 'risk' referring to possible 'bad' or 'negative' outcomes, i.e. outcomes conventionally located on the left-side tail of the probability distribution or better referred to as downside risk. Conversely, upside risk refers to 'good' or 'positive' possible outcomes conventionally located on the right-side tail of the distribution, which the decision maker runs the 'risk' of not obtaining. They further argued that, it is always better to specify risk for a decision problem under uncertainty by the entirety of the decision maker's set of subjective probability distributions for the choice of possible outcomes that may occur. This indicates that there is no single statistic that can be used to measure risk. Rather the complete probability distribution (or set of distributions) for the possible outcomes of a particular choice can fully depict the risk that a particular choice involves for the decision maker. Moreover, the third view of risk implies that the concepts of 'more risky versus 'less risky' prospects are unsatisfactory and careful analysts will confine themselves to describing risky prospects as ‘preferred’ versus ‘not preferred’, or as ‘risk efficient versus ‘not risk efficient’.

5.1.3 Sources and Types of Farm-System Risk

Different approaches are used to classify sources and types of risk. For example, MCCONNELL and DILLON (1997) categorized the risks faced by farm-system managers as coming from two sources: (1) the external environment, mainly the natural, economic, social, policy and political environments in which the farm-system has to operate. All these sources of risk are more or less equal on those farm systems which share the same external environment. (2) the internal operational environment of the farm-system. These types of risks occurs only on the particular farm, and are related to the health, inter-personal relations between farm-household members, the inter-generational transfer of the farm and the use of credit to finance the farm’s operations.

Other classification for sources of risk was given by HARDAKER et al, (1997), who classified the sources of risk in agriculture as coming from two main sources, business and financial risk. Business risk is defined as the aggregate effect of all the uncertainties influencing the profitability of the firm independently of the way in which it is financed. It has its impact on measures of farm business performance such as the net cash flow generated by the farming activities or the net farm income earned.

Under business risk the four following types of risks are recognized:

(a) Production risk, which comes from many unpredictable factors such as weather, incidence of pests and diseases and other uncontrollable factors. New technologies are considered as an interesting source of risk in that as they are new, farmers will lack experience on them and thus being cautious, are likely to subjectively assess them as more risky and less profitable than they possibly are.

(b) Market or price risk, which is often significant since farmers almost all over the world are being exposed to unpredictable competitive markets for inputs and outputs and hence prices of inputs and outputs are seldom known for certain at the time when farm decisions are made.

(c) Institutional risk, which originates from changes in the government laws and rules that affect farm production and hence farm profitability. For example, changes in income tax-provisions or in the availability of various incentive payments form a significant source of risk to farmers.

(d) Human or personal risk, which is related to the people who operate the farm. Death or illness of one of the principal persons in the farm may cause serious losses to production or substantially increase costs.

In contrast with the business risk, financial risk results from the methods of financing the business. The use of borrowed fund to finance farm operations forms one source of financial risk associated with leverage. There are also financial risks in using credit, most significant of these being unexpected rises in interest rates on borrowed funds, unanticipated calling-in of a loan by the lender, and a possibility of lack of availability of the loan finance when required. It is always recognized that yield, output prices and financial risks are the most important ones in agriculture and are therefore the main emphasis for the present study. However it should be noted that these types of risks are more or less related to the external rather than the internal operational environment of the farm-system.

5.2 Decision Analysis, Utility Theory and Certainty Equivalent Concepts

Before providing the details of the theoretical part of the study methodological approach, it is necessary first to give some basic information about the concept of decision analysis, subjective expected utility and the concept of certainty equivalent that are related to the methods of analysis used for this study. These aspects will be introduced in the sections to come.

5.2.1 Decision Analysis: General Background

Decision analysis refers to the collection of methods that are continuously been developed to try to rationalize and assist choice in an uncertain world (HARDAKER et. al, 2004). As illustrated by figure (5.1), important risky decisions are best dealt with by splitting choices further down into separate judgments based on the uncertainty that affects the possible consequences of the decision and on the preferences of the decision maker for different consequences. Then the two parts of the analysis are reunited to show what the ‘best’ choice is for a ‘rational’ decision maker. Finding the best choice may be a simple or a complex task depending on the nature of the problem under investigation. In this decision analysis approach, a ‘good’ decision certainly does not guarantee a good outcome since this approach is based on the proposition that a good decision is one that is consistent with what the person making the decision believes about the uncertainty surrounding that decision and is also dependent on that person’s preferences for the alternative possible consequences.

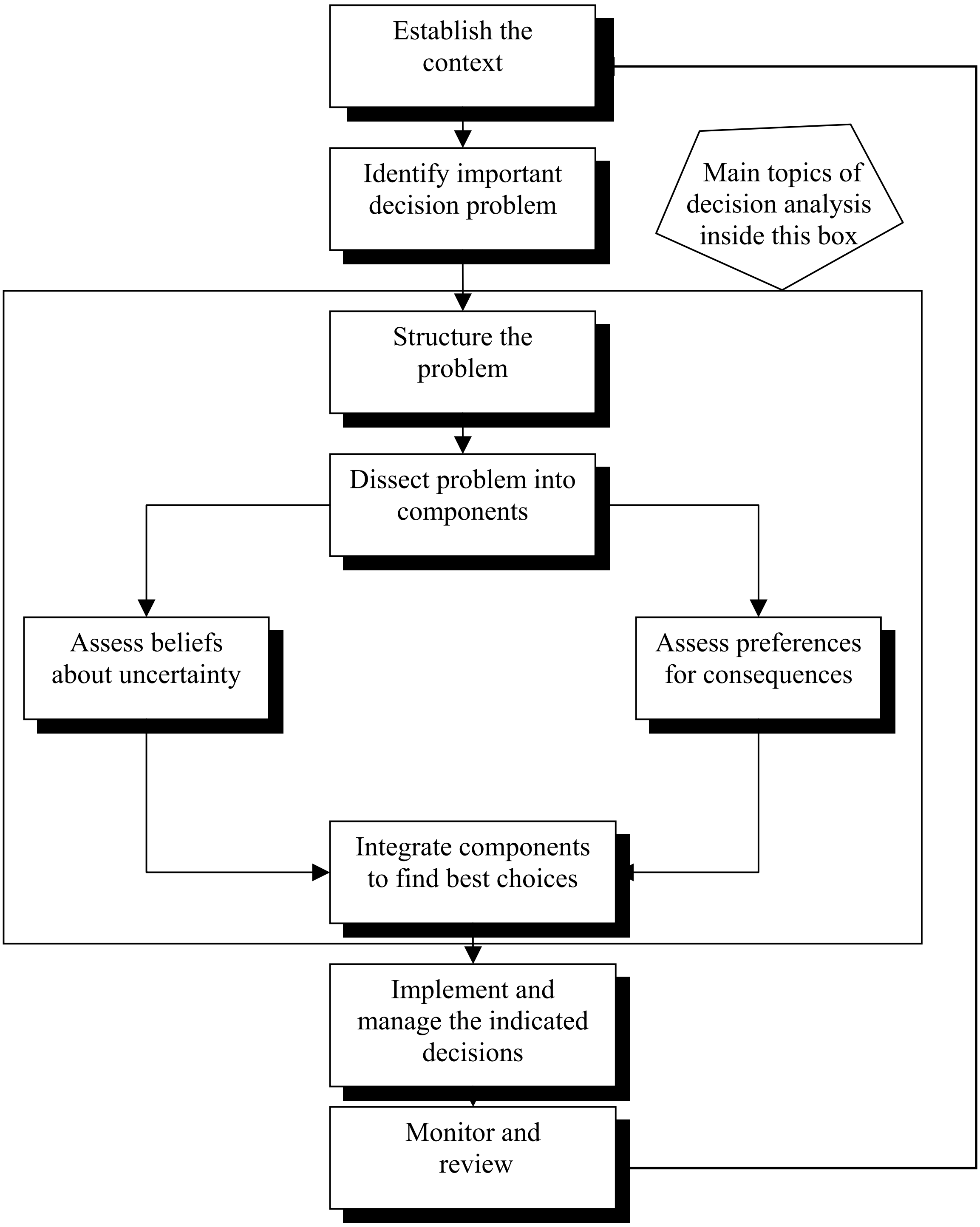

Figure 5.1: Steps in Risk Management Showing the Process of Decision Analysis

Source: HARDAKER et al, 2004

5.2.2 The Concept of Subjective Expected Utility (*SEU*)

As stated by ANDERSON et al, (1977) modern theory of utility plays a key role in decision analysis. To assess risky alternatives, utility analysis provides the practical means whereby preferences are shaped up and consistent choices simplified. A utility function is simply a device for assigning numerical utility values to consequences in such a way that a decision maker should act to maximize subjective expected utility if he is to be consistent with his expressed preferences. This implies the use of Bernoulli's principle or, as it is often called, the expected utility theorem. The principle states that for a decision maker who accepts the perfectly reasonable axioms of ordering, transitivity, continuity, and independence[4], there exists a utility function U which associates a single utility value $U(a_j)$ with any risky prospect $a_{j.}$ Moreover the function has the following properties:

1. If a_1 is preferred to a_2, then $U(a_1) > U(a_2)$ and vice versa.
2. The utility of a risky prospect is its expected utility value. This is obtained by evaluating the expected value of the utility function in terms of the risky prospect's consequences, i.e.,

$$U(a_j) = E\left[U(a_j)\right] \qquad (1)$$

The expectation being based on the decision maker's subjective distribution of outcomes. In the case of discrete outcomes

$$U(a_j) = \sum_i U(a_j S_i) P(S_i) \qquad (2)$$

Where:
S_i = events or uncertain states of nature over which the decision maker have no control
$P(S_i)$ = probabilities of occurrence of the uncertain events S_i

And in the case of a continuous distribution of outcomes of the uncertain events S, f (S)

$$U(a_j) = \int U(a_j S) f(S)\, ds \qquad (3)$$

3. The function U is defined only up to a positive linear transformation.

It is also argued that subjective expected utility theory is a logical approach to risky decision making based on the above mentioned axioms. This theory is thus remarkable in that it brings together and integrates the three crucial elements of risky decision making, which are (a) decision maker's personal preferences about possible outcomes, (b) decision maker's personal degrees of belief in the

[4] Full definitions of the four axioms are given in appendix (5.1).

occurrence of possible outcomes and (c) use of decision maker's own personal preferences and probabilities, which takes into account the decision maker's personal responsibility and accountability for what ever decision is taken.

Decision analysis has been used prescriptively to help policy makers and planners make choices and to help suggest which technology options might be best recommended to risk-averse farmers. It also been used as a behavioral theory to explore lag in adoption of new farming technologies or likely responses of farmers to risk-reducing measures such as crop insurance or price stabilization.

5.2.3 The Concept of the Certainty Equivalent (*CE*)

Comparison of the certainty equivalents of alternative risky choices is probably the most practical useful guide available for farmers in their risky decision making. Different from many other available guides, it perhaps approaches the implicit spontaneous way in which they make their risky choices. Certainty equivalent was defined by HARDAKER et. al, (2004). They stated that according to the *SEU*, for every decision maker faced with a decision with a risky payoff, there is a sum of money 'for sure' that would make that person indifferent to facing the risk or to accepting the sure sum (i.e. the sure prospect has the same utility value as the risky prospect). This sum is the lowest sure price for which the decision maker would be willing to sell a desirable risky prospect, or the highest sure payment the decision maker would make to get rid of an undesirable risky prospect. This sure sum is called the certainty equivalent (*CE*) of that decision maker for that risky prospect. The specification of a *CE* required the decision maker subjective probabilities associated with risky prospects and his or her preferences for the possible consequences set as utility values.

In summary, six components of a risky decision problem were stipulated by MCCONNELL and Dillon (1997) and HARDAKER et al (1997). These are:

1. Decisions, between which the decision maker must choose a_j. They are also called: choices, options, alternatives, actions, acts or risky prospects.
2. Events or uncertain states of nature S_j over which the Decision maker has no control.
3. Probabilities measuring the decision maker's beliefs about the chances of occurrence of uncertain events $P(S_j)$.
4. Consequences, outcomes or payoffs, indicate what might happen given that a particular act is chosen, and that a particular event or sequence of events occurs. Consequences from taking the *j-th* act given the *i-th* state of nature occurs are denoted by X_{ij}.

5. The decision maker's preferences for risky consequences, measured as utilities *U*(a_j) for the *j-th* act, where *U (.)* denotes the decision maker's utility function. By the application of the subjective expected utility (*SEU*) hypothesis, the utility of each action is its expected utility, where the expected value is calculated from the utility values of the consequences weighted by the corresponding subjective probabilities. Equivalently, preferences may be captured by the corresponding *CE* such that

$$U\,(CE_j) = U\,(a_j). \qquad (4)$$

6. A choice criteria or objective function i.e. choice of the act with the highest expected utility, which is equivalent to maximizing *CE*.

5.3 The Analytical Framework: Theoretical Approach

5.3.1 Introduction

Being rational, farmers typically make their risky decisions in a logical way. On the basis of their experience, traditional knowledge and other information available to them, farmers specify: (1) the alternative choices open to them; (2) the set of uncertain outcomes associated with each of these alternative choices; and (3) their personal subjective probability distribution for each of these sets of outcomes. Personal judgment is then exercised by the farmer to choose the alternative that has the most attractive probability distribution of outcomes. Such a process of choice is generally implicit or informal for small farmers, but it is more formal for commercially oriented farmers. Farmers may sometimes use more explicit formal procedures either themselves or through the services of professional advisors. When this is the case, farmers have at their disposal a variety of formal techniques to assist them evaluate the risky decisions and guide them in their risky choices (DILLON and HARDAKER, 1993). The most relevant of these formal approaches to risky choices are sensitivity analysis, stochastic budgeting, subjective expected utility analysis (including certainty equivalent analysis, decision trees and stochastic dominance analysis), risk-oriented mathematical programming and Monte Carlo simulation. These all, are somewhat overlapped and interrelated. With exception of sensitivity analysis, they can all cast in an expected utility framework based on the decision maker's personal preferences among outcomes and personal degrees of belief in their occurrence. Among these mentioned approaches, stochastic simulation and stochastic budgeting, which were the main tool of analysis for the present study and the stochastic efficiency methods are discussed in greater details.

5.3.2 Stochastic Simulation: General Approach

The objective of risky choice, as illustrated before, is either to find those decisions or alternative actions with the highest expected utility, or, when risk neutrality can be assumed, with the highest expected money value (EMV). A rational choice is the choice consistent with the decision maker's beliefs about the chances of all the uncertain consequences and with that person's relative preferences for those consequences. A helpful technique in such analysis is what is called stochastic simulation. On the other hand, we can notice that stochastic budgeting is in fact a simple form of stochastic simulation analysis. The only difference being that the latter often involves more elaborate modelling of the decision alternatives being simulated. Or in other words, stochastic budget can be regarded as a sub-category of stochastic simulation.

Within this study, the stochastic budgeting technique was used to evaluate different management strategies under uncertainty and then the stochastic efficiency methods were applied to rank these risky strategies for a given level of farmers risk-aversion. Before tackling the issue of stochastic budgeting, a brief account of stochastic simulation in general will be presented in the next section.

5.3.2.1 Stochastic Simulation as a Tool in Decision Analysis

Simulation was defined by HARDAKER et al (2004) as the use of an analogue in order to study the properties of the real system. Such simulation models are commonly used to analyze the so-called 'what-if' questions about a real system. They typically represent the relationships between variables and hence to imitate aspects of the performance of complex real systems such as exist in agriculture.
In stochastic simulation, selected random or stochastic variables or relationships are determined by specifying probability distributions to reflect important parts of the uncertainty in the real system. Repetitive sampling is used to generate values from specified input distributions. Experiments can be performed to repeat the evaluation for different settings of the decision variables. Stochastic simulation is often the only way to model the complexity in a system. Typically there are many inputs, interactions and non-linearities, all combined with uncertainty and variability in a complex way, a stochastic simulation model can help to make a systematic assessment of what might happen.

The purpose of stochastic simulation in risk analysis is to determine probability distributions of consequences for alternative decisions to enable the decision maker to make a good and a well-informed choice. A common approach is to simulate the consequences of a range of alternative decisions in order to be able to compare the outcome distributions. In most cases, the outcome of each decision alternative can be reflected by the distribution of a single performance measure, such as terminal wealth or income. The stochastic consequences can be distilled down to a single measure of the utility or CE for each choice alternative analyzed, if an appropriate utility function is available, otherwise, the comparisons for the simulated outcomes might be conducted by applying the stochastic efficiency methods, and when more than one output measure is of interest, multi-attribute methods may be suitable.

5.3.2.2 Stochastic Budgeting Principles

This approach was used as an analytical tool to investigate the study objectives. But before explaining the approach, some definitions and some weaknesses of the deterministic budgets were introduced first. KAY (1986) defined budgeting as a method of comparing alternatives on paper before committing resources to a particular plan or course of action. It is a forward planning tool, as budgeting is used to develop plans for the future and can be applied to a single enterprise, a part of the farm business, or the whole farm business. Economic principles combined with budgeting forms provide the manager with a powerful set of tools for performing the planning function of management. ENGLE (1997) argued that budget analysis is an important step in economics research, but it is a static analysis that does not take into account the following:

- Factors such as fluctuations in prices, yields, and costs;
- Farming system interactions in terms of labor, marketing, and resource constraints;
- Social, economic, or welfare effects of the technology; and
- Market factors.

The above mentioned variables are important for farmer's decisions when uncertainty exists and when adopting of a new technology by farmers depends upon these variables.

The same view was introduced by HULL (1980). His argument is that in reality, the events and conditions planned for will not turn out as assumed. A common approach to this problem is to conduct sensitivity analysis as part of the planning exercise in order to determine the range of possible results. But in a sensitivity analysis usually, changes in only one variable at a time is considered, and hence the effects on the performance measure of combinations of errors in different variables are, therefore, largely ignored. Moreover, when many variables are uncertain, sensitivity analysis of the effect on financial performance for more than just a few variables becomes tedious and difficult to interpret. Furthermore, the sensitivity analysis gives no indication of the likelihood of a particular result being achieved. To overcome these problems an alternative approach of stochastic budgeting is introduced. This approach accounts for some of the main uncertainties in the evaluation process and then gives an indication of the distribution of outcomes. In this framework uncertain variables can be expressed in stochastic terms, and many combinations of variable values can be analyzed to provide a full range of possible outcomes.

The stochastic budget analysis is like ordinary budget except that uncertainty in some variables in the budget are recognized and taken into account. Stochastic or risk budgeting is carried out by attaching probabilities of occurrence to the possible values of the key variables in a budget, thereby generating the probability distribution of possible budget outcomes (DILLON and HARDAKER, 1993 and HARDAKER et al, 1997). The probabilities used should be those of the decision maker, i.e. his or her personal or subjective probabilities based on experience, intuition and/or any other available information for example historical data. Stochastic features are introduced to a budget by specifying probability distributions for selected variables, usually those judged to be more important in affecting the riskiness of the selected measure or measures of performance. Then a sampling procedure is used to evaluate the budget for a sufficiently large number of scenarios, with a record made of the distribution of the performance measure made across these scenarios. Output can be in the form of the probability distribution of the selected performance measure or (measures) perhaps summarized in terms of moments of the distribution, such as mean, variance, or standard deviation. Or may be graphed in the form of a probability density function (PDF) or cumulative distribution function (CDF).

As in ordinary budgeting, it is then possible in stochastic budgeting to vary the decision rule and to evaluate alternative options to find the best one amongst a finite number of alternatives (HARDAKER et al, 1997). Thus, in a farm management analysis, a stochastic budget can be constructed in various forms, e.g. as a partial budget, whole-farm budget, cash-flow budget, profit budget or a budget for investment appraisal. It also may represent a single or multi–period budget.

Because the CDF is more convenient to work with rather than the PDF as argued by HARDAKER et al, (1997 and 2004), it was used to display stochastic budget results in this study. The section to follow, gives a brief description of this function, also Appendix (5.2) gives some more information about the CDF, the PDF and their relationship.

The cumulative distribution function *F(x)* as defined by HARDAKER et al, (1997; 2004), is a function that gives the probability *P* that the variable *X* will be less than or equal to *x*, i.e. :

$$F(x) = P(X \leq x) \qquad (5)$$

Where *F(x)* ranges from zero to one.

For illustration, the CDF in figure (5.2) shows a cumulative probability *F(x)*. Denoting outcome by *R*, this cumulative distribution shows the probability that *R* will be less than or equal to any nominated value *R**, i.e., $P(R < R^*)$ and the probability that *R* will exceed any nominated value *R**, which probability is necessarily equal to one minus the probability that *R* will be less than or equal to *R**, i.e., $P(R > R^*) = 1-P(R \leq R^*)$. For example, reading from the cumulative distribution sketch from figure (5.2), the probability that outcome will be no more than *R* is P* $(R \leq R^*)$ = 0.364. Conversely, the probability that annual outcome will exceed *R** is 1-0.0.364 = 0.636).

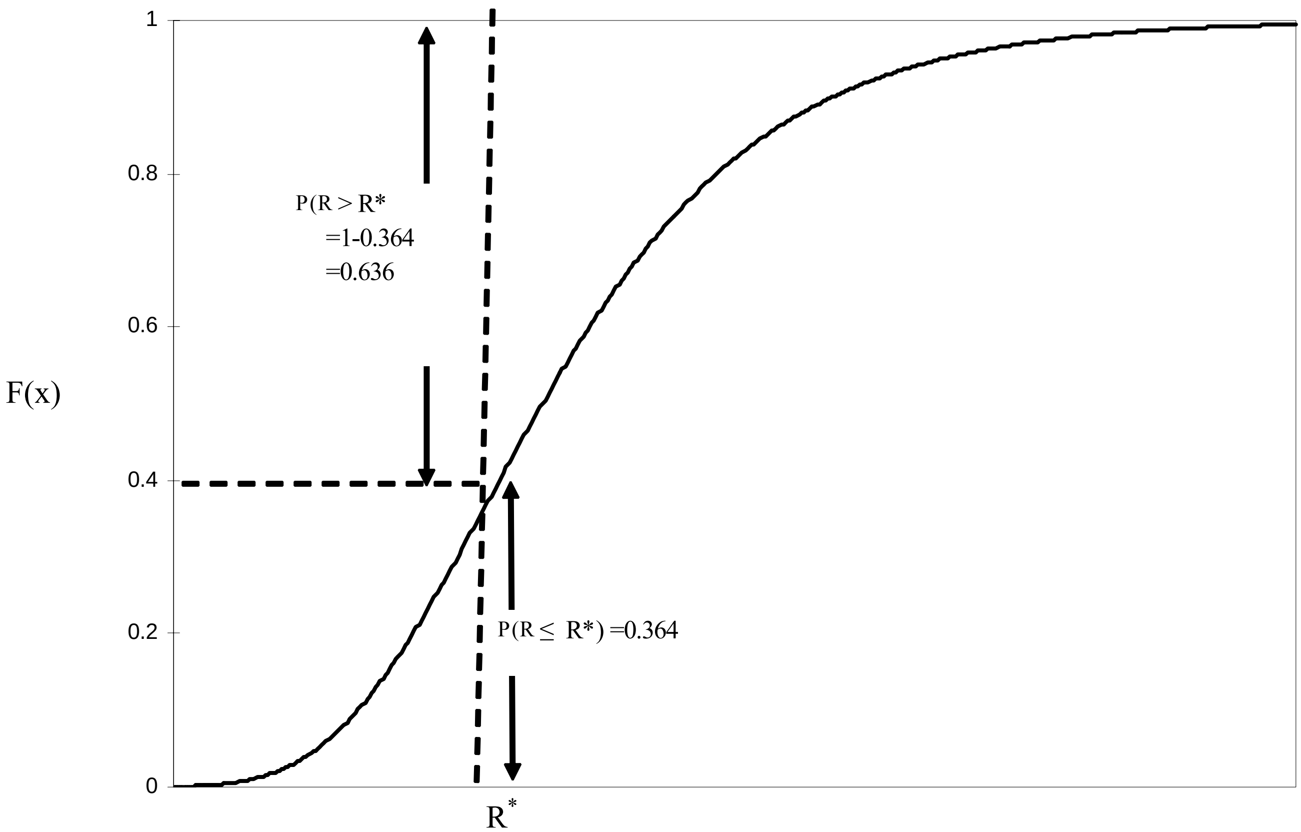

Figure 5.2: Illustration of the Cumulative Distribution Function *CDF*

RICHARDSON and NIXON (1986) developed the stochastic whole-farm budgeting model FLIPSIM (Farm level income and policy simulator). FLIPSIM simulates, under price and yield risk, the annual economic activities of a representative farm over a multiple-year-planning period. This model has been used for policy analysis (e.g. KNUTSON et al., 1997), comparing risk management strategies (e.g. KNUTSON et al., 1998), technology assessment and financial analysis.

5.3.2.3 Stochastic Simulation and Stochastic Budgeting Software

HARDAKER et al, (1997 and 2004) argued that the availability of specialist add-ins for spreadsheet software such as Microsoft Excel or Lotus 1-2-3, has made the practice of stochastic simulation and hence stochastic budgeting much easier than before. A package such as @ risk from Palisade, can be added to software such as Excel or Lotus 1-2-3 as an add-in module to the spreadsheet packages so as to carry out stochastic functions not available with the main program. The program @ Risk uses probability distributions to describe uncertain values in Excel and Lotus worksheets. Over 35 types of functional form for the probability distributions are available to suit different applications. A formula is entered in the relevant cell to specify the chosen distribution and its parameters. Repetitive sampling is used in @ Risk simulation to generate values from distributions. For each iteration, a set of samples is obtained representing a possible combination of values that could occur. These sets of possible values are then used to evaluate the problem. With enough iterations, the distribution of the output variables will converge to a stable distribution. @ Risk calculates all relevant statistics of the input and output distributions. The statistics include those based on the first four moments (i.e., mean, standard deviation, skewness and kurtosis), the minimum and maximum values, and percentiles.

@ Risk has the advantage that the simulation model is developed in Excel, Which is known to many analysts. The program is also designed specifically for risk analysis, unlike some general simulation software.

5.3.2.3.1 Basic Sampling Techniques

As explained before, repeated sampling from specified distributions of input variables lies at the core of stochastic simulation and stochastic budgeting techniques. Therefore, the basic principle of this sampling process is presented in the following two sections.

5.3.2.3.1.1 Monte Carlo Sampling

HARDAKER et al, (1997, 2004) and PALISADE 1997, have described the Monte Carlo sampling method. This method represents the basis for the sampling techniques. The CDF as illustrated by figure (5.2) is the key to Monte Carlo sampling procedure. In this technique the inverse function is used, namely the value of x implied by a given value of F(X). The inverse function can be written as:

$$X = G\,(F\,\{X\}) \qquad (6)$$

This inverse function can be used to generate values of x on the horizontal axis with the frequency that for a large sample will represent the original distribution. Such a sample is generated (at least conceptually) by selecting uniformly distributed values u between zero and one (which means that every value of u from zero to one is equally likely), then putting each such number into equation (6) for F(x) to find the corresponding x value, i.e.:

$$X = G\,(u) \qquad (7)$$

CDF values of u on the vertical axis are sampled and each sample gives a corresponding x value on the horizontal axis. This procedure is illustrated in figure (5.3) for a single variant. Samples for x are more likely to be drawn in areas of the distribution with higher probabilities of occurrence (where the CDF is steepest). With enough iterations, Monte Carlo sampling will recreate the distribution. As full convergence is approached, additional samples do not noticeably change the shape or statistics of the sampled distribution. One measure of convergence is that the mean changes by less than a specified threshold percentage as the number of iterations increases. However, other statistics probabilities such as skewness or percentile can be chosen instead as the basis for testing convergence.

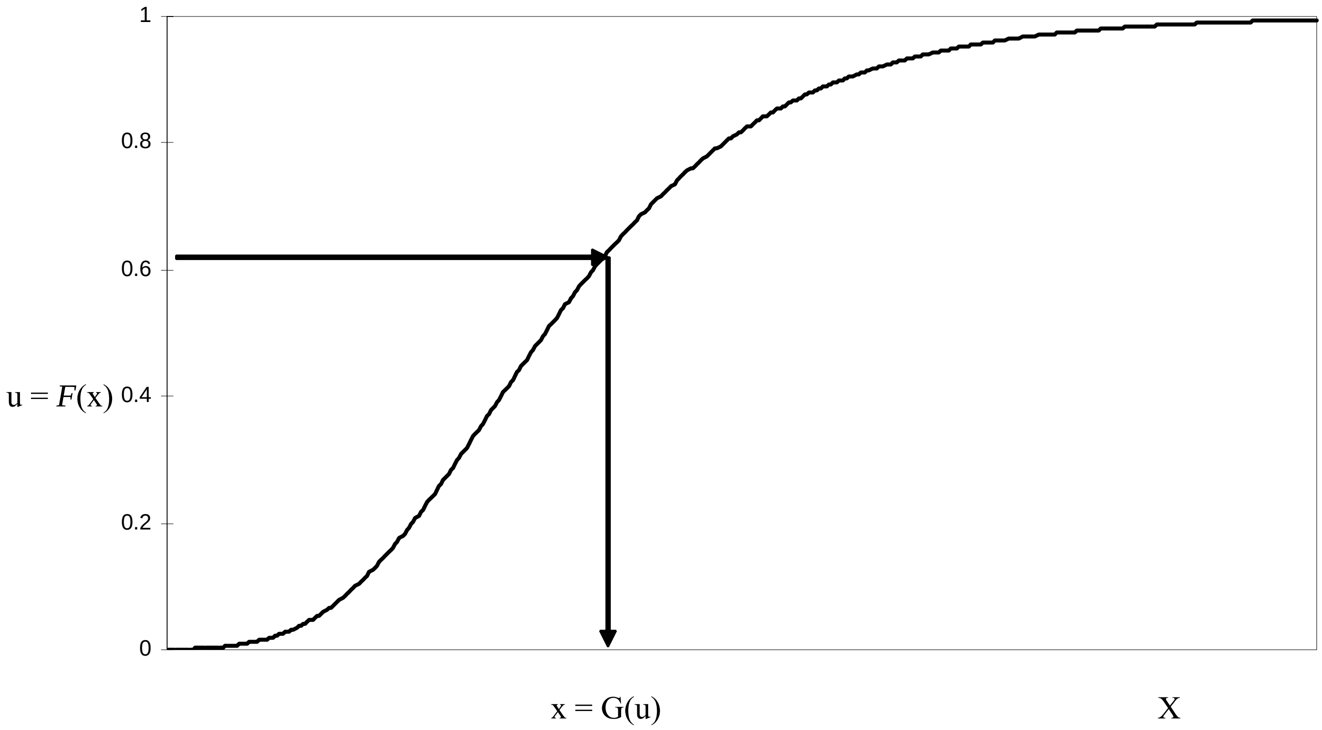

Figure 5.3: The Principle of Monte Carlo Sampling using the Inverse *CDF*

Source: HARDAKER et al, (2004)

5.3.2.3.1.2 Latin Hypercube Sampling

Latin hypercube is a relatively new stratified sampling technique used in simulation modeling. It is a modified form of Monte Carlo sampling that enables convergence of a sampled distribution with the specified distribution in fewer samples compared to Monte Carlo sampling. The technique commonly used during Latin hypercube sampling is ‘sampling without replacement’. The CDF is divided into *n* intervals of equal probability, where *n* is equal to the number of iterations to be performed. Figure (5.4) illustrates stratification with five iteration of a normal distribution. Each iteration involves a two-step procedure. First, one of the *n* intervals is selected using random number generator. As illustrated in the figure, the cumulative probability scale in this case has been divided into equi-probable intervals. Therefore a random integer (1, 2, …., 5) is generated to pick an interval. A new random number is then generated to determine where within the interval the sampled value of *F(x)* should lie. As in ordinary Monte Carlo sampling, *x* is then calculated for the value of *F(x)* by putting this into *x = G (u)*, where *u* now is first scaled to lie in the range of *F(x)* corresponding to the chosen interval of *x*. the same procedure is repeated for the required number of iterations with the fact that intervals once chosen are not eligible to be sampled again i.e. they are already represented in the sampled set.

Latin hypercube sampling gives benefits in terms of increased sampling efficiency and faster run-times especially when running large simulation models. It also helps when analyzing situations where low-probability outcomes are represented in input probability distributions. This technique ensures that such events are properly represented in the simulation outputs. (HARDAKER et al, 2004 and PALISADE, 1997).

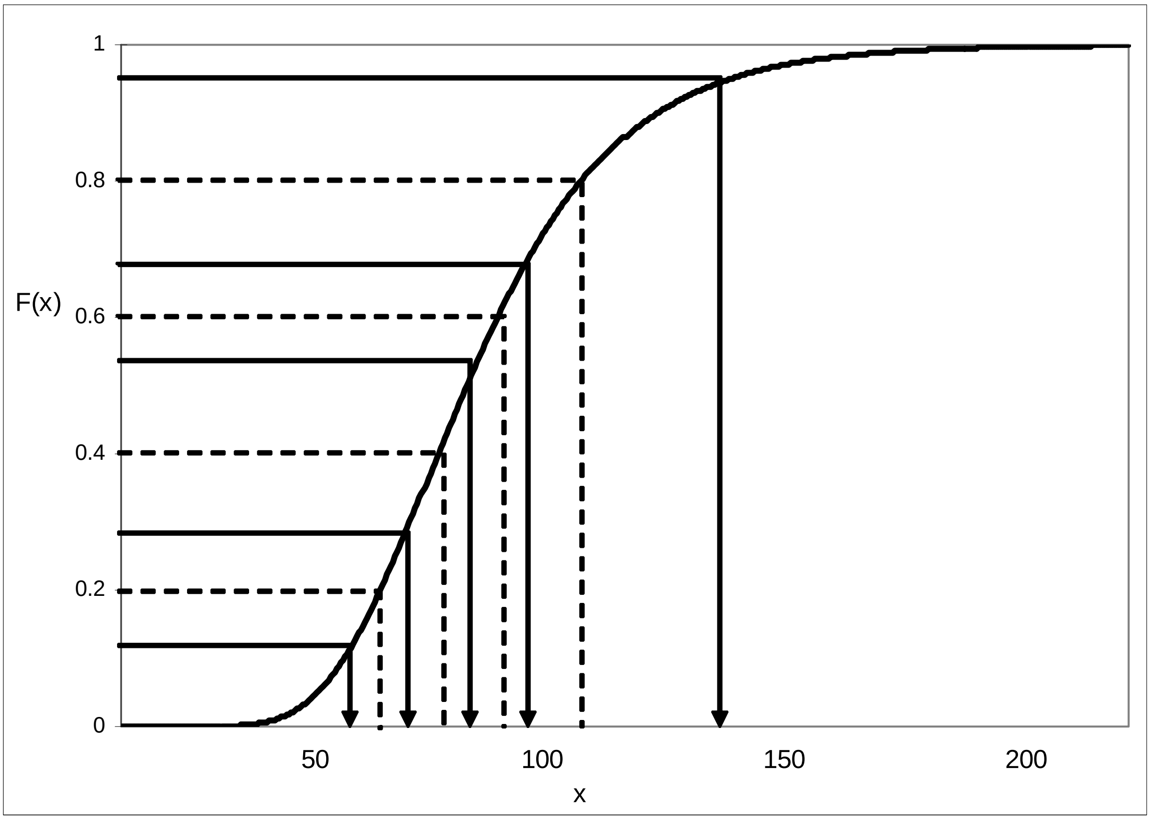

Figure 5.4: The Principle of Latin Hypercube Sampling

Source: HARDAKER et al, (2004)

5.3.3 Stochastic Efficiency Methods

Getting the results of stochastic budgeting for the different risky alternatives under consideration in form of CDFs, the stochastic efficiency techniques described in turn below can be used to rank the risky prospects for a specified range of farmer's risk-aversion. Different forms of stochastic efficiency analysis are recognized which vary according to the assumptions made about the nature of the relevant utility function and the risk attitudes implied. In these methods which are based firmly on the notion of direct expected utility maximization, the alternative risky prospects are compared in principle in terms of full distributions of outcomes.

Stochastic dominance methods which require pairwise comparison of alternatives were introduced first. These methods are defined by HARDAKER et al, (2004) as a decision rule that gives a partial ordering of risky prospects for decision makers whose preferences correspond to specified conditions about their utility functions. It is argued that in stochastic dominance analysis, placing fewer restrictions on the utility function, the results will be more generally applicable and hence the criteria will be less powerful in selecting between alternatives. However, only a partial ordering of alternatives into efficient and dominant sets are usually obtained in efficiency analysis. The criteria work by the determination of the dominated alternatives, such that those which are not dominated represent the efficient set. Stochastic dominance methods are helpful when the preferences for a single decision maker are not precisely known and also in situations involving more than one decision maker, such as analyzing policy alternatives or extension recommendations for a group of many individual decision makers. However, the method of stochastic efficiency analysis called SERF introduced by HARDAKER et al, (2004) and which was used within this study, reduces most of the computational problems connected with dominance analysis.

In the following sub-sections, forms of efficiency analysis are described in an order that involves progressively stronger assumptions about risk preferences, therefore producing progressive reductions in the size of the efficient set.

5.3.3.1 First-Degree Stochastic Dominance (FSD)

FSD is used to order alternatives for decision makers who prefer more wealth to less, has positive marginal utility for the performance measure i.e. $U^{(1)}(X) > 0$. The bounds for absolute risk-aversion with respect to wealth, $r_a(\mathrm{w})$, are:
$-\infty < r_a(\mathrm{w}) < +\infty$.
For illustration, if there are two actions A and B, A dominates B in the first-degree sense, if:
$F_A(x) \leq F_B(x)$ for all x, with at least one strong inequality.
Where, A and B are two actions

$F_A(x)$ and $F_B(x)$ are the probability distribution of outcomes, x, defined by cumulative distribution functions (CDFs) for A and B respectively.

Graphically, this means that the CDF of A must always lie below and to the right of the CDF of B. If two CDFs cross, then neither dominates the other in the first-degree sense, indicating the limited discriminatory power of FSD (Hardaker et. al, 2004).

5.3.3.2 Second–Degree Stochastic Dominance (SSD)

For SSD the restriction on the utility function is that the decision maker is risk averse for all values of x, and thus have a utility function of positive but decreasing slope, i.e., $U^{(1)}(x) > 0$ and $U^{(2)}(x) < 0$. The bounds for the absolute risk-aversion coefficient r_a are $0 < r_a(\mathrm{w}) < +\infty$.
With (SSD) A is preferred to B if:

$$\int_{-\infty}^{x^*} F_A(x)\, dx \leq \int_{-\infty}^{x^*} F_B(x)\, dx \text{ , for all values of } x^* \qquad (8)$$

With at least one strong inequality. Hence, under this criterion outcome distributions are compared based on areas under their CDFs. This requires that the curve of the cumulative area under the CDF for the dominant alternative lies every where below and to the right of the curve for the dominated alternative. In general, SSD has more discriminatory power than FSD (HARDAKER et al, 2004).

In empirical work it is often found that these forms of analysis are not discriminating enough to yield useful results, meaning that the efficient set can still be too large to be easily manageable.

5.3.3.3 Stochastic Dominance with Respect to a Function (SDRF)

SDRF has stronger discriminatory power than the ordinary FSD and SSD methods through the introduction of more bounds on risk aversion coefficients. For SDRF the absolute risk aversion bounds are reduced to $r_1(\mathrm{w}) \leq r_a(\mathrm{w}) \leq r_2(\mathrm{w})$, and ranking of risky scenarios is defined for all decision makers whose absolute risk aversion function lies anywhere between lower and upper bounds $r_1(\mathrm{w})$ and $r_2(\mathrm{w})$ respectively where r_1 and r_2 are two usually positive numbers. Moreover, the narrower are the bounds set on risk aversion, the more powerful the rule. Also the methods require assumptions about the form of the utility function to be used. Usually, the negative exponential functional form is used for convenience. The method is sequentially to select utility functions, *U*, which have risk-aversion coefficients within the bounds, and then discover for which of these functions the following expression is minimized.

$$\int_{-\infty}^{+\infty} \{F_B(x) - F_A(x)\} U^{(1)}(x)\, dx \qquad (9)$$

Where *A* and *B* are two risky prospects and x is the performance criterion.
A is preferred to B if the minimum of the above expression is positive. If it is zero then the prospects cannot be ordered. If the minimum is negative then B could be preferred to A (HARDAKER et al, 2004)

5.3.3.4 The SERF Method

HARDAKER et al, (2004) introduced a new, simple more transparent and more discriminating SDRF method, which is called stochastic efficiency with respect to a function (SERF). The method works by identifying utility efficient alternatives for ranges of risk attitudes, not by finding (a subset) of dominated alternatives. Conversely, all the alternatives over the range of risk aversion are compared simultaneously; only those that are optimal for some values of the risk aversion coefficients are identified as efficient. Therefore, a smaller efficient set can be obtained by SERF method compared to conventional SDRF. The SERF orders alternatives in terms of certainty equivalents (*CEs*) as a selected measure of risk aversion is varied over a defined range. It is argued that it makes more sense to compare the alternatives in terms of certainty equivalents (*CEs*) over the range of risk aversion of interest, since *CEs* can be more readily interpreted. SERF can be applied for any utility function for which the inverse function can be computed based on ranges in the absolute, relative, or partial risk aversion coefficient, as appropriate. One additional advantage of SERF is that it requires no special software. The method can be implemented in worksheet software such as Excel allowing for graphical presentation of results that can be understood by a wide range of potential users.

To illustrate the SERF method and according to the *SEU* hypothesis, the utility for each risky alternative can be calculated depending on the degree of risk aversion r and stochastic outcomes of x as:

$$U(x,r) = \int U(x,r)\, f(x)\, dx \qquad (10)$$

for the chosen form of the utility function.
Then U is calculated for selected values of r in the range r_1 to r_2.

It is argued that partial ordering of alternatives by *CE* is the same as partial ordering them by utility values. However, for greater convenience the *CEs* for each of these values of U are found by:

$$CE\,(x,r) = U^{-1}\,(x,r) \qquad (11)$$

The calculation of the *CE* depends on the utility function specified. Different utility functions imply the use of different formulas for *CE* calculations.

The *CE* representation is preferred to leaving results in utilities not only because *CEs* are easier to interpret than utility values, but also because this method allows inclusion of EMV in cases where $U(x,r)$ is undefined for $r = 0$. This method end up with a vector of *CEs* for each of the *n* alternatives calculated for several values of r within the bounds $r_1 \le r \le r_2$. At each r_i the efficient set contains only the alternative(s) that yield(s) the highest *CE*. The efficient set can be identified over a subset of the full range of r_i, as may be required for policy analyses. Only those alternatives which have the highest (or equal highest) CE for some values of r in the relevant range, are included in the efficient set. All other alternatives are dominated in the SERF sense.

The *CEs* of the alternatives can be presented in tabular or graphical form which allows for ready identification of the efficient set. Moreover, the graph provides a visual method to explain how preferences among risky alternatives change over the range of r. This is denoted in SERF graph with the value of *r* where the *CE* curves cross and it is called BRAC (breakeven risk aversion coefficient).

As with SDRF, the SERF method requires the choice of a particular form for the utility function and associated measure of risk aversion. However, the CARA function (negative exponential utility function) is often best recommended to be adopted as a reasonable approximation of the actual but most probably unknown utility function with the degree of risk aversion defined by a range of the absolute risk aversion coefficient r_a. The advantage of CARA function is that the coefficients of absolute risk aversion can be applied to consequences measured in terms of wealth or income.

5.4 Empirical Approach for Analyzing Business and Financial Risks

In making a decision about a business investment or future strategic choice, farmers in the study region have to account for many aspects. Among other things, they have to think about the following questions: what future gross margins for sorghum and sesame are realistic to use in farm planning? Could the adoption of forest and animal activities minimize the risk? What prices might be obtainable for gum arabic and sheep in the future? Could the adoption of the recommended new technology be profitable or could it increase the risk? On the other hand is it safer to diversify by using different sources of capital (borrowed and equity capital)? If borrowed capital is to be used, how much to use from it and how much to use from equity capital? These and other similar uncertainties imply a need for stochastic budgeting.

Within this study a stochastic budgeting model of business risk of an average farm in Gedaref area of eastern Sudan over a time horizon of twenty years is presented. A thousand feddans farm was used as a unit of analysis in which sorghum and sesame crops are mainly grown by farmers. In this area, farmers have also the possibility of growing gum arabic trees and keeping some animals specially sheep to manage production risk through diversification.

On the other hand, borrowing substantial amounts of money to run large investments implies increasing financial risk due to leverage. Therefore, within this study financial risk analysis was also conducted to assess different levels of leverage including the actual financial structure practiced by farmers and then their effect on the existing risk was evaluated.

5.4.1 Business Risk Analysis

The business risk analysis seeks to evaluate eight different risky strategies under both traditional and some improved cultural practices. The traditional practices indicate farmers' current cultural practices in growing sorghum and sesame crops, while the improved practices of growing sorghum and sesame within the context of this study imply mainly the use of improved seed varieties, application of fertilizer and the use of herbicides instead of hand weeding. Within this analysis eight separate budgets were prepared to calculate annual farm income for each strategy over the twenty years of the planning period. Then the net present values (NPVs) for the twenty years planning horizon were separately calculated for the different strategies under consideration.

The planning period of twenty years was chosen in this study because; one of the activities to be evaluated is gum arabic, the most important economic product of *Acacia Senegal* which has a life span of twenty years.

As explained earlier, the purpose of the current analysis is to compare different uncertain investment and production strategies with respect to financial viability over a twenty years planning period. The long term planning period entails the use of Cost Benefit Analysis (CBA). The method generally compares the gains (benefits) and losses (costs) over a given period of time, associated with an investment project or with a policy. If benefits exceed costs, an investment/policy decision is justified. In case there are many such projects or policies for a limited budget, the method provides criteria for making choices and setting priorities among several alternatives competing in the use of limited resources. In Cost Benefit Analysis, gains and losses stretch out over time. Individuals however tend to prefer the present to the future, and so, value costs and benefits in the future as worth less than costs and benefits now. This ‘present orientation’ is paramount and has to be accounted for. Future gains and losses are therefore discounted at some ‘discount rate’, which expresses how the value of money diminishes over time so as to express benefits and costs in present value terms. The benefit-cost rule becomes that the present value of benefits must exceed the present value of costs. Several appraisal indicators are used in the cost benefit analysis these include:

- The net present value (NPV). It is the difference in monetary terms between the discounted sums of costs and benefits of the project over its life span. For a project to be economically viable, the NPV must be positive.

- The internal rate of return (IRR), which is the discount rate that when applied to the future streams of costs and benefits, will produce a NPV of zero. If the IRR is greater than the opportunity cost of capital (generally considered as the cut-off rate), then the project will be acceptable.

- The benefit-cost ratio (BCR) which is the ratio of benefits to costs of a project. A project will be deemed acceptable if the BCR >1.

- The pay-back period, which is the period of time it takes for the total net benefits of the project to equal the initial investment.

When analyzing mutually exclusive alternatives, NPV is the preferred selection criterion such that to accept the alternative with the greatest NPV. Neither the IRR nor the BCR can be used for choosing among such alternatives as they may give incorrect ranking among independent projects. The IRR does not distinguish between projects of different scales, because it looks only at the rate of return on outlay, irrespective of the size of that outlay.

The business risk model within the context of this study gives a separate full distribution of the NPV for the stream of net cash flow for the determined strategies at the end of the planning period represented by their cumulative distribution functions (CDFs). The different CDFs obtained are then ranked using stochastic efficiency analysis which is based on the *SEU* approach expressed in terms of their *CEs*. Accordingly the risk-efficient strategy or strategies under the traditional and the improved cultural production practices are then obtained for different levels of farmers risk aversion.

The whole-farm stochastic budgets used in this study incorporate stochastic gross margins for sorghum and sesame crops produced under traditional practices, stochastic prices of sorghum, sesame, gum arabic and live sheep and stochastic yield and variable costs for sorghum and sesame grown under improved technology. The models simulate the farm performance under the business risk over the specified planning period.

5.4.1.1 Overview of the Investment Strategies

In the study area, prices of agricultural outputs and inputs are highly volatile due to market instability. This is especially true when long-term planning is considered. On the other hand, factors such as weather (especially rainfall variability) and plant and animal diseases cause farm products yield uncertainty. These together cause higher activity gross margins volatility, especially for sorghum and sesame crops. The prices of forest products (mainly gum arabic) and prices of animal products (mainly live sheep) largely follow the world market prices and also vary between the years. For simplicity, in the stochastic budgets the fixed cost items and other possible changes are assumed to be at the same level throughout the planning period. The plan was prepared according to 2003 information for the planning period 2003-2023.

For the growing season 2003/2004, farmers were concerned that the existing level of production was not only risky but also too low to return an adequate level of profit in the future as will be shown by the deterministic budget presented in the coming chapter. Therefore, a range of alternative investment and management strategies should be investigated to help farmers deciding which one to adopt starting 2003.

Two groups of strategies were identified for evaluation. The first one includes the strategies from one to four in which farmers use the traditional cultural practices in growing their crops while the second one includes the strategies from five to eight which entails farmer’s improved cultural practices in growing sorghum and sesame crops. Accordingly, the strategies among which farmers can choose include the following:

1. Strategy one, in which farmers continue to grow the whole farm (1,000 feddan) with sorghum and sesame under traditional practices. 80% of the land grown with sorghum and the remaining 20% grown with sesame. The traditional cultural practices used to grow these two crops indicate farmers current practices explained in section (3.4.2).

2. In strategy two, besides growing sorghum and sesame, farmers grow 10 % of the total farm land with acacia trees[5] and the remaining 90% of land is divided between sorghum and sesame crops in the same ratio of 4:1. As a result, the area of sorghum declined from 800 fed to 720 fed and the area of sesame from 200 fed to 180 fed.
3. Farmers in strategy three grow sorghum and sesame using the same cultural practices and the same area distribution as described in strategy one above. However, farmers additionally invest in keeping about 180 heads of sheep. This herd rears usually on natural pasture in the area and some other areas south of Gedaref during the rainy season. During the dry season, sheep depends mainly on crop residue and there is no fodder grown especially for them on the farm land. The number of sheep used in the analysis is the average number of sheep kept by the surveyed farmers (those who keep animals besides farming their land).
4. Strategy four involves additional investment in both forest and animal production. Growing acacia trees includes the same area and the same cultural practices described in strategy two, while keeping sheep entails the same number of animals and the same animal husbandry as explained in strategy three. Sorghum and sesame are grown traditionally, but because of land cut for acacia trees, sorghum land is restricted to 720 feddan instead of 800 feddan and sesame land to 180 feddan instead of 200 feddan.
5. strategy five through eight are as follows:

Strategy five is similar to strategy one, strategy six is similar to strategy two, strategy seven is similar to strategy three and strategy eight is similar to strategy four. The difference between the second group of strategies (five to eight), each from its counterpart in the first group (one to four), is that some improved practices for growing sorghum and sesame were introduced to the second group. These improved practices include growing improved varieties of sorghum and sesame, applying nitrogen fertilizer in form of urea, and using of herbicides for weed control instead of hand weeding. The additional costs involved here, entails the cost of the improved seeds, fertilizer and herbicides and their application. A summary of the eight strategies under investigation and the share of sorghum, sesame and gum arabic in the farm land in each strategy are given in figure (5.5).

For convenience the eight strategies described above will be nominated only by their numbers in the coming chapters e.g. strategy one, strategy two …up to strategy eight.

[5] Growing 100 fed of the total farm area with acacia trees is the recommendation of Ministry of Agriculture and Natural Resources to prevent desertification in the area.

Traditional Practices Strategies	Improved practices Strategies
1. Sorghum (80%) + sesame (20%)	5. Sorghum (80%)+ sesame (20%)
2. Sorghum (72%) + sesame (18%) + gum arabic (10%)	6. Sorghum (72%) + sesame (18%) + gum arabic (10%)
3. Sorghum (80%) + sesame (20%) + sheep	7. Sorghum (80%) + sesame (20%) + sheep
4. Sorghum (72%) + sesame (18%) + gum arabic (10%) + sheep	8. Sorghum (72%) + sesame (18%) +gum arabic (10%) + sheep

Figure (5.5): Investments Strategies Available to Farmers, Gedaref , Sudan

5.4.1.2 Estimation Procedure of the Empirical Model

The traditional whole-farm budgeting based on fixed-point estimates of production, prices and financial variables assisted by sensitivity analysis is argued to be of a little help to estimate financial results. This is especially true when many variables included in the budget are uncertain. As a result, the alternative techniques of stochastic budgeting are introduced. This approach accounts for some of the main uncertainties in the evaluation process and moreover gives an indication of the distribution of outcomes.

The stochastic budgets used in this study are built up from deterministic whole-farm budgets, formulated in an Excel spreadsheet. The models produce separate financial reports of the NPV at end of the 20-years planning period for each of the eight strategies under evaluation. The financial reports are derived from equations linking the farm production activities, capital, financial and tax obligations. Consumption activities were excluded from the analysis, since this farming system is market oriented and the research concentrate mainly on investigating the profitability and risk-efficiency of the new investments compared to the existing ones. On the other hand, income from off-farm activities was also excluded from the analysis since farmers are reluctant to give any information in this regard. Therefore, the analysis within the context of this study concentrates mainly on the farm business enterprises.

Stochastic features were introduced into the budget by specifying probability distributions for the variables assumed to be most important in affecting the riskiness of the selected measure of financial performance. To keep the model practicable and reasonably transparent, only those stochastic variables assumed to be most important for the decision making process were modeled using probability distributions. The probability distributions used in this study were partially based on historical data (objective frequencies) and partially based on subjective judgments.

Given that the available historical data is sufficient and relevant, historical inflation corrected gross margins of traditional sorghum and sesame, prices of sorghum, sesame, gum arabic and sheep in addition to the variable costs of improved sorghum and sesame were entered separately to BestFit software from palisade. The historical data used are for the period 1990-2004. BestFit software assigned a set of probability distributions to the given set of historical data of each stochastic variable included in the budgets. Comparing the resulting set of the probability distributions according to the statistics generated by the program and by applying some selection criteria, the best probability distribution for each uncertain variable included in the budget was then chosen. The probability distributions assigned by BestFit to each uncertain variable in the budgets are shown in chapter seven, figures (7.1) and (7.6).

Due to lack of historical data, the probability distributions for improved sorghum and sesame yields were elicited from an expert in the study area. This expert gave judgments of the lowest, highest and most likely values for yields of sorghum and sesame in the study area for the coming few years. Accordingly, improved sorghum and sesame yields were assumed to be approximately triangularly distributed, with a maximum value of 6 sacks/fed, most likely value of 4.5 sacks/fed and a minimum value of 3 sacks/fed for sorghum and a maximum value of 3.5 kantar/fed, most likely value of 2.6 Kantar/fed and a minimum value of 1.7 kantar/fed for sesame.

One important aspect that is to consider in stochastic budgeting is the question of the stochastic dependency between variables (HULL, 1980; HARDAKER et al, 1997). The distribution of performance variables may be seriously compromised if important stochastic dependencies are ignored. Different methods are applied to account for stochastic dependency between variables. For detailed information about these methods, their advantages and disadvantages see HULl, (1980); and HARDAKER et al, (1997 and 2004). Within this study a rank correlation matrix was built for the uncertain variables included in the budgets. The associations between the uncertain variables included in the budgets of the different strategies under traditional and improved practices were found to be low. Nevertheless, a moderate positive relationship exists between the historical, inflation corrected gross margins of traditional sorghum and sesame crops. A correlation coefficient of 0.52 was obtained between the gross margins of these two crops which is significant at 0.05 level. The obtained correlation coefficient was then used in the stochastic budget to account for the stochastic dependency between sorghum and sesame gross margins. Other stochastic variables in the budget (improved sorghum and sesame prices, yields and variable costs, gum arabic prices and the prices of sheep) were treated independently in the simulation process since the correlation analysis showed a weak non-significant relationship between them.

According to its advantages mentioned elsewhere within this chapter, a Latin hypercube sampling procedure with @risk add-in software from palisade was used to evaluate the budgets for large number of iterations. In the simulation, values of parameters entering into the model were chosen from their respective probability distributions by Latin hypercube sampling and were combined according to functional relationships in the model to determine an outcome. The process was repeated a large number of times to give estimates of the output distributions of the performance measure which expressed as cumulative distribution functions (CDFs) and summarized in terms of the moments of the distributions. The results presented here are based on 2200 sample simulation experiments. Because the simulated distributions of results changed very little as more sample experiments were used, it can be concluded that the number of samples was sufficient to provide stable outcomes. For the 2200 iterations used in the current simulation process, the mean and standard deviation of the outcome change by less than the specified convergence level of 1.5%. This indicates that the number of iterations used was sufficient to provide stable outcomes. The random generator used in the simulation process was seeded to ensure that the same set of random samples would be sampled for each strategy evaluated.

Based on the above justification, the net present value (NPV) of farm income was used in the current study as a measure of performance in the stochastic budgeting analysis at the end of the twenty years planning period to evaluate the proposed eight strategies in terms of their risk efficiency. To calculate the NPV for the eight strategies under consideration, farm income was obtained separately for each strategy in each year of the planning period. To get annual farm income, the cash costs were deducted from the cash benefits in each strategy.

To obtain annual net farm income in traditional and improved sorghum and sesame enterprises, the 2003/2004 fixed costs levels were used in the stochastic budgets and for simplification purposes they are assumed to be at the same level throughout the planning period. In case of traditional sorghum and sesame, fixed costs in each case are deducted from the two crops gross margins which were entered in the stochastic budget as probability distribution obtained from historical data for the period 1990-2004. On the other hand, improved sorghum and sesame variable costs, yields and prices are represented in the stochastic budgets in form of probability distributions obtained from historical data for variable costs and prices and elicited as subjective probabilities for the two crops yields.

Regarding gum arabic costs and returns in the stochastic budgets, the fixed and variable costs are varied[6] over the first four years of the planning period. From the fifth to the 20th year, costs are assumed to be constant at the same level of 2003/2004. Yield of gum arabic is also assumed to be constant at 2003/2004 level over the whole planning period.

Concerning sheep enterprise, costs are also varied[7] during the first four years of the planning period and assumed to be at the same level from the fifth year and thereafter, while yields from sheep are assumed to be constant at the level of 2003/2004 throughout the planning horizon.

On the other hand, prices of gum arabic and sheep were represented in the stochastic budgets by their probability distributions obtained from historical data over the period 1990-2004.

Based on the above information farm income and then NPV were calculated for each strategy based on the types of activities included in each strategy as described in section (5.4.1.1). In the stochastic budgets all values are corrected for inflation including the stochastic variables and other costs items (fixed and variable costs). The eight stochastic budgets concerning the eight strategies under investigation are presented in chapter seven, figures (7.1) and (7.6).

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[6] The first four years of the planning period involve the repayment (principal + interest) of the loan obtained to buy acacia tree seeds and seedlings. Additionally this four years period, is the period of acacia tree establishment during which no output of gum arabic is obtained which in turn causes the variable costs to vary during this period as will be illustrated by gum arabic deterministic budget presented in the coming chapter.

[7] For sheep enterprise, as in gum arabic the principal and interest for the loan obtained to buy the first sheep herd are paid during the first four years of the planning period causes some differences in costs during this period compared to the rest of the planning period.

The discount rate used for calculating the NPV at the end of the planning period, is 12%. This discount rate was chosen according to suggestions by MUSTAFA et al (1995) who argued that the discount rates used in investment appraisal in developing countries ranges between 15-18 percent and usually a discount rate of 12% is used. Moreover, this discount rate is the real discount rate declared by the Bank of Sudan for the year 2003/2004.

The NPV in the current analysis was calculated according to the following formula:

$$\text{NPV} = \sum_{i=o}^{n} \frac{c_i}{\left(1 + \frac{r}{100}\right)^i} \qquad (12)$$

Where,

c_i = the net cash flow in year i (i = 0, 1, 2, ….. n), represented by farm income in this study.

n = the planning period which equals twenty years in the current analysis.

r = the discount rate.

The calculation procedure of production costs and revenue for each farm activity in the study area to obtain net farm income as in the deterministic budget presented in the next chapter, the following formulae have been used:

First the revenue was calculated according to the following formula:

$$R_c = P_c Y_c \qquad (13)$$

Where, R = the revenue (value of production) of specific activity per feddan in Sudanese Dinars (SD); P = the average price per sack for sorghum and per kantar for sesame and gum arabic and per head for sheep; all expressed in Sudanese Dinars; Y = the average yield of the activities given in sacks for sorghum, kantars for sesame and gum arabic and in heads for sheep; and c = is the index for the different activities.

The cost of production was calculated as follows:

$$TC_c = \sum_s P_s I_c \qquad (14)$$

Where,

TC = total costs of production per feddan in SD

P = the price of used inputs in SD

I = the amount of used inputs per feddan.

c = is the index for the activities

s = is the index for the inputs used

The gross margins were calculated as follows:

$$GM_c = R_c - TC_c \qquad (15)$$

Where,

GM = the gross margin (income per feddan) of certain activity in Sudanese Dinars.

c = is the index for the activities.

The fixed costs were calculated as follows:

$$FC = D + I + T + i \qquad (16)$$

Where,

FC = fixed cost per feddan in SD

D = annual machinery depreciation

I = annual machinery insurance

T = annual taxes

i = interest on capital investment

Net farm income was calculated for each activity according to the following formula:

$$\Pi_c = GM_c - FC_c \qquad (17)$$

Where,

Π = net farm income for each activity in SD

c = is the index for the activities

For the stochastic budgeting analysis, farm income in each strategy was obtained according to the formula below:

$$\Pi_t = \sum_{c=2}^{n} \Pi_c \qquad (18)$$

Where,

Π_t = the farm income generated from the whole farm plan in SD

Π_c = the farm income earned from each activity in SD

c = the index for the activities included in each strategy ranging from 2-4 activities.

5.4.2 Ranking Risky Strategies

To present the financial feasibility of alternative strategies, the CDFs of the performance measures are informative. For example, from the CDF, the likelihood of occurrence of some measures of interest can be found for each of the analyzed strategies. However, LIEN and HARDAKER (2001) argued that it is usually important to account for farmers' risk attitude when planning farm business under uncertainty. Previous studies which considered farmers' attitudes to risk, have found risk aversion to have an important effect on the choice of the whole-farm management plan (e.g. NANSEKI and MOROOKA, 1991; KINGWELL, 1994; PANNELL and NORDBLOM, 1998).

Assuming that farmers are risk averse and that beliefs and preferences vary among farmers, it is therefore, equally important in farm planning to account for farmers' beliefs about the chances of occurrence of uncertain consequences and for the preferences regarding these consequences, reflecting farmers degree of aversion to risk. As explained in previous sections of this chapter, the subjective expected utility (*SEU*) hypothesis is the best framework for structuring these two components into a model of a risky choice.

Therefore, in the analysis that follows, the method of stochastic efficiency with respect to a function (SERF) was used to rank the risky prospects in terms of their certainty equivalent. Because the decision maker's exact risk aversion is unspecified, the problem was solved by using lower and upper bounds $r_1(w)$ *and* $r_2(w)$ of absolute risk aversion, and farmers absolute risk aversion $r_a(w)$ lies somewhere between these two bounds.

A range of relative risk aversion with respect to wealth $r_r(w)$ of 0.5 and 4.0 proposed by ANDERSON and DILLON (1992) is assumed in this study. $r_r(w)$ of 0.5 denotes hardly risk aversion at all while $r_r(w)$ of 4 denotes extremely risk aversion. On the other hand, utility and risk aversion are not expressed in terms of wealth, but in terms of income. Therefore the following relationship was used to obtain absolute risk aversion with respect to income:

$$r_r(z) = zr_a(z) = zr_a(w) = (z/w)r_r(w) \qquad (19)$$

Where,
$r_r(z)$ = relative risk aversion with respect to income
$r_a(z)$ = absolute risk aversion with respect to income
$r_r(w)$ = relative risk aversion with respect to wealth
$r_a(w)$ = absolute risk aversion with respect to wealth
z = income
w = wealth

The ranges for $r_r(z)$ and $r_a(z)$ are approximated by use of equation (19). Farm assets used for wealth and farm income used for income. To calculate farmers' utility, the negative exponential function *U* was chosen which is expressed as follows:

$$U = 1\text{-}exp(-cz) \qquad (20)$$

Where,
c = the coefficient of absolute risk aversion
z = net income

According to the *SEU* hypothesis, farmers utility is equivalent to their expected utility weighted by their probabilities, this defined by the following equation:

$$U(w,r(w)) = \int U(w,r(w))\,dF(w) \approx \sum_{i=1}^{m} U(w_i, r(w))P(w_i), \quad r_1(w) \le r(w) \le r_2(w) \qquad (21)$$

Where,
The second term in equation (21) represents the continuous case and the continuous case is converted to its discrete approximation in the third term for computational purposes.
P(w) = is the probability for states *i*
m = states of nature for each risky strategy.

For greater convenience, the utilities were converted to *CEs* by taking the inverse of the utility function. Given that the negative exponential utility function was used in this analysis.

21 fractiles values were obtained for each risky strategy from the CDFs resulted from @risk stochastic budget analysis. These are, f0.00, f0.05, f0.1, f0.15, f0.20 … f1.0. The fractile values were assumed to have the same probabilities, consequently, a probability of 1/21 (0.0476190) was assigned to each fractile value and then applied in equation (21).

After getting the *CE* for each strategy for the specified range of farmers' risk aversion, then the risk premiums concept was used to determine the confidence of decision makers in a particular preferred risky alternative. This is done by subtracting the *CE* for a less preferred alternative from the dominant alternative at a specified range of risk aversion; this will result in a utility weighted risk premium (*RP*) of:

$$RP_{l,d,r_i} = CE_{d,r_i(w)} - CE_{l,r_{i_i}(w)} \qquad (22)$$

Where,
l = denotes the less preferred risky prospect or alternative
d = denotes the dominant risky alternative

5.4.3 Financial Risk Analysis

The current and the recommended large investments to manage business risk in the study area, usually involve borrowing substantial amounts of money implying a significant increase in financial risk of the business due to leverage. Therefore, the financial risk analysis was conducted to evaluate different financial structures under the mechanized rain fed sub-sector conditions. Different levels of leverage including farmer's actual debt/equity ratio for the traditional sorghum and sesame farming system and the system incorporating additionally sheep enterprise. The effect of the specified levels of leverage on farmer's return to capital and farmer's return to equity on both systems was then obtained.

6 ANALYSIS OF COSTS AND RETURNS OF THE DIFFERENT ENTERPRISES IN GEDAREF AREA

The purpose of this chapter is to provide information about the different agricultural enterprises in Gedaref region. Also included are their production practices and economic feasibility using the data of the growing season 2003/04. The chapter starts by presenting costs and returns of traditional sorghum and sesame, which are the main crops in the region and in addition the comparative assessment of the two crops is included. In the second part, costs, capital needs and returns of the recommended technology to grow sorghum and sesame and the accompanying changes in the capital labor combination are discussed. In the third part, the analysis of costs and returns for the forest and livestock enterprises are presented. The deterministic budget built within this chapter for each enterprise in the study area represents the base for the stochastic budgeting analysis in the next chapter.

6.1 Calculation and Analysis of Costs and Returns of Traditional Sorghum and Sesame

6.1.1 Costs Calculation

In general the traditional crop husbandry in the study area involves the following practices:

a. Use of a four- wheeled tractor of about 65-75 hp.
b. Use of a set of wide level disc harrows fitted with a seed box for tillage and planting operations.
c. Growing of traditional varieties of sorghum and sesame.
d. One to two plowing operations. The second disking during which, planting is completed.
e. One to two manual weeding operations.
f. Manual harvesting of both sorghum and sesame. Sorghum is then threshed using stationary threshers or by using combine harvesters as stationary harvesters (AHMED, 1994).

For the growing season 2003/2004, the costs and returns per feddan and per farm for the two main crops in the study area (sorghum and sesame) were separately calculated and analyzed. An average farm of 1,000 feddan in Gedaref area has been used as a unit of analysis. Costs and returns calculations and analysis are based on information gathered from the State Ministry of Agriculture in Gedaref, Mechanized Farming Corporation and from the author's field survey 2003/2004.

6.1.1.1 Variable Costs Assumptions and Determination

The variable expenses for producing sorghum and sesame include the costs of labor engaged in the different field operations, costs of materials used in the agricultural production, costs of machinery and any other additional costs, which vary with the production process. The following are detailed descriptions of farming activities constituting the variable costs for both sorghum and sesame.

- Land preparation and sowing: These two operations are usually done mechanically in single operation for both sorghum and sesame. Their costs include the costs of labor for land cleaning, costs of machinery maintenance, the costs of gasoline, oil and lubricants and the costs of seeds.
- Weeding: cost of weeding includes wage and food costs of laborers and the costs of hand held equipments used in the weeding operation.
- Harvesting (cutting, piling and threshing): These costs include wage and food costs of laborers alongside the costs of hand held equipments used in the harvesting processes of cutting, piling and threshing of sesame. Labor costs of sorghum harvesting include the costs of cutting and piling. Threshing of sorghum is done mechanically and it is usually performed on custom basis.
- Marketing: This includes the packaging and transporting costs.
- Some additional variable costs in cash were the costs of maintenance of labor camps and water source (haffir[8]) in the scheme area, in addition to the monthly salaries of the scheme manager and the scheme guard. The above mentioned general variable costs were divided between sorghum and sesame on the basis of their share of the total area grown.
- Zakat[9]: this represents 10% of the total produce, paid to the government after harvest.

6.1.1.2 Fixed Costs Determination

Fixed costs calculations in the current analysis comprise machinery depreciation, insurance, taxes, interest on capital investment and the land fees. Machinery included in the calculation of fixed costs was 75 hp tractor and a disk fitted to a planter because nearly all farmers in the study area possess these two types of machines. Only a negligible number of farmers have their own combine harvester and therefore it is not considered in fixed costs calculations within this study.

[8] Haffir is a local name for water source, which represents a big hole dig in the ground to keep rainfall water.
[9] Zakat is an Islamic fee levied annually from farmers by the government as 10% from crops total output.

The details of the fixed costs for producing sorghum and sesame crops include the following items:

1. Machinery Depreciation:

The method used to calculate depreciation is the straight line method (the most common method). According to McCONNELL and DILLON (1997) the annual depreciation was calculated using the formula below:

$$\text{Annual depreciation} = \frac{machinery\ \cos t - salvage\ value}{useful\ life}$$

In calculating depreciation, a useful life of 20 years was assumed for farmers' machinery (tractor and disk planter) following the report of the surveyed farmers and agricultural engineers in the study area.

2. Insurance was calculated as 1% from machine price according to information from Traffic Headquarters in Medani, Sudan 2004.
3. Taxes which represent a fixed amount of money paid annually by farmers to the government calculated as 1% from machine price.
4. Interest on capital investment: according to KAY (1986) was calculated as follows:

$$\text{Interest} = \frac{(machinery\ value + salvage)}{2} * \ \text{int}erest\ rate$$

5. Land cost: land is leased by the government to the farmers on a contract basis of 25 years for an annual price of SD 25 per feddan.

Fixed costs for buildings are not included in the analysis since there are no permanent buildings that have significant costs, neither for crops nor for animals. Only temporary camps (huts) for permanent labor during the cropping season of June to January are used. The huts are newly built or maintained only if the field is to be cultivated and therefore their costs were included as variable costs items (seasonal labor usually uses simple huts made of straw during the period of weeding and harvesting operations).

The fixed costs in cash involved the property tax and the land fees paid annually by farmers to Mechanized Farming Corporation (MFC). In turn, they get a certificate with which they can apply for credit from the Agricultural Bank of Sudan or any other formal commercial financial institution. The non-cash adjustments to income were the depreciation of machinery, insurance and interest. Like the general variable costs, also the fixed costs were divided between sorghum and sesame in terms of their area coverage in relation to the total farm area.

6.1.2 Analysis of Costs and Returns of Traditional Sorghum and Sesame Cultivation

6.1.2.1 Analysis of Costs

Table (6.1) summarizes the costs structure for traditional sorghum and sesame cultivation for the growing season 2003/2004. Considering the operating costs in table (6.1) one can notice the following: The total cash variable costs for growing one feddan of sesame from land preparation till marketing of the produce was SD 12,964. This is equivalent to almost double the variable costs required to produce one feddan of sorghum, which amounted to about SD 6,255, representing respectively about 79.2% and 78.9% of the total costs of producing sorghum and sesame.

Cash fixed costs for sorghum and sesame production represented a small share of the total production costs of the two crops and were 8.7% and 10.2% respectively. The low share of cash fixed costs in aggregate costs of sorghum and sesame explains the low value of land, the main item in the fixed cash expenses, which in turn gives the farmers the opportunity to rent their land when they have no financial resources to meet the production costs. On the other hand, the non-cash expenses amounted to 12.1% from sorghum total production costs while they contributed 10.9% to sesame total costs.

Considering the cash expenses (operating costs plus cash fixed costs) per unit area for both sorghum and sesame, it is clear from the table that cash expenses of sesame exceeded that of sorghum by 111%. This is also true if the total area grown was considered. Although sorghum occupied 80% (800 feddans) of the total farm area, it contributed only to 65.5% of farm total cash costs (SD 5,553,702) compared to SD 2,930,149 cash expenses needed to grow the 200 feddan of sesame. The cash cost for sesame production represented 34.5% of farm total cash expenses although only 20% on average of the farm area was covered by this crop last season. This result imply the high cost of producing sesame compared to sorghum, which in turn explains why farmers limit sesame area to a level below 20% of total farm area although its returns considerably exceed that of sorghum. Hull 1980 argued that high costs enterprises are associated with high level of risks. Hence justifying the observed farmers behavior towards sesame crop by limiting its area, which explains on one hand their risk aversion and on the other hand the limited availability of cash capital to farmers. However the cash costs of producing sorghum and sesame represented 87.9% and 89.1% of their total costs respectively (table 6.1).

Table 6.1: Structure of Cost Items of Traditional Sorghum and Sesame, Gedaref Area, 2003/2004

Cost	Sorghum		Sesame	
	SD/fed.	%	SD/fed.	%
Cash operating cost	6,255	79.2	12,964	78.9
Cash fixed cost	687	08.7	1,687	10.2
Cash expenses	6,942	**87.9**	14,651	**89.1**
Non-cash expenses	953	12.1	1,787	10.9
Total cost	7,895	**100**	16,438	**100**
Cash expenses/sack	3,018		6,104	

6.1.2.2 Analysis of Costs According to Field Operations

Table (6.2) shows the structure of costs of production by operation per feddan of traditional sorghum in Gedaref area for the growing season 2003/2004. As illustrated earlier in this chapter, the three main operations on sorghum and sesame fields are land preparation and sowing, weeding and harvesting. The table displays that the costs of weeding and harvesting were the highest among the other operations; each represented 26% of the total cash costs. Although, one of the three operations of sorghum harvesting (head cutting, piling and threshing) is done mechanically (threshing), obviously the main reason behind the high cost of harvesting and weeding is the intensive labor use in these two operations. Cost of sowing represented only 13% of the total cash costs; this is because it is efficiently conducted by tractors. On the other hand, marketing cost reached 22 % of the cash costs; including the cost of transporting the produce to Gedaref city auction where the farmers usually sell their products.

Table 6.2: The Structure of Cash Costs of Traditional Sorghum by Operation, Gedaref Area, 2003/2004

Operation	Cost SD/fed.	Percentage
Land preparation and sowing	869	13
Weeding	1,814	26
Harvesting	1,781	26
Marketing	1,586	22
Transfers	662	10
Others	230	3
Total operation costs	**6,942**	**100**

Table (6.3) illustrates the cost of inputs used in the production of sorghum. Labor represented the highest cost among other input items, it reached 50% of total cash costs while machinery represented only 18% and purchased input materials about 11%.

Table 6.3: The Structure of Cash Costs of Traditional Sorghum by Input Items, Gedaref Area, 2003/2004

Inputs	Costs SD/fed.	Percentage
Labor	3,493	50
Machinery	1,244	18
Materials	777	11
Transfers	828	12
Others	600	9
Total inputs costs	**6,942**	**100**

Table (6.4) demonstrates the traditional sesame cash costs according to the farm operations. It is clear that harvesting of sesame is the most expensive operation; it represented about 43% of total sesame cash expenses and this is because it is entirely done by labor. Harvesting of sesame is a crucial phase; farmers could lose all of their production if the process is not completed in a short time. So, farmers are obliged to employ large number of laborers with relatively high wage rates, which contribute to the prevailing high harvesting costs. Until now research efforts in Sim Sim project and in the ARC did not provide a mechanical substitute for the current manual harvesting of sesame. This is attributed to the biological features of sesame plant. Sesame crop needs to be collected in a short time before the period of capsules maturing, and then piled in a special way until the capsules are completely dried. The capsules would then open automatically and finally the laborer pours the sesame from the capsules in a white sheet. Weeding of traditional sesame represented about 16% of cash costs; it is also a major manual operation. Land preparation and sowing of sesame like in sorghum contributed a relatively low share of the cash costs (12%) while marketing of sesame represented about 15%.

Table (6.5) shows the total variable costs according to the costs of inputs used in sesame production. The input of labor represented 62% of total cash expenses of sesame; this is because all sesame operations except land preparation and sowing are done manually. Other inputs of machinery and materials like in sorghum represented 12% and 11% of cash costs respectively. About 12% of the cash costs were transferred to the government as Zakat for both sorghum and sesame.

Table 6.4: The Structure of Cash Costs of Traditional Sesame by Operation, Gedaref Area, 2003/2004

Operations	Cost SD/fed.	Percentage
Land preparation and sowing	1,729	12
Weeding	2,383	16
Harvesting	6,263	43
Marketing	2,239	15
Transfers	1,662	11
Others	375	3
Total operations costs	**14,651**	**100**

It is understandable that manual operations in sesame and sorghum have a considerable share in the cost of production. These results show that more efforts are needed to introduce economically efficient technology to replace the use of manual labor.

Table 6.5: The Structure of Cash Costs of Traditional Sesame by Input Items, Gedaref Area, 2003/2004

Inputs	Cost SD/fed	Percentage
Labor	9,222	62
Machinery	1,732	12
Materials	1,565	11
Transfers	1,762	12
Others	370	3
Total inputs costs	**14,651**	**100**

6.1.2.3 Analysis of Returns

Using 2003/2004 average yields and prices of sorghum and sesame, table (6.6) illustrates returns of the two crops per feddan and per area grown. To calculate returns of sorghum and sesame, a yield of 2.3 sacks/fed of sorghum and 2.4 kantar/fed of sesame were used. While per unit prices of SD 2,842/sack and SD 6,809/kantar (SD 12,255/sack[10]) were used for sorghum and sesame respectively.

[10] One sack of sesame equal to 1.8 kantar

From the table one can notice that gross returns of one feddan of sesame were SD 16,340; which is 2.5 times the gross returns earned from one feddan of sorghum (SD 6,536). The table also shows that both sorghum and sesame incomes were above their cash operating costs; in sorghum it exceeded operating costs by 4.5% while in sesame the income was above the operating costs by 26%. This is apparently because yield break even point to cover the operating costs at the prevailing 2003/2004 prices was below sorghum and sesame yields per unit area. And also the price break even point is below 2003/2004 market prices per sack of sorghum and sesame (table 6.6).

Although cash costs for growing one feddan of sesame almost doubled that required to grow one feddan of sorghum (2.1 times), the net cash income earned from a feddan of sesame was 5.2 times greater than net cash returns from one feddan of sorghum (one feddan of sesame earned a net cash income of SD 1,690 compared to SD –406 for sorghum i.e. cash returns from sorghum did not cover its cash expenses). In total, the area under sesame (20% of the total grown area) contributed 38.5% of total farm cash receipts (SD 3,268,000), while sorghum grown area (80% of total farm area) contributed 61.5% (SD 5,228,800) of total farm cash receipts which amounted to SD 8,496,800 (table 6.6). With regard to the total net cash farm income, it was negative for sorghum production amounted to SD -324,800 while sesame total net cash income was positive and reached an amount of SD 338,000. This gain from sesame production was enough to cover the loss from sorghum production and to make net cash income for the whole business of SD 13,200 (table 6.6).

From the analysis of sorghum and sesame costs and returns for the growing season 2003/2004, one can conclude that although the costs of producing sorghum were much lower than that of producing sesame, the income from sorghum production was not enough to cover its cash expenses. On the other hand, sesame production was profitable enough to cover sorghum losses and to provide the farmer with a little margin. This is attributed to the last year high sesame prices compared to the previous years prices. Also it can be noticed from table (6.6) that sorghum and sesame production in Gedaref area had a negative net farm income. Both crops were unable to cover their total costs resulting in a total loss for the whole business of SD -1,106,800.

Table 6.6: Structure of Returns from Traditional Sorghum and Sesame, Gedaref Area, 2003/2004

Item	Sorghum Per fed.	Sesame Per fed.	Total Per farm
Cash receipts (SD)	6,536	16,340	8,496,800
Income above operating cost (SD)	281	3,377	900,200
Net cash income (SD)	-406	1,690	13,200
Net farm income (SD)	-1,359	-98	-1,106,800
Income/operating costs (%)	4.5	26	
Break even yield (sack/fed)	2.2	1.05	
Break even price (SD/sack)	2,720	9,724	

6.2 Analysis of Costs and Returns of Improved Sorghum and Sesame

Both the high costs of manual operations and continuous deterioration in soil fertility have urged research centers in the study area to engage in provision of improved techniques to replace the current inefficient labor use. Research held in Sim Sim center in southern Gedaref region during the period 1984-1992, which is still continuing in the ARC up to now has came up with a package of improved technology recommended for the region. As illustrated earlier in section (4.2.5), this recommended package agrees with the prevailing technology of using tractors of 65 to 75 horsepower for land preparation and sowing for the 1,000 feddan farm. This package also incorporates the use of herbicides instead of hand weeding, and the application of mineral fertilizers alongside the use of improved seed varieties for both sorghum and sesame crops. Until now, no research has provided answers on replacement of manual methods by technology use in harvesting sesame and sorghum. Therefore, the improved technology package within the context of this study can only be viewed as addition of herbicides, fertilizers and improved seeds input items to the prevailing traditional techniques.

6.2.1 Costs and Returns of Improved Sorghum

In table (6.7), 2003/2004 yields, costs and returns of traditional sorghum are compared with those of the improved one. Due to the large increase in sorghum yield by 95.7% as a result of the application of improved practices, cash receipts of improved sorghum exceeded that of the traditional by 95.7%. Both traditional and improved sorghum had positive returns over the operating cost while both of them showed a negative income above total costs with a lower extent of 90.9% in the improved sorghum. Only the improved sorghum showed positive returns over the total cash expenses which exceeded that of traditional sorghum by 341.5%. However the increase of operating and total cash expenses as a result of use of the improved practices significantly reached 68.5% and 70% respectively but cash expenses per output were lower by 13.1% in the improved sorghum compared to the traditional one. Although the primary indicators show the profitability of the investment, the venture in the improved technology in the region is not favored by farmers because of its high cost and because of the high hazards of losses.

Table 6.7: Comparison of Yields, Costs and Returns per Feddan of Traditional and Improved Sorghum, Gedaref Area, 2003/2004

Item	Traditional Sorghum	Improved Sorghum	Difference (%)
Yield	2.30	4.50	95.7
Cash receipts	6,536	12,788	95.7
Operating cost	6,255	10,538	68.5
Cash expenses	6,942	11,807	70.1
Non-cash expenses	953	1,104	15.9
Total cost	7,895	12,911	63.5
Income above operating cost	281	2,249	700.8
Net cash income	-406	981	-341.5
Net farm income	-1,359	-123	-90.9
Cash expenses/ sack	3,018	2,624	-13.1

* Yield is in sacks, income and costs are in Sudanese Dinars (SD)

6.2.2 Costs and Returns of Improved Sesame

Table (6.8) compares costs and returns of traditional and improved sesame per feddan considering 2003/2004 yields, inputs and outputs quantities and prices. As can be seen from the table, both traditional and improved sesame showed positive returns over both the variable and the total cash expenses but the income above operating costs and above cash costs was lower in the improved sesame than in the traditional one by 22% and 52% respectively. However, both of them exhibited negative net farm income although the total loss per feddan in the improved sesame was much higher than that of the traditional one. Because of the slight increase in the yield of sesame as a result of applying the improved practices, the increase in cash receipts is only 8.3%. While the increase in operating cost is 16.2% and in cash expense is 15.3%, non-cash expenses increased by 9.6% and total costs by 14.7%. In contrast to sorghum, cash expenses of producing one sack of improved sesame is higher than that required to produce one sack of traditional sesame by 6.4%; as mentioned before this is attributed to the slight increase in sesame yield as a result of applying the new technology compared to the increase in costs.

Table 6.8: Comparison of Yields, Costs and Returns per Feddan of Traditional and Improved Sesame, Gedaref Area, 2003/2004

Item	Traditional Sesame	Improved Sesame	Difference (%)
Yield	2.4	2.6	8.3
Cash receipts	16,340	17,702	8.3
Operating cost	12,964	15,070	16.2
Cash expenses	14,651	16,891	15.3
Non-cash expenses	1,787	1,959	9.6
Total cost	16,438	18,849	14.7
Income above operating cost	3,377	2,632	-22
Net cash income	1,690	812	-52
Net farm income	-98	-1,147	1,074
Cash expenses/sack	6,105	6,496	6.4

* Yield is in kantar, costs and income are in Sudanese Dinars

6.2.3 Change in Capital Labor Combination

Although it has the name mechanized farming, the traditional ongoing cropping system in Gedaref area intensifies labor use rather than capital. On the other hand the recommended technology intensifies capital. However what has been achieved up to now regarding the technology application includes some changes in the structure of the cost components as depicted by figure (6.1) and (6.2). In figure (6.1) the components of traditional and technology cash costs for producing sorghum are shown; the relative labor use decreased to 30% of the total cash costs in the modern production system, in which case it was about 50% in the *traditional* budget. This decrease is attributed to the replacement of manual weeding by the chemical herbicides. The application of herbicides will lay off 2.93 man days per feddan of labor that could have been used in weeding operation. This in turn, may have substantial effect on the labor market, which is now expected to have surplus labor that will compete only for the harvesting operation. As a result labor wages for this operation, which represents 56% of total labor needs per farm, as expected would considerably decrease.

The increase of capital use as a result of applying the new technology, which is the application of herbicides, improved seeds and mineral fertilizers, implied an increase in the relative costs of materials from 11% in the *traditional* budget to 37% in the *modern technology* budget. The use of farm machinery is not affected by the application of the recommended level of technology; this is because there is no additional task for machinery since harvesting is still manually conducted and thus it represented 18% of the *traditional* budget and 11% of the *modern technology* budget. Transfers including Zakat and the marketing fees in the Gadaref Auction, whose values depend on the quantity of the crops produced, certainly would go up with the increase of output as a result of applying the technology package; they composed 13% of the *modern technology* budget in comparison to 12% of the *traditional* budget of sorghum.

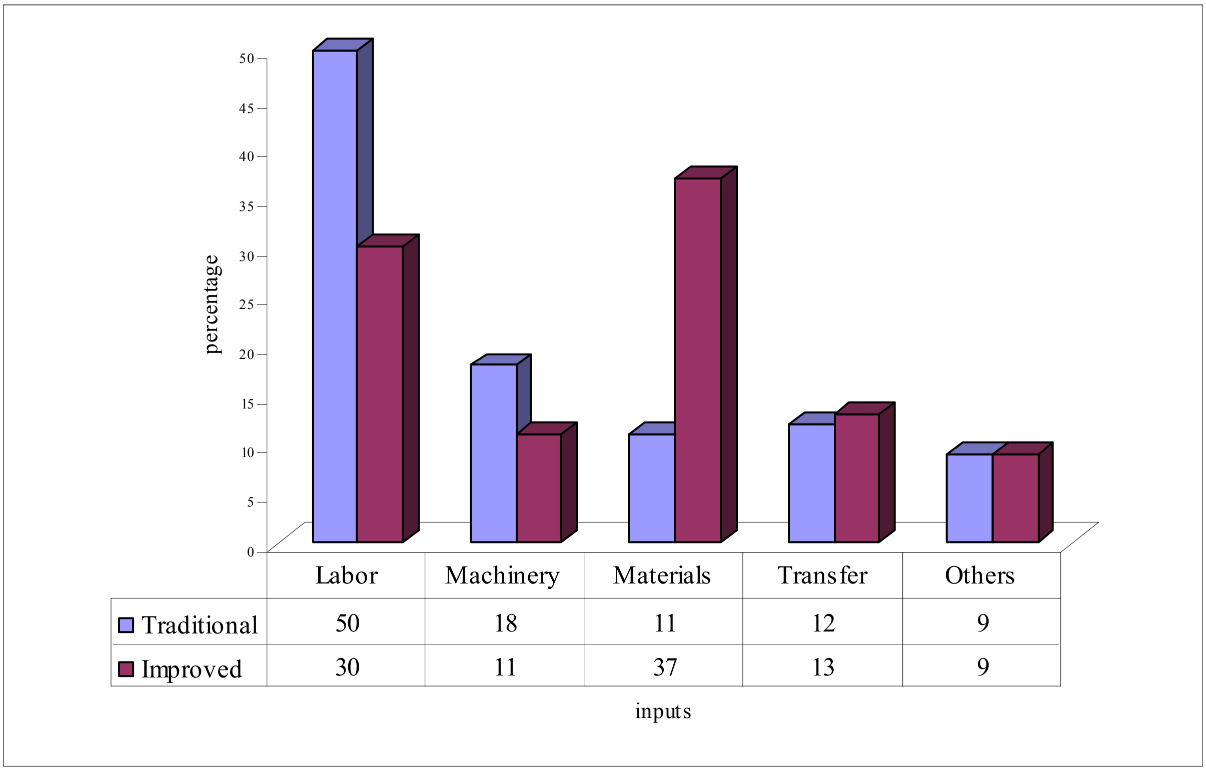
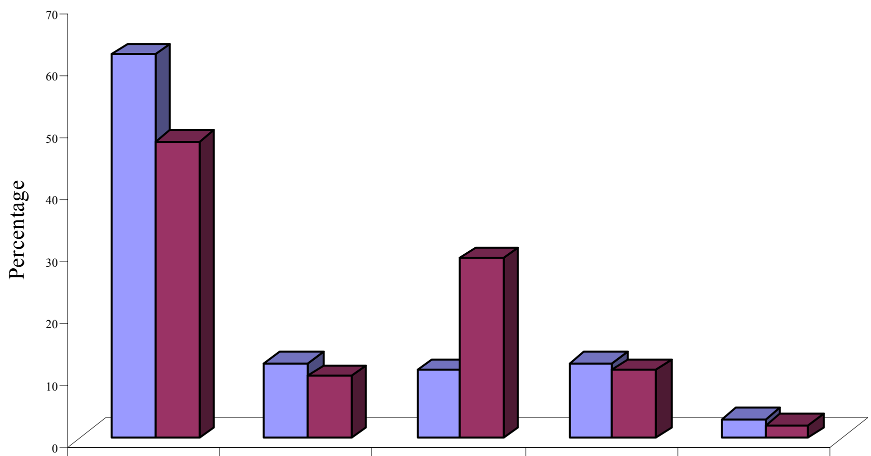


Figure 6.1: Sorghum Inputs Costs as Percentage from Total Cash Costs under Traditional and Improved Practices, Gadaref Area, 2003/04

Figure (6.2) shows the modifications of costs structure in sesame crop as a result of applying the new recommended technology. Labor cost decreased to 48% in the modern technology budget compared to 62% in the traditional budget for sesame production. The change in labor cost of sesame production is not as high as that of sorghum because the larger part of it originates from harvesting operations which have not been changed as a result of applying the technological package. The major component of capital use i.e. input materials increased to 29% in the modern technology budget compared to 11% in the traditional budget. The change accounted by transfers was relatively less because of meager increase in yield despite the use of modern technology. However, although the use of herbicides in sesame has reduced the cost of weeding the increase in the costs as a result of application of fertilizers outweighed the total increase in returns.



	Labor	Machinery	Materials	Transfers	Others
Traditional	62	12	11	12	3
Improved	48	10	29	11	2

Inputs

Figure 6.2: Sesame Inputs Costs as Percentage from Total Cash Costs under Traditional and Improved Practices, Gedaref Area, 2003/04

6.3 Analysis of Costs and Returns of Gum Arabic Production

Aiming at protecting the natural cover from the encroachment of cropping activities, the State Ministry of Agriculture in Gedaref region introduced a law of planting 10% of the farm total area with forest trees as a shelter belt. The inclusion of shelter belts in the mechanized farming system of Gedaref started in 1994 which consist of planting lines or retained national forests. However, these measures have not yet been fully enforced.

The establishment, production costs and returns of acacia trees in the rain-fed areas of Gedaref are calculated according to information gathered from the Gum Arabic Farmers Union and the States Ministry of Agriculture. In the first year the operations of pre-planting and planting of the trees are estimated considering the density of 300 trees per feddan. The acacia forest plantation can be raised by direct planting of seedlings or by sowing acacia seeds using tractor and wide level disc and the latter is the common practiced method in the Gedaref region.

Acacia Senegal tree starts to produce gum arabic, which is its most important economic product, after four years since planting. The costs and returns of gum production vary from the first to the fifth year of the tree age, and from the fifth till the 20th year of the tree age, costs and returns are assumed to be of the same level. Different budgets for each year during the first five years of the tree life were calculated for gum arabic enterprise. The first year budget (2003/2004) described the cost of establishing the acacia forest; these included the cost of land preparation, sowing and weeding. During the years from the second to the fourth (2004/2005 – 2006/2007), no significant variable costs were incurred except that of weeding. From the fifth to the 20th year of the tree age, acacia tree starts to produce gum arabic and hence the additional labor costs of gum tapping, collection and marketing were included.

Similar to the variable costs, fixed costs for gum arabic production also vary over the first five years. The capital used to establish acacia forest is assumed to be borrowed from bank according to *Murabaha* form, which is to be repaid within four years with 12% *Hamish Murabaha* (interest). The cost of seeds and seedlings, which is relatively high, was treated as fixed cost and hence distributed over the years of acacia tree expected life span, which is about 20 years. Accordingly, the fixed cost deducted during the first, second, third and the fourth year of the tree establishment included the taxes on machinery, land fees and the annual interest paid on trees investment. From the fifth to the 20th year the forest fees which are paid to the government and the fixed costs of gum tapping equipments were added. The unpaid costs are represented by the non-cash overhead costs that included machinery depreciation, insurance and machinery interest besides the annual costs of seeds or seedlings. The cash capital used to meet the variable expenses of gum production is assumed to be non-borrowed capital; therefore, its costs were treated as non-cash costs.

Table (6.9) displays the structure of the costs in the first year of acacia forest establishment. The table shows that the operating cost represented 82% and 52.1% of cash costs and total costs respectively. Weeding is the most expensive operation which represented 86.7%, 71.4% and 45.2% of operating, cash and total costs respectively. The overhead cash cost was 17.6% and 11.1% of cash and total costs respectively. The cash costs reached SD 2,603 per feddan which was 63.2% of total costs, while non cash costs was 36.8% of total costs.

Table 6.9: Costs Structure per Feddan of Gum Arabic Trees in the First Establishment Year, Gedaref Area, 2003/2004

First year cost	Cost SD	%from operating cost	% from Total cash cost	% from total cost
Operating costs:				
Preplanting and planting	285	13	11	6.9
Weeding	1,861	**87**	**71**	**45**
Total operating cost	**2,145**	**100**	**82**	**52**
Cash overhead costs:				
Taxes	55		2.1	1.3
Land fees	25		1.0	0.6
Interest on trees investment	378		15	9.2
Total cash overhead costs	**458**		**18**	**11**
Total Cash Cost	**2,603**		**100**	63
Investment and ownership cost/ Non-cash overhead cost:				
Machinery depreciation	240			5.8
Insurance	60			1.5
Interest	432			11
Seeds & seedlings	525			13
Interest on operating capital	257			6.3
Total non-cash overhead costs	**1,514**			**37**
Total Costs	**4,117**			**100**

Table (6.10) explains the costs structure of the second, third and the fourth year during which acacia trees do not start gum production. During these years the operating costs are greatly decreasing, they constituted only the weeding costs which corresponded to about 35% of total costs. The fixed cash and non-cash costs were more or less the same as in the first year with only slight differences.

Table 6.10: Costs Structure per Feddan of Gum Arabic Trees of the Second, Third and the Fourth years, Gedaref Area, 2003/2004

Item	Second year		Third year		Fourth year	
	Cost SD	%	Cost SD	%	Cost SD	%
Operating Costs:						
Preplanting and planting	0	0	0	0	0	0
Weeding	205	35	205	35	205	35
Total operating cost	**205**	**35**	**205**	**35**	**205**	**35**
Cash Overhead Costs:						
Taxes	55	9.4	55	9.4	55	9.4
Land fees	25	4.3	25	4.3	25	4.3
Interest on trees investment	294	51	294	51	294	51
Total Cash Overhead Costs	**374**	**65**	**374**	**65**	**374**	**65**
Total Cash Cost	**578**	**100**	**578**	**100**	**578**	**100**
Investment and ownership cost/ non-cash overhead cost:						
Machinery depreciation	240		240		240	
Insurance	60		60		60	
Interest	432		432		432	
Seeds & seedlings	525		525		525	
Total Non-Cash Overhead Costs	**1,257**		**1,257**		**1,257**	
Total Costs	**1,835**		**1,835**		**1,835**	

From the fifth to the 20th year of the tree life span (the years of gum production) the costs structure is assumed to be at the same level during this period. Table (6.11) shows the various cost items at the fifth year. The additional costs of tapping, collecting and marketing of gum arabic were added to reach 37.9%, 41.4% and 20.7% from the operating costs respectively. The operating cost represented 71.4% of the total cash costs and 44.6% of total costs. The cash expenses were 62.4% from total costs while the non-cash costs were 37.6%.

Table 6.11: Costs Structure per Feddan of Gum Arabic Trees at the Fifth Year of life, Gedaref Area, 2003/2004

Fifth year	Costs SD	%from operating costs	%from total cash costs	%from total costs
Operating costs				
Tapping	687	38	27	17
Collection	752	41	30	19
Total marketing cost	376	21	15	9.2
Total operating costs	**1,815**	**100**	**71**	**45**
Cash overhead costs:				
Taxes +Zakat	701		28	17
Land fees	25		0.98	0.6
Forest fees	0.5		0.02	0.01
Total cash overhead costs	726		30	18
Total cash cost	**2541**		**100**	**62**
Investment and ownership cost/ non-cash overhead cost:				
Machinery depreciation	240			5.9
Insurance	60			1.5
Interest	432			11
Seeds & seedlings	525			13
Hand tools	58			1.4
Interest on operating capital	218			5.3
Total non-cash overhead costs	**1,532**			**38**
Total costs	**4,073**			**100**

6.3.1 Analysis of Gum Arabic Returns

As stated above, acacia tree starts to produce gum arabic at its fifth year. Consequently, calculations of gum arabic returns started at the fifth year of the tree establishment. An average yield of 1.7 kantar/feddan was used in the analysis according to reports from acacia trees growers in the study area. Average gum arabic 2003/2004 market prices obtained from Gedaref crops market, which is equal to SD 3,999.9/kantar were used to calculate gum arabic returns.

Table (6.12) shows gum arabic returns from one feddan of acacia trees during the years of production. As it is clear from the table, gum arabic earned enough income to cover the operating, cash and total costs, and hence provided the farmer with a positive net farm income of SD 2,727 per feddan. The break even yield for gum arabic was 0.45 kantar/fed well below the attained yield in the season

2003/2004 (about 27% of the actual yield in the specified season). On the other hand, break even prices were SD 1,067/Kantar (27% of 2003/2004 gum arabic market prices). The good returns achieved from growing gum arabic, attributed to its low cost of production, its good yield and its good prices as well.

Table 6.12: Gross and Net Returns per Feddan of Gum Arabic, Gedaref Area, 2003/2004

Items	Values*
Gross receipts	6,800
Gross margins	4,985
Net cash income	4,259
Net farm income	2,727
Break even yield (kantar/fed)	0.45
Break even price (SD/kantar)	1,067

* Gross and net returns of gum arabic are in Sudanese Dinars

6.3.2 Comparison of Costs and Returns of Sorghum, Sesame and Gum Arabic

Table (6.13) depicts the costs and returns per unit area of growing sorghum and sesame compared to costs and returns of producing gum arabic during the fifth year of production considering 2003/2004 yields and prices for the three enterprises. It is noticeable from the table that the cost of producing gum arabic was well below the costs required to produce sorghum or sesame. The operating, cash and total costs required to produce one feddan of gum arabic were lower by 71%, 63% and 48% respectively from those required to produce one feddan of sorghum. Moreover, they were respectively lower by 86%, 83%, and 75% of the operating, cash and total costs required to produce one feddan of sesame.

On the other hand, the returns obtained from growing one feddan of acacia are much higher than those obtained from growing sorghum or sesame. As can be seen from table (6.13), the gross margins and net cash income earned from a feddan of gum arabic were higher by 1674% and 1149% respectively of the returns obtained from a feddan of sorghum. Also they were higher by 48% and 152% than sesame gross margins and net cash income per feddan respectively.

Table 6.13: Comparison of Costs and Returns of Sorghum, Sesame and Gum Arabic, Gedaref Area, 2003/2004

Item	**Sorghum SD/fed.**	**Sesame SD/fed.**	**Gum arabic SD/fed.**	**Difference GA/SO* (%)**	**Difference GA/SE* (%)**
Operating costs	6,255	12,964	1,815	71	86
Cash costs	6,942	14,651	2,541	63	83
Total costs	7,895	16,438	4,073	48	75
Gross margins	281	3,377	4,985	1,674	48
Net cash income	-406	1,690	4,259	1,149	152

*GA indicates gum arabic, SO sorghum and SE sesame

On the other hand, growing 100 feddans from the 1,000 feddans farm area with gum arabic instead of growing them with sorghum and sesame earned additional net income of SD 402,747 using 2003/2004 market prices and yields of gum arabic, sorghum and sesame as indicated by the partial budget presented in table (6.14).

Table 6.14: Partial Budget for Growing 100 Feddan with Gum Arabic Instead of Sorghum and Sesame

Additional costs (SD)		**Additional income (SD)**	
From gum arabic*:		From gum arabic*	680,000
Fixed costs	5,800		
Variable costs	181,453		
		Reduced costs (SD)	
Reduced income (SD)		From sorghum & sesame:	
Sorghum + sesame	849,680	Fixed costs	0
		Variable costs	759,680
(A)Total annual additional costs and reduced income	1,036,933	(B)Total annual additional income and reduced costs	1,439,680
		Net change in profit (B-A)	**402,747**

* Costs and returns from gum arabic are those at the fifth year of production.

From the results displayed in tables (6.13) and (6.14) above, it can be seen that gum arabic production is profitable enough to cover its total costs and to compensate farmers for losses from not growing sorghum and sesame only during the years of gum production (from the fifth year and afterwards). The problem lies within the first four years of the tree establishment since during this period there are considerable expenses and no output from the tree.

The financial and environmental benefits gained from growing gum arabic trees can be attainable in the long run. But the low cash income obtained from growing sorghum and sesame and the limited availability of cash capital to farmers explain their behavior towards gum arabic production. Therefore efforts should be done to support growing gum arabic trees so that farmers could be able to withstand the losses through the first four years of growing the tree and then have the chance to enjoy its various benefits during the years of gum production.

6.4 Analysis of Costs and Returns of Sheep Production

Livestock in the study area is dominated by sheep production and therefore sheep rearing is proposed for the farmers as a component of risk-mitigating strategies. The main reasons behind this strategy are as follows:

- Sheep is characterized by high fertility with two deliveries in a single season, the first is in autumn and the second is in winter. In addition, they are adapted to the harsh environment of the region.
- In Sudan the demand on sheep meat is high especially during the time of religious and social occasions. Furthermore, prices of sheep are reasonable, which facilitates the processes of buying and selling when needed.

The rearing system practiced in the region is described as extensive, that the herds spend the rainy season (June to November) in the neighboring natural pasture and return to the Gedaref area during the dry season after harvest in November to feed on crop residues, particularly sorghum.

6.4.1 Sheep Costs and Returns

To calculate costs and returns of sheep production within this study, the sampled farmers average herd size of 180 heads of sheep was used as a start point for the number of sheep that farmers can keep beside their crops activities. In Gedaref area sheep are kept for their meat and they are sold as live animals. Table (6.15) shows the structure of costs and returns of sheep production in the study area. The operating costs items involved the costs of purchasing supplement water during the dry season (October–March), labor cost, veterinary and medicines cost, hay and marketing cost and the cost of borrowed capital to meet the variable expenses. Fixed cost for sheep production included the interest on livestock investment. The original herd of sheep assumed to be obtained by farmers through a loan from bank in *Murabaha* form. This loan is to be repaid within four years period with *Hamish Murabaha* (interest) of 12%.

As shown by the table, the operating costs represented about 82% of the total costs. Labor cost was the highest in the costs structure representing about 45% of the total variable costs. The availability of drinking water for animals during the dry season is the main problem facing farmers, and hence its cost represented about 13% of total operating costs. Although the sheep herds are fed from the farm, cutting and piling of sorghum straw have costs that represented about 19% of the total variable costs.

Production of livestock in Gedaref region is mainly for commerce. The autumn offspring are sold in December, while winter offspring are sold in July. As it can be seen from table (6.15), the gross returns were over the operating costs by 141% and the net income was over the total costs by 81%. This indicates the very high returns from livestock investment in the region.

One important thing to mention about sheep production is that its marketing coincides with cash requirements for some agricultural operations. The returns from sheep sales during July can help to provide cash required to pay labor wage for weeding of sorghum and sesame. On the other hand, returns from sheep selling in December can be used to finance sorghum and gum arabic harvesting.

Table 6.15: Structure of Costs and Returns of Sheep Production, Gedaref Area, 2003/2004

Item	Per herd (SD)	Per head (SD)	% from operating costs	% from Total costs
Cash receipts	1,800,000	10,000		
Operating costs:				
Purchased supplement (water)	70,000	389	13	11
Veterinary and medicine	30,000	167	5.6	5
Labor	240,000	1,333	45	37
Hay	100,000	556	19	16
Marketing cost	31,960	178	6	5
Interest on operating cost	56,700	315	11	9
Total operating costs	528,595	2,937	100	82
Cash overhead costs				
Interest on livestock investment	92,571	514		14.5
Miscellaneous (Zakat)	20,000	111		3
Total cash overhead cost	112,571	625		17.5
Total costs	641,167	3,562		100
Gross income	1,271,405	7,063	141	
Net income	1,158,834	6,438		81

6.5 Sensitivity analysis

HULL (1980) suggested that to test the significance of risk in a particular system, sensitivity analysis for some uncertain variables in that system should first be performed before conducting any risk analysis. Therefore in the following section sensitivity analysis for the most important uncertain variables included in the stochastic budgeting analysis is conducted and the results are presented. The uncertain variables considered to be important and proposed to be included in the risk analysis for the current farming system of growing sorghum and sesame in Gedaref area include the gross margins of sorghum and sesame crops. The net farm income for each of the above mentioned enterprises was then calculated as shown in table (6.16). The inflation corrected minimum, most likely and maximum values for the historical gross margins of traditional sorghum and sesame are obtained from time series data for the period (1990-2004) and then used for calculating farm income. The 2003/2004 fixed costs levels corrected also for inflation were deducted from the minimum, most likely and maximum gross margins of sorghum and sesame crops to obtain inflation corrected net farm income for each case as shown in table (6.16).

The results for sensitivity analysis are shown in the table (6.16). As can be seen from the table, there was a big difference between the net farm incomes when the minimum, most likely and maximum values of the gross margins of sorghum and sesame were used. They varied between SD -10.7, SD 6.2 and SD 27 in their real values for sorghum when the minimum, most likely and maximum gross margins respectively were used in the calculations of net farm income. For sesame crop as illustrated in the table, net farm income varied from SD -11.1 when minimum gross margins were used to SD -5.9 when the most likely value was used and reached SD 55.3 for the maximum value.

From the sensitivity analysis performed above it can be concluded that the variability of sorghum and sesame gross margins is significant to cause variation in net farm income generated from the business. Accordingly, the analysis of risk will be conducted in the next chapter and the results will be presented and discussed.

Table 6.16: Sensitivity Analysis of Sorghum and Sesame Crops under Various Gross Margins levels, Gedaref Area, Sudan

	Sorghum		**Sesame**	
	Gross margins SD/fed	Net farm income SD/fed	Gross margins SD/fed	Net farm income SD/fed
Minimum	5.4	-10.7	0.14	-11.1
Most likely	11.6	6.3	5.3	-6.0
Maximum	32.3	27.0	66.7	55.4

7 RESULTS OF STOCHASTIC BUDGETING AND STOCHASTIC EFFICIENCY ANALYSIS

In this chapter the current and the proposed strategies to mitigate the business risk under both traditional and improved cultural practices in growing sorghum and sesame crops are evaluated and ranked in terms of their risk efficiency using stochastic budgeting and stochastic efficiency methods and the results are presented and discussed. This chapter is comprised of three main sections. The first section is based on the results of stochastic budgeting representation of production strategies when the conventional cultural methods are practiced. The results of the stochastic budgeting analysis for the strategies under the improved techniques are presented in the second section while the effect of different financial leverage on the level of business risk is evaluated in the third section.

7.1 Stochastic Budgets Results for the Strategies under the Traditional Practices

The stochastic budget representation of the strategies one to four that presented in section (5.4.1.1) for the twenty year planning period (2003/2004-2022/2023) is illustrated in figure (7.1) in an Excel format. In this figure the @ Risk functions, which are used to represent the uncertain quantities, and the Excel formulation of the output function for the performance measure of interest (NPV in this study), are indicated in column V together with the formulation of the equation for obtaining farm income at the 20th year of the planning period. The distribution of the stochastic input variables considered for this study are obtained using BestFit software for historical, inflation corrected gross margins of sorghum and sesame crops and historical inflation corrected prices of gum arabic and sheep enterprises (see section 5.4.1.2). The specified input and output variables are set at their mean values in the corresponding cells in column U until the simulation started. The mean values for the uncertain variables were obtained from the inflation corrected time series data of sorghum and sesame gross margins and gum arabic and sheep prices for the period (1990-2004).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Strategy One	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	
2	Sorghum gross margin per fed (SD)																				6.2	=RiskInvgauss(15.202, 28.486, RiskShift(-8.9565), RiskCorrmat(NewMatrix,2))
3	Sesame gross margin per fed (SD)																				23.6	=RiskInvgauss(30.331, 57.24, RiskShift(-6.6913), RiskCorrmat(NewMatrix,1))
4	Total cost per farm (SD)	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	3893.5	
5	Farm income (SD)	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	5830.8	=((800*U2)+(200*U3))-U4
6	NPV		0.12																		43553.2	=RiskOutput("NPV (strategy one)") + NPV(C6,B5:U5)
7																						
8																						
9	Strategy Two	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	
10	Sorghum gross margin per fed (SD)																				6.2	=RiskInvgauss(15.202, 28.486, RiskShift(-8.9565), RiskCorrmat(NewMatrix,2))
11	Sesame gross margin per fed (SD)																				23.6	=RiskInvgauss(30.331, 57.24, RiskShift(-6.6913), RiskCorrmat(NewMatrix,1))
12	Gum arabic yield per fed (kantar)	0	0	0	0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	
13	Gum arabic price per kantar (SD)																				22.5	=RiskLoglogistic(1, 16.044, 2.4443)
14	Gum arabic variable cost per fed (SD)	7	0.7	0.7	0.7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
15	Total cost per farm (SD)	4144.3	2975.3	4033.5	4033.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	4027.5	
16	Farm income (SD)	3911.2	5710.2	4652.1	4652.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	7749.1	=(720*U10)+(180*U11)+(((U12*U13)-U14)*100)-U15
17	NPV		0.12																		48656.7	=RiskOutput("NPV (strategy two)") + NPV(C17,B16:U16)
18																						
19																						
20	Strategy Three	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/20	2021/22	2022/23	
21	Sorghum gross margin per fed (SD)																				6.2	=RiskInvgauss(15.202, 28.486, RiskShift(-8.9565), RiskCorrmat(NewMatrix,2))
22	Sesame gross margin per fed (SD)																				23.6	=RiskInvgauss(30.331, 57.24, RiskShift(-6.6913), RiskCorrmat(NewMatrix,1))
23	Sheep price per head (SD)																				46.7	=RiskInvgauss(45.699, 105.872, RiskShift(1))
24	Sheep yield (head)	180	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	180	
25	Sheep variable cost per herd (SD)	1716	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	1716	
26	Total cost per farm (SD)	4258.9	4192.2	4192.2	4192.2	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	3958.4	
27	Farm income (SD)	12155.3	19275.5	19275.5	19275.5	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	19509.2	12455.8	=(800*U21)+(200*U22)+((U24*U23)-U25)-U26
28	NPV		0.12																		137924.6	=RiskOutput("NPV (strategy three)") + NPV(C28,B27:U27)
29																						
30																						
31	Strategy Four	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/20	2021/22	2022/23	
32	Sorghum gross margin per fed (SD)																				6.2	=RiskInvgauss(15.202, 28.486, RiskShift(-8.9565), RiskCorrmat(NewMatrix,2))
33	Sesame gross margin per fed (SD)																				23.6	=RiskInvgauss(30.331, 57.24, RiskShift(-6.6913), RiskCorrmat(NewMatrix,1))
34	Gum arabic yield per fed (kantar)	0	0	0	0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	
35	Gum arabic price per kantar (SD)																				22.5	=RiskLoglogistic(1, 16.044, 2.4443)
36	Gum arabic variable cost per fed (SD)	7	0.7	0.7	0.7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
37	Sheep price per head (SD)																				46.7	=RiskInvgauss(45.699, 105.872, RiskShift(1))
38	Sheep yield (head)	180	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	180	
39	Sheep variable cost per herd (SD)	1716	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	1716	
40	Total cost per farm (SD)	4509.7	4332.1	4332.1	4332.1	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	4092.5	
41	Farm income (SD)	10235.6	18096.7	18096.7	18096.7	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	21427.5	14374	=(720*U32)+(180*U33)+(((U34*U35)-U36)*100)+((U38*U37)-U39)-U40
42	NPV		0.12																		142184.6	=RiskOutput("NPV (strategy four)") + NPV(C42,B41:U41)

Figure 7.1: Excel Format for the Representation of the Traditional Strategies (One - Four) Budget

The main statistics obtained from running the stochastic budget with @ Risk for 2200 iterations with Latin hypercube sampling for the strategies from one to four were summarized in table (7.1). The table shows the simulation results for NPV of net farm income for the specified strategies at the end of the twenty year planning period (season 2022/2023). The statistics shown in the table are maximum, minimum, mean, mode, range, standard deviation and coefficient of variation (CV) for NPV of the net farm income for the four strategies under consideration. As shown in the table, the results indicate that the coefficient of variation (CV) for strategy one and two is high while it is relatively low for strategy three and four. It ranges between 36% to 95% (36% for strategy four, 40% for strategy three, 76% for strategy two and 95% for strategy one). These results reflect some degree of instability in farm income at the end of the planning period, especially in strategies one and two. From table (7.1) one can derive that in some characteristics each of the strategies has advantage over the others. However strategy four contains the most preferable characteristics followed by strategy three while strategy one has the least favourable characteristics in terms of risk efficiency.

Table 7.1:@ Risk Simulation Results for NPV of Net Farm Income for Different Strategies under Traditional Practices, Gedaref Area, Sudan

Name	Net farm income SD/1000 fed farm			
Description	Output			
	Strategy (1)	Strategy (2)	Strategy (3)	Strategy (4)
Minimum	-11,271	-2,330	45,891	53,481
Maximum	296,861	275,113	498,151	476,562
Mean	43,423	48,542	137,884	142,160
Std Dev	41,113	37,069	54,544	51,438
Mode	14,206	22,353	116,136	100,125
Range	308,131	277,444	452,261	423,081
CV (%)	95	76	40	36

CV: Coefficient of variation

Figures (7.2), (7.3), (7.4) and (7.5) show the distributions for the NPV of farm income presented in form of CDFs generated at the end of the planning horizon for each of the production strategies when the traditional practices are used by farmers to produce their agricultural crops. In each figure, the X axis represents the value of the NPV in Sudanese Dinars (SD) while the Y axis represents the cumulative probability.

Farmers could attain negative net farm income at the end of the planning period in strategies one and two. Figures (7.2) and (7.3) show that the CDFs of strategies one and two lie to the left of the point representing zero farm income, implying a loss at the end of the planning period, which were at varying degrees between the two strategies. These two figures also indicate that choosing strategy one or two entails nearly a 5.5% and a 0.1% chance respectively, of incurring losses at the end of the planning period. Conversely, farmers have about 94.5% chance of earning profit by the end of the planning period if they choose strategy one and nearly 99.9% chance of getting profits from strategy two at the end of the same planning period. On the other hand, figures (7.4) and (7.5) points out that the possibility of farmers to lose by the end of the twenty years planning horizon is zero if they choose strategy three or four. The CDFs for strategies three and four lie to the right of the point representing zero farm income, which indicates the profitability of these two strategies at the end of the planning period.

Figure (7.2) and table (7.2) indicate that ninety percent of NPV of net farm income in strategy one lies between the values of SD -852 and SD 122,251, which have the cumulative probability of 0.05 for the lower bound and 0.95 for the upper bound. This means that 90% of net farm income for this strategy lies within the range of SD 123,103. The expected value of the NPV of net farm income for this strategy is SD 43,423 with a standard deviation of 41,113. The probability of getting this expected value and less is 0.60 and hence the probability of getting the expected value and more is 0.40.

Table 7.2: The Cumulative Probabilities for Some Key Values in Strategy One, Gedaref area, Sudan

Description	Values (SD)	Cumulative Probability
Zero	0	0.055
5th percentile	-852	0.05
Mean	43,423	0.60
95th percentile	122,251	0.95

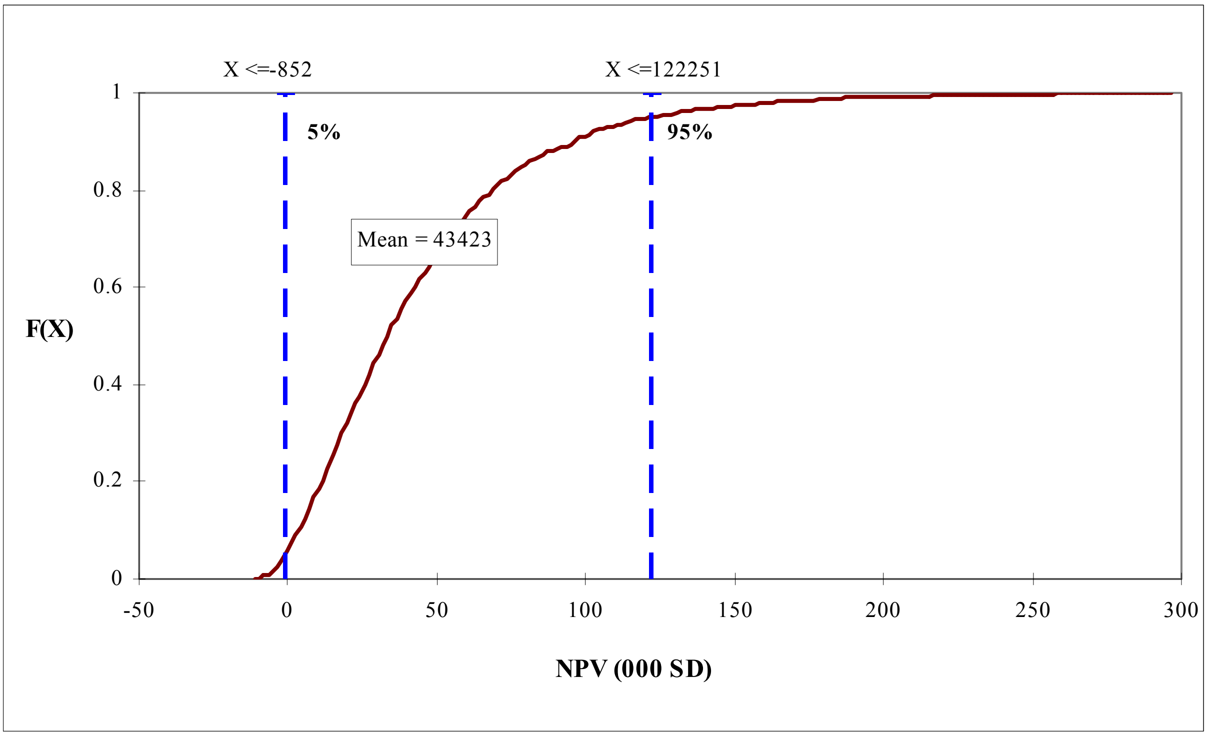


Figure 7.2: CDF of NPV for Strategy One: Traditional Sorghum and Sesame, Gedaref area, Sudan

For strategy two, the information given by figure (7.3) and table (7.3) shows that ninety percent of the NPV of net farm income lies between the values SD 8,102 and SD 119,302 which have the cumulative probability of 0.05 for the lower bound and 0.95 for the upper bound and hence 90% of net farm income for the current strategy lies within the range SD 111,200. The expected value of NPV of farm income for this strategy is SD 48,542 with SD 37,069 standard deviation. The probability to get this expected value and less is 0.60 and hence the probability to get the expected value and more is 0.40.

Table (7.3): The Cumulative Probabilities for Some Key Values in Strategy Two, Gedaref area, Sudan

Description	Values (SD)	Cumulative probability
Zero	0	0.01
5th percentile	8,102	0.05
Mean	48,542	0.60
95th percentile	119,302	0.95

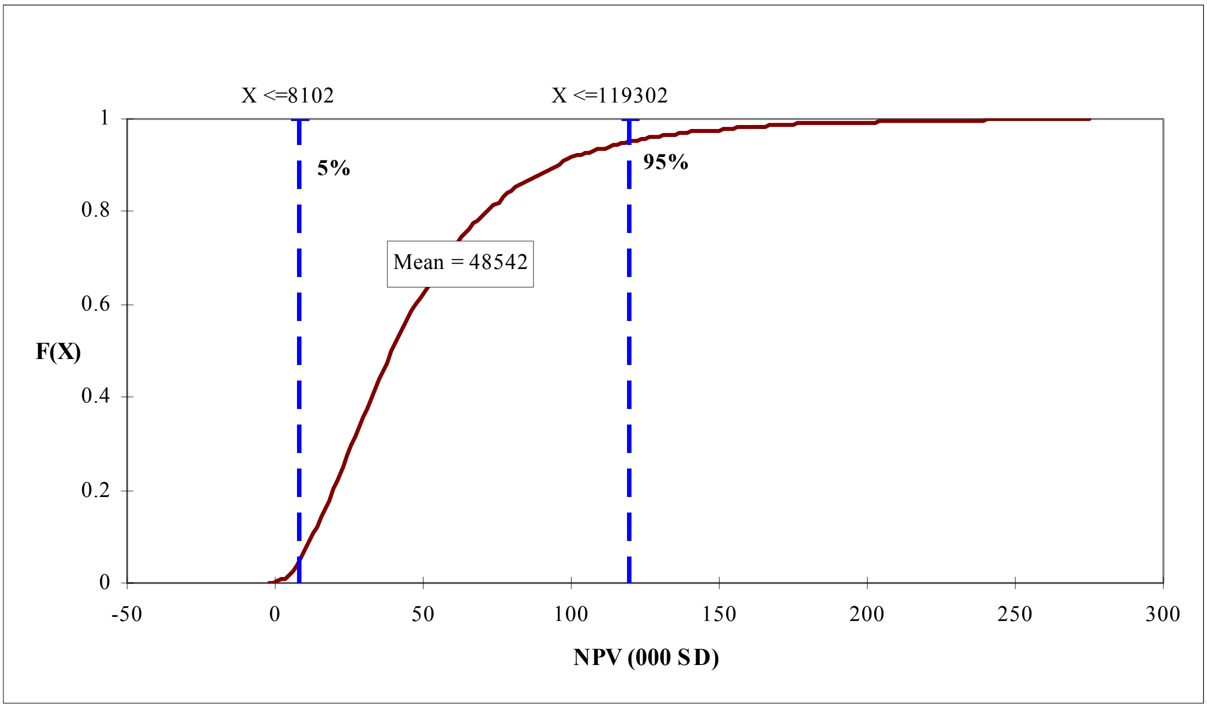


Figure 7.3: CDF of NPV Strategy Two: Traditional Sorghum and Sesame and Gum Arabic Trees, Gedaref Area, Sudan

Figure (7.4) and table (7.4) illustrate that ninety percent of the NPV for farm income in strategy three lies within SD 71,991 as a lower bound with cumulative probability of 0.05 and SD 241,196 as the upper bound with cumulative probability of 0.95. This in turn indicates that 90% of net farm income for this strategy lies within the range of SD 169,205. The expected value of NPV of net farm income in this strategy is SD 137,884 with SD 54,544 standard deviation. The probability of getting the expected value and less is 0.58 and hence the probability of getting the expected value and more is 0.42.

Table 7.4: The Cumulative Probabilities for Some Key Values in Strategy Three, Gedaref area, Sudan

Description	Values (SD)	Cumulative Probability
5^{th} percentile	71,991	0.05
Mean	137,884	0.58
95^{th} percentile	241,196	0.95

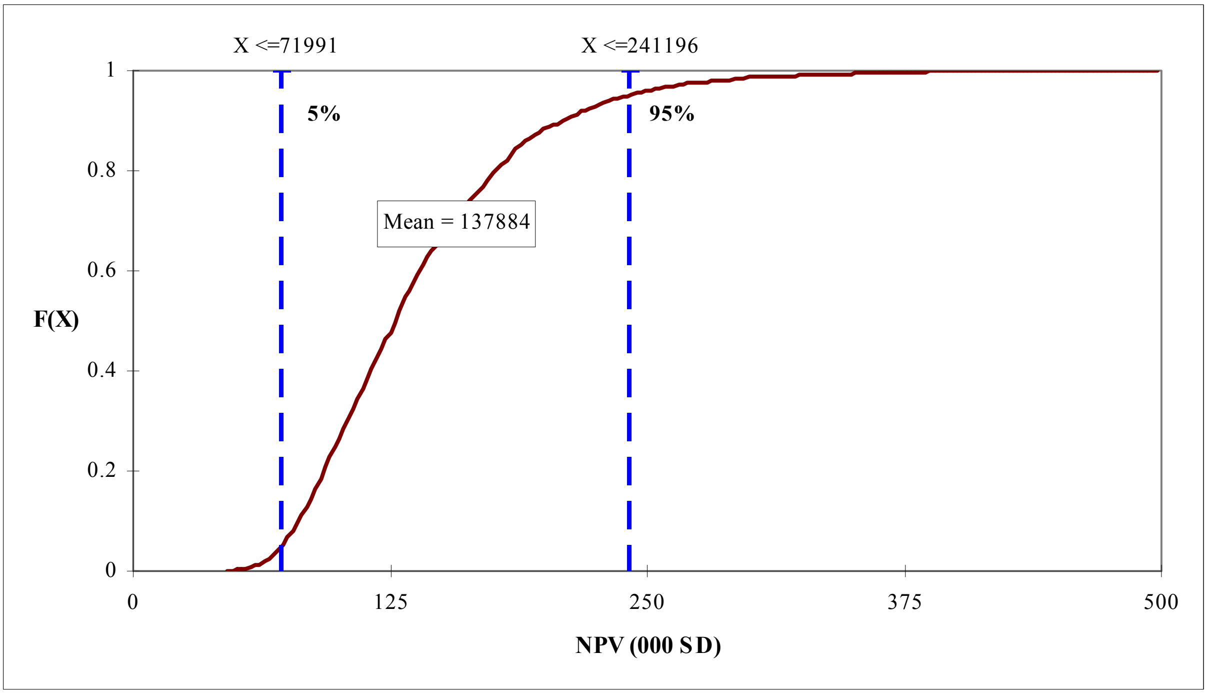


Figure 7.4: CDF of NPV Strategy Three: Traditional Sorghum, Sesame and Sheep Production, Gedaref Area, Sudan

Regarding strategy four, the information given by figure (7.5) and table (7.5) depicts that ninety percent of the NPV of net farm income lies between the value SD 80,515 with the cumulative probability of 0.05 for the lower bound and the value of SD 236,470 as the upper bound with cumulative probability of 0.95. Accordingly, 90% of net farm income lies within the range SD 155,955 for this strategy. The expected value of NPV of net farm income for strategy four is SD 142,160 with SD 51,438 standard deviation. The probability of getting this expected value and more is 0.41, while the probability of getting the expected value and less is 0.59.

Table 7.5: The Cumulative Probabilities for Some Key Values in Strategy Four, Gedaref area, Sudan

Description	Values (SD)	Cumulative Probability
5th percentile	80,515	0.05
Mean	142,160	0.59
95th percentile	236,470	0.95

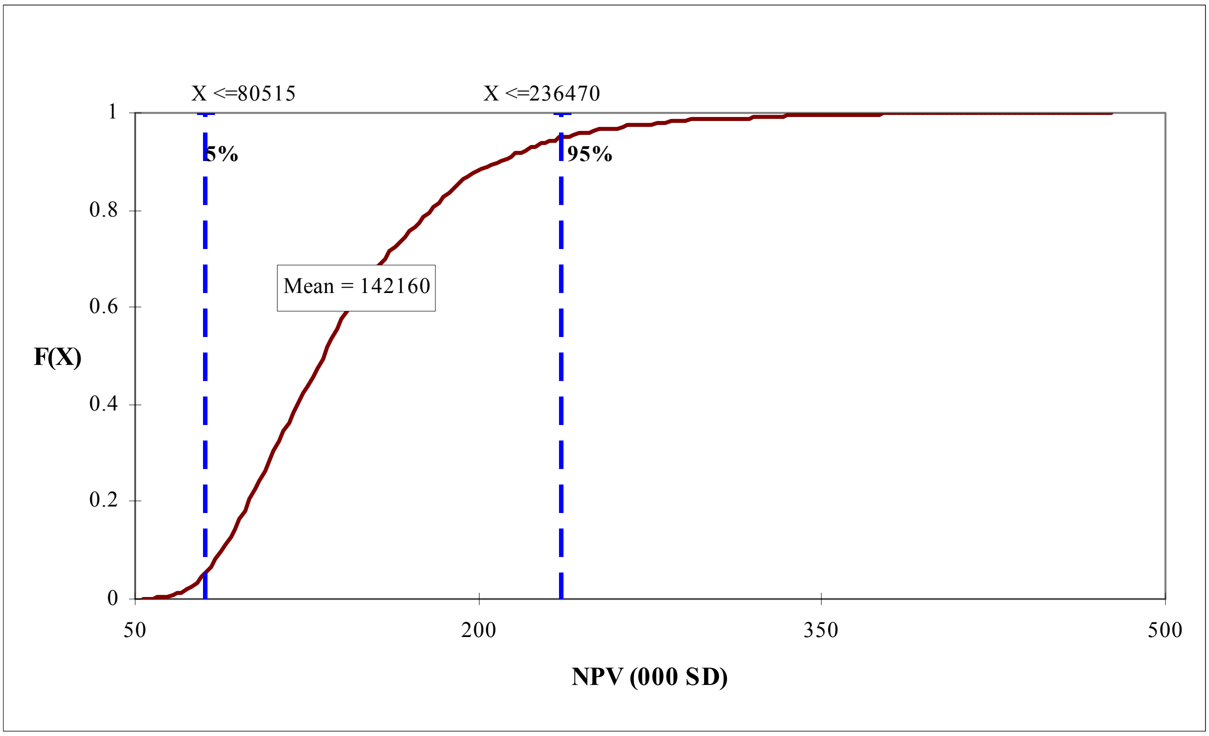


Figure 7.5: CDF of NPV Strategy Four: Traditional Sorghum and Sesame, Gum Arabic and Sheep Production, Gedaref Area, Sudan

Also as they can be derived from diagrams (7.2), (7.3), (7.4) and (7.5), the probabilities of getting farm income equal to or less than the cash expenses that farmers can not avoid paying for the next growing season are as follows:
Using 2003/2004 inflation corrected costs levels and assuming that input levels and prices remained the same as those of 2003/2004 at the end of the planning period, there is a probability of 0.38 to attain farm income of SD 27,541 and less in strategy one, compared to a 0.30 probability of achieving SD 25,611 and less net farm income in strategy two. Alternatively, there are 62% and 70% chances of obtaining farm income at the end of the planning period equivalent to the cash expenses and more in strategies one and two respectively. On the other hand, from diagrams (7.4), (7.5) and table (7.1) it can be noticed that the minimum values achieved in strategies three and four are respectively SD 45,891 and SD 53,481, which are well above the required cash expenses under these two strategies; which amounted to SD 29,622 in strategy three and SD 27,693 in strategy four. It is also observed that there are no considerable differences in the chances of obtaining income enough to cover variable costs and even to cover total costs from those of obtaining income enough to cover cash expenses. This is because the majority of the costs in large scale mechanized farming in Gedaref are concentrated on the variable costs and only minor additional costs are involved as fixed costs.

Figure (7.6) compares the four production alternatives under traditional practices according to their CDFs. From this figure it can be seen that the CDFs graphs of strategies three and four lie to the right of those of strategies one and two. Thus, according to the stochastic dominance criteria, strategies three and four are preferred to strategies one and two in a first degree stochastic sense, i.e. they are preferable for a wide range of absolute risk aversion levels ($+\infty > r_a < -\infty$).

Therefore based on the above results, it can be concluded that ranking the different strategies according to their CDFs graphs (figure, 7.6) or according to their statistics (table 7.1), strategies three and four dominate strategies one and two. The risk efficiency achieved in the two specified strategies may be attributed to the introduction of animals (sheep) to the prevailing farming system, whose characteristics as an effective risk mitigating enterprise were discussed by ANDERSON and DILLON (1992). They attained the same results and further argued that better results can be attained when different animals with different characteristics are introduced to any farming system.

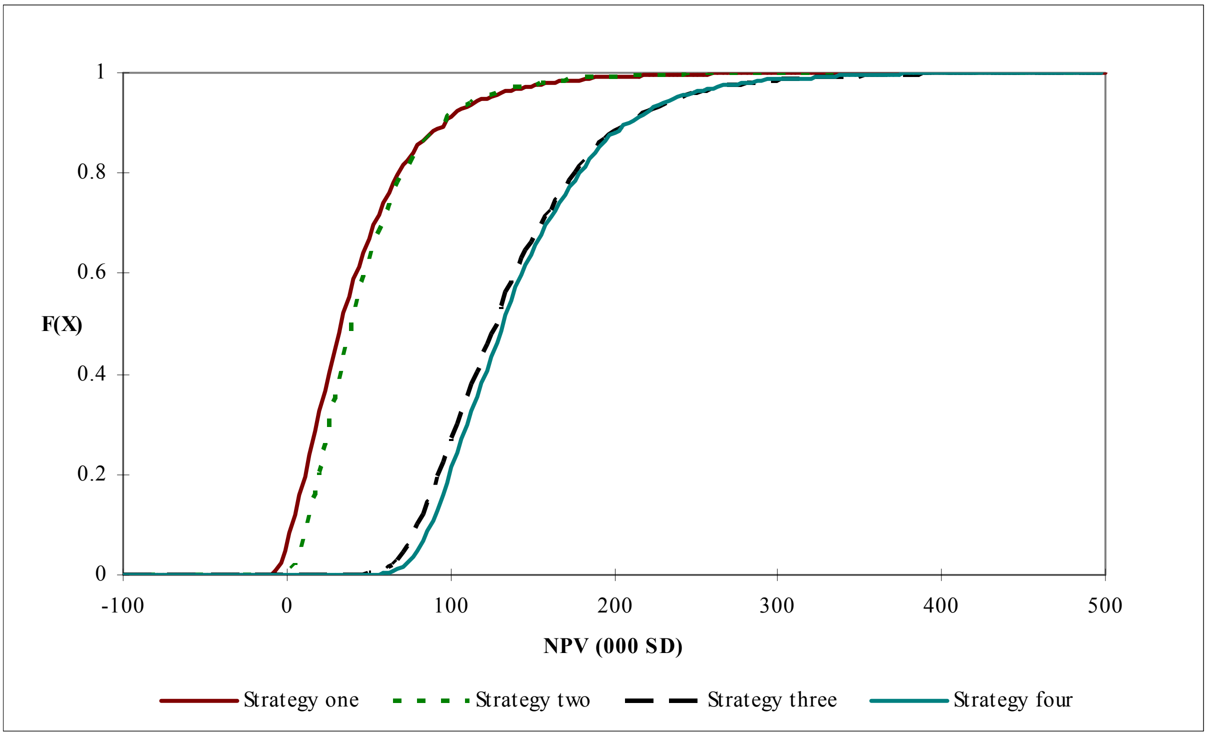


Figure (7.6): CDF Graphs Comparison among the Four Strategies under the Traditional Practices, Gedaref Area, Sudan

7.1.2 Comparison of the Proposed Strategies to the Current Farming System

In the following section, each of the proposed strategies is compared to the existing farming system (growing traditional sorghum and sesame) to see the effect of diversification by introducing gum arabic trees and keeping animals on the level of risk involved in the current farming system. Accordingly, strategies two, three and four are compared separately to strategy one and the results are presented respectively in figures (7.7), (7.8) and (7.9).

Figure (7.7) compares the distribution of the NPV for strategy one (growing sorghum and sesame only) to that of strategy two which includes additionally gum arabic trees. As can be seen from the diagram no major differences in the distributions of the two strategies considered and no major changes can be observed in the minimum, maximum and in the expected values. However, a slight increase is observed in the minimum and expected values in strategy two while the maximum value revealed a slight decrease (table 7.1). The coefficient of variation for strategy two decreased by 19% implying less variation in the NPV in this strategy compared to strategy one. Therefore it can be concluded that introducing acacia trees to the prevailing farming system has a minor effect on mitigating the risk involved in strategy one.

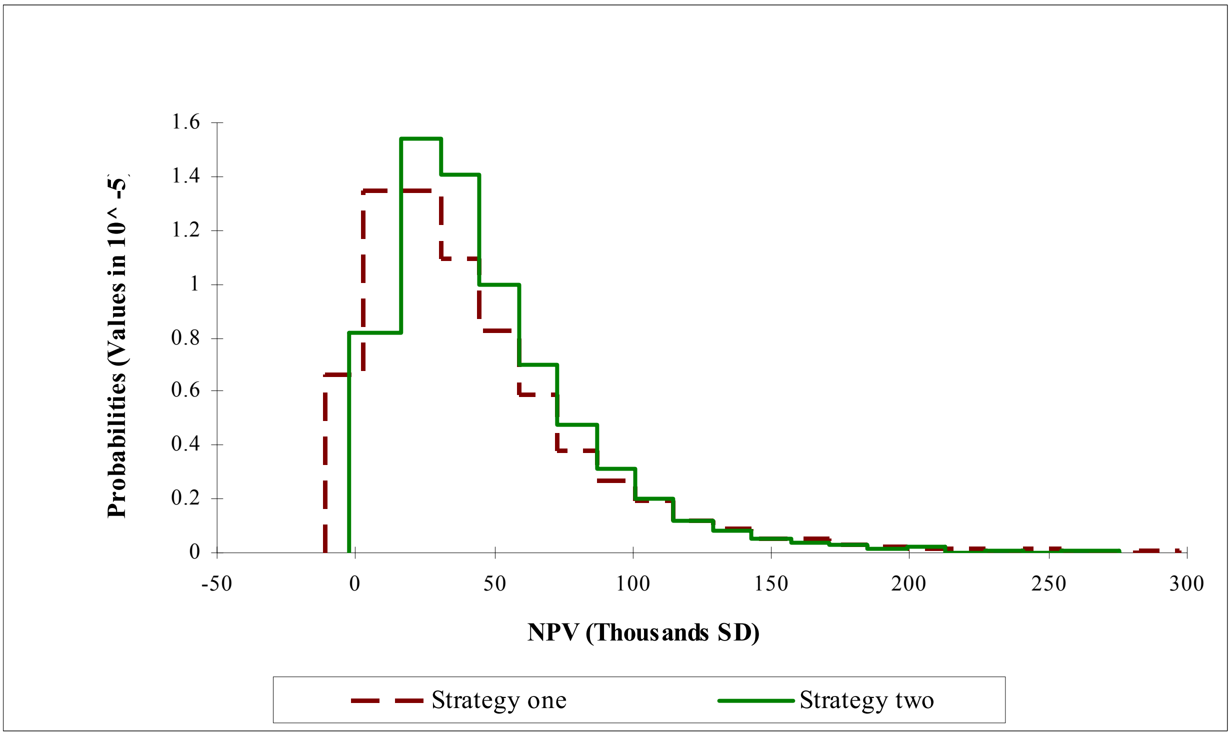


Figure 7.7: Distribution of NPV for Strategy One Compared to Strategy Two, Gedaref Area, Sudan

Figure (7.8) compares strategy one (growing sorghum and sesame) to the option of keeping animals besides growing sorghum and sesame (Strategy three) while figure (7.9) compares strategy one to the option of keeping animals and growing gum arabic trees besides sorghum and sesame crops (strategy four).

In figure (7.8) a comparison of the distributions of the NPV of farm income for strategies one and three are presented. There is a shift in the distribution towards higher values of farm income in strategy three with higher probabilities of occurrence for these values. Moreover the simulation results demonstrated in table (7.1) show that the minimum, maximum and expected values for this strategy largely exceed those for strategy one. A decrease of 55% in the coefficient of variation is observed, which reflects a more stable farm income at the end of the planning period when sheep production is introduced to the current farming system in Gedaref area.

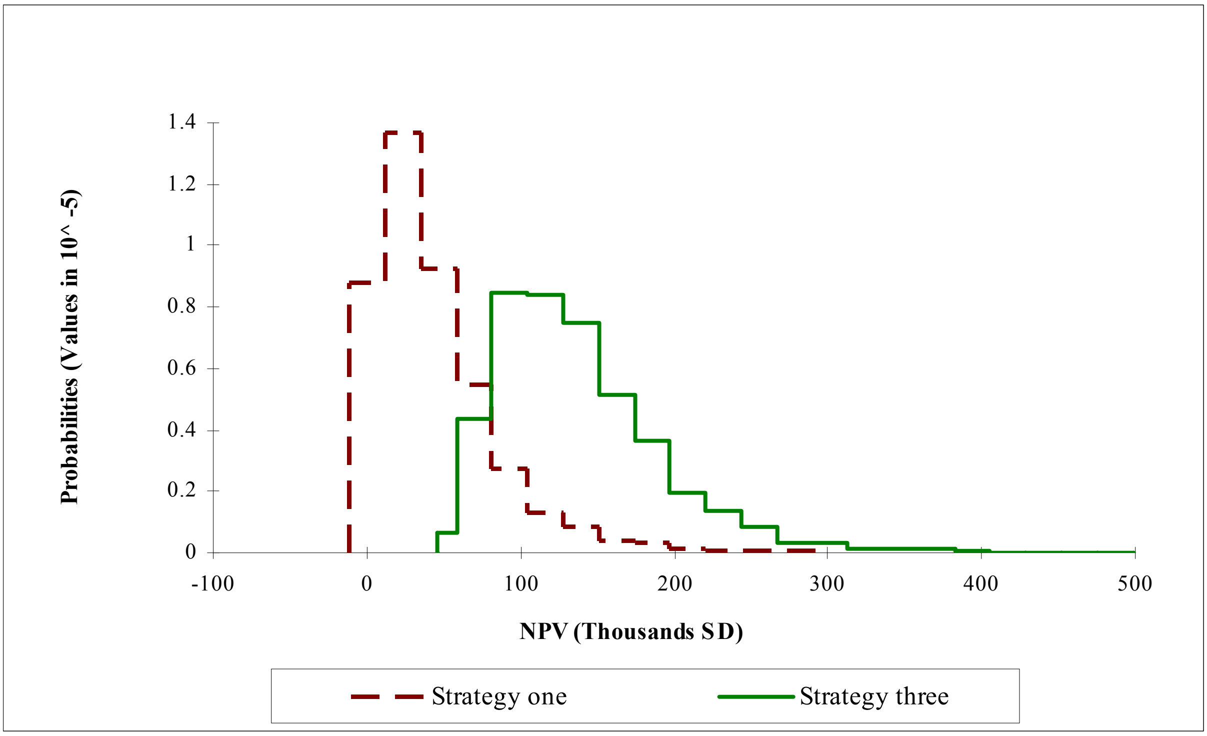


Figure 7.8: Distribution of NPV for Strategy One Compared to Strategy Three, Gedaref Area, Sudan

A comparison of NPV of farm income distribution for strategy one and four is illustrated in figure (7.9). Like strategy three, strategy four distribution shifts towards higher values of farm income indicating higher probabilities for higher values of farm income in strategy four compared to strategy one. The minimum maximum and expected values are also largely increased in this strategy compared to strategy one. The coefficient of variation decreased by 59% as seen in table (7.1) indicating more stability by introducing sheep production and growing gum arabic trees besides sorghum and sesame.

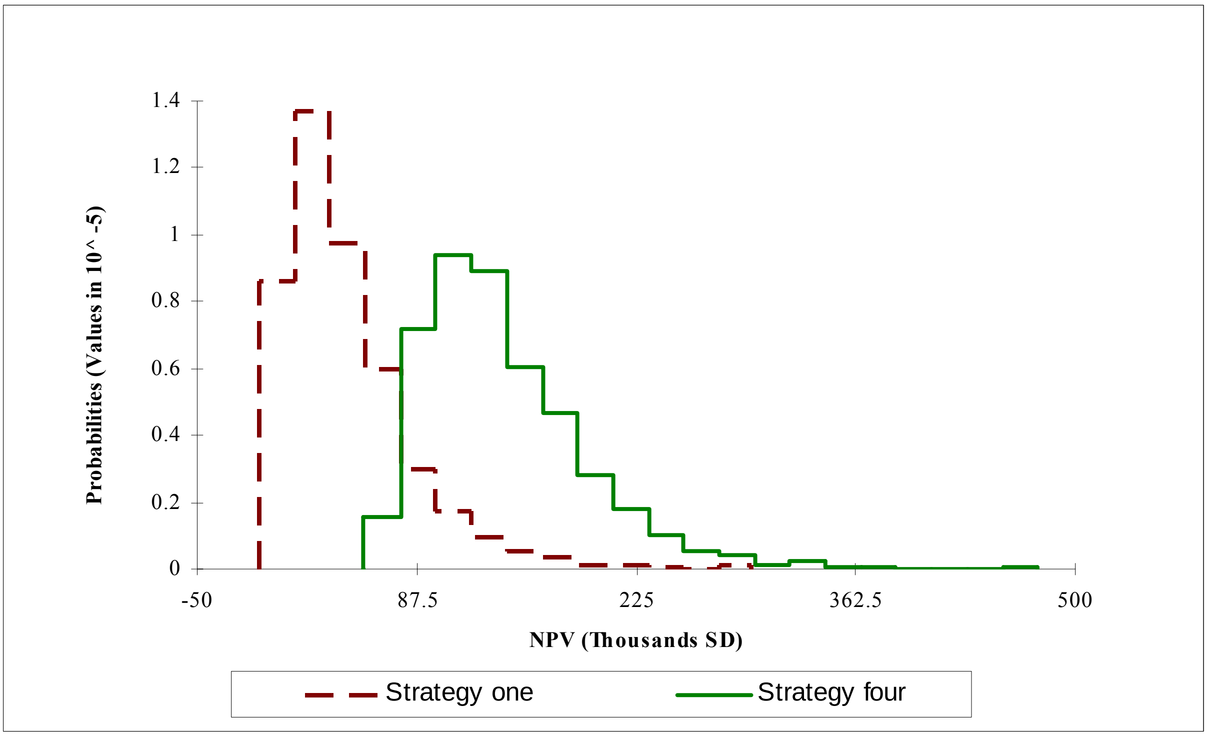


Figure 7.9: Distribution of NPV for Strategy One Compared to Strategy Four, Gedaref Area, Sudan

7.1.3 Results of NPV Sensitivity to the Uncertain Variables

After getting the NPV for the different strategies under investigation at the end of the twenty years planning period, a question arises as to which factors mostly influenced the NPV in each strategy. @Risk Tornado graphs presented in figures (7.10), (7.11), (7.12) and (7.13) for strategies one, two, three and four respectively, were built using step-wise regression to answer this question.

From these graphs the following results are observed:

Figure (7.10) shows that in strategy one a one standard deviation increase in sorghum gross margins increases NPV by 0.76 standard deviations. While a one standard deviation increase in sesame gross margins increases NPV by only 0.39 standard deviations.

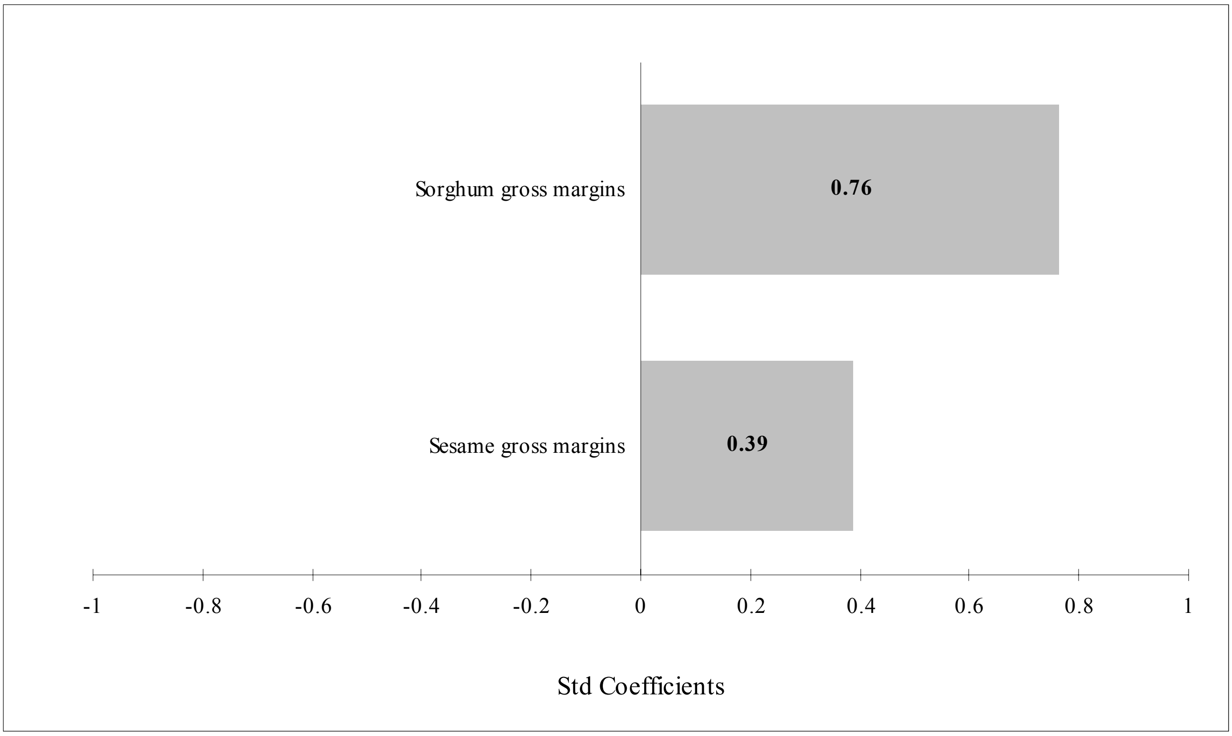


Figure 7.10: Regression Sensitivity for NPV of Net Farm Income, Strategy One, Gedaref Area, Sudan

For strategy two, a one standard deviation increase in sorghum gross margins increases NPV by 0.76 standard deviations. On the other hand, a one standard deviation increase in sesame gross margins increases NPV by 0.39 standard deviations, while the gum arabic prices have low effect that a one standard deviation increase in gum arabic prices increases the NPV by only 0.06 as shown in figure (7.11).

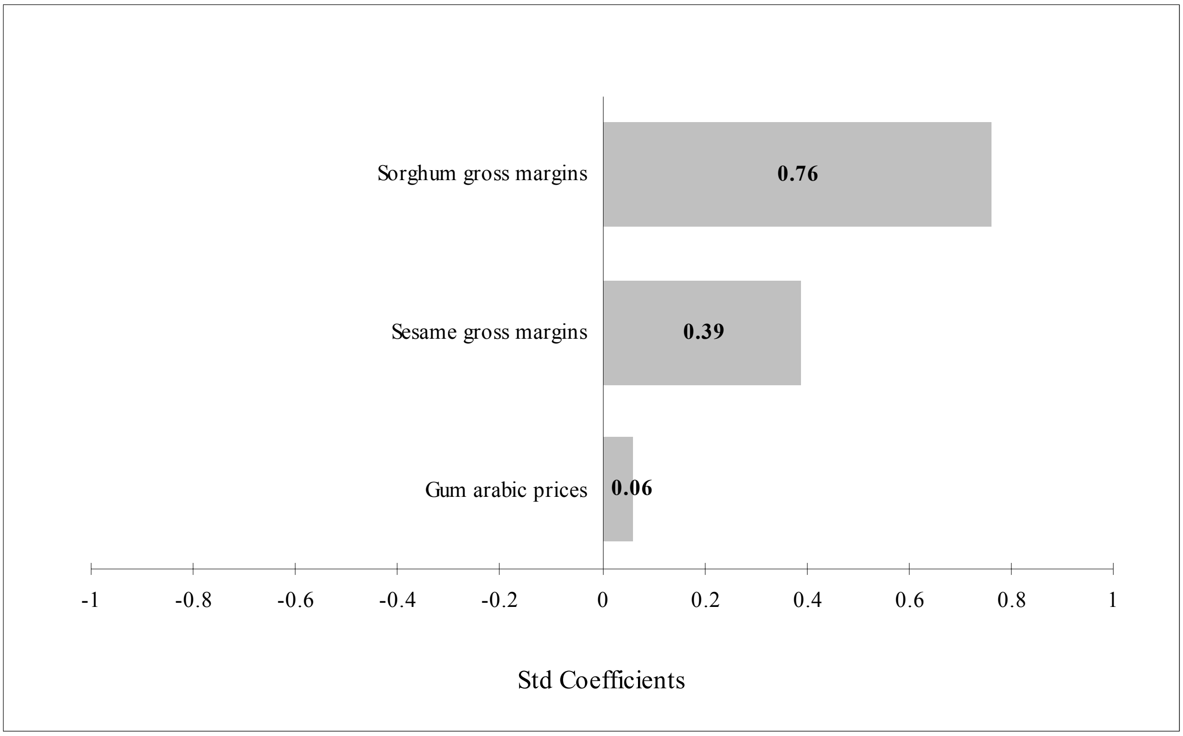


Figure 7.11: Regression Sensitivity for NPV of Net Farm Income, Strategy Two, Gedaref Area, Sudan

In figure (7.12) all the three uncertain variables seem to have an effect on the NPV of net farm income with sheep prices having the greatest effect. A one standard deviation increase in its value increases NPV by 0.63 standard deviations. On the other hand a one standard deviation increase in Sorghum gross margins increased NPV by 0.58 standard deviations and by 0.29 standard deviations in sesame gross margins.

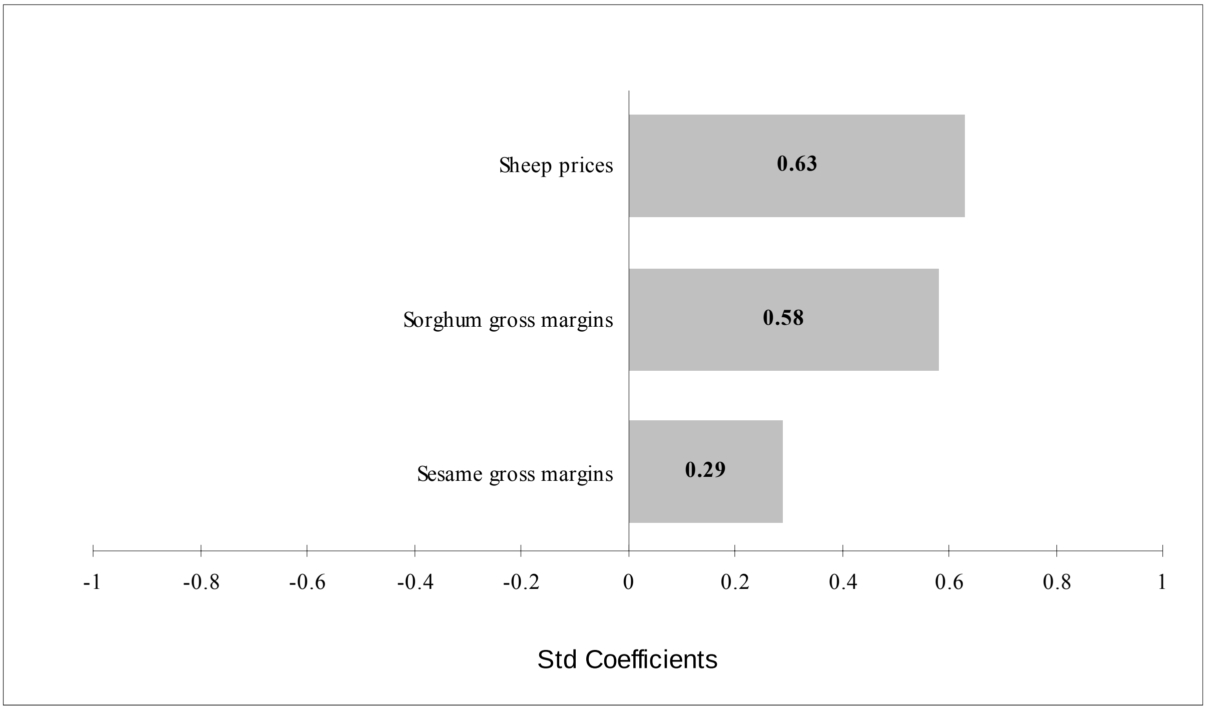


Figure 7.12: Regression Sensitivity for NPV of Net farm Income, Strategy Three, Gedaref Area, Sudan

For strategy four (figure 7.13), sheep prices and sorghum gross margins had the highest influence on NPV compared to sesame gross margins and gum arabic prices. A one standard deviation increase in sheep prices increased NPV by 0.67 standard deviations while an equivalent margin of increase in standard deviations of sorghum gross margins increased the NPV by 0.55 standard deviations. On the other hand a one standard deviation increase in sesame gross margins increased the NPV by 0.28 standard deviations while gum arabic prices had only a slight effect on NPV, a one standard deviation increase in gum arabic prices increased NPV by only 0.04 standard deviations.

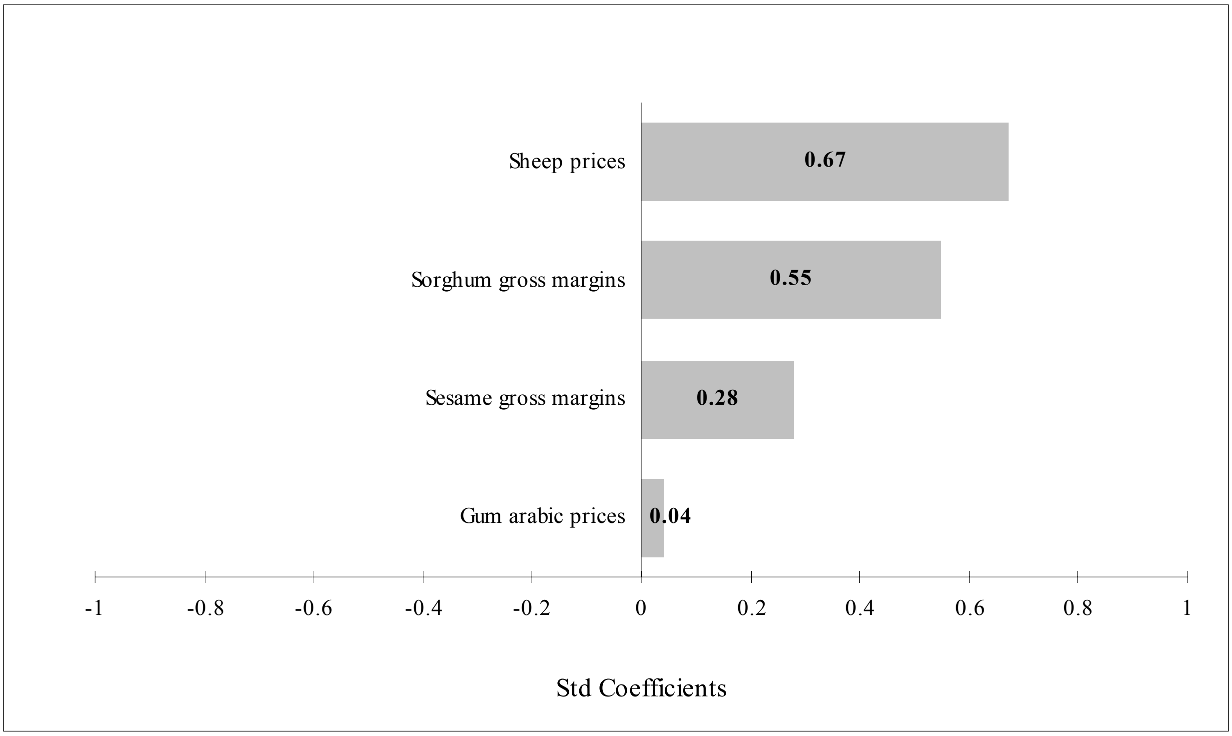


Figure 7.13: Regression Sensitivity for NPV of Net Farm Income, Strategy Four, Gedaref Area, Sudan

From the results shown in figures (7.10), (7.11), (7.12) and (7.13), it can be concluded that sorghum gross margins are the most important factors that have the greatest effect on the NPV for all the four strategies. Equivalently, sheep prices have also a strong effect on NPV for the strategies in which they are involved i.e. strategies three and four, in which cases their influence exceeded that of sorghum gross margins. To a lesser extent, sesame gross margins have also an effect in all the strategies. On the other hand gum arabic prices have the lowest effect on the NPV in strategies two and four in which it is adopted.

7.1.4 Results of Stochastic Efficiency Analysis (SERF Results)

The CDFs graphs for the strategies from one to four presented in figure (7.6) are informative, giving an idea about the risk-efficient strategies in terms of their probabilities distributions. As stated in section 5.4.2 in chapter five, accounting to farmers' attitude to risk besides their beliefs about the uncertain events is equally important when planning farm business under uncertainty. Accordingly, SERF method results which incorporate farmers' aversion to risk besides the probabilities of outcome when ranking the risky strategies under consideration are presented in the following section.

Figure (7.14) shows SERF results for strategies one to four under traditional practices over the absolute risk aversion level with respect to income $r_a(z)$ in the range of 0.00333 to 0.02667, which corresponds to relative risk aversion coefficient $r_r(z)$ in the range 0.33 to 2.67 assuming a negative exponential utility function. The above determined range of $r_r(z)$ is equivalent to a range of relative risk aversion with respect to wealth, $r_r(w)$, between 0.5 and 4. The range for $r_r(z)$ and $r_a(z)$ are approximated by use of equation (19), with wealth *w* equal to SD 150,000 and income *z* equal to SD 100,000 (both in real values). As can be seen from the graph, the points of highest *CE* values are comprised of values for strategy four only, suggesting that this strategy is the risk-efficient strategy.

ELAMIN (1992) estimated relative risk aversion coefficient with regard to wealth $r_r(w)$ of 1.5 to 2.54 for rain-fed traditional farmers in western Sudan. Based on these findings and the fact that farmers in Gedaref area are large scale farmers, narrower risk aversion range of 1.5 to 2.0 can be assumed for this group. This specified range of farmers relative risk aversion is equivalent to a range of farmers absolute risk aversion $r_a(z)$ of 0.01 to 0.013, which was used in the risk premium calculation presented below.

Taking the concept of risk premiums into consideration for farmers in the study area to switch from the less preferred strategy one (growing sorghum and sesame traditionally) to the dominant strategy four (growing traditional sorghum and sesame besides gum arabic and sheep enterprises) for the specified range of relative risk aversion, the following results can be derived from figure (7.14):
The risk premium (RP) between the above specified strategies measured by the vertical distance between the *CE* curves for strategies one and four ranges between SD 96,000 at $r_a(z) = 0.01$ to SD 92,000 at $r_a(z) = 0.0133$. In other words, the gains that farmers in the study area would obtain if they move from strategy one to strategy four or the minimum sure amount that would have to be paid to farmers to switch from strategy one to four are within the range of SD 92,000 to SD 96,000 in real terms for $r_a(z)$ ranges from 0.0133 to 0.01.

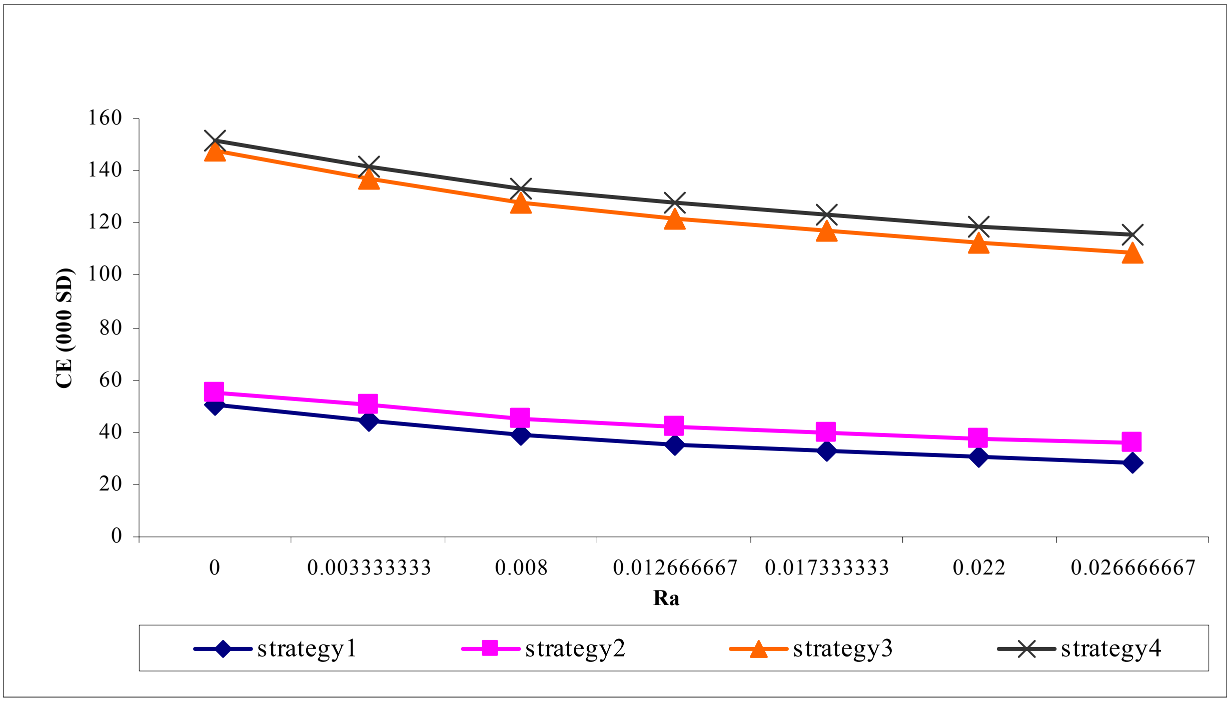


Figure 7.14: CE Graphs for the Different Strategies under Traditional Practices, Gedaref Area, Sudan

7.2 Stochastic Budgets Results for the Strategies under the Improved Practices

In this section the results of the stochastic budgeting and stochastic efficiency analysis for the production strategies under the improved practices in growing sorghum and sesame crops are presented and interpreted.

The stochastic budget demonstrations for the strategies five to eight described in section (5.4.1.1) indicating farmers' improved cultural practices in growing sorghum and sesame crops explained in section (4.2.5), are illustrated in figure (7.15) in an Excel format. As in the strategies under the traditional cultural practices, in the strategies five to eight, @risk functions for the uncertain input variables, the NPV and the function for the farm income at the 20th planning year are illustrated in column V. The values of the uncertain input and output variables are set at their mean values in column U until the simulation started.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
45	Strategy Five	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	
46	Sorghum yield per fed (sack)																				4.5	=RiskTriang(3,4.5,6)
47	Sorghum price per sack (SD)																				14.3	=RiskInvgauss(13.288, 53.251, RiskShift(1))
48	Sorghum variable cost per fed (SD)																				29.7	=RiskLoglogistic(1, 27.282, 5.7362)
49	Sesame yield per fed (kantar)																				2.6	=RiskTriang(1.7,2.6,3.5)
50	Sesame price per kantar (SD)																				23.7	=RiskPearson5(9.9626, 203.52, RiskShift(1))
51	Sesame variable cost per fed (SD)																				34.5	=RiskGamma(17.565, 1.9077, RiskShift(1))
52	Total cost per farm (SD)	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	4397.8	
53	Farm income (SD)	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	28709.1	=(((U46*U47)-U48)*800)+(((U49*U50)-U51)*200)-U52
54	NPV		0.12																		214441.3	=RiskOutput("NPV (strategy five)") + NPV(C54,B53:U53)
55																						
56																						
57	Strategy Six	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/202	2021/22	2022/23	
58	Sorghum yield per fed (sack)																				4.5	=RiskTriang(3,4.5,6)
59	Sorghum price per sack (SD)																				14.3	=RiskInvgauss(13.288, 53.251, RiskShift(1))
60	Sorghum variable cost per fed (SD)																				29.7	=RiskLoglogistic(1, 27.282, 5.7362)
61	Sesame yield per fed (kantar)																				2.6	=RiskTriang(1.7,2.6,3.5)
62	Sesame price per kantar (SD)																				23.7	=RiskPearson5(9.9626, 203.52, RiskShift(1))
63	Sesame variable cost per fed (SD)																				34.5	=RiskGamma(17.565, 1.9077, RiskShift(1))
64	Gum arabic yield per fed (kantar)	0	0	0	0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	
65	Gum arabic price per kantar (SD)																				22.5	=RiskLoglogistic(1, 16.044, 2.4443)
66	Gum arabic variable cost per fed (SD)	7	0.7	0.7	0.7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
67	Total cost per farm	4598.2	4487.3	4487.3	4487.3	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	4481.4	
68	Farm income (SD)	24501.6	25242.5	25242.5	25242.5	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	28339.6	=(((U58*U59)-U60)*720)+(((U61*U62)-U63)*180)+(((U64*U65)-U66)*10
69	NPV		0.12																		201612.4	=RiskOutput("NPV (strategy six)") + NPV(C69,B68:U68)
70																						
71																						
72	Strategy Seven	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/202	2021/22	2022/23	
73	Sorghum yield per fed (sack)																				4.5	=RiskTriang(3,4.5,6)
74	Sorghum price per sack (SD)																				14.3	=RiskInvgauss(13.288, 53.251, RiskShift(1))
75	Sorghum variable cost per fed (SD)																				29.7	=RiskLoglogistic(1, 27.282, 5.7362)
76	Sesame yield per fed (kantar)																				2.6	=RiskTriang(1.7,2.6,3.5)
77	Sesame price per kantar (SD)																				23.7	=RiskPearson5(9.9626, 203.52, RiskShift(1))
78	Sesame variable cost per fed (SD)																				34.5	=RiskGamma(17.565, 1.9077, RiskShift(1))
79	Sheep price per head (SD)																				46.7	=RiskInvgauss(45.699, 105.872, RiskShift(1))
80	Sheep yield (head)	180	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	180	
81	Sheep variable cost per herd (SD)	1716	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	1716	
82	Total cost per farm (SD)	4763.2	4696.4	4696.4	4696.4	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	4462.7	
83	Farm income (SD)	35033.6	42153.8	42153.8	42153.8	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	42387.5	35334.071	=(((U73*U74)-U75)*800)+(((U76*U77)-U78)*200)+((U80*U79)-U81)-U82
84	NPV		0.12																		308812.7	=RiskOutput("NPV (strategy seven)") + NPV(C84,B83:U83)
85																						
86																						
87	Strategy Eight	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/202	2021/22	2022/23	
88	Sorghum yield per fed (sack)																				4.5	=RiskTriang(3,4.5,6)
89	Sorghum price per sack (SD)																				14.3	=RiskInvgauss(13.288, 53.251, RiskShift(1))
90	Sorghum variable cost per fed (SD)																				29.7	=RiskLoglogistic(1, 27.282, 5.7362)
91	Sesame yield per fed (kantar)																				2.6	=RiskTriang(1.7,2.6,3.5)
92	Sesame price per kantar (SD)																				23.7	=RiskPearson5(9.9626, 203.52, RiskShift(1))
93	Sesame variable cost per fed (SD)																				34.5	=RiskGamma(17.565, 1.9077, RiskShift(1))
94	Gum arabic yield per fed (kantar)	0	0	0	0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	
95	Gum arabic price per kantar (SD)																				22.5	=RiskLoglogistic(1, 16.044, 2.4443)
96	Gum arabic variable cost per fed (SD)	7	0.7	0.7	0.7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
97	Sheep price per head (SD)																				46.7	=RiskInvgauss(45.699, 105.872, RiskShift(1))
98	Sheep yield (head)	180	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	180	
99	Sheep variable cost per herd (SD)	1716	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	3068.3	1716	
100	Total cost per farm (SD)	4963.6	4786	4786	4786	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	4546.3	
101	Farm income (SD)	30826	38687.2	38687.2	38687.2	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	42017.9	34964.5	=(((U88*U89)-U90)*720)+(((U91*U92)-U93)*180)+(((U94*U95)-U96)*100)+((U98*U
102	NPV		0.12																		295983.9	=RiskOutput("NPV (strategy eight)") + NPV(C102,B101:U101)

Figure 7.15: Excel Format Representation of the Improved Strategies (Five-Eight) Budgets

The main statistics obtained from running the stochastic budget with @ Risk for the strategies five to eight are summarized in table (7.6). As in the stochastic budget of the traditional strategies, 2200 iterations with Latin hypercube sampling were used. The table shows the simulation results for NPV for farm income for the specified strategies at the end of the twenty years planning period (2003/04-2022/23). The statistics shown by the table are the maximum, minimum, mean, mode, range, standard deviation and the coefficient of variation for the four strategies under consideration. As can be seen from the table, the results show that the coefficient of variations for strategies five and six are higher than the coefficient of variations for strategies seven and eight. These are 32%, 34%, 44% and 46% for strategy eight, seven, six and five respectively. The results reveal some degree of farm income variation for the four strategies at the end of the planning period. However, the variation in farm income is lower in the improved strategies compared to the traditional ones as depicted by the values of the coefficient of variation. In terms of risk efficiency, the table also shows that strategy eight has the most preferred characteristics followed by strategy seven while strategy five involved the least favourable characteristics.

Table 7.6: @ Risk Simulation Results for NPV of Net Farm Income for the Improved Strategies, Gedaref Area, Sudan

Name	**Net farm income SD/1000 fed farm**			
Description	**Output**			
	Strategy (5)	**Strategy (6)**	**Strategy (7)**	**Strategy (8)**
Minimum	-70,251	-55,413	-55	14,783
Maximum	922,351	837,269	998,422	913,340
Mean	215,227	202,322	309,688	296,783
Std Dev	98,712	88,918	104,204	94,999
Mode	182,909	177,385	266,619	376,111
Range	992,603	892,683	998,477	898,556
CV%	46	44	34	32

CV: Coefficient of variation

Figures (7.16), (7.17), (7.18) and (7.19) show the distributions for the NPV of net farm income presented in form of CDFs graphs generated at the end of the planning period for each of the production strategies when the improved cultural practices for growing sorghum and sesame are used by farmers.

As shown by the figures, by applying strategies five, six or seven farmers can attain negative net farm income at the end of the planning period. The CDFs graphs of the three specified strategies are situated to the left of the point representing zero farm income indicating that farmers may lose at the end of the planning period. Farmers will incur losses by the end of the planning period with a nearly 0.2% chance if they choose strategy five or six as suggested by figures (7.16) and (7.17) and tables (7.7) and (7.8). On the other hand figure (7.18) and table (7.9) indicate only a 0.1% chance to lose by the end of the same planning period if farmers choose strategy seven. On the contrary, farmers have about 99.8% chance to earn profit by the end of the planning period if they choose strategy five or six and nearly 99.9% chance of getting profits from strategies seven at the end of the same planning period. Conversely, choosing strategy eight implies a 100% chance of getting profits at the end of the twenty years planning period (strategy eight starts to the right of the point of zero income (figure 7.19)).

Figure (7.16) and table (7.7) show that in strategy five ninety percent of the NPV of farm income lies between the values SD 92,678 and SD 398,526 which have the cumulative probability of 0.05 for the lower bound and 0.95 for the upper bound. This indicates that 90% of net farm income in strategy five lies within the range SD 305,849. The expected value of the NPV of farm income for this strategy is SD 215,227 with SD 98,712 standard deviation. The probability of getting this expected value and less is 0.58 and hence the probability of getting the expected value and more is 0.42.

Table 7.7: The Cumulative Probabilities for Some Key Values in Strategy Five, Gedaref Area, Sudan

Description	Values (SD)	Cumulative probability
Zero	0	0.002
5th percentile	92,678	0.05
Mean	215,227	0.58
95th percentile	398,526	0.95

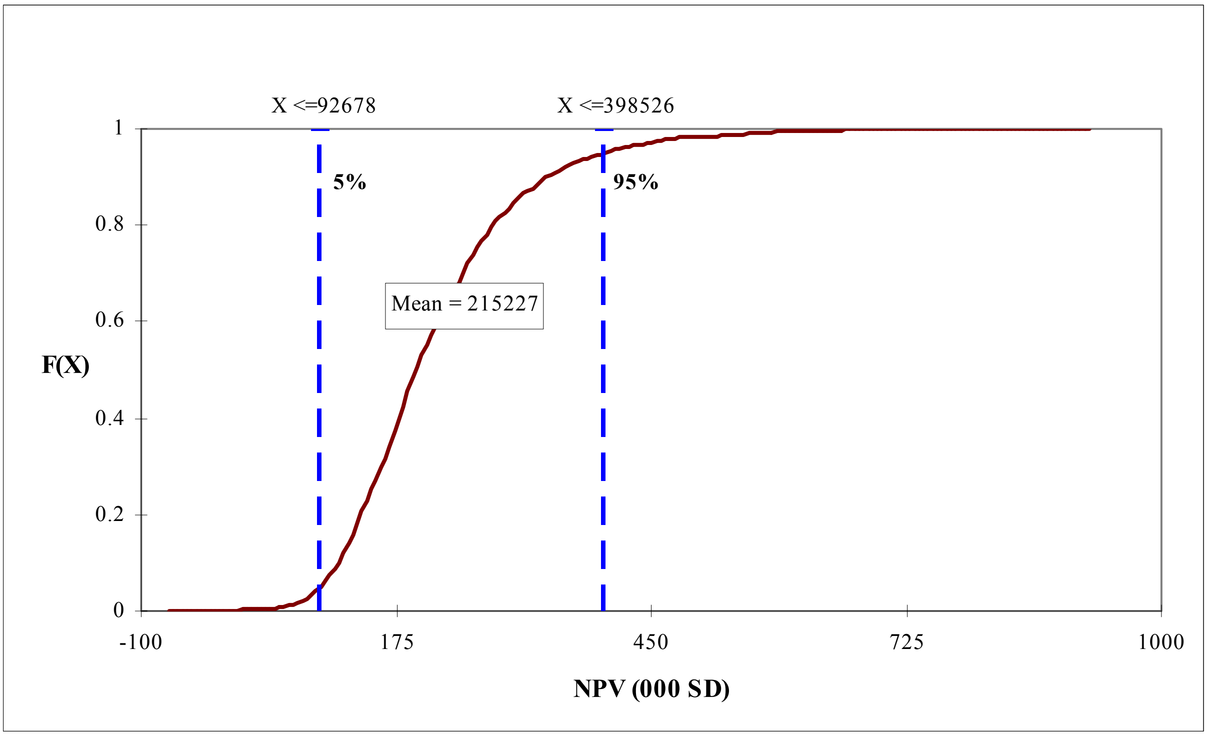


Figure 7.16: CDF of NPV for Strategy Five: Improved Sorghum and Sesame, Gedaref Area, Sudan

For strategy six, the information provided by figure (7.17) and table (7.8) illustrates that ninety percent of the NPV lies between the values SD 90,959 and SD 366,697 with the cumulative probability of 0.05 for the lower bound and 0.95 for the upper bound and hence 90% of farm income for this strategy lies within the range SD 275,738. The mean value of NPV for strategy six is SD 202,322 with SD 88,918 standard deviation. The probability of getting this expected value and less is 0.58 and hence the probability of getting the expected value and more is 0.42.

Table 7.8: The Cumulative Probabilities for Some Key Values in Strategy Six, Gedaref Area, Sudan

Description	Values (SD)	Cumulative probability
Zero	0	0.002
5th percentile	90,959	0.05
Mean	202,322	0.58
95th percentile	366,697	0.95

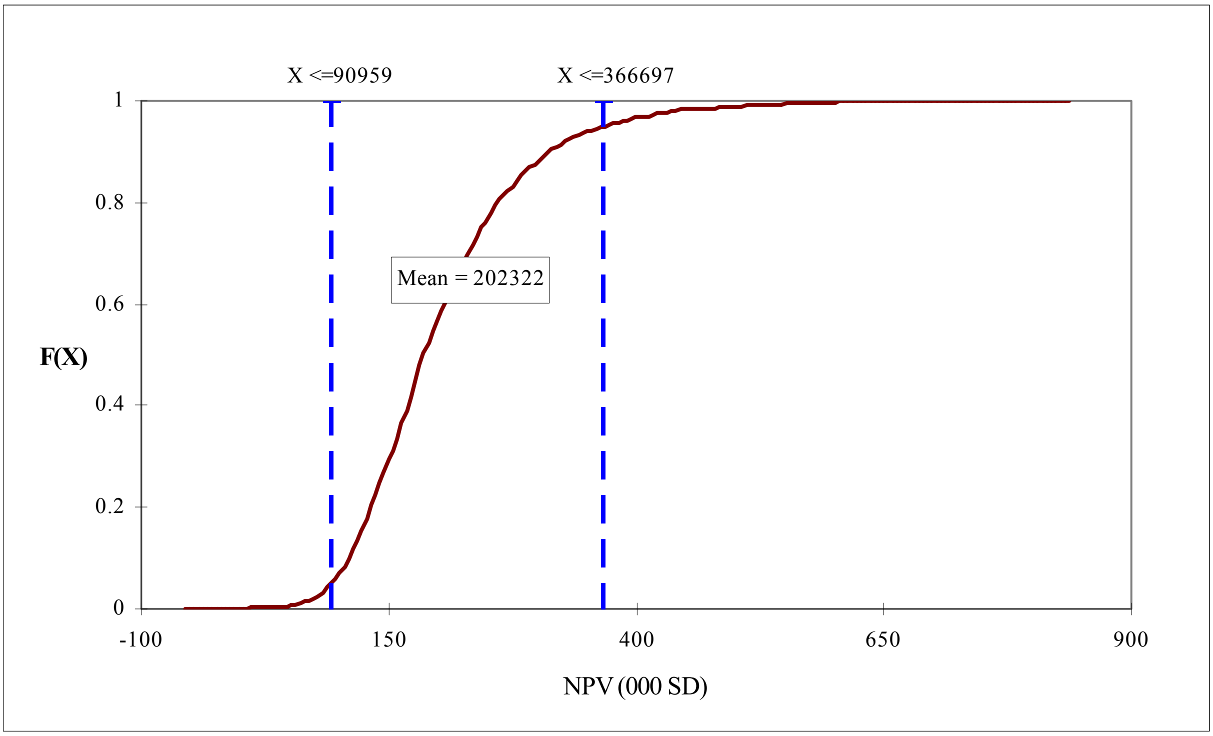


Figure 7.17: CDF of NPV of Strategy Six: Improved Sorghum and Sesame and Gum Arabic Trees, Gedaref Area, Sudan

Figure (7.18) and table (7.9) demonstrate that ninety percent of the NPV in strategy seven lies within the range of SD 322,826. This range has a lower limit of SD 176,488 with a cumulative probability of 0.05 and an upper limit of SD 499,314 with a cumulative probability of 0.95. A mean value of SD 309,688 and standard deviation of SD 104,204 of NPV are obtainable in strategy seven. There is a probability of 0.57 to get this mean value and less and hence the probability of getting the mean value and more is 0.43.

Table 7.9: The Cumulative Probabilities for Some Key Values in Strategy Seven, Gedaref Area, Sudan

Description	**Values (SD)**	**Cumulative Probability**
Zero	0	0.001
5th percentile	176,488	0.05
Mean	309,688	0.57
95th percentile	499,314	0.95

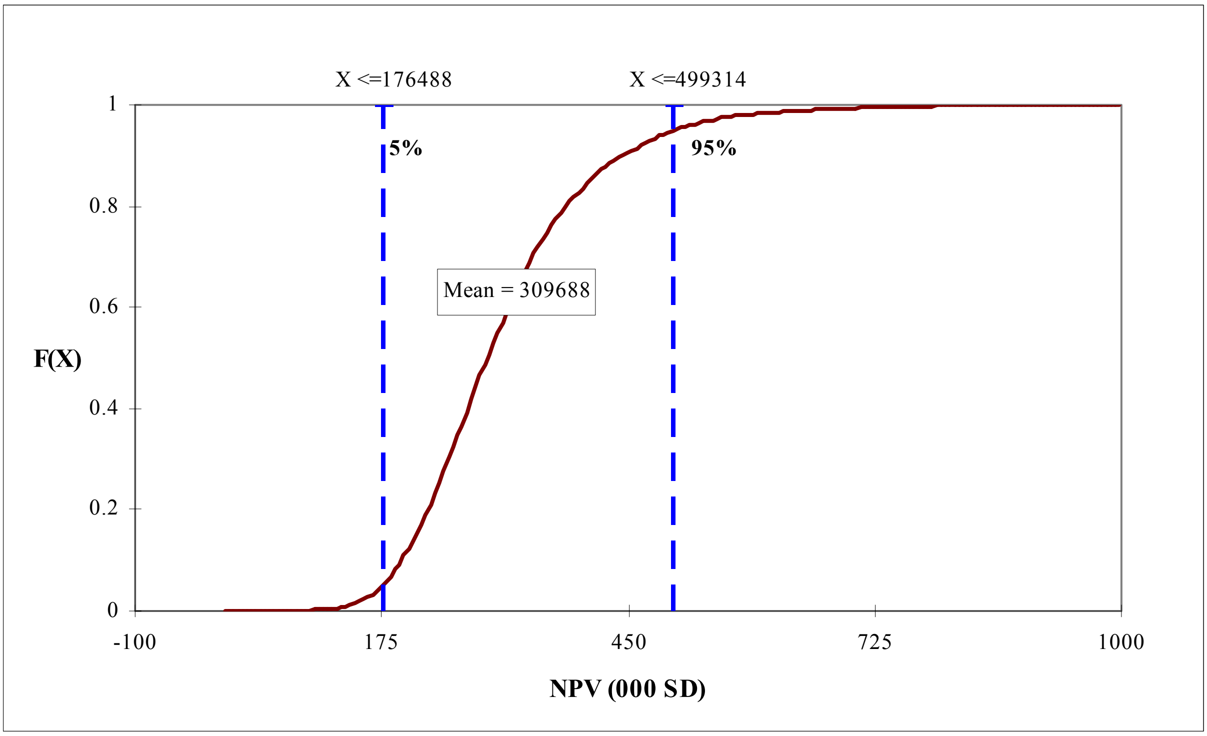


Figure 7.18: CDF of NPV for Strategy Seven: Improved Sorghum and Sesame and Sheep Production, Gedaref Area, Sudan

For strategy eight, figure (7.19) and table (7.10) depict that ninety percent of NPV of farm income lies between the values SD 174,774 and SD 468,329, which have the cumulative probability of 0.05 for the lower bound and 0.95 for the upper bound. Accordingly, 90% of farm income lies within the range SD 293,555 for this strategy. The mean value of NPV of farm income for strategy eight is SD 296,783 with SD 94,999 standard deviation. The probability of getting this expected value and more is 0.44, while the probability of getting the mean value and less is 0.56.

Table 7.10: The Cumulative probabilities for Some Key Values in Strategy Eight, Gedaref area, Sudan

Description	Values (SD)	Cumulative Probability
Zero	0	0
5th percentile	174,774	0.05
Mean	296,783	0.56
95th percentile	468,329	0.95

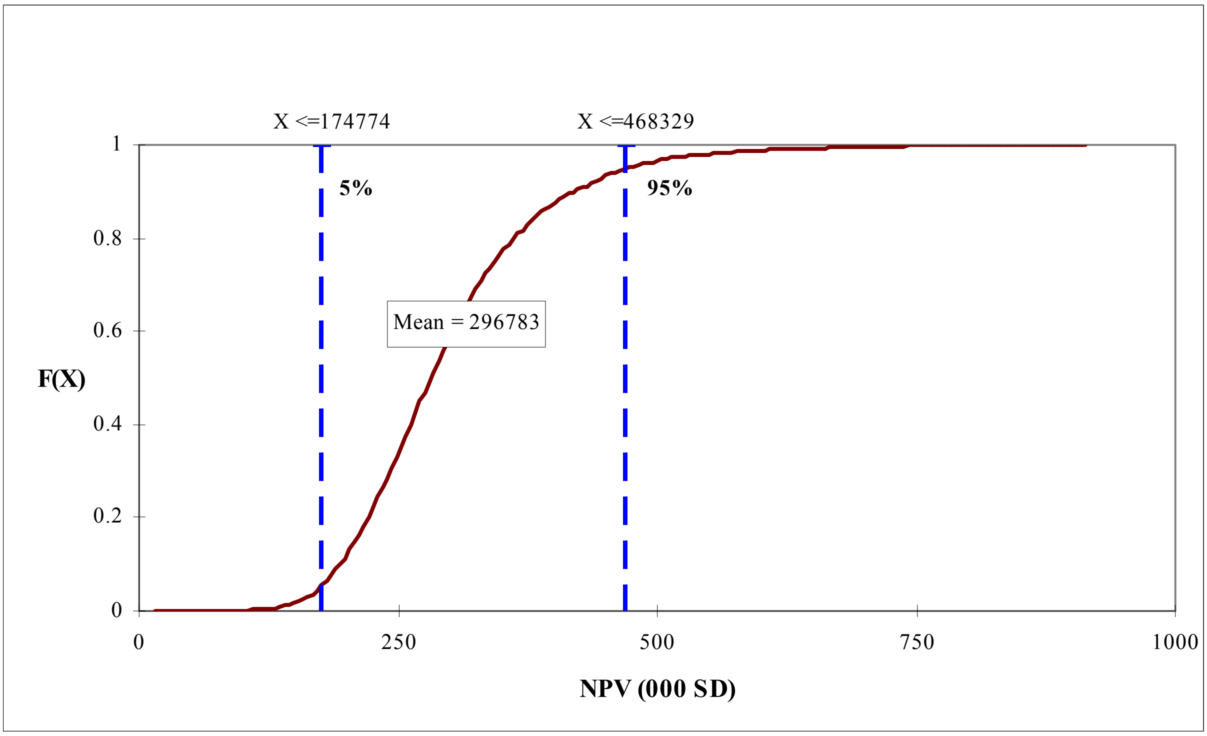


Figure 7.19: CDF of NPV for Strategy Eight: Improved Sorghum and Sesame, Gum Arabic Trees and Sheep Production, Gedaref Area, Sudan

Also from diagrams (7.16), (7.17), (7.18) and (7.19) it can be observed that the probabilities of getting income enough to cover the cash expenses required for the agricultural production for the next growing season were as follows:
Taking 2003/2004 costs levels and assuming that inputs levels and prices are not changing during the twenty years period, there is a chance of 0.5% to attain farm income of SD 41,628 and less in strategy five, compared to 0.4% chance to achieve SD 38,290 and less farm income in strategy six, a 0.1% chance to get SD 43,409 and less farm income in strategy seven and a 0.05% chance to maintain farm income of SD 40,071 and less in strategy eight. Conversely, there is a chance of more than 99.5% to obtain farm income equivalent to cash expenses and more in the strategies from five to eight. Like in the traditional strategies, there are no considerable differences in the chances of obtaining income enough to cover variable costs and total costs, from those for obtaining income enough to cover cash expenses, since the majority of the costs is concentrated on the variable costs items and only slight additional costs are involved as fixed costs.

Figure (7.20) compares the four production risky prospects under improved practices according to their CDFs. The figure indicates that the CDFs graphs of strategies seven and eight lie to the right of the CDFs graphs of strategies five and six. According to the stochastic dominance criteria, strategies seven and eight dominate strategies five and six in a first degree stochastic sense, i.e. they are preferable for a wide range of absolute risk aversion level ($+\infty > r_a < -\infty$). Based on the above results, it can be concluded that ranking the different strategies according to their CDFs graphs shown in figure (7.20) or according to their statistics performed in table (7.6), strategies seven and eight dominates strategies five and six. Like in strategies three and four, the risk efficiency achieved in strategies seven and eight is attributed mainly to the introduction of animals (sheep) to the farming system.

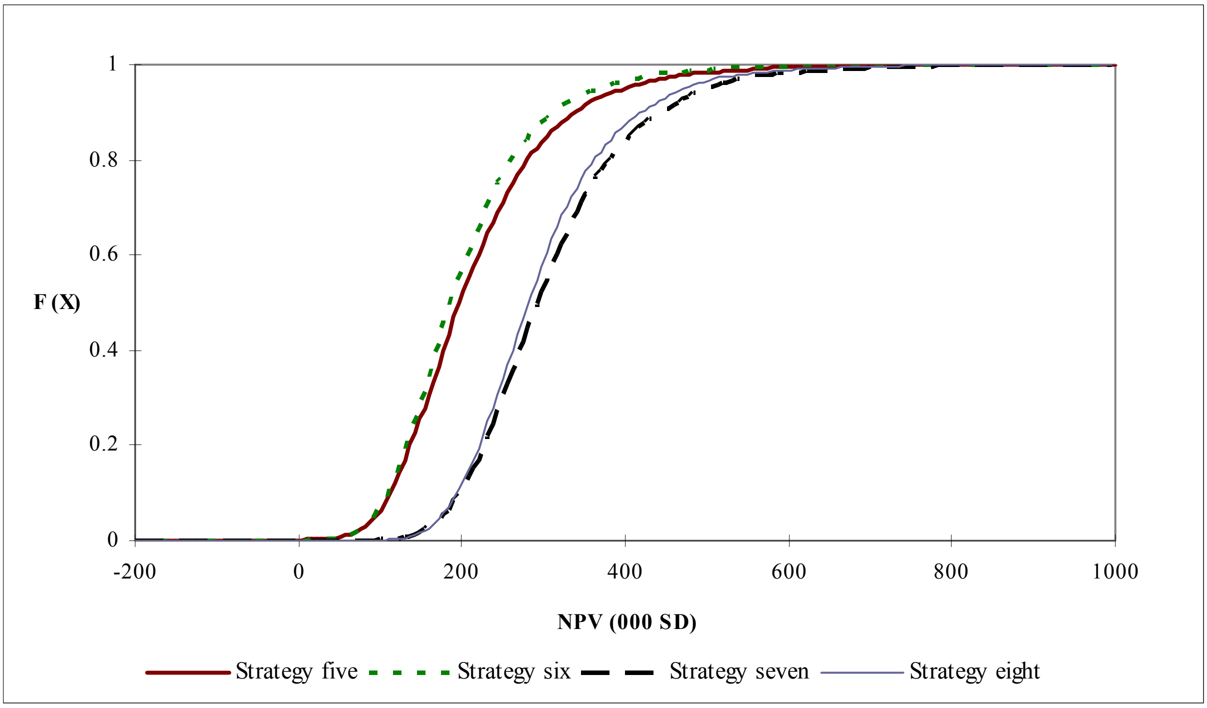


Figure 7.20: CDF Graphs Comparison for the Different Strategies under Improved Practices, Gedaref Area, Sudan

7.2.1 Results of NPV Sensitivity to the Uncertain Input Variables

Like in the traditional strategies the factors which have the most influence on the NPV for each strategy under the improved practices in growing sorghum and sesame crops are determined through @ Risk Tornado graphs using step-wise regression. The results are shown by figures (7.21), (7.22), (7.23) and (7.24) for strategies five, six, seven and eight respectively.

From the Tornado graphs the following results are obtained:
Figure (7.21) indicates that in strategy five, a one standard deviation increase in sorghum prices increases NPV by 0.89 standard deviations while a one standard deviation increase in sorghum variable costs decreases NPV by 0.28 standard deviations. The NPV for net farm income increases by 0.25 standard deviations when sorghum yield increases by one standard deviation. On the other hand less

effect is observed for sesame crop. The NPV increases by only 0.15 and 0.07 respectively when sesame prices and yield increase by one standard deviation. Sesame variable costs decrease the NPV by only 0.06 standard deviations when they increase by one standard deviation. These results indicate that the source of variability in this strategy is sorghum enterprise, particularly sorghum prices which had the largest effect compared to the other uncertain variables.

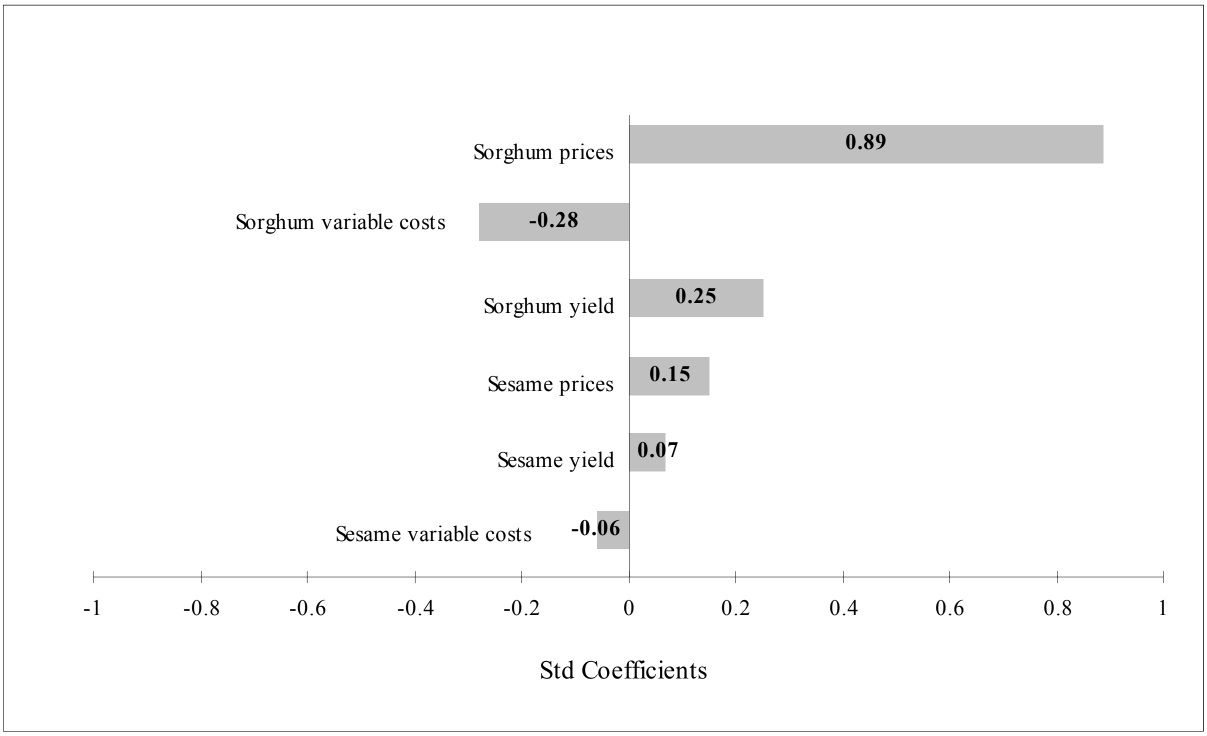


Figure 7.21: Regression Sensitivity for NPV of Net Farm Income, Strategy Five, Gedaref Area, Sudan

For strategy six, a one standard deviation increase in sorghum prices increases NPV by 0.89 standard deviations. On the other hand sorghum variable costs decrease the NPV by 0.28 when they increase by a one standard deviation while sorghum yield increases the NPV by 0.25 standard deviations when it increases by one standard deviation. A lower effect is observed for sesame enterprise. It increases the NPV for net farm income by 0.15 and 0.07 respectively when its prices and yield increase by one standard deviation. Like in strategy five sesame variable costs decrease the NPV by 0.06 when it increases by one standard deviation. Gum arabic prices have the least effect among other stochastic variables. Therefore, its increase by one standard deviation increases the NPV only by 0.02 standard deviations (figure 7.22). As in strategy five, sorghum has the dominant effect in this strategy as a source of fluctuation specially sorghum prices which have the most effect among other stochastic variables.

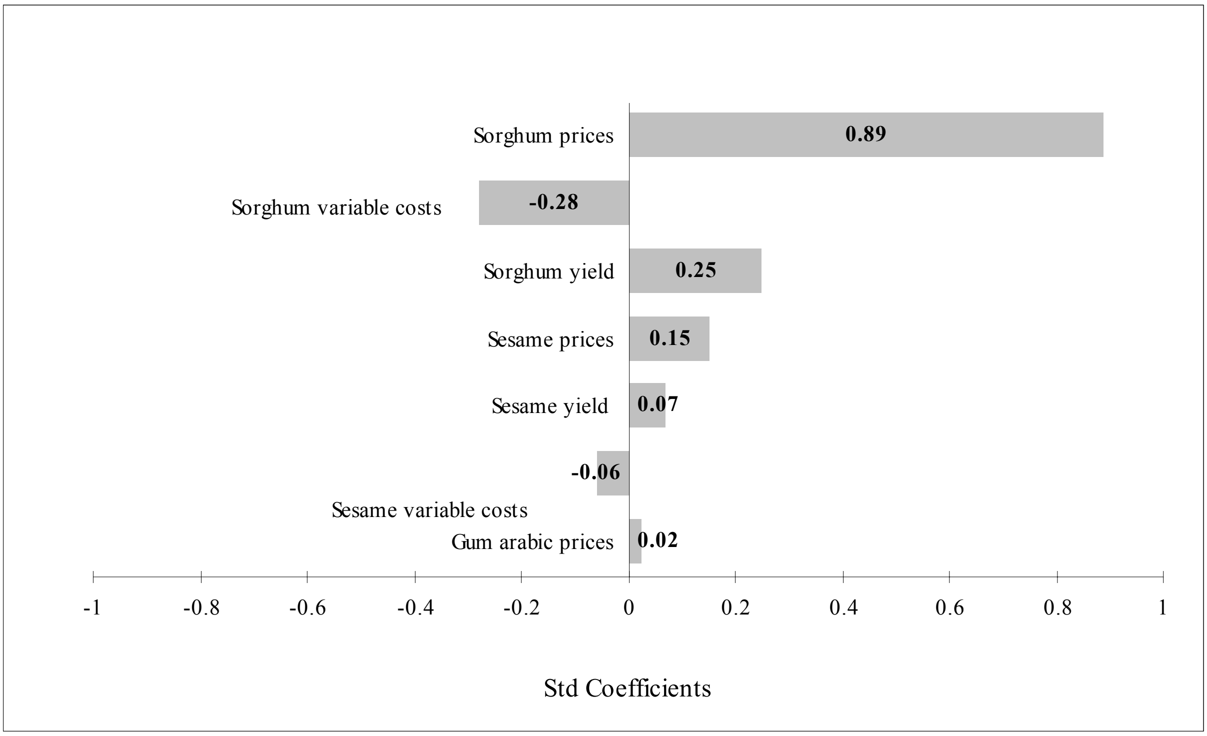


Figure 7.22: Regression Sensitivity for NPV of Net Farm Income, Strategy Six, Gedaref Area, Sudan

Figure (7.23) shows the sensitivity of the NPV of farm income to the stochastic variables included in strategy seven. In this strategy, sorghum and sheep prices have the leading effect. The former increases the NPV by 0.84 when it increases by one standard deviation while the latter increases it by 0.33 when it increases by one standard deviation. Sorghum yield and variable costs have also a considerable effect on the farm income fluctuations. They increase farm income respectively by 0.24 and 0.27 standard deviations when they increase by one standard deviation. On the other hand, sesame prices, yield and variable costs have lower contribution to farm income variation. Sesame prices and yield increase farm income respectively by 0.15 and 0.05 standard deviations while sesame variable costs decrease farm income by 0.06 standard deviations when they increase by one standard deviation.

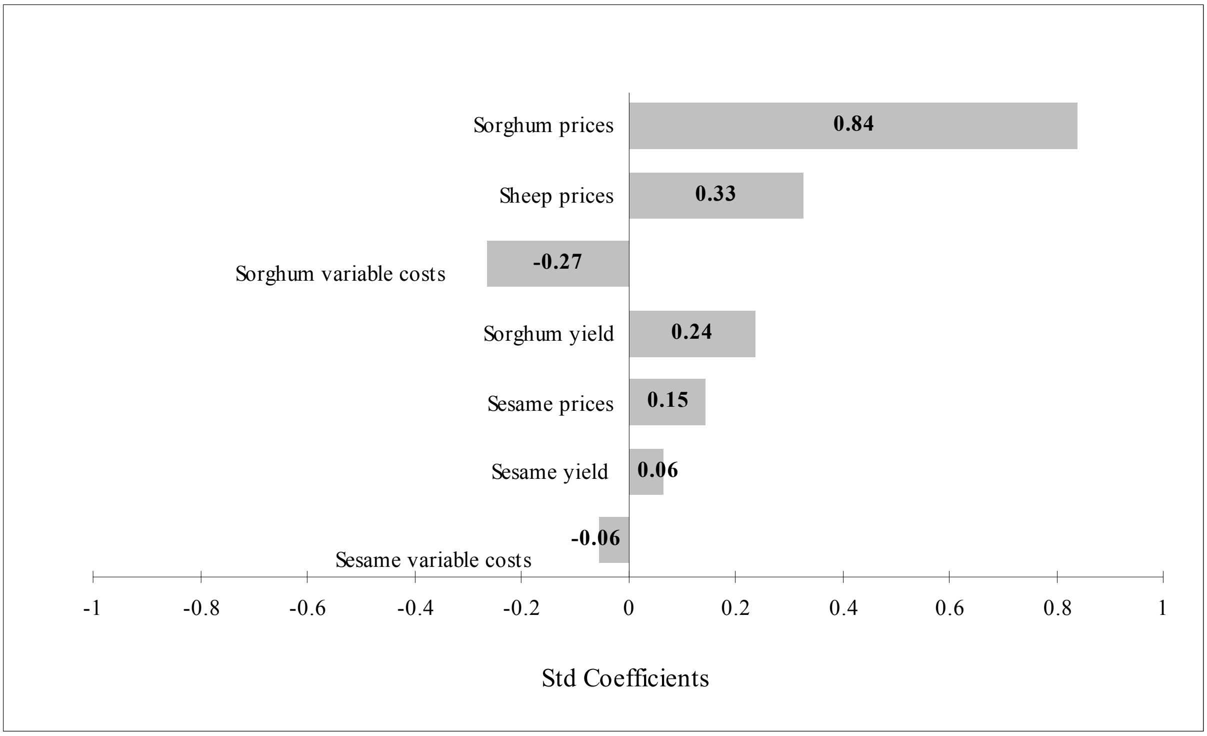


Figure 7.23: Regression Sensitivity for NPV of Net Farm Income, Strategy Seven, Gedaref Area, Sudan

As shown by figure (7.24), in strategy eight sorghum prices are found to have the highest influence on farm income instability compared to sheep, gum arabic and sesame prices and costs. The results show that they increase the NPV of farm income by 0.83 standard deviations when they increase by one standard deviation. Sheep prices, sorghum yield and sesame prices are observed to affect the farm income respectively by 0.36, 0.23 and 0.14 standard deviations when they increase by one standard deviation while sorghum variable costs decrease it by 0.26 standard deviations when they increase by one standard deviation. The results revealed a negligible effect of sesame yield, sesame variable costs and gum arabic prices on farm income uncertainty. Sesame yield and gum arabic prices increase farm income by 0.06 and 0.02 standard deviations respectively when they increase by one standard deviation while sesame variable costs decrease it by 0.06 standard deviations when they increase by one standard deviation.

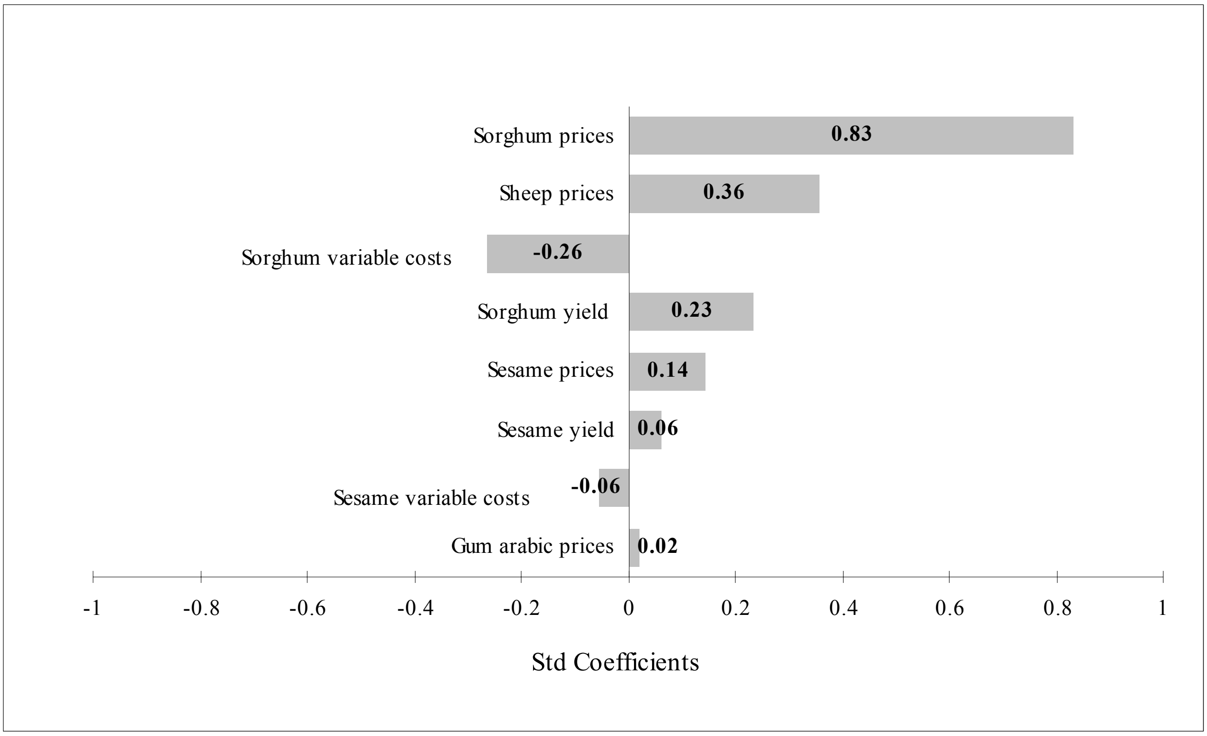


Figure 7.24: Regression Sensitivity for NPV of Net Farm Income, Strategy Eight, Gedaref Area, Sudan

From the results shown by figures (7.21), (7.22), (7.23) and (7.24) it can be concluded that the sorghum price is the most important factor that has the greatest effect on the NPV variability for all the four strategies under the improved practices. Sheep prices have also a considerable effect on the strategies in which they are involved i.e. strategies seven and eight. Other variables like sorghum yield, sorghum costs and sesame prices have also an effect in all strategies but at lower extent than sorghum and sheep prices. On the other hand, sesame yield and variable costs have the least effect followed by gum arabic prices which have insignificant effect on the NPV in the strategies in which this crop is adopted i.e. strategies six and eight.

7.2.2 Results of Stochastic Efficiency Analysis (SERF Results)

As stated earlier, it is also important to consider the farmer's attitude to risk alongside their beliefs about the uncertain events when planning farm business under uncertainty. Therefore, the stochastic efficiency analysis, which incorporates these two factors, was conducted for strategies five to eight and the results are presented in this section.

Figure (7.25) shows SERF results for strategies five to eight under the improved practices for sorghum and sesame over the absolute risk aversion $r_a(z)$ range of 0.0017 to 0.0133, which corresponds to relative risk aversion coefficient $r_r(z)$ in the range 0.45 to 3.6 assuming a negative exponential utility function. This range is equivalent to a range of relative risk aversion with respect to wealth, $r_r(w)$, between 0.5 and 4. The range for $r_r(z)$ and $r_a(z)$ are approximated by use of equation (19) (chapter five), with wealth *w* equal to SD 300,000 and income *z* equal to SD 270,000.

As can be seen from the graph, the points of highest *CE* values are comprised of values for strategies seven and eight only, implying that these two strategies form the risk-efficient set. The SERF results show that the value of $r_a(z)$ where *CE* curves for strategies seven and eight cross is $r_a(z) = 0.0086$ i.e. where $r_r(z) = 2.3$. This indicates that subsets of the SERF efficient-set can be formed for the above specified risk aversion levels. Thus, the SERF efficient-set contains only strategy seven for farmers with risk aversion levels less than 0.0086 and strategy eight for farmers with risk aversion levels greater than 0.0086.

Taking the concept of risk premiums into consideration, for farmers in the study area to switch from the less preferred strategy five to the dominant strategy seven, for the specified range of relative risk aversion with respect to wealth $r_r(w)$ of 1.5 to 2.0, which is equivalent to absolute risk aversion $r_a(z)$ of 0.005 to 0.0067, the following results can be deduced from the figure:

The risk premium (RP) between the specified strategies measured by the vertical distance between the *CE* curves for strategy five and seven, ranges between SD 85,000 at $r_a(z) = 0.005$ to SD 87,000 at $r_a(z) = 0.0067$. This implies that the minimum sure amount that would have to be paid to farmers to switch from strategy five to seven or the benefits that farmers could gain if allowed to move from strategy five to strategy seven are in the range SD 85,000 to SD 87,000 for $r_a(z)$ range of 0.005 to 0.0067.

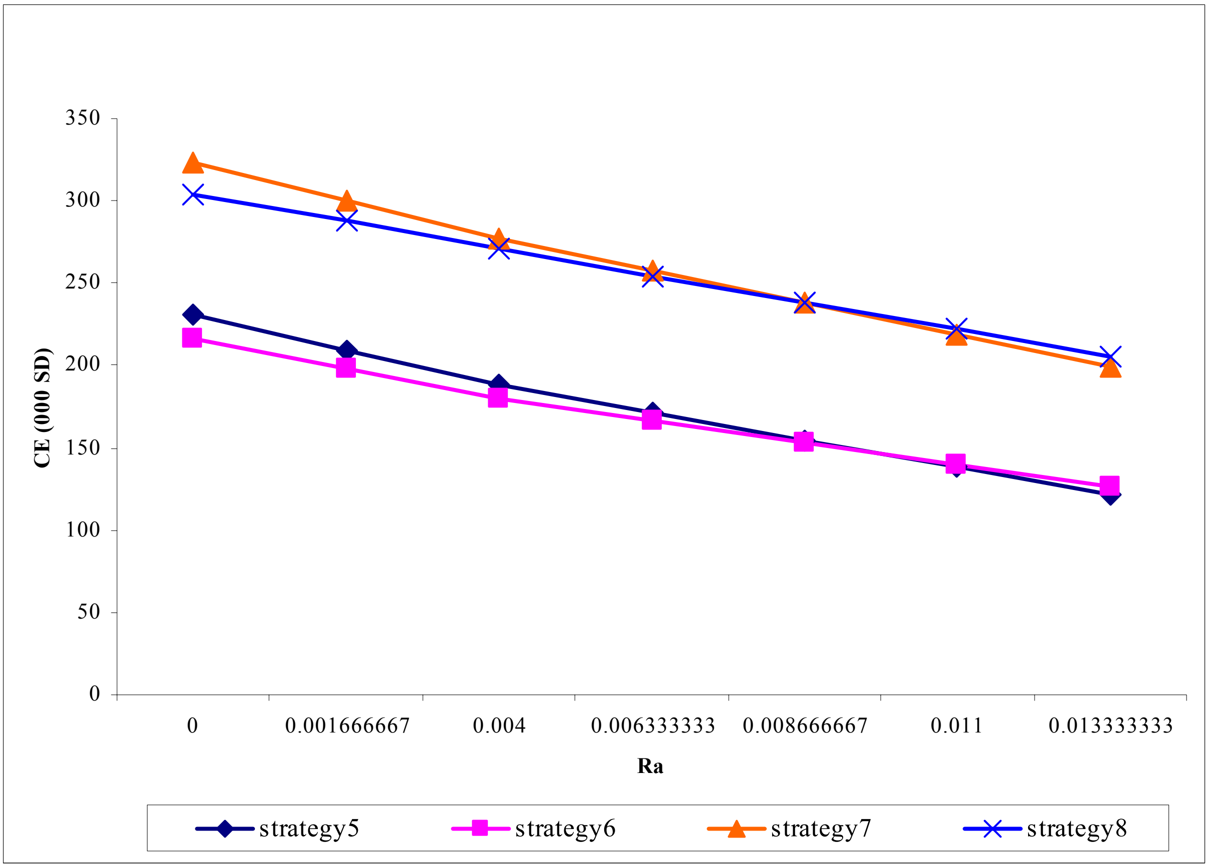


Figure 7.25: CE Graphs for the Different Strategies under Improved Practices, Gedaref Area, Sudan

On the other hand, the minimum sure amount that have to be paid to farmers or the gains that farmers would earn if they shift from strategy five to strategy eight are in the range SD 82,000 to SD 85,000 at the absolute risk aversion level $r_a(z)$ range of 0.005 to 0.0067.

7.3 Comparison of the Strategies under the Traditional and Improved Practices

In this section each strategy in which the modern practices of using the improved seeds, herbicides and fertilizer when growing sorghum and sesame is compared to its counterpart strategy under the traditional practices to see the effect of introducing the recommended practices on the level of risk involved in each farming system. Accordingly, strategy five is compared to strategy one, strategy six is compared to strategy two, strategy seven is compared to strategy three and strategy four is compared to strategy eight. The results are shown in figures (7.26), (7.27), (7.28) and (7.29).

Figure (7.26) compares the distribution for strategy one and five. The diagram shows that the distribution for strategy five skewed to the right towards higher values of farm income implying higher probabilities for higher values of farm income. Also in this strategy the maximum and mean values revealed a large increase while the minimum value showed a large decrease compared to strategy one (table (7.1) and (7.6)). On the other hand, the coefficient of variation reduced by 49% in strategy five than in strategy one, which indicates more stability in farm income in this strategy as a result of using the improved practices.

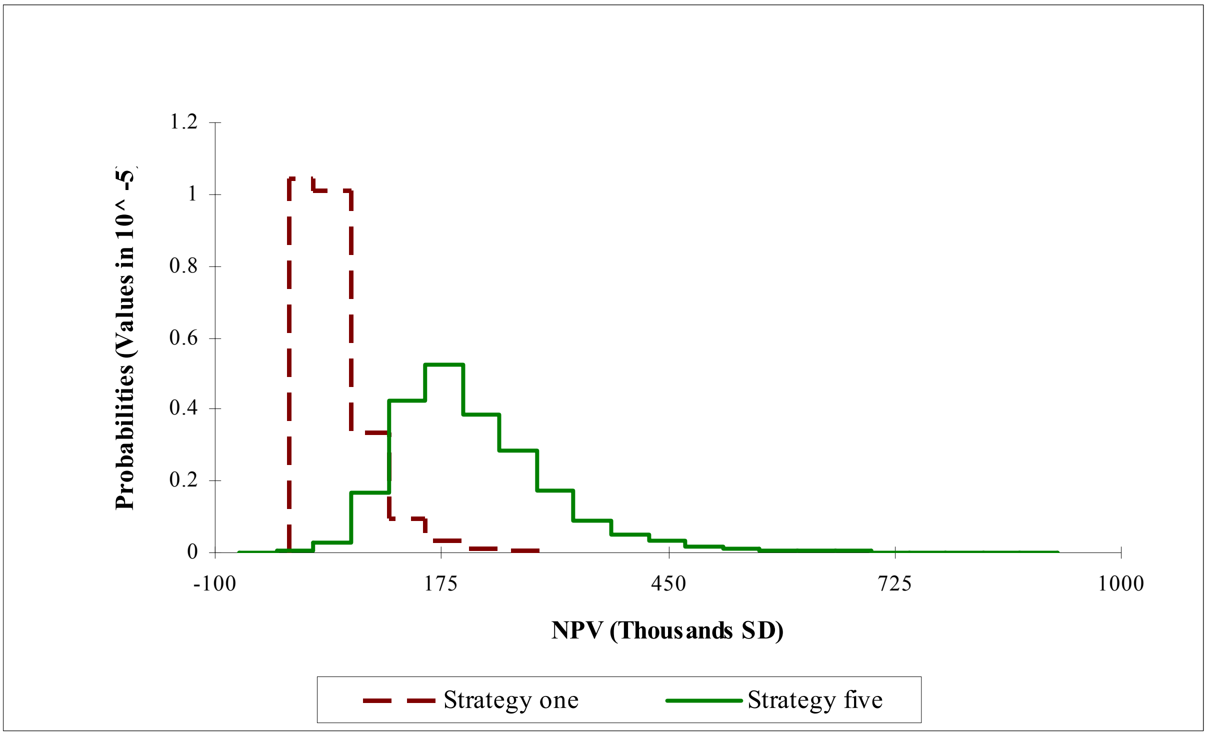


Figure 7.26: Distribution of NPV for Strategy One Compared to Strategy Five, Gedaref Area, Sudan

In figure (7.27) a comparison between strategy two and six, which represent the practice of growing sorghum and sesame under both traditional and improved practices besides growing gum arabic trees is presented. This shows there is a shift in the distribution of strategy six towards higher values of farm income and hence higher probabilities of higher values of farm income are obtained. Additionally, the maximum and expected values in this strategy largely exceeded those of strategy two while the minimum value showed a large decrease (table (7.1) and (7.6)). The coefficient of variation in strategy six decreased by 32% compared to that of strategy two, reflecting a more stable farm income at the end of the planning period when the improved practices are used by farmers in the Gedaref area.

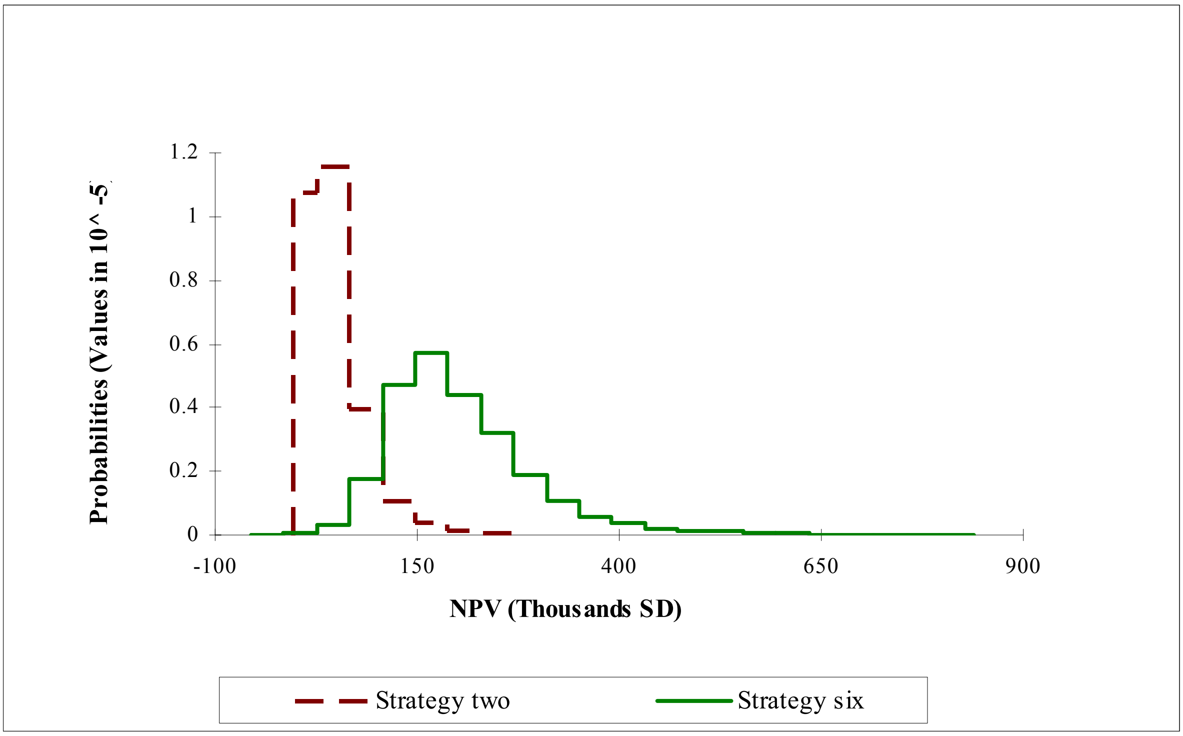


Figure 7.27: Distribution of NPV for Strategy Two Compared to Strategy Six, Gedaref Area, Sudan

Figure (7.28) compares the options to grow sorghum and sesame under traditional and improved practices besides keeping animals as is the case for strategy three and seven respectively. The maximum and mean values when using the improved practices are extremely greater than those when using the traditional practices (table (7.1) and (7.6)). Moreover, there is a relative reduction in farm income fluctuations by the end of the planning period in strategy seven as a result of using improved practices in growing sorghum and sesame. This is explained by the 6% decrease in the coefficient of variation in this strategy than for that of strategy three. From the figure it can be observed that strategy seven slightly skewed to the right towards the higher values of NPV of farm income with higher probabilities of occurrence compared to strategy three.

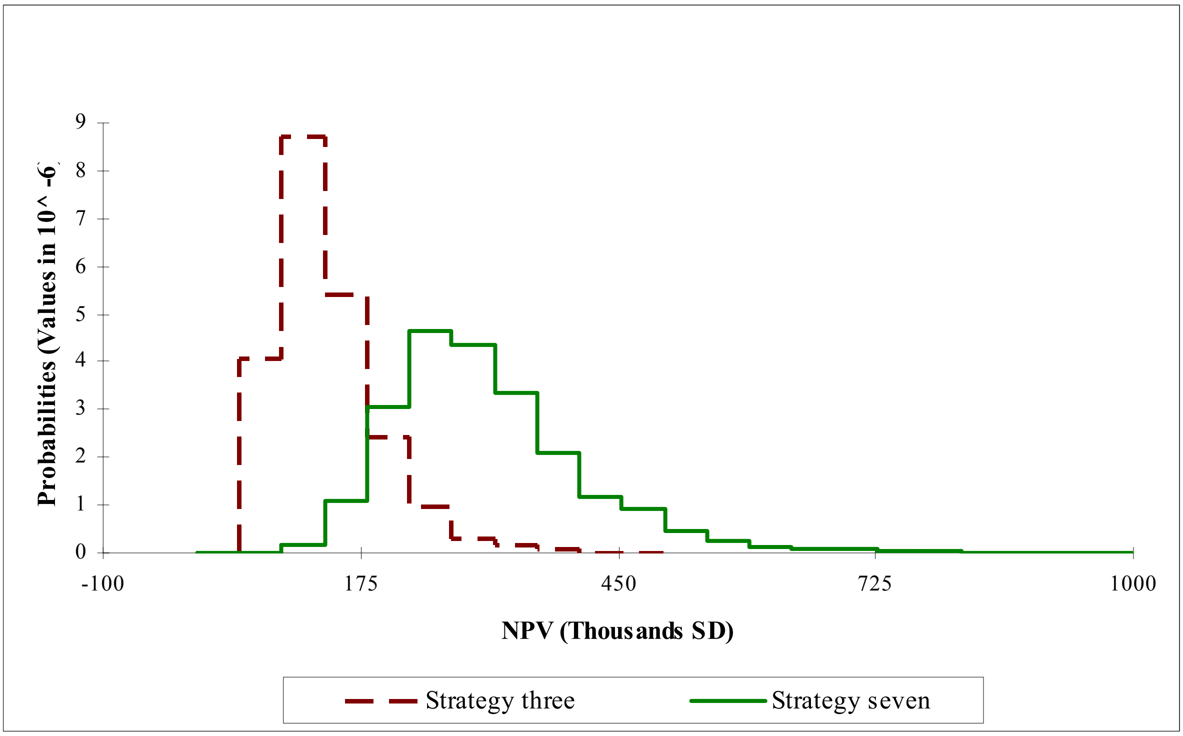


Figure 7.28: Distribution of NPV for Strategy Three Compared to Strategy Seven, Gedaref Area, Sudan

A comparison between strategies entailing enterprises of growing sorghum, sesame and gum arabic alongside keeping animals using traditional or improved practices, which are strategies four and eight respectively, illustrated by figure (7.29). This shows there is a shift to the right in the distribution of strategy eight towards higher values of farm income compared to strategy four indicating higher probabilities for the higher values of farm income in this strategy. As in the other strategies under improved practices, the maximum and mean values showed a large increase in strategy eight, while a sharp decrease was noticed in the minimum value (table (7.1) and (7.6)). The relative stability of farm income due to the use of the improved practices in growing sorghum and sesame can be detected through the 4% reduction in the coefficient of variation in strategy eight compared to strategy four (table (7.1) and (7.6)).

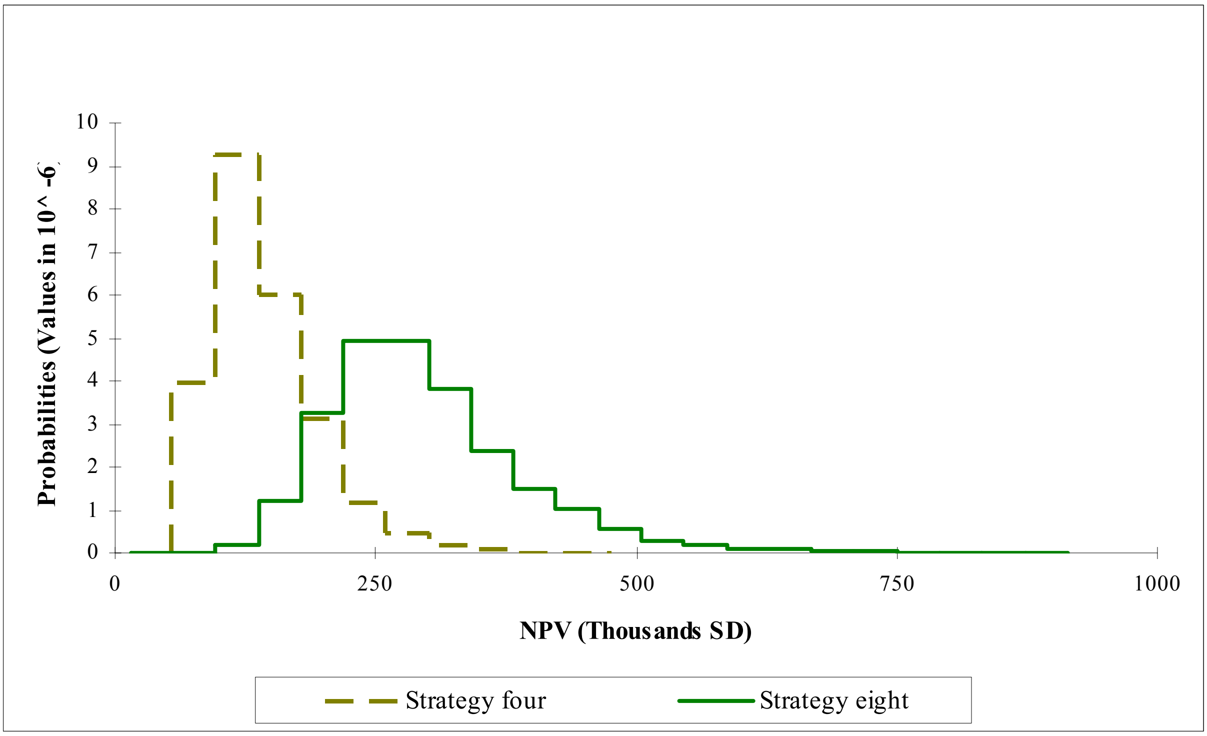


Figure 7.29: Distribution of NPV for Strategy Four Compared to Strategy Eight, Gedaref Area, Sudan

7.4 Results of Financial Risk Analysis

Like business risk, financial risk is also of importance in the study area, especially so when considering how the farm business in Gedaref area is usually financed. The way the farm business uses debt capital can have major implications for risk exposure. A key concept in this regard is financial leverage, which is defined by Robison and BARRY (1987) as the use of credit and other fixed-obligation financing relative to the use of equity capital. The degree or amount of leverage is measured by the debt/equity ratio, and hence leverage increases with the increase in this ratio.

As shown by the survey, about 52% of farmers in the study area are accustomed to use borrowed capital from formal and informal sources to finance their agricultural operations. It was estimated that about two fifth on average of the total invested capital is non-equity capital. Therefore the following analysis tries to evaluate the effect of leverage on business risk in the study area. The financial risk analysis within the context of this study was limited to the current farming system of growing traditional sorghum and sesame as the most preferred and most practiced system by farmers in the study area as derived from the field survey. The effect of leverage level was also evaluated for the farming system incorporating sheep production to the system of growing sorghum and sesame traditionally. The latter is the second preferred farming system in the study area and already practiced by some farmers as indicated by the results of the field survey.

7.4.1 Results of the Current Farming System of Traditional Sorghum and Sesame

For the current system of growing sorghum and sesame, the total investment to grow the 1,000 feddan farm was estimated to amount to SD 11,178,840 of which SD 4,603,052 (41%) is borrowed capital and SD 6,575,788 (59%) is non-borrowed capital. The cost of borrowed capital was estimated as a combination of the cost of borrowing for *Salam* and *Murabaha* financial forms. Accordingly, a rate of 19% per year was used in the evaluation process. Due to the lack of data, the financial risk analysis was restricted only to the formal method of finance dominated in the study area (*Salam* and *Murabaha* forms from the Agricultural Bank of Sudan and other commercial banks in the area).

Using 2003/2004 statistics of yields, output prices and input costs, different levels of financial leverage were evaluated. These include 0, 0.7, 1.0, and 1.5. The 0.7 leverage level represents the actual debt/equity ratio used by farmers in the study area for this farming system.

As shown in table (7.11), the farm business has a negative rate of return on total investment of -1.8%. Under this rate of return to capital, the rate of return on owner's equity varies from -1.8%, -16%, -22%, and -33% for the 0, 0.7, 1.0 and 1.5 leverage levels respectively. From the above results, it can be noticed that because the business incur losses equal to 1.8 percent of the total capital, these losses were added to the interest on borrowed capital, and hence the total loss increased rapidly as leverage increases. Equity capital must bear the burden of its own loss; the loss on borrowed capital plus the interest on borrowed capital and the result was a rapidly increasing loss of equity capital as leverage increases (table 7.11). Therefore, it can be concluded that the increase in the financial leverage had magnified the impact of variability of farm returns. This is particularly true because the business' overall rate of return was much less than the borrowing rate, therefore the owner suffering specially with the increasing level of leverage.

Table 7.11: Effect of Financial Leverage in Magnifying the Impact on Equity of Variability of Returns of the Existing Farming System

Items \ Debt/equity ratio	0	0.7	1.0	1.5
Farm size (fed)	1,000	1,000	1,000	1,000
Total investment (SD)	11,178,840	11,178,840	11,178,840	11,178,840
Equity capital (SD)	11,178,840	6,575,788	5,589,420	4,471,536
Debt capital (SD)	0	4,603,052	5,589,420	6,707,304
Interest rate on loan	0.19	0.19	0.19	0.19
Interest on debt (SD)	0	874,580	1,061,990	1,274,388
Farm net income (SD)	-201,902	-201,902	-201,902	-201,902
Return on capital (%)	-0.01806	-0.01806	-0.01806	-0.0180611
Margin after interest (SD)	-201,902	-1,076,482	-1,263,892	-1,476,290
Return on equity (%)	-0.018	-0.163	-0.226	-0.33

7.4.2 Results of the Farming System Incorporating Traditional Sorghum, Sesame and Sheep enterprises

Considering costs and returns of the growing season 2003/2004, the farming system incorporating traditional sorghum and sesame and sheep enterprises in Gedaref area required a total investment of SD 12,359,907 of which SD 5,149,961 (40%) was equity and SD 7,209,946 (60%) was borrowed fund (table 7.12). An interest rate of 14.7% was used in the evaluation process. This interest was obtained from a combination of interest paid for capital borrowed to finance sorghum and sesame operations (*Salam* and *Murabaha*) and the interest for capital borrowed through *Murabaha* form to purchase the sheep herd and meet their other variable expenses.

To evaluate the effect of financial leverage on risk in the study area for the above specified farming system, the leverage levels of 0, 0.5, 1.0, and 1.4 were used in the analysis. The 1.4 level represents the actual debt/equity ratio practiced by farmers in Gedaref region to finance this particular farming system.

Table (7.12) shows the amount of total investment, the equity, debt, return to total capital invested and return to the owner's equity for the chosen levels of leverage. As can be seen from the table, the return to the overall capital invested positively reached 9%, which is relatively small compared to the borrowing rate. Therefore under this rate of return to total capital, the rate of return to owner's equity decreased with increasing leverage level. It varies from 9%, 6%, 3%, and 1% respectively for the debt/equity ratios of 0, 0.5, 1.0, and 1.4.

As can be seen from the table, the return to total capital is less than the interest rate on borrowed capital; accordingly return to equity is adversely affected by increased leverage. In this case the borrowed capital did not earn enough income to pay the interest. Part of the income from equity capital was used to pay the interest, which made the return to equity less than the return to all capital. Therefore, in the current situation the combination of a high leverage and a low return to total capital required the use of equity capital to pay part of the interest leading to the decreasing return to owner's equity as the leverage increases.

Although the rate of return to equity in this farming system is positive and a little bit larger than that obtained in the system of growing sorghum and sesame under traditional practices, the increase in leverage had also increased the impact of variation of farm returns as in the first option but for a lesser extent.

From the results presented in table (7.11) and (7.12), it can be concluded that lower returns to owner's equity were obtained with increasing leverage because the borrowing interest rate was higher than the overall return to total capital invested. Higher leverage had even a greater impact if the return on total capital happens to be negative. The effects of both low returns and high leverage combined to confirm the principle of increasing risk, which states that as the debt/equity ratio or leverage increases, the borrower has a greater risk of losing equity capital.

Table (7.12): Effect of Financial Leverage in Magnifying the Impact on Equity of Variability of Returns of the Farming System Incorporating Sorghum, Sesame and Sheep Enterprises

Debt/equity ratio / Items	0	0.5	1	1.4
Farm size (fed)	1,000	1,000	1,000	1,000
Total investment (SD)	12,359,907	12,359,907	12,359,907	12,359,907
Equity capital (SD)	12,359,907	8,239,938	6,179,953	5,149,961
Debt capital (SD)	0	4,119,969	6,179,953	7,209,946
Interest rate on loan	0.147	0.147	0.147	0.147
Interest on debt (SD)	0	605,635	908,453	1,059,862
Farm net income (SD)	1,106,138	1,106,138	1,106,138	1,106,138
Returns on capital (%)	0.09	0.09	0.09	0.09
Margin after interest (SD)	1,106,138	500,503	197,685	46,276
Return on equity (%)	0.09	0.06	0.03	0.01

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary of Major Findings

Since farming is always a risky business it is important to account for the risk in farm planning. Accordingly, the main objective of this study is to analyze the economics of large scale mechanized rain-fed farming of Gedaref in eastern Sudan considering the risk involved.

It is confirmed that the mechanized rain-fed agricultural sub-sector has considerable potential for building a national food stock and for generating foreign exchange through export which could contribute substantially to agricultural development and hence the development of the economy as a whole. The agricultural production in this sub-sector of Gedaref area is generally characterized by a high degree of instability. This is mainly attributed to the nature of the agricultural production in this system which associated with high degree of uncertainty. The uncertainty arises from dependency of the agricultural production on uncontrollable weather conditions (erratic and variable rainfall) which cause great fluctuations on crops yield at one hand, and the large fluctuations in input and output prices which restrict the reliability on price predictions on the other hand. Financial risk in the study area due to leverage is also important as majority of farmers depends on substantial amounts of borrowed funds to finance the agricultural production. The instable farm income resulting from business and financial risk coupled with lack of infrastructure in the area may affect production decisions, delay adoption of the new technology, prohibit long-term investment in agriculture and hence delay the agricultural development in this sub-sector. It is argued that the adoption of the recommended improved technology in the area can increase farm income while diversifying by introducing sheep and gum arabic enterprises to sorghum monoculture of Gedaref may lead to farm income stability. Under these arguments in favor of diversification and use of improved technology, this research work aims mainly at studying and analyzing the performance of the mechanized rain-fed sector of Gedaref under uncertainty. Specifically, the study has evaluated different production strategies in terms of risk efficiency under both the current traditional and the proposed improved cultural practices.

The study mainly applies a stochastic budgeting approach to evaluate the current and the proposed production strategies under the traditional and the improved cultural practices. The analysis is based on a deterministic budget analysis which used NPV of farm income as a measure of performance over twenty years planning horizon. The strategies under investigation include the options of growing sorghum and sesame in the total farm area, incorporating gum arabic and/or sheep enterprises to the current farming system of growing sorghum and sesame under both traditional and some improved cultural practices. Sources of uncertainty considered in the stochastic budget are the gross margins of the traditional sorghum and sesame, prices of gum arabic and sheep and the yield, prices and variable costs of improved sorghum and sesame. These stochastic variables are integrated in the budget as probability distributions obtained from BestFit software from Palisade. The simulation is done using @ Risk software that allows the representation of uncertainty as probability distributions and then performs stochastic simulation using Latin hypercube technique and the results are then given also as probability distributions.

In a second step to rank the risky alternatives under investigation for a specified level of farmers' risk aversion with respect to income, the stochastic efficiency method (SERF) is applied. This method is based on the subjective expected utility hypothesis (*SEU*) through which the risk-efficient set with the highest certainty equivalent values are obtained assuming negative exponential utility function.

To study the financial position and the strength of the business, different levels of leverages and their effects on the owner's equity were evaluated and then their effect on business risk is investigated for the production system of growing sorghum and sesame traditionally, and the system which incorporates sheep production to traditional sorghum and sesame enterprises.

The results of the field survey have emphasized the main features of the Mechanized Rain-fed large scale farming system of the Gedaref and shaped up farmer's attitudes and behavior regarding economical and environmental constraints. Farmers' degree of awareness is high because they have a good level of education and a fair experience in agriculture and hence they are capable of taking their agricultural decisions. These decisions are not only affected by farmers' attitude to risk but also by problems such as financial constraints, lack of infrastructures and other basic services.

In the study area, the mono-culture of sorghum in an extensive system is the dominant crop activity although it involves different types of risks. The empirical research results have emphasized the positive role of the new recommended improved practices of sorghum and sesame in increasing and maintaining stability of farm income. But these technologies are not fully adopted by farmers because of their high costs in response to the high probability of loss under this farming system conditions, besides farmers lack of knowledge about these technologies due to the absence of effective extension services in the area. Farmers are pressed by the financial institutions and by the high costs of labor which forced them to sell their crops in unsuitable time thus loosing a considerable amount of expected profits.

Analysis of costs and returns of sorghum and sesame for the growing season, 2003/2004 showed that, the significant high costs of producing sesame compared to sorghum indicates its risky nature and explains why farmers in the study region limit its area compared to the area grown with sorghum although its returns considerably exceeds that of sorghum. Total returns from sorghum and sesame are enough to cover their operating and cash costs but at the same time they are short to cover the business total expenses.

The application of the improved technological packages for sorghum considerably increased its yield resulting in good returns from this crop in spite of its high costs compared to the traditional sorghum. However, the cash costs per one sack of improved sorghum are much less than the cash costs per one sack of traditional sorghum. For sesame crop, the slight increase in sesame yield as a result of applying the improved techniques coupled with the high costs of production resulted in higher total loss in the improved sesame compared to the traditional one. Unlike sorghum the cash costs per unit of output is higher in the improved sesame compared to the traditional sesame. On the other hand, the application of the improved technology for sorghum and sesame has made a considerable transformation in the capital labor combination. Labor share in the costs of production for both crops has substantially decreased while the costs of materials inputs have largely increased.

The results of stochastic simulation showed that, applying the strategies under the traditional practices from one to four may help the farmers to lower the chances of a loss at the end of the twenty years planning period if they choose strategy one or two. But their chance to earn profit at the end of the same planning period is 100% if they choose strategy three or four. Moreover, the CDFs graphs and the different statistics resulting from stochastic simulation indicate that strategies three and four are preferable to strategies one and two in a first degree sense, i.e. they are preferable for a wide range of farmers’ absolute risk aversion level ($+\infty > r_a < -\infty$).

For the strategies under the current traditional practices, the sensitivity of the NPV of farm income to the uncertain variables included in the stochastic budget revealed that, sorghum gross margins are the most important factor that has the greatest effect on the NPV for all four strategies. Sheep prices have also strong effect on NPV in strategies three and four and even their influence in strategy four exceeded that of sorghum gross margins. Sesame gross margins have an effect in all strategies but for a lesser extent than sorghum gross margins and sheep prices. On the other hand, gum arabic prices have the lowest effect on the NPV in strategies two and four.

In the strategies from five to eight under improved practices, farmer's chance to lose at the end of the planning period is very small in strategies five, six and seven while their chance of gain is 100% in strategy eight at the end of the same planning period. The CDFs graphs and the statistics generated from the stochastic simulation for the strategies under improved practices showed that, strategy seven which incorporates animal production to the system of growing improved sorghum and sesame and strategy eight which involves additionally gum arabic enterprise, are the dominant alternatives in terms of risk efficiency in a first degree sense. They are preferable for a wide range of farmers' risk aversion. The results of comparing the distribution of each strategy under traditional practices to its counterpart under improved practices indicated that, the application of the improved technological packages has a positive impact in maintaining income stability in all strategies compared to the traditional practices in growing sorghum and sesame crops.

Examining the sensitivity of the NPV to the budget stochastic variables for the strategies from five to eight, the resulted tornado graphs indicated that, sorghum price is the most important factor that have the greatest effect on the NPV variability for all four strategies under improved practices. Sheep prices have also a considerable effect in strategies seven and eight. Other variables like sorghum yield, sorghum costs and sesame prices have also an effect in all strategies but for a lower extent than sorghum and sheep prices. On the other hand, sesame yield and variable costs have the least effect followed by gum arabic prices which have insignificant effect on the NPV in strategies six and eight.

Considering both farmers' attitude to risk besides their beliefs regarding uncertain events, the stochastic efficiency analysis derived strategy four as the risk-efficient among the strategies under the traditional practices and strategies seven and eight as the risk-efficient among the strategies under the improved practices for farmers' relative risk aversion range with respect to wealth $r_r(w)$ of 0.5-4. In the improved strategies, farmers' attitude to risk in the study area did not affect the choice of the risk-efficient plans which remain the same for a wide range of farmers' risk aversion while in the traditional strategies the risk-efficient set is restricted to strategy four only when farmers' attitude to risk is considered.

The introduction of forest activities of *Acacia Senegal* which produces gum arabic is characterized by its low costs of production, its high profitability in addition to its environmental benefits all in the long run. Gum arabic can play an important role in mitigating risk of sorghum and sesame system in the long run and if it is coupled with a profitable enterprise like sheep it could also contribute to the farm income stability even in the short run. The high costs of establishment during the first four years of acacia tree life coupled with the low farm income from the traditional production of sorghum and sesame have made it a less attractive alternative to farmers.

Introducing sheep activity to the farming system of Gedaref is a suitable decision to mitigate not only the available business risk but also financial risk. Sheep enterprise additionally has many favorable economic and environmental characteristics and their marketing coincides with cash requirements for some field operations of sorghum, sesame and gum arabic crops.

Although the use of borrowed capital can increase business profit as well as the return to equity capital under favorable conditions, the financial risk analysis of the two analyzed farming systems in the study area showed that increasing borrowed capital had magnified the impact of variability of farm return in both systems and hence resulted in large losses of equity capital. This is because the realized returns in these two systems turned out to be very low (less than the borrowing rate). Higher leverage had even greater impact as the return on total capital turned to be negative in the farming system of growing traditional sorghum and sesame. Low returns and high leverage combined to confirm the principle of increasing risk, which states that as the debt/equity ratio or leverage increases, the borrower has a greater risk of losing equity capital. Therefore, under the uncertain conditions of mechanized farming of Gedaref, the level of leverage used by farmers should carefully be controlled so as to avoid large losses of equity capital.

8.2 Conclusions and Recommendations

To enhance development in the rain-fed mechanized farming of Gedaref area and based on the research results the following main recommendations should be considered:
In the private sector of rain-fed mechanized farming of eastern Sudan, the role of government in providing incentives in terms of modern input supply, better infrastructure and other basic services should be improved. The extension services should be strengthened through broadening the extension work, enhancing extension staff's qualification and providing them with better necessary facilities.
The credit system should be improved. Credit should be expanded to farmers to continue to access loans from banks, particularly medium and long term-loans to invest in agricultural production. The credit system should also be more flexible with simpler form and procedures for credit application, longer term for repayment and closer monitoring and follow up.

The application of the recommended improved cultural practices is proved to be useful in various aspects in the study area. Therefore, efforts to share risk with farmers by the state through promoting the new technology use could be one of the solutions. Moreover, rotational system can also be introduced and enhanced to prevent environmental deterioration and to increase and stabilize farm income.

Sheep and gum arabic production has favorable economic and environmental characteristics both in the short and long-term. Therefore, government intervention by subsidizing gum arabic tree establishment during the first four years of the tree life and by providing facilitated special credit program for these purposes could help in adopting this activity by farmers. To motivate sheep production adoption by farmers, initial subsidies and special facilitated credit programs are also helpful. Moreover, other services like drinking water availability during the dry season and better veterinary services should also be provided.

In the farming system of Gedaref, the results showed that sorghum prices are the main source of uncertainty in the system. Therefore, efforts to stabilize sorghum prices through maintaining a substantial national reserve will keep the prices at reasonable level for both producers and consumers.

Because of the short production season in this farming system (June-December), the off-farm activities could play an important role in increasing farmers' income and mitigating the risk involved in the agricultural activities. Therefore, efforts to facilitate and create chances to invest in off-farm activities through co-operatives and other governmental and non-governmental bodies can help in this regard.

ZUSAMMENFASSUNG

Problemstellung und Zielsetzung

Die Abhängigkeit landwirtschaftlicher Produktion von Witterungsbedingungen stellt die Landwirtschaft schon seit jeher vor ein gesondertes Risiko, das es zu kalkulieren gilt. Die vorliegende Studie analysiert unter Berücksichtigung dieses Risikos die Wirtschaftlichkeit des mechanisierten Regenfeldbaus in der Region Gedaref im Osten Sudans.

Vorhergehende Studien belegen die Bedeutung des mechanisierten Regenfeldbaus für den Aufbau nationaler Nahrungsreserven und die Erzielung exportgestützter Deviseneinnahmen, wodurch letztlich nicht nur die landwirtschaftliche, sondern auch die gesamtwirtschaftliche Entwicklung gefördert wird.

Der Regenfeldbau ist jedoch eine Art der Landbewirtschaftung, die systembedingt mit einem hohen Grad an Instabilität und Unsicherheit verbunden ist, so auch in der Provinz Gedaref. Einerseits führen unkontrollierbare Niederschläge (zeitlich unregelmäßig und in der Menge variabel) zu stark schwankenden Ernteerträgen, andererseits werden gültige Preisprognosen durch schwankende Preise für In- und Outputs erschwert. Hinzu kommt, dass die Mehrheit der Landwirte in der Untersuchungsregion in ihrer Produktion erheblich von Fremdkapital abhängt und das finanzielle Risiko der einzelnen Landwirte zusätzlich mit dem Grad der Fremdkapitalaufnahme steigt. Die aus dem unternehmerischen und finanziellen Risiko resultierenden instabilen Betriebseinnahmen in Verbindung mit einer schlechten Infrastruktur in der Region dürften die Produktionsentscheidungen der Landwirte beeinflussen, dabei gleichzeitig die Einführung neuer Technologien verzögern und längerfristige Investitionen in der Landwirtschaft verhindern, wodurch letztlich die Entwicklung des Regenfeldbaus verzögert wird.

Es lässt sich jedoch zeigen, dass durch Einführung neuer Technologien das landwirtschaftliche Einkommen in der Region gesteigert werden kann. Zudem würden die Erzeugung von Gummiarabikum und die Haltung von Schafen eine Produktionsdiversifizierung in den Sorghum-Monokulturen von Gedaref bedeuten und so zu einer Stabilisierung der Einkommen beitragen.

Auf Grundlage dieser Argumente, die für die Einführung verbesserter Technologien und eine Diversifizierung der Landwirtschaft sprechen, analysiert die vorliegende Arbeit die Wirtschaftlichkeit des mechanisierten Regenfeldbaus unter Berücksichtigung wetterbedingter Risiken. Insbesondere sollen verschiedene Produktionsstrategien in Bezug auf ihre Risikoeffizienz evaluiert werden. Die gegenwärtigen traditionellen Anbautechniken werden dabei den vorgeschlagenen verbesserten Verfahren gegenübergestellt.

Methoden

In dieser Studie wird ein stochastischer Ansatz der Kostenplanung angewendet, um die momentanen und die vorgeschlagenen Produktionsstrategien unter Verwendung sowohl traditioneller als auch verbesserter Anbautechniken zu bewerten. Die Untersuchung basiert auf einer deterministischen Finanzanalyse, die bei einem Planungszeitraum von zwanzig Jahren den Betriebseinkommens als Leistungsmaß nutzt. Untersuchungsgegenstand ist der Anbau von Sorghum und Sesam auf der gesamten Kulturfläche bei gleichzeitiger Zulassung von Gummiarabikum- und/oder Schaferzeugung innerhalb der gegebenen Produktionsmethoden unter Verwendung von einerseits traditionellen und andererseits verbesserten Anbautechniken. Die Risikoquellen in der stochastischen Budgetanalyse sind der Bruttogewinn für das traditionell erzeugte Sorghum und Sesam, die Preise und Erträge von Gummiarabikum und Schafen, sowie die Preise und variablen Kosten von Sorghum und Sesam im verbesserten Anbausystem. Simulationen erfolgten mit der Software „@ Risk“, die eine Darstellung der zufallsabhängigen Variablen in einer Wahrscheinlichkeitsverteilung erlaubt und daraus unter Verwendung einer Hyperkubustechnik stochastische Simulationen errechnet. Die Ergebnisse werden ebenfalls als Wahrscheinlichkeitsverteilung ausgegeben.

Um in einem zweiten Schritt eine Rangfolge der untersuchten Risikoalternativen für ein spezifiziertes Risikoaversionsniveau eines Landwirts bilden zu können, wurde die stochastische Effizienzmethode (SERF) angewendet. Die Methode basiert auf der subjektiven Nutzenhypothese (Subjective Expected Utility: SEU), welche die Risikoeffizienz mit dem höchsten Sicherheitsäquivalent unter der Annahme einer negativen exponentiellen Nutzenfunktion ermittelt.

Um die finanzielle Ausstattung der Betriebe zu untersuchen, wurden verschiedene Niveaus der Fremdkapitalaufnahme und deren Einfluss auf das Eigenkapital der Betriebsinhaber bewertet und anschließend der Effekt auf das Geschäftsrisiko bei traditionellem Anbau von Sorghum und Sesam und bei Anwendung des Systems, welches die Einbindung von Schafhaltung in tradtionellen Sorghum und Sesam Betrieben ermöglicht.

Empirische Ergebnisse und Diskussion

Das Ergebnis der stochastischen Simulation weist für die Landwirte geringere Verluste aus, wenn sie die erste Strategie (Sorghum und Sesam) oder zweite Strategie (Sorghum, Sesam und Gummiarabicum) über einem Planungszeitraum von zwanzig Jahren verfolgen. Die Wahrscheinlichkeit am Ende desselben Planungszeitraumes Profit zu erzielen, ist jedoch bei Verfolgung der dritten Strategie (Sorghum, Sesam und Schafe) oder vierten Strategie (Sorghum, Sesam, Schafe und Gummiarabicum) 100%. Die Ergebnisse der stochastischen Simulation zeigen klar, dass risikoaverse Landwirte $(+ \infty > ra < -\infty)$ mit der Strategie III oder IV besser fahren als mit den Strategien I und II.

Bezogen auf das stochastische Einkommen zeigt sich unter traditionellen Bedingungen, dass der Bruttogewinn bei Sorghum eine sehr wichtige Einflussgröße für alle der vier Strategien darstellt, wenn man die Sensitivität des Kapitalwertes am landwirtschaftlichen Einkommen näher betrachtet. Der Bruttogewinn von Sesam beeinträchtigt ebenfalls die Vorzüglichkeit aller vier Strategien, jedoch in einem viel geringeren Umfang als Sorghum oder der Preis für Schafe. Demgegenüber hat Gummiarabikum bei den Strategien II und IV die niedrigste Wirkung auf den Kapitalwert

Die Wahrscheinlichkeit, am Ende des Planungszeitraumes mit den Strategien V bis VIII Verluste zu erzielen, ist sehr gering, insbesondere bei Verfolgung der Strategien V, VI und VII. Die Wahrscheinlichkeit mit Strategie VIII Gewinne zu machen, ist jedoch im selben Planungszeitraum 100%. Sowohl die graphischen CDF-Darstellungen als auch die Statistiken aus den stochastischen Simulation zeigen für die Strategien unter verbesserten Bedingungen, dass Strategie VII, in der die Eingliederung von Tierzucht in das System ermöglicht wird, und Strategie VIII, die zusätzlich auch die Erzeugung von Gummiarabikum zulässt, bezogen auf die Risikoeffizienz ersten Grades die zu bevorzugenden Alternativen darstellen. Diese Strategien sind für eine Vielzahl von risikoaversen Landwirte vorteilhaft. Die Ergebnisse der vergleichenden Analyse zeigen, dass die Anwendung von verbesserten Technologien bei gleichzeitig verbesserten Produktionsverfahren und -bedingungen einen positiven Einfluss auf die Einkommensstabilität im Vergleich mit dem traditionellen Anbau von Sorghum und Sesam hat.

Wird der Kapitalwert bezüglich seiner Sensitivität auf die Variablen des stochastischen Budget in den Strategien V bis VIII überprüft, zeigen die Tornadodarstellungen, dass der Sorghumpreis der wichtigste Faktor mit größter Wirkung auf die Variabilität des Kapitalwerts für alle vier Strategien unter verbesserten Bedingungen darstellt. Ein ähnliches Bild zeigt sich für die Schafspreise in den Strategien VII und VIII, wo sie einen erheblichen Einfluss haben. Andere Variablen wie Sorghumertrag, Sorghumkosten und Sesampreise wirken sich ebenfalls in allen anderen Strategien aus - allerdings in geringerer Weise als Sorghum- und Schafspreise. Auf der anderen Seite haben nach den Preisen für Gummiarabikum die Sesampreise und die variablen Kosten die schwächsten Auswirkungen. Deren Effekte sind in den Strategien VI und VIII nicht signifikant.

In Bezug auf die Risikobereitschaft eines Landwirtes und den Glauben an die Unvorhersagbarkeit von Wetterereignissen stellt die stochastische Effizienzanalyse die Strategie IV bei traditioneller Bewirtschaftung und die Strategien VII und VIII unter Verwendung verbesserter Anbautechniken als erfolgversprechendste heraus. Diese Ergebnisse sind auf risikoaverse Landwirte und einen Wohlstand rr(w) von 0,5 - 4 bezogen. Unter verbesserten Anbaubedingungen hat die Risikobereitschaft des Landwirtes keine Auswirkung auf die Wahl des Risikoeffizienzplanes.

Trotz aller Risiken ist der extensive Anbau von Sorghum in Monokultur die dominierende Landbewirtschaftung in der Region. Die empirischen Forschungsergebnisse sprechen allerdings für die Einführung von verbesserten Praktiken im Sorghum- und Sesamanbau, um das Einkommen zu erhöhen und gleichzeitig zu stabilisieren. Die Landwirte können jedoch wegen hoher Kosten, die aufgrund des hohen Verlustrisikos des Anbausystems entstehen, den Einsatz dieser neuen Technologie nicht vollständig realisieren. Zudem fehlen in der Region das notwendige Knowhow über diese neuen Technologien und Experten. Zusätzlich herrscht ein hoher Druck von Seiten der Finanzinstitute und des Arbeitsmarktes über die Lohnkosten. Die Landwirte sind dadurch letztlich gezwungen, ihre Erträge zu ungünstigen Zeiten mit Profitverlust zu verkaufen.

Die Einführung von Aufforstungsaktivitäten durch Acacia Senegal, einem Gummiarabikumproduzenten, führt langfristig zu geringen Produktionskosten bei gleichzeitig hoher Profitabilität und Vorteilen für die Umwelt. Der integrierte Anbau von Gummiarabikum kann langfristig das Risiko in Sorghum- und Sesamesystemen minimieren und in Kombination mit Schafzucht sogar eine kurzfristige Einkommensstabilisierung bewirken. Die hohen Einführungskosten in Verbindung mit dem allgemein niedrigen Einkommen aus dem traditionellen Sorghum- und Sesamanbau machen die Anpflanzung von Acacia-Bäumen jedoch während der ersten vier Jahre für Landwirte wenig attraktiv.

Schafzucht als zusätzlicher Produktionszweig in den Anbausystemen im Gedaref ist nicht nur geeignet unternehmerische Risiken, sondern auch finanzielle Risiken zu minimieren. Neben Vorteilen für Wirtschaft und Umwelt fällt der Schafverkauf zeitlich mit den jährlichen Investitionen in den Feldbau von Sorghum, Sesam und Gummiarabikum zusammen.

Obwohl der Einsatz von Fremdkapital zu hohen Gewinnen und unter guten Bedingungen auch zu einer Erhöhung des Eigenkapitals führen kann, ergab die Finanzrisikoanalyse der beiden untersuchten Anbausysteme für die Untersuchungsregion das Gegenteil. Ein erhöhter Fremdkapitaleinsatz kehrte die Vorteile diversifizierter Farmerträge in beiden Systemen um und führte so zu großen Kapitalverlusten. Der Grund dafür lag in den äußerst niedrigen realisierten Einkommen in diesen beiden Systemen (jeweils unter dem Zinssatz). Einen umso stärkeren Einfluss hatte ein höherer Eigenkapitalanteil, da der traditionelle Sorghum- und Sesamanbau insgesamt von Verlusten begleitet ist. Niedrige Erlöse und hoher Fremdkapitalaufwand (erhöhtes Verhältnis von Fremd- zu Eigenkapital) sind hier letztlich das Risiko für den Landwirt, Eigenkapital zu verlieren. In den mechanisierten Anbausystemen in der Region Gedaref mit ihren unsicheren Anbaubedingungen muss daher das Niveau des Fremdkapitaleinsatzes sorgfältig abgewogen werden, um Eigenkapitalverluste zu verhindern.

Maßnahmen, die ein erhöhtes und stabilisiertes landwirtschaftliches Einkommen und damit die Weiterentwicklung des mechanisierten Regenfeldbaus im Gedaref zum Ziel haben, sollten daher in der Anbauplanung eine zentrale Rolle spielen.

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APPENDICES

Appendix 4.1 Study Questionnaire

Farmer No.______________

Age ___________________ Education __________________

Total scheme area_________________ Fed.

Owned__________________ fed. Rented___________________ Fed.

Source of finance: ( ) private ( ) bank ( ) others
Type of credit: ( ) long term ( ) short term
Duration of credit__________________
Purpose____
Method of repayment: ( ) lump sum
( ) installment, number of installments………………duration between installments______________
Type of security required_________________

Machinery owned by farmer

Machinery type	Model (year)	Purchase year	Purchase price	Scrap value	Taxes/year	Insurance/year
Tractor						
Disk						
Planter						
Lorry						
Terella						
Lister						
Sprayer						
Harvester						

Do you have sources of income other than agriculture during or outside the growing season?
( ) Yes ( ) No
If yes

Income source	Income/year	time/year
____________	__________	__________
____________	__________	__________

Do you apply fertilizer for sorghum and/ or sesame? ( ) yes ( ) no
Reasons in both cases…………………………………………………………………..
……………………………………………………………………………………….

Do you apply any rotation? ( ) yes ( ) no
If yes, which rotation…………………………………………………………………
If no, what are the reasons……………………………………………………………
Do you use chemical herbicides for sorghum and/or sesame? ( ) yes ( ) no

What are the reasons in both cases?………………………………………………

Did you receive any extension services this season? ( ) yes ( ) no
If yes in which form……………………………………………………………………………..
Why do you not grow sesame, or why its area is small compared to sorghum? ………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
What do you do to reduce the different types of risk……………………………………………

What is the date of marketing for sorghum_________________
Sesame________________

1. Animal production

Item	Cattle	Sheep	Goats	Camels
Animal number				
Labor number				
Labor cost				
Water source				
Water cost				
Fodder source				
Fodder cost				
Veterinary cost				
Mortality rate				
Animal products				
Sold animal No.				
Marketing fees				

Markets for live animals ________________________

Reasons for keeping animals besides crop production

____

What are the main problems facing agricultural production in the area?

description	Type of problem
Cost of production	
soil	
rains	
Pest and diseases incidence -crops -animals	
Finance	
extension	
Others (materials availability…etc.	

Appendix (5.1) Decision Analysis Approach Axioms

The decision analysis approach outlined in figure (5.1) is founded on a set of axioms. Axioms are propositions that are sufficiently self-evident that they can be regarded as widely accepted truths. Anderson, Dillon and Hardaker (1977) provided one of many versions of the axioms that underlie decision analysis. These axioms relate to choices amongst risky prospects, each of which is characterized by a probability distribution of outcomes. Possible outcomes of all risky prospects are assumed to be measured in one dimension, such as money value of terminal wealth.

These axioms are:

1. Ordering. Faced with two risky prospects, a_1 and a_2, a decision maker either prefers one to the other or is indifferent between them.

2. Transitivity. Given three risky prospects, a_1 , a_2 and a_3 , such that the decision maker prefers a_1 to a_2 (or is indifferent between them) and also prefers a_2 to a_3 (or is indifferent between them), then the decision maker will prefer a_1 to a_3 (or be indifferent between them).

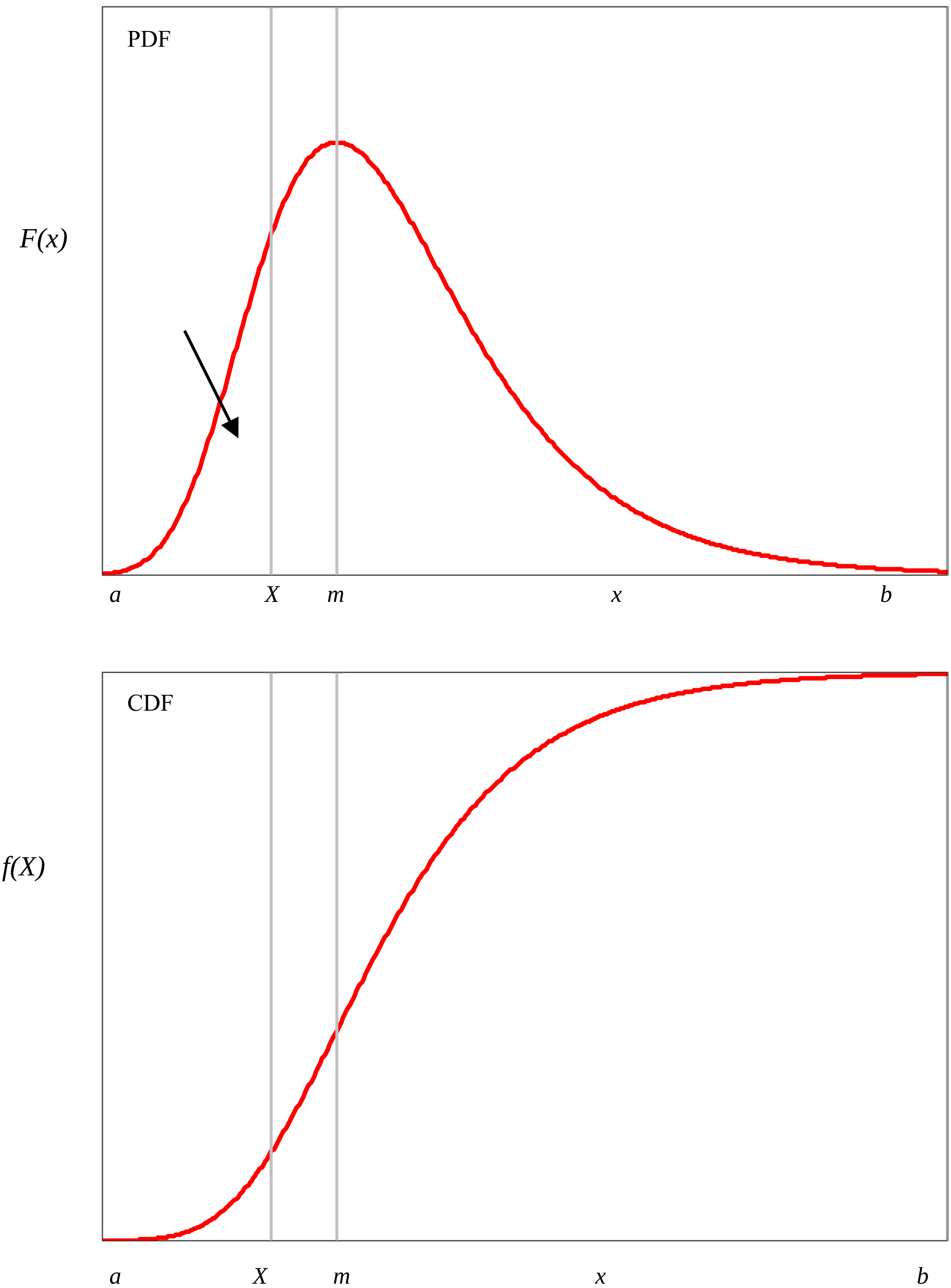
3. Continuity. If a decision maker prefers a_1 to a_2 and a_2 to a_3 , then there exists a subjective probability $P(a_1)$, not zero or one, that makes the decision maker indifferent to a_2 and a lottery yielding a_1 with probability $P(a_1)$ and a_3 with probability $1-P(a_1)$.

4. Independence. If the decision maker prefers a_1 to a_2 and a_3 is any other risky prospect, the decision maker will prefer a lottery yielding a_1 and a_3 as outcomes to a lottery yielding a_2 and a_3 when $P(a_1) = P(a_2)$.

Other axiomatic formulations are provided by Quiggin (1993) which are more relevant to modeling behavior rather than for prescriptive use.

Appendix (5.2) Definition of PDF and the CDF

Hardaker et. Al, (1997, 2004) defined the probability density function (PDFs) and the cumulative distribution function (CDFs) and explained the relationship between the two. The PDFs have many different forms, but the most common one is bell shaped with a central peak indicating the most likely value or mode of the uncertain quantity and with low-probability 'tail' on either side of the peak stretching out to the upper and the lower extremes in the figure below (upper part). The PDF for an uncertain quantity X is conventionally denoted by $f(X)$. In this case, $f(x)$ is a typical bell-shaped distribution ranging from a minimum value of a to a maximum of b and with a mode at m. it has the property that the area under the whole curve is one. Some problems are associated with the use of PDFs in decision analysis, because they may be difficult to draw, specially it is difficult to make sure that the area under the curve is really equal to one, as the rules of probability require. More convenient in most situations are the cumulative distribution functions (CDFs). The CDF for an uncertain quantity x is conventionally denoted by F(x), (the figure below, lower part). The relationship between a PDF and CDF is illustrated by reference to the figure below.



The Relation between the PDF and CDF