Environmentally-oriented Economic Analysis of the Rain-fed Agricultural Sector in North Upper Nile State Sudan

By

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Dedication

This work is dedicated to:

My late parents may the Almighty Allah include them in his mercy

My Brothers and sisters

My wife and daughters

With love

Acknowledgement

First of all 1 render my thanks and praise to Almighty Allah, who offered me the health and strength to accomplish this work. It is my pleasure to acknowledge with sincere thanks and most grateful appreciation to the continuous help and support, substantial guidance, continuous inspiration, kindness and most valuable assistance to my supervisor Dr. Mohamed Eljack Ahmed, throughout the study. Thanks are also due to family of the Upper Nile University for their unlimited co-operation, assistance and support. My deep thanks and love to my brothers, especially Engineer Omar, sisters, wife, daughters for their patient, moral support and unlimited help. Also especial thanks to relatives and friends. Great thanks are also due to my friend Dr. Mutasim Mekki Mahmoud for his advice, encouragement, patience and continuous support. I am very much indebted to all my colleagues particularly Dr. Abubker Elhouri, Dr. Abdelrouf, Dr. Khalid, Dr. Nagla and Dr. Somia for their assistance in improving my work.

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Abstract

This study was conducted at Renk county Upper Nile State during 2007\08 seasons with the aim of environmentally oriented economically analyze the rain-fed agricultural production sector, investigate farmers' technical efficiency and determine optimum cropping pattern. The study depended on both primary and secondary data. Primary data were collected by means of multi-stage stratified random sampling techniques of 150 farmers through questionnaire. The secondary data were collected from different relevant sources. Varieties of analytical techniques were applied to reach to the stated objectives: change in productivity approach, gross margin analysis, descriptive statistic, stochastic frontier production function and linear programming (LP). Results of the change in productivity approach and gross margin analysis indicated that, the productivity of all crops, particularly sorghum, were deteriorating over time due to mono-cropping, non-application of both recommended technical packages and shelter-belt. Accordingly, many farmers forced to abandon their land to be covered by sands which leads to soil degradation. Likewise, poor productivity negatively affected framers technical efficiency and cropping patterns. Results also revealed that, sesame in mechanized sector and groundnut in traditional sector had the highest cost of production. Sorghum in the mechanized sector and groundnut in the traditional sector were the leading crops in terms of a substantial and encouraging profit. The mean production technical efficiency analysis revealed that there is scope for increasing all crops produced in the study area by different degree of percentage, although sorghum in mechanized and groundnut in traditional sector were the most efficiently produced crops. The analysis of determinants of technical efficiency indicated that sowing date, weeding number, rain fall distribution, seeds rate, harvesting cost and off farm income were the most important factors determining production technical efficiency. The main occupation, level of education, agriculture credit, extension service and family size had significant effects on frames technical inefficiency of crops production. The results of optimal solution of the linear programming (LP) models in mechanized sector indicated the present of a highly significant profit compared with the current situation as the majority of the land was allocated for sorghum where as it indicated the present of a reasonable profit in traditional sector as most of the land was allocated for groundnut and sorghum. It also showed that, labor and capital were the most limiting factors of crop production in the study area. The study recommended enacting the law of allocating 10-20% of the agricultural land in the rain – fed sector to forest cultivation, establishment of a well equipped agricultural extension program, adoption of recommended technical packages, adoption of water harvesting techniques and providing credit and production inputs at the right time and place in order to improve farmers livelihoods and the sustainability of the environmental development.

المستخلص

أجريت هذه الدراسة بمقاطعة الرنك ولاية أعالى النيل في موسم 2007م – 2008م و هدفت لإجراء تحليل اقتصادي موجهة بيئيا لقطاع الانتاج الزراعي المطري و تحليل الكفاءه الفنية للمزراعين وتحديد التركيبة المحصوليه المثلى . أعتمدت الدراسة على كل من المعلومات الأولية والثانوية حيث جمعت المعلومات الأولية عن طريق العينة الطبقية العشوائية المتعددة من 150 مزارع عن طريق الأستبانة ، وجمعت المعلومات الثانوية من عدة مصادر ذات صلة بالموضوع . أستخدمت طرق تحليلة مختلفة للوصول للأهداف المذكورة وتمثلت في مدخل التغيرفي الأنتاجية ، تحليل هامش الربح ، التحليل الوصفي ، دالة الإنتاج المجالى العشوائى والبرمجة الخطية. أشارت نتائج تحليل مدخل التغير فى الإنتاجية وتحليل هامش الربح بأن إنتاجية كافة المحاصيل خاصة الذرة متدهورة مع الزمن بسبب الزراعة الاحادية و عدم تطبيق كل من الحزم التقنية الموصى بها و الاحزمة الشجرية. و بناء عليه اجبر عدد كبير من المزارعين لهجر اراضيهم الزراعية لتغطي بالرمال مما ادي لتدهور التربة. كما اثر ضعف الانتاجية سلباً علي كفاء المزارعين الفنية و التركيبة المحصولية في المنطقة. كما أظهرت النتائج ايضاً أن محصول السمسم فى القطاع الألى والفول السودانى فى القطاع التقليدى سجلا أعلى تكاليف انتاج ، بينما إحتلت الذرة في القطاع الألى والفول السودانى فى التقليدى المرتبة الاولى من حيث الربح العالى المشجع. أظهر تحليل متوسط كفاءة الإنتاج الفنية إمكانية زيادة أنتاجية كل المحاصيل المنتجة بمنطقة الدراسة بدرجات متفاوتة وأن الذرة فى القطاع المطرى والفول السودانى فى القطاع التقليدى أكثر المحاصيل المنتجة كفاءة . أوضح تحليل محددات الكفاءة الفنية بأن تاريخ الزراعة ، وعدد مرات الحش ، توزيع الأمطار، الوقود ، معدل البذر ، تكلفة الحصاد والدخل من خارج المزرعة هى أكثر العوامل المحددة لكفاءة الإنتاج الفنية . كان تاثير المهنة الرئيسية ، والمستوى التعليمي ، التمويل الزراعى ، الخدمات الأرشادية ، وعدد أفراد الاسرة معنوي و قوى في عدم كفاءة المحاصيل لانتاجية. اوضحت نتائج الحل الأمثل لنموذج البرمجه الخطية وجود ربحية عالية جداً للقطاع الالي حيث خصصت الغالبية العظمى من أراضيه لمحصول الذرة بينما أشارت لوجود ربحية معتدلة فى القطاع التقليدى الذى خصصت معظم أراضيه لمحصولي الفول السودانى والذرة . كما أوضحت بأن العمالة ورأس المال هي أكثر العوامل المحددة للانتاج في منطقة الدراسة . اوصت الدراسة بتفعيل قانون تخصيص نسبة 10-20% من أراضي الزراعة المطرية للغابات ، إنشاء برامج إرشاد زراعي فعال ، تبني الحذم التقنية الموصى بها ، تبني برامج حصاد المياه ، وتوفير التمويل ومدخلات الانتاج في الزمن والمكان المناسب لضمان رفع المستوي المعيشي للمزارعين مع إستدامة التحسين البيئي .

List of Abbreviations

ABS	Agricultural Bank of Sudan
ARC	Agricultural Research Corporation
CD	Cobb-Douglas
CPA	Comprehensive Peace Agreement
FAO	Food and Agriculture Organization
Feddan(Fed)	Land area unit, equivalent to 4200 meters(One feddan=0.42 ha
FNC	Forest National Corporation
GDP	Gross Domestic Product
GNP	Gross National Product
KG	Kilogram
LP	Linear Programming
MFC	Mechanized Farming Corporation
MFNE	Ministry of Finance and national Economy
MVP	Marginal Value Productivity
NGOs	Non-Governmental Organization
SDG	Sudanese Pound (1US$=about2.9SDG)
UN	United Nations
UNS	Upper Nile State

CHAPTER ONE

1. Introduction

1.1 The role of agriculture to Sudan economy:

The agricultural sector comes in the forefront of the productive sectors in the Sudan for many years, contributing substantially to the GDP (36%) (Table 1.1).It provides employment for about 55% of total labor force and livelihood to about 70% of the population (Ministry of Finance, and National Economics, (MFNE), 2008).

Table 1.1 Percentage contributions of the different economic sectors to the GDP during 2000-2008

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agriculture	46.4	45.6	46.4	45.8	44.5	39.6	39.2	36.2	35.9
Manufacture	21.4	22.8	23.1	23.9	25.4	28.3	28.3	33	31.4
Service	32.2	31.6	30.9	30.3	30.1	32.1	32.5	30.8	32.7

Source: MFNE, 2008

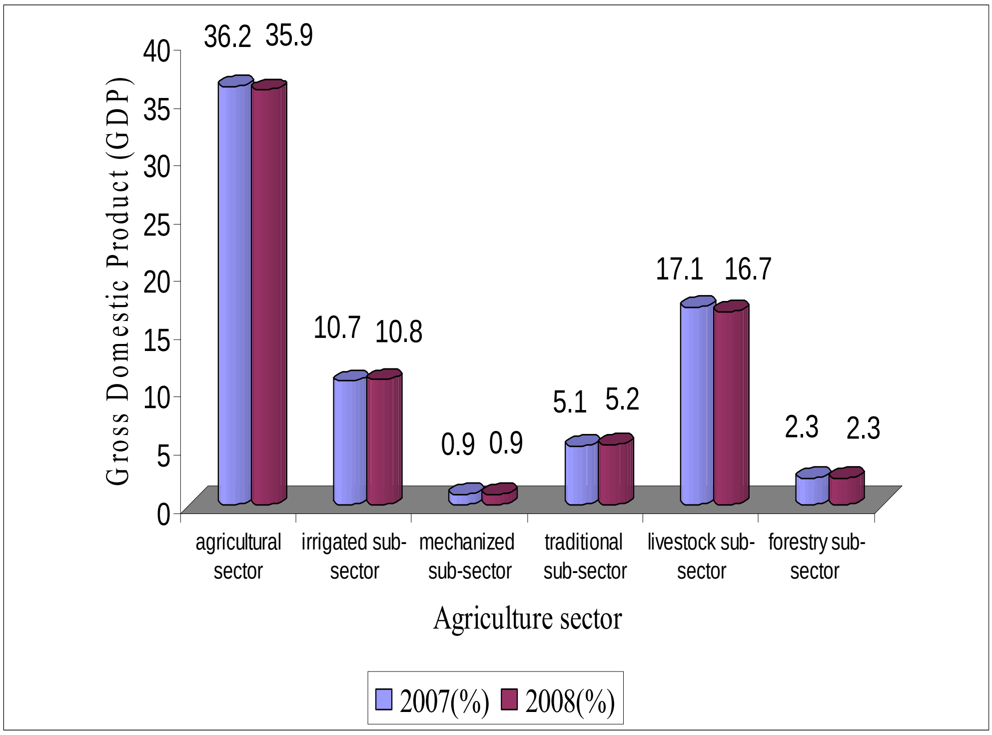
It is clear that the contribution of agricultural sectors on the GDP dropped from 46.4 in 2000 to 35.9 in 2008, while its growth rate increased from 2.4% in 2007 to 5.1% in 2008. This was attributed to the high growth of the irrigated, traditional rain fed agricultural subsectors in addition to livestock from 3.5%, 6.2% and 2.5% in 2007 to 7.2%, 7.0%and 3.7% in 2008, respectively, although the growth rate of both forestry and mechanized rain-fed agricultural subsector fell from 3.0% and 23.8% in 2007 to 1.9% and 4.8% in 2008, respectively, Table (1.2).Within the agricultural sector, the irrigated sub-sector contributed about 10.7% and 10.8 of GDP in 2007 and 2008 respectively, ranking second after livestock, whose shares were about 17.1% and 16.7% in the same respective period. Traditional rain fed sub-sector came third with a share of about 5.1% and 5.2.0% of GDP in 2007 and 2008 respectively, followed by mechanized rain fed sub-sector which contributed about, 0.9% of GDP in 2007 and 2008 respectively, (Figure 1.1).

Table 1.2 Growth rate (%) of the agricultural sub-sectors during 2007-2008

	2007	2008
Agricultural sector	2.4	5.1
Irrigated sub-sector	3.5	7.2
Mechanized rain fed sub-sector	23.8	4.8
Traditional rain fed sub-sector	6.2	7
Livestock sub-sector	2.5	3.7
Forestry sub-sector	3	1.9

Source: MFNE, 2008

Fig 1.1 Percentage contributions of the agricultural sub-sectors to GDP during 2007-2008



Source: Ministry of Finance and National Economics (2008)

1.2 Farming systems in Sudan

The country's agricultural policy was directed towards supporting the agricultural sectors to achieve economic safety, food security, self sufficiency, import reduction and supporting the producers. Crops in the Sudan are produced under three main sub-sectors: irrigated agriculture, mechanized rain fed farming and traditional agriculture. The agrarian production contributed with 56.5% of the total agricultural sector in 2007 (MFNE, 2007).

1.2.1 The irrigated agriculture sub-sector

The irrigated agriculture sub-sector covers two million hectares, with irrigation water sources coming mainly from the Nile and its tributaries by gravity flow from the dams, pump uplifting from the rivers or from flood irrigation in the Gash and Toker deltas (250,000 feddan). Some small areas are irrigated from other sources such as groundwater. The Gezira Scheme represents half the irrigated area (2,12 million feddan). The irrigated sub-sector includes three other major corporations, New Halfa (500,000 feddan), Rahad (300,000 feddan) and Suki (115,000feddan). The main crops grown in the irrigated sub-sector are cotton, sorghum, groundnuts, wheat, sugarcane, legumes, sunflower, maize, fruits, vegetables and fodder. On the average, sub-sector accounts for about 64 percent of the total crops contribution to the GDP (Ministry of Agriculture and Forestry, 2009)

1.2.2 The mechanized rain-fed farming sub-sector

The mechanized rain-fed farming sub-sector started in the mid-forties in limited areas in the vicinity of Gadarif. Over the time the mechanized area was increased to about 6 million hectares in the areas of Gadarif, Senar State, Blue Nile State, White Nile State, Southern Kordofan State, Upper Nile State and Kasala State (Ministry of Agriculture and Forestry, 2009).The cropped area varies with respect to the rainfall variation .Table (1.3) shows the cultivated area in different sub-sectors. The main crops produced in this sub-sector are sorghum, which covered 85 percent of the total cultivated area and contributes about 65 percent of the total sorghum produced in Sudan, followed by sesame which covered 10 percent of the total cultivated area and contributes about 53 percent of the total sesame produced in Sudan. Also considerable areas are cultivated with sunflower, cotton, and guar. The sub-sector accounts for about 18 percent of the crops contribution to the GDP (Ministry of Agriculture and Forestry, 2009).

1.2.3 The traditional rain-fed farming sub-sector

The Ministry of Agriculture and Forestry, (2009) stated that the area of traditional rain-fed farming sub-sector is about 9 million hectares and is distributed over the western, southern, and central Sudan. The area of this traditional sub-sector is communally owned by the members of the tribes and it contributes about 90 percent of total millet production, 48 percent of groundnut, 28 percent of sesame, 11 percent of sorghum and 100 percent of gum Arabic production in the Sudan .The sub-sector is considered as the main producer of livestock.

Table (1.3) the cultivated areas during 2006/07 and2007/08 seasons (area in million feddans).

Sector	Season2006/07	Season 2007/08
The mechanized rain-fed agriculture	2.7	2.1
The traditional rain-fed agriculture	13.9	11.7
The irrigated agriculture	22.2	27.2
The total cultivated areas	38.7	41.0

Source: Ministry of Agriculture 2008

1.2.4 Agriculture in the Upper Nile State

Agriculture in the Upper Nile State is concentrated in the northern part of the State, around Renk area, where the majority of crops are produced. The bulk of the cultivated area in the state is under rain-fed farming system (both traditional and mechanized) (FAO, 2000), although, the mechanized agricultural is given much attention from the authorities. Northern part of the Upper Nile State lies within the central clay plain of the Sudan (crop production zone). Renk County represents the second largest semi mechanized rain-fed area in the country after Gadarif State.

1.3 Problem statement and justification of the study

The rain-fed sector (mechanized and traditional) is the largest agricultural sector in the Sudan, covering substantial area of land, playing significant role in the farmers' income, providing food for the majority of Sudan's people and contributing considerably to the country's GDP and national income. This sector covers wide area of the country, ranging from east (Gadarif and Blue Nile areas) south (Renk area), west and central. Renk area is the major food production center in the south Sudan. Despite the importance of this sector to the Sundance economy as a whole, yet its full potential have not been realized, particularly in terms of efficient utilization of resources in order to maximize farmers' returns/profits. There are many obstacles hindering the growth of this sector among them is: the traditional procedures and practices used in mechanized rain-fed sub-sector which considered as the main reasons for the low quantity and quality of crop production. Generally farmers in the study area are far a way from the recommended technical packages. The credit always smaller than the required and comes behind schedule, resulting in the delay of the sowing date and pushing farmers to rely on cheap unreliable inputs. On the other hand, the socioeconomic characteristics of farmers, remoteness of the agricultural area and poor extension services force farmers to depend on unimproved seeds of low yielding varieties. In addition, there are great competitions on the labor force during the cultivating period {rainy season (August- October)}, due to limited number of skilled labor, hence, only financially capable farmer is willing to hired labor and secure his production. Farmers are compelled to sell at very low price at harvest to meet their finance obligation. The overall results are poor returns or losses, fluctuation in cultivated areas, soil degradation, persistent decline of crop yields and recurring crop failures, breakdown of traditional socially and economically accepted farming systems. This leads to serious local and national socio-economic and political repercussions. Reduced output of food and exportable crops (mainly oil seeds and gum Arabic) results in reduced household income and declines in hard currency gains to the country and hence a decrease in the GNP. Moreover, migration of the affected population causes serious social problems both for the farmer's family and for destination community. In addition deforestation may have adverse long-term irreversible environmental impacts such as desertification.

1.4 Objectives of the Study

The overall objective of the study is to economically analyze the rain-fed sub-sector in Renk County, north part of the Upper Nile State (environmentally-oriented), in order to improve the livelihoods of farmers through improving their agricultural returns, (income).

The specific objectives are:

1- To investigate the socio-economic characteristics of farmer's under different rain-fed sectors.

2- To estimate productivity and profitability of producing crops under changing environmental condition of rain-fed.

3- To identify and evaluate farmers technical efficiency of resources used between different rain-fed sector.

4- To investigate the main factors behind farmer's technical inefficiency for crops production.

5- To determine the optimum cropping combination, that will maximize the farmer's net return.

6. To draw some conclusions and recommendation from the analysis for improving yield in Rain fed sector.

1.5 The hypotheses of the study

To achieve the research objectives the following hypotheses will be tested:

1. Farmers in the rain–fed sector are characterize by high crops productivity
2. Farmers in the rain-fed sector are technically efficient.
3. Socio-economic factors are the main factors behind farmer's technical inefficiency.
4. The current crop combination in rain fed sector does not maximize farmers return from the crops grown.

1.6 Research methodology

1.6.1 Study area

This study was conducted in Renk County, which located in the northern part of the Upper Nile State along the eastern side of the White Nile and occupies an area of 32,000 km^2. The County is composed of five localities (Payams): North Renk, South Renk, Geiger, Jalhak and Chemmedi. Each of these localities is divided into number of administrative units; each administrative unit is consists of many villages (Buma). The major ethnic groups in Renk Country are the Shilluk, Denka Bellang, Nuer, Dagu, Burun, Funji and Selaim. Four main types of land use are identified in the study area: a) irrigated agriculture (125 thousand ha): here various crops including cereals, vegetables and horticultural crops are growing b) Traditional rain fed farming (105 thousand ha). c) Mechanized rain fed agriculture (1.5 million ha) and d) forests and rangelands (1.0 million ha), (Adam 2007).

Northern Upper Nile area is situated in the semi arid zone of the Sudan. The climate is basically formed of two distinct seasons which are the wet or rainy season (June – October) and the dry season (November- May). The annual precipitation (about 450 - 655 mm) per annum has increasingly become erratic in time and place with frequent long drought spells in the rain season.

1.6.2 Sources of data collections

Both primary and secondary data were used to fulfill the objectives of the study, although, primary data were the main data source. Primary data were collected by means of a well set structural questionnaire. Secondary data were collected from different institutional sources such as Federal Ministry of agriculture and Forestry, Ministry of Agriculture and Livestock - Upper Nile State, Federal Bureau of Statistics, Meteorological Corporation and various other related institutions. Data on the farmers' basic information such as the socio-economic characteristics; age, educational level, occupation, family size, and farmer's income, on farm and off farm income, animal ownership, crops yield, crops production cost and prices of output were collected.

1.6.3 Sampling techniques

Multistage stratified sampling technique was used to collect data from 150 farmers, 75 from each of the big two strata (mechanized and traditional rain-fed sub-sector). The population stratified into strata to create homogeneity among sub-samples, reduce costs and save in time. Stratification is very frequently employed in sample design because it increases homogeneity within the strata and allows the researcher to take a small representative sample to study the population. One administrative unit was randomly selected from each Payam. Two to three villages (total 12) were chosen randomly from each of the administrative unit. Non probability sampling technique (snow ball) was used to select 6-7 farmers from each village representing each of the two big strata (mechanized and traditional rain-fed sub-sector). This actual figure (6 or 7 farmers) was chosen in proportion of the total farmers per each village (Fig. 1). Snow ball sampling technique was used due to the difficulties of producing a list of all farmers in the study area, saving in time and money, and for security purpose.

1.7 Methods used for environmentally-oriented economic analysis

Environmental impact is one of the most significant considerations in the evaluation of economic development projects, but it is also an extremely difficult factor to measure. To overcome some of this difficulty, principles and methods for assessing and valuing the effects of development on the environment, commonly called economic valuation techniques have been developed (Hufschmidt et al. 1983). Different methods are appropriate depending on the types of effects. The various techniques are divided between those that are market oriented and those that are survey oriented. Here the techniques presented in descending order of reliance upon market information, beginning with those that rely on actual market prices, and ending with survey-based and other hypothetical methods.

Market – Based Methods

These methods are based directly on market prices or productivity. They are applicable where a change in environmental quality affects actual production or production capability.

Change–in–productivity Approach

Development products can affect production and productivity positively or negatively. The change–in–productivity approach is used to value the incremental output by using standard economic prices (Frank, 1995).

Loss-of-Earning Approach

Changes in environmental quality can have significant effects on human health. This approach is commonly used in valuing earnings that are forgone through premature death, sickness or absenteeism, and increased medical expenditures. This approach is relevant when considering road, industrial plant safety, and projects that result in significant effects on human health by changing environmental quality. The value of 'health approach' is often questioned on ethical grounds. It is argued that it dehumanizes life, which is of infinite value. In practice, however, society implicitly places finite values on human life and health when it makes policy and project decisions that affect environmental quality, worker's health or safety, etc. If this were not so, it would be justified to spend all of GDP on heath improvements (World Bank, 1991).In the case of increase or reduction in numbers of deaths, a first estimate is made by evaluating the projected loss in earnings of the individuals involved. The value of an increase or reduction in sickness can be approximated by adding medical costs to the loss in earnings (World Bank, 1991).

Defensive or preventive Expenditures

A variety of "defensive expenditures' is undertaken by individuals, firms, and movements in order to avoid or reduce unwanted environmental effects. Environmental damages are often difficult to assess, but defensive expenditures may be determined more easily in monetary terms than direct valuations of the environmental good in question. Such actual expenditures indicate that individuals, firms or governments judge the benefits greater than the costs. The defensive expenditures can then be interpreted as a minimum valuation of benefits. Frank (1995) mentioned that in many African countries, erosion imposes defensive expenditures downstream and irrigation system requires maintenance due to erosion. The biggest evaluation difficulty lies in knowing the production function, that is, how much the action being evaluated will reduce defensive expenditures.

Methods Based on Surrogate Market Values

This group uses market information indirectly. It includes change in property value approach, the wage differential approach, the travel cost method, and uses of marketed goods as surrogates for non marketed goods. Each technique has its particular advantages and disadvantages, as well as requirements for data and resources.

Wage Differential Approach

This approach is based on the theory that in a competitive market the demand for labor equals the value of the marginal product, and that the supply of labor varies with working and living conditions in an area. A higher wage is therefore necessary to attract workers to locate in polluted areas or to accept risky work. To the extent that the wage differential is attributable to the difference in environmental quality, it provides some measures of the willingness to pay for improvement. As in the case of the property value approach, the wage differential approach can only be followed if the labor market is very competitive. Also, the approach reflects only private, not social, valuation of health risks (World Bank, 1991). Based on African experience, the prospects of quantifying the wage differential to a defensible extent are low.

Travel Cost Approach

This approach was developed by Clawson and Knetsch (1966) in the United States. It is most often used in analyzing the economic benefits of recreational facilities in industrial countries (parks. lakes, forests, wilderness, etc.) .the same approach is also used to value travel time in projects dealing with fuel-wood and water collection .The principal assumption of this approach is that the visitors who travel farthest are regarded as being marginal in that they would not come with any additional costs, those closer are assumed to capture a surplus equal to the difference between the costs of the farthest visitors and their own actual costs (Frank. 1995)

Marketed Goods as Surrogates for Non Marketed Goods

This approach is used in situations where environmental goods have close substitutes that are marketed, and where, therefore, the value to the environmental good can be approximated by observed market prices (WB.1991). For example, the value of a non marketed fish variety can be valued at the price of the most similar fish being sold in local markets.

Methods Based on Potential Expenditures or Willingness-to-pay

This group is used when it is not possible to estimate the benefits of environmental quality protection or improvements. Thus, it may be possible to estimate benefits by calculating the costs of replacing the environmental services that have been destroyed by a project, 0r by estimating what people might be willing to pay to protect an environmental asset (World Bank, 1991).

Replacement Cost Approach

It is based on the premise that when an environment is degraded, the costs of replacing the losses can be estimated. This is relatively poor measure of willingness to pay, because it only estimates the costs of replacement not whether anyone would be willing to incur these costs. When all else fails, however, replacement costs do give an upper estimate to the willingness to pay (Frank, 1995). The replacement cost approach has been used to estimate the benefits of erosion prevention measures by calculating the cost of the fertilizer that would be needed to replace the nutrients lost through soil erosion. The method applies only if, in the absence of erosion control measures, the fertilizer would actually be applied (World Bank, 1991).

Shadow Project Approach

Used for evaluating projects with negative environmental impacts, this approach involves the design and costing of one or more "shadow projects" that would provide substitute environmental services to compensate for the loss of the original assets. This approach is essentially the same as the replacement cost approach; it is being mentioned increasingly as a way to make operational the concept of sustainability at the project level. It assumes to be more relevant when critical environmental assets are at risk (World Bank, 1991).

Contingent Valuation Method

The contingent valuation method uses surveys to ask the "what if" kind of question. It asks people what they are willing to pay for a benefit, and/or what they are willing to accept as compensation for toleration a cost. The method involves preparing and administrating a questionnaire to a sample from which generalization to the population can be made (Frank, 1995).The contingent valuation method has many shortcomings, including problems in designing, implementing and interpreting questionnaires (World Bank, 1991).The study analysis depends mainly on descriptive statistics, partial budget analysis, stochastic frontier production function and linear programming (LP) to reach to the stated objectives.

1.8 Organization of study

The study consists of seven chapters. Chapter one is divided into two part; basic elements of research and methods used for environmentally-oriented economic analysis. While chapter two gives background information about the Renk County - North Upper Nile State, chapter three describes farmer's resources allocation and gross margin analysis. Chapter four includes explanation of the technical efficiency of the farmer's in rain-fed sector. Chapter five includes a through explanation of the theoretical framework, specification of the model structure and empirical specification of the linear programming model. Chapter six presents and discusses the results of the basic linear programming model and discusses the results of different scenarios. Chapter seven presents the summary, conclusions and recommendations of the study.

CHAPTER TWO

Background Information on the North Upper Nile State (Renk County) (Study area)

2.1: Location:

Southern Sudan covers a total area of 648.051km^2 about one quarter of Sudan's total area. It lies between latitudes 3^o 5' N and 12^o N, and longitudes 23^o.5' and 36' E. It is a large basin gently sloping down northwards through which flow the Nile from Uganda, (Odara, 2004).

The Northern Upper Nile state area lies between latitude 10^{o}27' N and 12^{o}45' N, and longitude 28^o 5, and 35^o E at an elevation of 380m above the sea level .Its area is approximately 165,078.883 hectare. It borders Blue Nile to the northeast, southern Kordofan to the west and northwest, and the White Nile state to the North. Generally, the area extends from the Joda (Wanthaw and Kuak in the north to Melut and Kaka in the south, (Garang, 1991).

2.1.1: Topography:

Land topography is generally flat except for few sandy out crops(Gozes) occurring as very low spurs along seasonal streams such as Khor Adar, Khor Achier, Khor Karow Khor Dolied, Khor Mashuk, Khor Abu Khadra, Khor Yabos and Khor Neela, (Garang, 1991).

Also there are some plateaus such as Jebel Gelhak, Jebel hmed Agha Jebel Jogdeet, In addition to some mountains in Maban County, like Abu Gaya and Tombak mountains, (Adam, 2007)

2.1.2: Soils: Origin and Geology:

The southern provinces development team reported 1958 and Sudan soil survey 1974 classified these soil as predominantly clays and heavy loam, which are geologically categorized as montmorillitic clay minerals, the dark cracking cotton soil types.

The characteristics for this forest soil are the dark cracking clay vertisols, formed on colluio alluvium derived from basic rocks. The soil have high water holding capacity poor permeability and very plastic and sticky when wet. The northern areas with lighter rainfall have fertile alkaline cracking clay soils with patches of fertile loamy clays.

Two categories of soil types are recognized: heavy clays and clay soils formed in situ. These soils are derived from the alluvial clay material (50%). These central clay plain soils were traced to belong mainly to cetaceous sediments of Nubian Formation, (Alakahtar, 1994).

Physically these soils are characterized by deep cracking, granularity and columnar macro-structures especially on dryness at exposed sites. On wetting however, by rainfall or irrigation, these soils become heavily water-logged and show plasticity in texture. The latter properties are an advantage as they retard leaching and water erosions, which are potentially responsible for excessive loss of nutrients and hence drop in fertility level.

These soil are generally fertile and with Ph>8.0, salt content ranges between 0.1 – 0.5% and sodium values of between” 10-30.

The main limiting factor is nitrogen on the irrigated schemes or where higher rainfall amounts occur. Similarly higher organic matter content and general salinity together with sodium values rise on wetter sites, (Adam, 2007)

2.1.3 Climate:

Northern Upper Nile state area situated in the semi arid zone of the Sudan with two distinct seasons, rainy season (wet) starts at May to October and dry season starts at November to April. The area varies in temperature, relative humidity, rainfall and solar radiation due to season and directions.

2.1.3.1 Rainfall:

Northern Upper Nile State is lies in central rain lands; the extreme northern part of the Renk has a (5) month rainfall of 450 –655mm per annum, while the southern part receives 700 –780mm that spread over (6–7) months. According to Renk and Goz Rom meteorological stations, rainfall starts from

May and end at October with annual average precipitation rains between 450 to 550 mm. p.a.

According to the southern Sudan development report in 1954 records showed the commencement of rainfall as early as April and May. The main annual precipitation records were much higher than the present time especially in northern part of area which decreases yearly. Annual rainfall variations are observed with in the Northern Upper Nile State area, there is a progressive reduction north ward of the area where larger mechanized schemes which their trees cover completely clear felled.

2.1.3.2 Temperature:

The main annual temperature 26.5 ^{0}C with maximum annual of 29^{o}C and minimum of 23.8 C^0.There is increase in temperature northward due to decrease in vegetation cover and increase in evaporation (Table 2-1).

The average maximum temperature of the hottest month March or April is around 40^{o}C and the mean minimum temperature of the coolest month in January is 12-15^{o}C. Monthly maximum and minimum temperatures as well as annual means rainfall are the useful indicators of aridity, desertification effects on an area, (Garang, 1991).

2.1.3.3 Evaporation:

Is defined as the total amount of water that evaporates simultaneously from soil or water surface and that transpires from total cover, (Onak, 2004).

Its potential is the maximum quantity of water which evaporated by a uniform cover of dense short grass when the water supply to the soil is not limited. The mean daily evaporation is highest in April and lowest in August

Table 2-1: Climate parameter

Year	Precipitation (mm)	Temperature (C^o)	Relative Humidity (%)	Evapo-transpiration (mm)
1990	234.1	26.7	37	5
1991	350.8	26.2	43	9.5
1992	389.1	28	40	8.5
1993	355.6	23.8	40	6.4
1994	485.9	28.6	42	12.5
1995	390.7	28.7	39	13.3
1996	322.8	26.5	42	16
1997	385.9	28.4	42	12
1998	378.8	29	42	15
1999	473.4	29.1	43	11.7
2000	303.9	28.3	42	10.5
2001	322.8	26.5	41	13.5
2002	553	28.2	39	9.6
2003	426.3	28	40	15
2004	468	36.6	52.4	17.5
2005	551.3	38	41	11.5
2006	462	32.5	43	15.5

Source: Renk Meteorological station 2008.

2.1.3.4 Wind:

The winds at the study area prevail from different directions at different times of the year. The north-east or northerly and north westerly trade winds of moderate velocity prevail during winter, where as the south and south-east winds prevail during autumn.

2.1.3.5 Clouds:

Clouds prevail almost 8 months in the year, started before the beginning of the rainy season.

2.1.3.6 The Relative Humidity.

The relative humidity values are low reflecting the general aridity of the climate. The mean relative humidity percentage is lowest in April and highest in August.

Table 2-2: Temperature, relative humidity and evapo-transpiration:

Month	precipitation (mm)	Temperature ©	Relative Humidity %	Evapo-transpiration (mm)
Jan	-----	29.4	35.9	13
Feb	-----	27.8	30.3	17.1
Mar	-----	29.8	23.9	18.8
Apr	0.5	33.3	30.5	18.1
May	32.6	32.5	49.9	13.7
June	61.7	30.7	71.5	9.6
July	153.9	28.9	74.3	6.5
Aug	170.9	27.9	81.5	5.1
Sept	97.6	28.5	77.4	5.4
Oct	68.2	30	65.9	15.5
Nov	4.4	29	42.4	11.2
Dec	-----	26.3	38.8	12.7

Source: Renk Meteorological station, 2008.

2.1.4 Vegetation Cover:

The low rainfall woodland savannah vegetation types consist mainly of low thickets of thorny *Acacia mellifera* on heavy clay soils*; Terminalia, Sclerocarya, Anogessius, Prosopis* on Savannah wood; *Anogessius-Combertum hartiminanum* woodlands; and *Acacia seyal-Balanites aegyptiaca* grow along water courses and in mixture with species such as *Acacia fistula, Acacia senegal, Acacia laeta, Acacia nubica, Acacia tortilis* subspecies *raddiana.*

Other tree species of importance in the area are *Acacia seiberiana, Hyphaena* and *Dalbergia, spp. Terminalia laxiflora, Ziziphus spina-christi* and *combertum* species, (Harrison and Jackson, 1958); (FNC/FAO, 1989).

According to the most recent forest inventories FNC, 1989; 2003, land vegetation cover types appear to be predominantly trees area. This includes individual trees and stands classified under rangelands.

2.1.5 Animal resources

A great number of livestock are found. The total number is about 6.000.000 head, this includes cattle, sheep, goats, camels and donkeys. Animal resources are owned by both the natives and the nomads who usually come to this area on their seasonal movement looking for grazing land and water. They may go far South till Al Nasir and Akobo in the Southeast of Upper Nile State at the border with Ethiopia. They return back when rains start. Most animals are of local bread, they are small in size with little milk. No animal improvement program is carried out. Animal care like vaccination is usually carried out by Non-Governmental Organization (NGOs).

The main marketing locations for animals in the area are Renk, Shomadi, Jelhak, Kilo (15), Kilo (5), Geigar, Goz fami, Adham, and Faluj. It worth mentioned that the local tribes keep animal for social values not for its economic value, (Adam 2007).

2.1.6 Wild Life Species:

According to the director of wildlife department Renk, the area has been harbored by a good population of both wild animals and bird species. However, the animals later disappeared from the area especially in the northern parts, due to pouching and the adverse environmental changes caused by agriculture rain fed expansion, charcoal burning, over grazing, fire hazards, petroleum pipe line, wells and roads constructions.

The present wildlife species found in the area are: rats and rabbits, monkey, dig dig and gazelle, hyena, squirrels, foxes, pigs, hippos, crocodiles, ashlla (python), giraffe, buffalo, porcupines (Abu Shok) and various types of snakes and other types of reptiles.

The species of birds in and around the area include: yellow necked and spur fowl, tufted guinea fowl, wild dive, Parrots, ostriches, heron, and sparrows.

2.1.7 Population of the Area:

According to the Sudan national census that was held in 2008, the total population of country was 39.15 million heads. Out of this figure there was about 8.26 million heads of the people living in the south representing about (21%) of the total population, Central Bureau of Statistics (2008). Khartoum State is the highest populated state in the country (5.07 million) followed by South Darfur State (4.039 Million), Al Jazeera 3.58 million, and North Kordofan (2.92 million).

In southern Sudan, Jonglei State has the highest population numbers (1.36 million) followed by Central Equatoria State (1.10 million), Warrap State (0.97 million), Upper Nile State (0.96 million), Eastern Equatoria State (0.90 million), Northern Bahr El-Ghazal State (0.72 million), Lakes state (0.69 million), Western Equatoria State (0.61 million), Unity State (0.59 million) and Western Bahr El-Ghazal State (0.33 million).

Upper Nile State, particularly, the northern part, is very rich in terms of fertile land and abundant resources, that is why it is continue to attract internal displaced persons from various parts of the Sudan. The displaced people usually got many job opportunities especially in agriculture, forestry, animal husbandry and fisheries. On the other hand, Dinka (Abielang) is the most tribe inhabiting the east bank of White Nile of the State, with other tribes such as Maban, Nuer, Shilluk, Anyuak, (Shilluk is the most tribe inhabiting the western bank of White Nile). However, other tribes (immigrant settlers) such as Fur, Fallata, Sobaji, Umbororo and Arabs are also found in the state, they usually work in trading livestock raisings and agriculture. Although in the recent years many people of the state from different tribes engaged in the petroleum exploitation and production in Melut oil field.

2.1.7.1 Historical Background of Agriculture Production in Area:

Rain fed agriculture started in 1952 as slash and burn on small scales around the villages, from 1952 – 1969, Umm Dolieb agriculture scheme was established as the first mechanized rain fed schemes, it was an experimental scheme owned and administrated by the government with cooperation of local peoples, (Ajawin, 2006).

From 1960—1970, private sector agriculture schemes started when more than 120 000 feddans were demarcated and distributed to some pioneer farmers who administered the schemes. In 1970 Renk Mechanized Farming Corporation and El Doula Schemes was established as a branch administration of Mechanized Farming General Corporation, which was under umbrella of the rain fed agriculture administration in the Sudan.

Between 1960 and 1970, the productivity of agricultural rainfed crop extended into undemarcated surveyed lands. Currently there are (10) schemes in Eastern area namely, Goz Rom , Goz Rom extension, Akon, Umm Dullwis, Ataham, Ataham, south Shomidi, El Dola and East Umm Dullwis. More than 1416666 ha (3500000 feddans) forest lands were cleared without replanted, presently a total of 1560 222 feddan were under cultivation, (MFC El Renk 2007).

There was no crop rotation and no fertilizers application, also there was no shelterbelt and windbreak around schemes. The area was completely clear felled particularly northward, which lead to land degradation, reduction in crop yield and declining of some trees species in the area, (Abu Baker, 2007).

South Sudan has sparse population of about 5-8 persons per km^2 and consists of many tribes. About ninety percent of them live in rural areas depending primarily on agriculture for their livelihood. Crop production and animal raisings are the most important economic activities in south Sudan and sorghum (Dura) is the most staple cereal crop contributing to the bulk of food calories in the daily diets of majority of the communities.

Most tribes practice traditional rain fed agriculture. The most important crops are sorghum, sesame, groundnuts, maize, millet, sunflowers, vegetables and fruits.

Table 2.3: Agricultural Rain fed Schemes at Renk Area:

Name of Area	No of Scheme	Area (Feddans)	Clearance %
Goz Rom	235	192,333	70%
Etend of Goz Rom	235	81,750	65%
Akon	76	70,000	80%
El Dola (F)	5	5,000	100%
El Dola (In,F)	33	25,500	85%
Um-dolwise	2.8	162,750	75%
Extent of Umdolwise	48	48,000	0%
Atahm	245	245,000	45%
Shamodi	72	72,000	5%
Total	1,815	1,560,333	

Source: MFC Renk, 2007.

2.1.7.2 Mechanized Farming in the Central Rain Lands:

The total area under legal or licensed large-scale rain fed mechanized schemes increased from less than half a million hectares (one million feddans) in 1968 to about five million hectares (9 million feddans) by 1986. An equal area is farmed illegally by the same methods. These large-scale private schemes took over great stretches of traditional farm land, water points, grazing lands and herding routes, displacing millions of small producers. Large areas of forests were cleared (including about 95 per cent of the forests in eastern Sudan) to make way for the giant agricultural schemes, and with the trees went vital local sources of revenue from fuel wood and gum Arabic, (Suliman,1994).

Mechanized Farming Corporation, (MFC), was established in 1968, upon request from the World Bank to secure its first loan for the so-called supervised sector and to facilitate credit to private farmers.

The MFC supervised the expansion of mechanized agriculture into southern Kordofan, White Nile and Upper Nile Provinces. By 1975 the World Bank provided half of the total loans for the agricultural sector, specifically for private rain fed mechanized farming. The ecological and social stress caused by large-scale mechanized agriculture is well-documented, and can be held responsible for three types of conflict:

- Conflicts between traditional farmers (villages) and owners of the mechanized schemes. Cultivators are forced to sell their products cheaply; pastoral nomads are driven out of the best areas of their traditional pasture." Conflict among local people in the vicinity of the schemes, because of scarcity of cultivable land, obstruction of animal herding routes or in the search for fresh grazing land.- Conflict between the states such as southern Kordofan, White Nile, Upper Nile and Blue Nile states, as major backer of the scheme owners, and the small farmers and pastoralists

2.1.7.3 Irrigated Farming in the central Rain Lands

Irrigated agriculture began in Upper Nile by pumps in Malakal, in 1950s with small experimental schemes for growing rice and cotton to explore the possibility of their growing under irrigation, (Mabior, 2004).

Few vegetable plots are also noted in the areas between Geiger, Renk and Gelhak which are irrigated by small pumps on the river banks.

Long staple cotton is grown exclusively north of the Renk County along the White Nile River. These schemes are irrigated by pumping directly from the river with five inches diameter pumps.

2.1.7.4 Forestry activities

Forestry activities in the area are dominated mainly by exploitative utilization where forests and forest products are being central to the socio-economic well-being of the local inhabitants; such activity includes; charcoal burning, fuel wood collection, Gum Arabic tapping, fodder, fish and bush meat, fruits, leaves, seeds and pods collection.

2.1.8: Sources of Water:

The water sources in the area are the White Nile and few seasonal streams which run across the area but, the permanent drinking water sources in the agriculture schemes areas, are the haffirs which pool by water during rainy season. The main seasonal streams in the area are Khor Ashier, khor Karrow, khor Mashuk , khor Adar and khor Yabos. They lie within annual rainfall of between 500-800mm per annum, Harrison and Jackson, 1958).

2.1.9: Source of Energy:

Most of native people rely on biomass for their energy needs, this basically consist of wood, crop residues and animals dungs especially in villages, but in the towns such as Renk and Wadakona biomass is supplemented with oil and gas.

2.1.10: Accessibility to the Area:

The Northern Upper Nile area is served by the dry weather roads:

- Rebak- Renk –Palouge peace roads.
- Renk –Damazin through Jebel Guli in the east
- Renk- Malakal through Melut in the South by the Steamer
- Renk – Maben in the Southeast.
- Renk-Mazmum through Qoz Fami in northeast
- Palouge –Maut, Nasir
- Kosti –Kuak, Wadakon, Kaka

During rainy season, river communication is the major source of transport throughout the Upper Nile State. The river Nile transportation passes through the Renk from Kosti to Malakal the Capital of the state.

CHAPTER THREE

Socio-Economic Characteristics and Existing Farming System

This chapter focuses on the study of the socioeconomic characteristics of the framers', examine the existing farming systems in the North Upper Nile State (Renk County), besides, estimate net farmer's income obtained from the main crops produced in study area.

3.1 Socioeconomic characteristic of farmers in the study area

The socioeconomic characteristics studied here were farmers' age, educational level, family members and farm size.

3.1.1 Farmer age:

Farmer age is expected to have influence on productivity and output of an individual as it affects the mental and manual abilities. The results of the survey show that the average age of the farmer is 46, and 47.92 years in Mechanized rain-fed sector and Traditional rain-fed sector respectively (Table 3.1). This indicates that most of the farmers of the state are within the active age group. Accordingly, they are expected to be economically efficient farmers.

3.1.2 Farmer's Education levels:

Education level is an important factor that affects the economics situation of different human groups. Education increases a person's awareness of his environment and his ability to acquire and process information about his environment and to detect changes in it. It also enhances his ability to identify alternatives and to assess and compare the benefits and costs associated with each alternative. The education will enhance probability of adopting a new, presumably superior technology (Jamison and Lau, 1982). The level of farmer education has an important impact on the agricultural production

Results of descriptive statistics analysis showed that, the majority of the farmers (81%) in the traditional sector are illiterate or have low educational level as shown by the percentage of farmers who are illiterate (49.33%), have *Khalwa* (12%) or primary education (20%) ,Table (3.1). In contrast, the majority of farmers in the mechanized sector are educated (71%) as shown by the percentage of farmers who have secondary (44%) or university education (26.7%). Therefore, it is expected that, farmers in the mechanized sector are more efficient and have higher productivity than those of the traditional sector.

Table 3.1 The general characteristics of the household heads and family in North Upper Nile Renk County by Sectors

	Mechanized rain-fed sector	Traditional rain-fed sector
Average farmer age	50.42	47.92
Illiterate	1.3%	49.33%
Khalwa	8%	12%
Primary	20%	20%
Secondary	44%	17.33%
University	26.7%	1.33%
Average family size	7.5	6.43
Male	48.8%	44.79%
Female	52.2%	55.21%
Single farmers	10%	12.2%

Source: author's survey 2008.

3.1.3 Family:

Practicing cultural operations of crops is not an easy job, because crops activities require regular practices, these practices cannot be accomplished properly by one person, so allocating these practices among family members leads to the fact that each practice will be accomplished properly particularly if the size of family is large. Farmer's family members are considered as an important source of labor force in the traditional sector the North Upper Nile state.

From Table 3.1 it is clear that the average family size in the Mechanized rain-fed sector and Traditional rain-fed sector was 7.5, and 6.43 persons respectively, with female constituting the major family part 52.2% and 55.21% for the two sectors respectively. Women engagement in agricultural activity particularly in the traditional sector is highly considered.

3.1.4. Farm Size

The averagely holding size was found to be 1194 and 28 (feddans/farmer) in Mechanized and Traditional sectors respectively (Table 3.1.1) and (Table 3.1.2). It is worth to be mentioned here that, the total area allotted for each mechanized rain fed agricultural project was more than one thousand feddan. But due to one reason or another many farmers were enforced to sell/rent part of their land to solve their problems. Accordingly, the results revealed that about 17% of the farmers hold an area of less than one thousand feddan. On the other hand the majority of the farmers (62.7%) in the traditional sector hold an average land size of less than 35 feddan. Thus it is expected that farmers in the traditional sector are more technically efficient than others, because it’s easier for them to manage their small area, as most of them depends on family labors.

Table (3.1.1): Distribution of the Farmers according to their holding size (feddans/farmer): Mechanized sectors

Holding size	No	%
120- 360	3	4
360- 500	4	5.33
500- 720	5	6.67
720- 1000	2	2.67
1000-1500	24	32
1500-2000	5	6.67
2000- 2500	11	14.67
2500- 3000	4	5.33
3000- 4000	15	20
4000- 5000	1	1.33
5000 more	1	1.33
Total	**75**	**100%**

Source: author's survey 2008.

Table (3.1.2): Distribution of the farmers according to their holding size (feddans/farmer): Traditional sectors.

Holding size	No	%
5 -20	25	33.33
20- 35	22	29.33
35- 50	6	8
50- 80	11	14.67
80- 120	3	4
120 and more	8	10.67
Total	**75**	**100%**

Source: author's survey 2008.

3.2. Types of cultivated crops in the study area

Results of the descriptive statistical analysis revealed that, sorghum is the leading crops grown in the study area in terms of cultivated land. It occupies (66.12) and (57.35) percent of the total cultivated area for both the mechanized and the traditional sectors, respectively (Table 3.2).

Table 3.2 Types of crops grown and their cultivated areas in both Mechanized and Traditional sectors (%)

Crops	Mechanized sector (%)	Traditional sector (%)
Sorghum	66.12	57.35
Sesame	20.68	23.23
Groundnut	-	14.36
Sunflower	7.21	-
Millet	5.99	-
Cowpea		5.06

Source: author's survey 2008.

Sesame came second for both of the two sectors covering (20.68) and (23.23) percent of the total cultivated area for the two sectors (mechanized and traditional), respectively. These two crops (sorghum and sesame) covers the majority of the grown land in the study area (more than 80%), revealing the fact that, farmers in the northern part of the Upper Nile State are some how commercially oriented, growing sesame as a cash crops and sorghum as a main food crops. Although, groundnut (14.36%) and cowpea (5.06%) were the minor crops grown in the traditional sectors, sunflower (7.21%) and millet (5.99%) came third and fourth in the mechanized sector.

3.3 Animal ownership:

While sheep represent the main animals raised in the mechanized sectors, goats come first in the traditional rain-fed sector (Table 3.3). These two animals are usually raised by farmers in the study area due to their cheaper costs compared to other animals, easiness of management, in addition to, supplying farmers with their requirements of milk and cash. On the other hand, although, cattle are not commonly raised in the traditional sector, but in the mechanized sector are some how raised by many farmers. This result reflects the fact that, farmers in the mechanized sector are well off compared with those in the traditional one. However, it is worth to be mentioned that, farmers in northern part of the state usually raise animals not income generation but rather for satisfying their households needs or for on farm purposes. They do not sell their animals unless they are in a real need for cash or when their animal sizes and numbers are beyond their control, although, some of them raised animals for social purposes.

Table 3.3 The farmer's average animal ownership in North Upper Nile state by sectors

	Mechanized rain-fed sector	Traditional rain-fed sector
Sheep	40.05	3.93
Goats	19.72	6.43
Cows	12.85	0.57
Donkeys	0.00	0.62

Source: author's survey 2008.

3.4 Agricultural operations:

3.4.1. Land preparation:

Land preparation is one of the most important factors affecting crop yield. It's usually done by Wild level disc (primary tillage) in the Northern part of the Upper Nile state. It's noticeable that one operation of plowing is not enough, particularly for fallow land and land that are occupied by huge grasses and shrubs, but still one plowing is the common practice there, due financial problem and unavailability of sufficient amount of the machine. This operation is usually carried out in June, but sometimes can be delayed for sometimes. The postponement is done as a means for controlling weeds.

On the other hand, in the traditional sector land preparation is done manually in the period extended from last May to the beginning of June. However, it's important to be mentioned that using the same level of plowing annually might create compact layer beneath the surface land, resulting in water logging (Elshimy 2004). The over all results are: inefficient use of water, decreasing production, and inefficient weed control. In addition to the fact that many farmers adopt the policy of clearing more forest land in favour of crop production. These clearances a companied with the adoption of the same plowing level results in tremendous degradation of land, hence the environment as the whole. To overcome such problems farmers should be enlighten about the important of using deep plowing, even though, it's associated with additional cost.

3.4.2 Sowing date

The sowing date is one of the most important factors affecting the crop yields, particularly under changeable climatic conditions. Since the focus of this study is the farmers in the rain-fed sectors, accordingly, rainfalls are considered as the most limiting factor of crop production.

Although the optimum sowing date of sesame should before the second week of July, but still many farmers in the Mechanized sector (40%) and traditional sector (30%) delayed it till the beginning of August. Likewise, they did for sorghum as 30% for the mechanized sector and 22% for the traditional sector delay the sowing date till the mid of August, even though, the recommended one should be located within the first two weeks of July. Many factors hindered the farmers from sowing on the recommended time, the most important of them are:

a) Inability to prepare the land at the right time due to shortage and high cost of Wide level Disc

b) Lack of credit to buy inputs such as seeds and insecticide.

c) Environmental factors such as rainfalls

Consequently, poor productivity, pest and disease infestation and hence low income are expected to prevail in the study area.

3.4.3 Seed rate:

According to the law of diminishing return, there is positive relationships exist between additional units of seed rate and crops production, up to the certain level beyond which any increment of seed rates results in the reduction of production.

The major varieties of seeds used for all cultivated crops in the study area, except sunflower, are of local types. Normally, farmers depend on the previous season seed in their current cultivations. They do collect the seeds from the good and healthy plants, although, small amount seeds are bought from the markets. Unfortunately, the agricultural bank does not supply the farmers with their requirement of the certified seeds.

On the other hand, the results of the study of the mechanized sector showed that, farmers adopt the lower limits of the recommended seed rate for both sesame and sunflowers, but they adopt the upper one for millet (Table 3.4). This might be attributed to the fact that, seed prices of sesame and sunflowers are relatively expensive compared with millet. Despite the fact that, sorghum is the main crop grown in the study area, but farmers apply seeds-rate less than the recommended in order to reduce their costs, as sorghum represent the main crop grown and occupies cultivated large areas.

Traditional farmers usually apply large quantity of seed rates (upper limits of the recommended quantities for both the sesame and cowpea and more than the recommended for sorghum) compared with the mechanized sector. Although traditional farmers adopted the recommended amount of seed rate for some crops, but still they remain unaware about it. Consequently, additional costs were expected to be incurred by the traditional farmers, which might not be reflected in their productivity. Seed rate employed for groundnut production was less than the recommended because of the voluminous and expensiveness of seeds required for its cultivation. Accordingly, it is very important to establish proper extension units to enlighten farmers about the technical package. Likewise, encouragement of research for producing good and high yielding varieties of crops, in addition to, the production of certified seeds locally could also play a good role in improving traditional farmers' livelihoods.

Table (3.4) Recommended and actual seed rates (kg/fed) in mechanized and traditional sector

	Recommended*	Actual**	Gap%
	Mechanized sector		
Sorghum	3	2.70	-10
Sesame	1.5-2	1.57	
Sunflower	1.30-3.10	1.50	
Millet	2.5-3	3.00	
Traditional sector			
Sorghum	3	3.25	8.33
Sesame	1.5-2	2.00	-
Groundnut	25	22.20	-11.2
Cowpea	10-15	15	-

Source: *Ministry of Agriculture and forestry, 2008
** Author's survey 2008.

3.4.4 Weeding:

Grasses (weeds) is one of the main problems facing agricultural production in the North Upper Nile state for both sectors. Weeding methods is dominated by manual practices. Herbicides are rarely applied for weed control because it's expensive and difficult to be used by the majority farmers in the study area. The survey result showed that only 2% of the farmers in the mechanized and none in traditional sectors apply herbicides. Taking in mind the large quantity of rainfall that area witnesses which associated with grasses, it's therefore very important for the farmers to use selective herbicides to improve their productivity. The adoption of chemicals should be accompanied with extensive extension services.

3.5 Labor Resource Management:

Farm labor is one of the most important inputs for agricultural production. For peasant farming, family labor constitutes the main portion of the utilized labor force in production (Upton 1987).

Family labor depends on family size, age, composition, and domestic organization. Hired labor, on other hand, is usually governed by market mechanism. The hired labors are always used at the peak of high labor requirement. At this period, many operations with which the farmers' is less familiar or need much efforts take place ,e.g. sorghum cutting and collecting, sesame cutting, collecting and threshing etc. the hired labor in Rain fed sector comes from two sources, either locally resident in camps, near Rain fed schemes villages or migrant labor which comes from different Sudan tribes. The payment method for the hired labor varies in Rain fed. In operation like sowing, weeding and threshing, the payment method is on piece basis. Also some forms of daily wage and according to productivity payment method prevail for these operations depending on the type of agreement between the farmer's and pickers. If the tenant incurred the cost of transporting the pickers from their villages they are usually paid less per basket than the casual pickers who have no agreement with the tenant. The first group is usually given some food (e.g. sorghum flour, dried fish, sugar etc.), in addition, to the transport cost.

Tables (3.5 and 3.5.1,) show the average family and hired labor man days per feddan applied to major crops in different sectors. It is clear that there is a high demand for labor in July and August since the operations of land preparation, planting, and weeding are applied during these months. Another peak of demand for labor is in November and December since the majority of crops harvested in these months. The demand for labor for the different agricultural operations of the different crops in mechanized and traditional sectors is shown in Tables 3.5.2 and 3.5.3 respectively.

Table 3.5. Average monthly man days per feddan of the main crops in Mechanized Sector

Month	Sorghum		Sesame		Sunflower		Millet	
	Family	Hired	Family	Hired	Family	Hired	Family	Hired
June	-	-	-	2	-	2	-	-
July	-	4.2	-	8	-	7	-	4.2
August	-	3.3	-	3.5	-	2.3	-	3.1
September	-	3	-	-	-	-	-	2.3
October	-	-	-	6	-	-	-	-
November	-	-	-	7	-	0	-	8
December	-	6	-	-	-	6	-	2.5
January	-	3	-	-	-	3	-	-

Source: author's survey 2008.

Table 3.5.1 Average labor requirements (man-days/fed.) of the main crops in Traditional Sector

Month	Sorghum		Sesame		Groundnut		Cowpea	
	F	H	F	H	F	H	F	H
May	0.70	0.35	0.50	0.50	0.92	1.13	0.81	0.81
June	-	-	0.60	0.85	1.39	0.78	1.08	0.81
July	2.10	0.75	4.30	8.80	3.36	2.9	1.89	1.62
August	5.05	1.40	-	-	3.65	2.11	2.16	1.62
September	-	-	-	-	-	-	-	-
October	-	-	2.60	6.00	1.85	0.92	1.35	0.81
November	5.55	-	1.70	2.15	3.03	1.85	2.45	0.84
December	2.10	1.40	-	-	1.59	1.37	1.86	0.54
Total	15.40	3.90	9.70	18.30	15.79	11.06	11.60	7.05

Source: author's survey 2008.

Table 3.5.2 Average labor requirements (man days(m.d.)/fed.) of the main crops in Mechanized Sector

	Sorghum		Sesame		Sunflower		Millet	
Mandays/fed.	Family	Hired	Family	Hired	Family	Hired	Family	Hired
Land preparation	0	2.3	0	3.7	0	3	0	2.1
	2.3		3.7		3		2.1	
Sowing	0	2.2	0	2.3	0	2.3	0	2.3
	2.2		2.3		2.3		2.3	
Weeding	0	6	0	7.5	0	7	0	5.2
	6		7.5		7		5.2	
Harvesting	0	9	0	13	0	8	0	10.5
	9		13		8		10.5	
Total	19.5		26.5		20.3		20.1	

Source: author's survey 2008.

Table 3.5.3 Average labor requirements (man days (m.d.)/fed.) of the main crops in Traditional Sector

	Sorghum		Sesame		Groundnut		Cowpea	
Mandays/ fed	Family	Hired	Family	Hired	Family	Hired	Family	Hired
Land preparation	1.29	0.50	1.03	1.29	2.27	1.23	1.26	1.18
	1.79		2.32		3.50		2.44	
Sowing	1.39	0.35	0.71	1.94	2.40	1.40	1.96	0.55
	1.74		2.65		3.80		2.51	
Weeding	5.28	1.49	3.68	6.88	5.05	3.90	4.70	1.42
	6.77		10.56		8.95		6.12	
Harvesting	7.26	1.74	4.3	8.17	6.40	4.20	5.88	1.70
	9.00		12.47		10.60		7.58	
Total	19.30		28.00		26.85		18.65	

Source: author's survey 2008.

3.6 Gross Margin Analysis season 2007-2008

Here the productivity and profitability of producing crops under both mechanized and traditional rain-fed sector were studied. This was done through investigating costs, returns and profits.

3.6.1 The total cost of production:

The result of the gross margin analysis (Table 3.6a and 3.6b) indicated that, average total variable costs of production per fed for the mechanized sector were SDG120, 160SDG, 145SDG, and SDG120 for sorghum, sesame, sunflower and millet crops respectively. In traditional sector the average total variable costs of production per fed for sorghum, sesame, groundnut and cowpea were respectively SDG110, SDG152, SDG235 and SDG167. In the mechanized sector sesame recorded the highest costs of production since it is labor intensive crop and requires additional cultural practices. The total variable costs of production of groundnut and cowpea were higher than those of sorghum and sesame, since farmers applied more numbering of weeding for groundnut and obtained higher yields.

3.6.2 Crops returns

3.6.2.1 Productivity in the short-run

The average productivity of crops in mechanized sector was 2.75, 1.1, 4 and 2.2 sacks per feddan for sorghum, sesame, sunflower and millet respectively (Table 3.6a). In Traditional sector the average productivity for sorghum, sesame, groundnut and cowpea were 2.75, 1.1, 8.5 and 2.2 sacks per feddan, respectively (Appendix A). While the highest farmer's productivity in the Mechanized sector obtained form sunflower, it was obtained from groundnut in the traditional sector.

Table 3.6a Gross margin analysis of major crops in Mechanized sector

	Sorghum (sack)	Sesame (kantar)	Sunflower (sack)	Millet (sack)
Productivity (unit/fed.)	2.75	2.2	4	2.2
Price (SDG/unit)	88	105	50	90
Total revenue (SDG/fed.)	242	231	200	198
Cost of production (SDG/fed.)	120	160	145	120
Gross margin (SDG/fed.)	122	71	45	68

Source: author's survey 2008.

One sack approximately= 95kg One kantar =100 lbs

Table 3.6b Gross margin analysis of major crops in Traditional sector

	Sorghum (sac/fed)*	Sesame ** (kuntar/fed)	Groundnut (sack/fed)	Cowpea (sack/fed)
Productivity (unit/fed.)	2.75	2.20	8.5	2
Price (SDG/unit)	82	105	45	88
Total revenue (SDG/fed.)	225.5	231	382.5	176
Cost of production (SDG/fed.)	110	152	235	167
Gross margin (SDG/fed.)	115.5	79	147.5	9

Source: author's survey 2008.

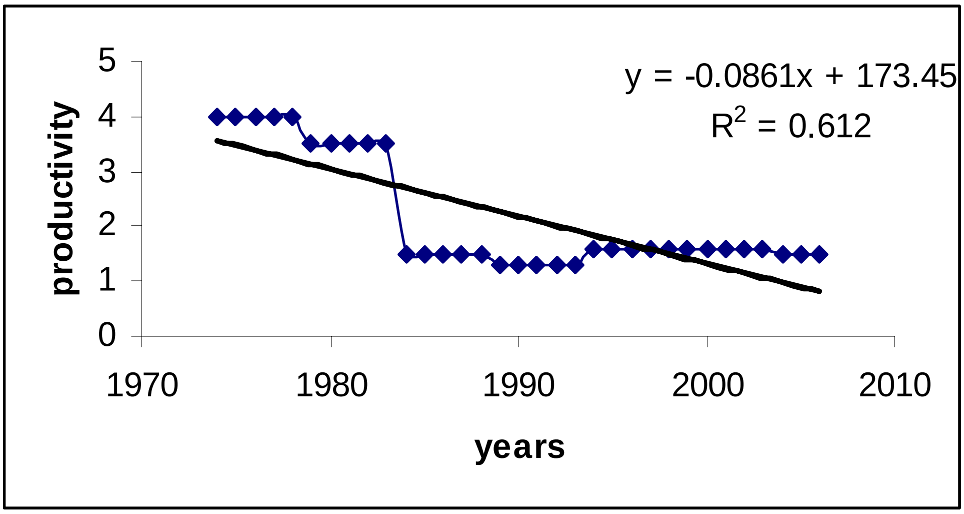
* One sack approximately= 95 kg

** One kantar =100 lbs

3.6.2.2 General trend of the sorghum average productivity in the long-run during 1974/2010

Result of the regression analysis showed declining trend of sorghum productivity in the mechanized sector of upper Nile State - Sudan over years (Fig 4.1). The main reasons behind the declining-productivity were mainly farmers' practices such as continuous mono-cropping, and non-proper land preparation (yearly plowing at the same level by machine), in addition to, environmental factors such as rainfall fluctuation which largely resulted from the human practices. This declining productivity forced many farmers to abundant their lands to be covered by the moving sands which resulted in soil degradation.

Fig 3.1 General trend of the sorghum average productivity in the long-run during 1974/2010



On the other hands, it was found that, the majority of farmers (96%) in the mechanized sector of the study area did not adopt the recommended packages of allotting at least 15% of their lands to forest crops. In comparing the productivity of the farms with and without shelterbelts it was obvious that, the productivity for both sorghum and sesame in farms with shelterbelts exceeds that one of farms without shelterbelt by more than double. Table (3.6.c)

Table 3.6.c Productivity of sesame and sorghum in the mechanized sector with and without shelterbelts

	Schemes with shelterbelts	Schemes without shelterbelts
Percentage	4	96
Average productivity of sorghum sack/fed	3.22	1.45
Average productivity of sesame kuntar/fed	2.65	1.3

Source: author's survey 2008.

3.6.2.3 Total revenue

The productivity per feddan and prices were used to calculate the total revenue per feddan. On average the total revenue for the crops grown in Mechanized sector were SDG242, SDG231, SDG200 and SDG198for sorghum, sesame, sunflower and millet respectively, while for those grown in Traditional sector, they were SDG225.5, SDG231, SDG382.5 and SDG176 for sorghum, sesame, groundnut and cowpea respectively. In Mechanized sector the sorghum crop scored higher total revenue due to relatively higher prices followed by sesame and then sunflower. In Traditional sector, groundnut crop scored the higher total revenue due to its relatively high productivity, followed by sesame and then sorghum, while millet scored the lowest total revenue due to low productivity and prices. The total revenue of sorghum in mechanized sector was higher than that of traditional sector, while those of sesame was the same in two sector due to the same prices and productivity obtained in the two sectors.

3.6.2.4 Gross margin

The average gross margins per feddan for sorghum, sesame sunflower and millet crops in Mechanized sector were SDG122, SDG71, SDG45 and SDG68, respectively, while in Traditional sector the gross margins were SDG115.5, SDG79, SDG147.5 and SDG9 for sorghum, sesame, groundnut and cowpea, respectively. In Mechanized sector sorghum crop recorded the highest gross margin followed by sesame. The sorghum crop scored the highest gross margin due to the relatively high productivity obtained and relatively good prices, while sesame crop came second although its price was relatively high due to the low productivity obtained at that season. Millet crop came at the tail due to its low productivity obtained and high production costs. In Traditional sector the most profitable crops were groundnut and sorghum followed by sesame, while cowpea crop came last.

CHAPTER FOUR

Technical Efficiency of Farmer's in the Rain fed Sector

This chapter is divided into two parts: part one deals with conceptual framework of the technical efficiency models. Part two: covers the results and discussion of the technical efficiency program.

4.1 Part one (Conceptual Framework)

4.1.1 Introduction

The agricultural sector is one of the most widely researched areas in the empirical analysis of efficiency (Ornella, 2000). To study the empirical analysis of efficiency it is important to know the following function:

1) Production function gives the maximum possible output which can be produced from given quantities of a set of inputs.

2) Cost function gives the maximum level of cost at which it is possible to produce some level of output, given input prices.

3) Profit function gives the maximum profit that can be attained, given output price and input prices.

For each of the above functions, the concept of maximal or minima is important. The word frontier may meaningfully be applied in each case because the function sets a limit to the range of possible observations. Thus, for example, one may observe points below production frontier (firms producing less than maximal possible output) but no points can lie above the production frontier.

The amounts by which a firm lies below its production and profit frontier and the amount by which it lies above its cost frontier can be regarded as measures of inefficiency (Finn, 1957).

The least squares-based regression techniques are usually used to estimate the parameters of production, cost and profit functions. It is notable that each of these studies has used least squares techniques, in which error terms were assumed to be symmetrically distributed with zero means. Producers operating on their production frontier are labeled technically efficient, and producers operating beneath their production frontier are labeled technically inefficient. Producers operating on their cost frontier are labeled cost efficient, and those operating above their cost frontier are labeled cost inefficient. Likewise, producers operating on their revenue frontier are labeled revenue efficient, and producers operating beneath their revenue frontier are labeled revenue inefficient. Producer operating on their profit frontier are labeled profit efficient, and producers operating beneath their profit frontier are labeled profit inefficient (Lovell, 2000).

4.1.2 Production Possibility Frontier

Production Possibilities Frontier (PPF) shows the maximal combinations of two goods that can be produced during a specific time period given fixed resources and technology and making full and efficient use of available factor resources. A PPF is normally drawn as concave to the origin because the extra output resulting from allocating more resources to one particular good may fall. This is known as the law of diminishing returns and can occur because factor resources are not perfectly mobile between different uses, for example, re-allocating capital and labor resources from one industry to another may require re-training, added to a cost in terms of time and also the financial cost of moving resources to their new use.

To be on the production-possibilities frontier, all resources must be used. Unemployed resources indicate that more goods and services could be produced, which means that the economy was not on the frontier initially. In addition, resources must be used properly. If society randomly assigns people to jobs or if it assigns jobs on the basis of political reliability, it will not produce as much as it could. It will require some people with little intellectual ability to perform jobs that require great intellectual ability, and it will require some people with little strength and endurance to perform jobs that demand much strength and endurance. If switching people among jobs can increase output, the original situation was not on the production-possibilities frontier and thus not economically efficient (Rahman, 2002).

4.1.3 Efficiency

Paul Heyne (2000) defined efficiency as a relationship between ends and means. When we call a situation efficient, we are claiming that we could achieve the desired ends with less means, or that the means employed could produce more of the ends desired. Less and more in this context necessarily refer to less and more value. Thus, economic efficiency is measured not by the relationship between the physical quantities of ends and means, but by the relationship between the value of the ends and the value of the means.

4.1.4 Economic Efficiency

Efficiency is one of the most important concepts. There are several meanings of the term - but they generally relate to how well an economy allocates scarce resources to meets the needs and wants of consumers (Tutor2u, 2006).

4.1.5 Technical Efficiency

Technical efficiency refers to the ability of a firm to produce the maximum possible output from a given set of input and given technology. A technically efficient firm will operate on its frontier production function. Given the stated relationship (equation 2.1) the firm is technically efficient if it produces on its outer-bound production function to obtain the maximum possible output which is feasible under the current technology. Putting it differently a firm is considered to be technically efficient if it operate at a point on an iso-quant rather than interior to the iso-quant (Rahman, 2002).

$$y = f(x) \qquad (2.1)$$

Greene (1993) provided a formal definition of technical efficiency: a producer is technically efficient; if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if reduction in any one other input or a reduction in at least one output. Thus a technically inefficient producer could produce the same outputs with less of at least one input to produce more of at least one output.

The level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal or potential production. The measurement of firm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a firm's actual production point lies on the frontier it is perfectly efficient. If it lies below the frontier then it is technically inefficient, with the ratio of the actual to potential production defining the level of efficiency of the individual firm.

Farrell's (1957) definition of technical efficiency led to the development of methods for estimating the relative technical efficiencies of firms. The common feature of these estimation techniques is that information is extracted from extreme observations from a body of data to determine the best practice production frontier. From this the relative measure of technical efficiency for the individual firm can be derived. Despite this similarity the approaches for estimating technical efficiency can be generally categorized under the distinctly opposing techniques of parametric and non-parametric methods.

4.1.6 Allocative Efficiency

Allocative efficiency is achieved when the value consumers place on a good or service (reflected in the price they are willing to pay) equals the cost of the resources used up in production. Condition required is that price equal marginal cost. When this condition is satisfied, total economic welfare is maximized (Tutor2u, 2006).

Pareto defined allocative efficiency as a situation where no one could be made better off without making someone else at least as worth off. Thapa (1998) cited that the allocative efficiency as the ability of a firm to obtain maximum profit from the application of conventional inputs with a given set of firm-specific input and output prices at a given technology. The index of allocative efficiency is obtained in two steps:

First, determine the profit-maximization level of individual inputs algebraically by equating the marginal value product of respective inputs. This means solving simultaneously the firm-specific production function and the marginal value productivity condition yielding the optimum variable inputs.

Second, compute the input-specific allocative efficiency as the ratio of profit at the actual use level of inputs to profit at the optimal level of input (Thapa, 1998).

In Figure 1(a), the firm is producing a given level of output (y_1^*, y_2^*) using an input combination defined by point A. The same level of output could have been produced by radially contracting the use of both inputs back to point B, which lies on the iso-quant associated with the minimum level of inputs required to produce (y_1^*, y_2^*) (i.e. Iso(y_1^*, y_2^*)).

The input-oriented level of technical efficiency is defined by:

$$(\mathbf{TE_I}(\boldsymbol{y},\boldsymbol{x})) = \mathbf{0B/0A.}$$

However, the least-cost combination of inputs that produces (y_1^*, y_2^*) is given by point C (i.e. the point where the marginal rate of technical substitution is equal to the input price ratio w_2/w_1). To achieve the same level of cost (i.e. expenditure on inputs), the inputs would need to be further contracted to point D.

The cost efficiency is therefore defined by:

$$\mathbf{CE(y,x,w) = 0D/0A.}$$

The input allocative efficiency is subsequently given by:

(AE_I(y,w,w)) = CE(y,x,w)/TE_I(y,x), or 0D/0B in Figure 1.1(a) (Kumbhaker and Lovell 2000).

The production possibility frontier for a given set of inputs is illustrated in Figure 1(b) (i.e. an output-orientation). If the inputs employed by the firm were used efficiently, the output of the firm, producing at point A, can be expanded radially to point B. Hence, the output oriented measure of technical efficiency can be given by:

$$\mathbf{TE_O(y,x) = 0A/0B.}$$

This is only equivalent to the input-oriented measure of technical efficiency under conditions of constant returns to scale. While point B is technically efficient, in the sense that it lies on the production possibility frontier, higher revenue could be achieved by producing at point C (the point where the marginal rate of transformation is equal to the price ratio p_2/p_1). In this case, more of y_1 should be produced and less of y_2 in order to maximize revenue. To achieve the same level of revenue as at point C while maintaining the same input and output combination, output of the firm would need to be expanded to point D.

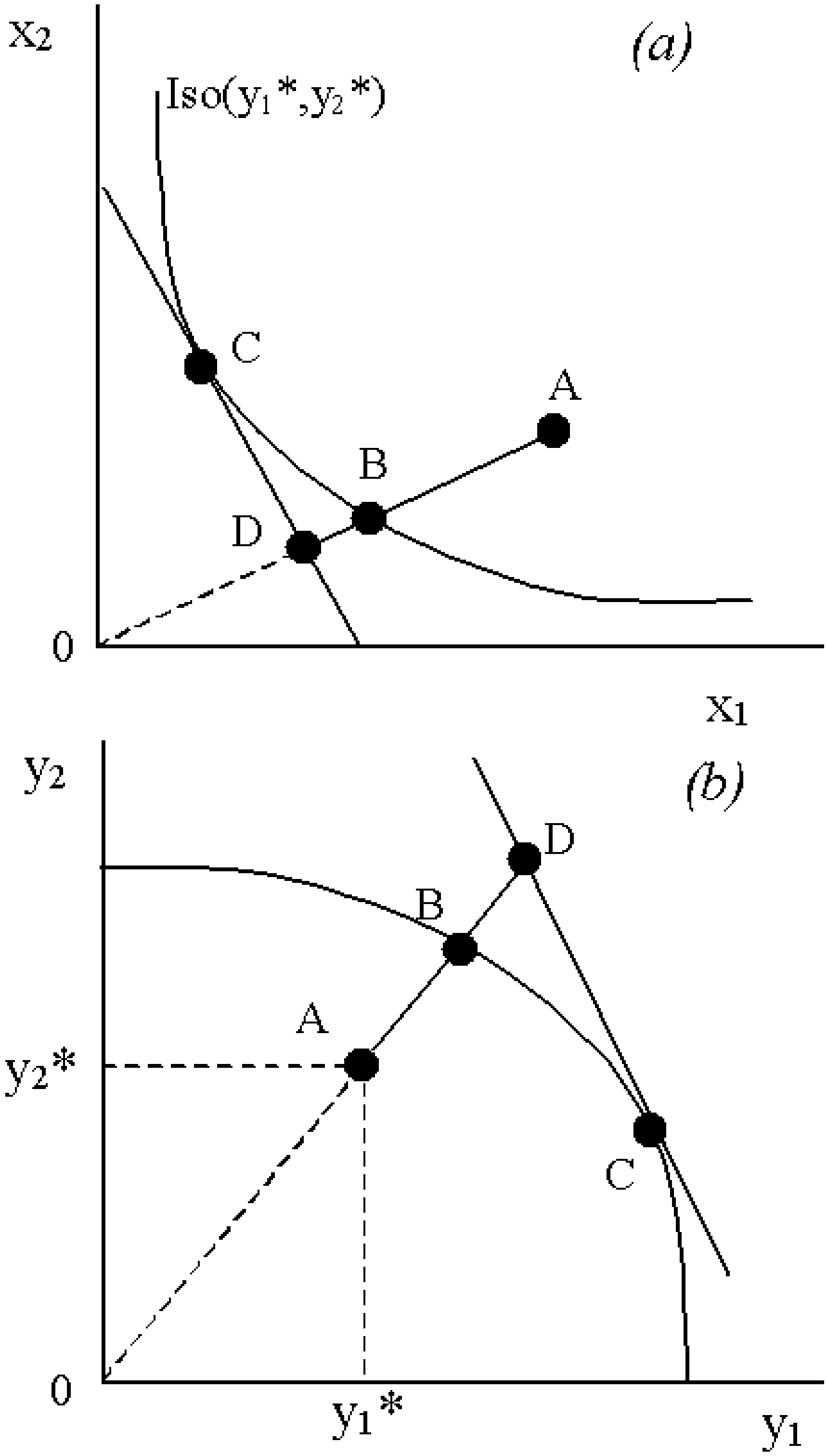
Hence, the revenue efficiency is given by:

$$\mathbf{RE(y,x,p) = 0A/0D.}$$

Output allocative efficiency is given by:

$AE_O(y,w,w) = RE(y,x,w)/TE_I(y,x)$, or 0B/0D in Figure 1(b) (Kumbhaker and Lovell 2000)

Figure 4. 1 Input (a) and output (b) oriented efficiency measures



Source: Rahman, 2002

4.1.7 Production Efficiency

Productive efficiency refers to a firm's costs of production and can be applied both to the short and long run. It is achieved when the output is produced at minimum average total cost (AC). For example we might consider whether a business is producing close to the low point of its long run average total cost curve. When this happens the firm is exploiting most of the available economies of scale. Productive efficiency exists when producers minimize the wastage of resources in their production processes (Tutor2u, 2006).

Kebede (2001) cited that productive efficiency has two components. The purely technical, or physical, component refers to the ability to avoid waste by producing as much output as input usage allows, or by using as little input as output production allows.

4.1.8 Static Efficiency

Static efficiency exists at a point in time and focuses on how much output can be produced now from a given stock of resources and whether producers are charging a price to consumers that fairly reflects the cost of the factors of production used to produce a good or a service (Tutor2u, 2006).

4.1.9 Exchange Efficiency

A second condition necessary for an economy to be economically efficient is exchange efficiency, which exists when there are no mutually advantageous trades possible. If there is a possible trade that would benefit one trans-actor and in no way harm the other, then further improvement is possible and the original situation is not economically efficient. Further trade would increase value people perceive, and thus increase economic efficiency (www.tutor2u.net/privacy.asp).

4.1.10 Product- Mix Efficiency

Even if an economy is on its production-possibilities frontier, it may not be economically efficient. Not all points on the production-possibilities frontier have the same value. Hence, to be economically efficient, an economy must find that point on the production-possibilities frontier or that mix of products that have the highest value. This final condition of economically efficiency may be called product-mix efficiency (www.tutor2u.net/privacy.asp).

4.2 Techniques of Efficiency Measurement:

Here various approaches to efficiency analysis, econometric methods and the non-parametric data envelopment analysis (DEA) methods are usually used. The econometrics approach has been motivated to develop stochastic frontier model based on the deterministic parameter frontier of Aigner, D.J., Lovell.

4.2.1 Stochastic Production Frontier

Stochastic frontier production functions have been the subject of considerable econometric research during the past two decades, originating with a general discussion of the nature of inefficiency in Farrell (1957). In traditional economic theory, efficiency is generally assumed as an outcome of price-taking, competitive behavior. In this context (and assuming no uncertainty), a production function shows the maximum level of output that can be obtained from given inputs and the prevailing technology. However, variations in maximum output can also occur either as a result of stochastic effects (e.g., good and bad weather states), or from the fact that firms in the industry may be operating at various levels of inefficiency due to mismanagement, poor incentive structures, less than perfectly competitive behavior or inappropriate input levels or combinations. The econometric technique developed by Battese and Corra (1977), allows for a decomposition of these effects and a precise measure of technical inefficiency defined by the ratio of observed output to the corresponding (estimated) maximum output defined by the frontier production function, given inputs and stochastic variation (Tom Kompas 2001).

The stochastic production frontier according to Aigner, Lovell, and Schmidt (1977), Battese and Corra (1977) and Meesusen and Van den Broeck (1977) is motivated by the idea that deviations from the production frontier may not be entirely under the control of the production unit under study. These models allow for technical inefficiency, but they also acknowledge the fact that random shock outside the control of producers can affect output. They account for measurement error and other factors, such as effects of weather, luck, etc., on value of the output variable, together with the combined effects of unspecified input variables in the production function. The main virtue of stochastic frontier models is that at least in principle these effects can be separated from the contribution of variation in technical inefficiency (Kebede, 2001).

Rahman (2002) stated that several methods have been developed for the empirical estimation of the frontier models (Fig 4.2). These different methods to estimate the frontier efficiency models can be categorized according to:

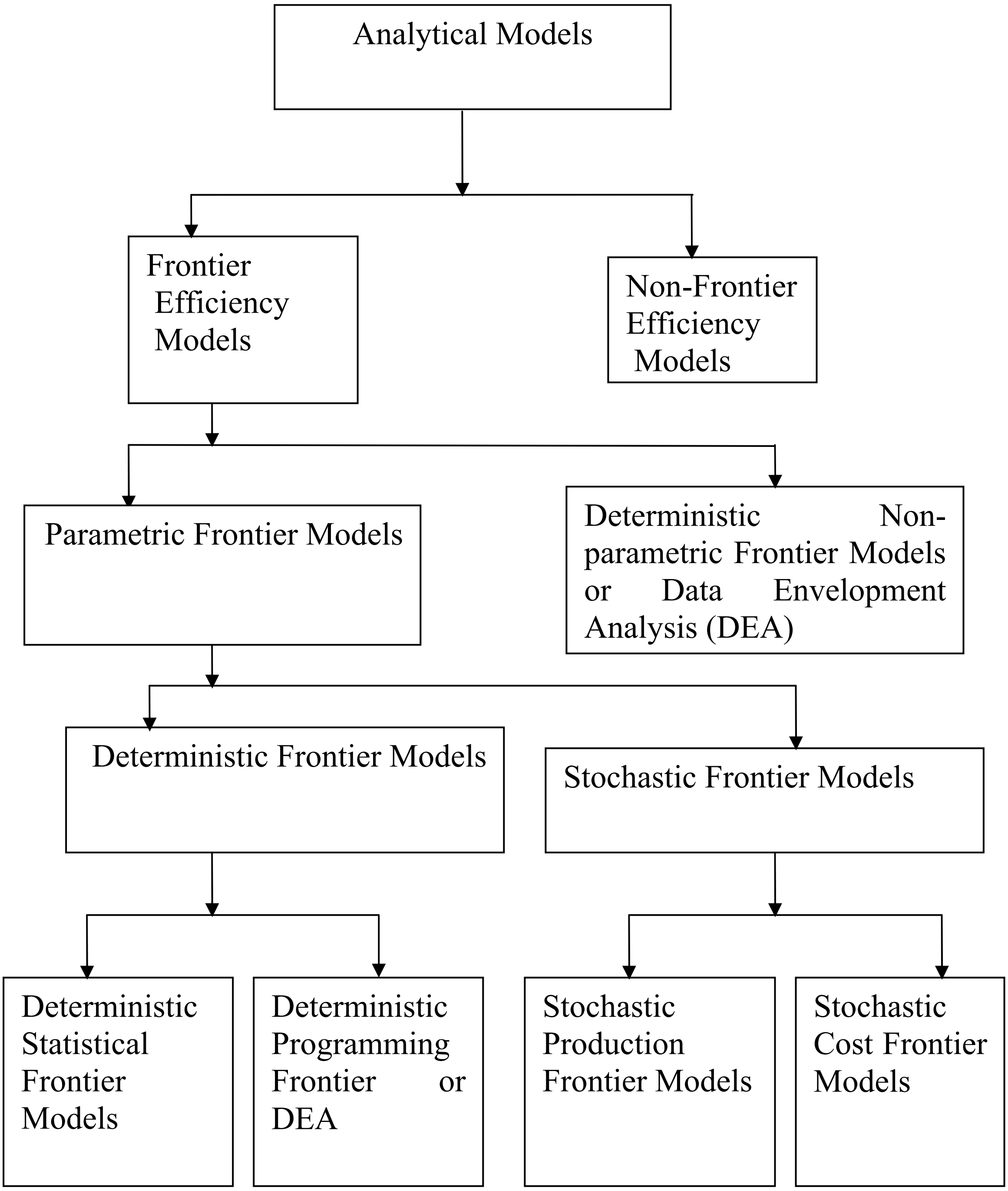
(a) The way the frontier is specified; the frontier may be specified as parametric function of inputs or as deterministic nonparametric function;

(b) The frontier may be estimated either through programming techniques or through the explicit use of statistical procedures;

(c) The deviation from the frontier is interpreted; deviations may be interpreted simply as inefficiencies or they could be treated as mixtures of inefficiency and statistical noise; that is, frontier may be deterministic or stochastic;

(d) The frontier is optimized (dual approach); the frontier may be production frontier or cost frontier.

Figure (4.2): Analytical Models for measuring Production Efficiency



Source: Rahman, 2002

4.2.2 Conceptual Model Specification

Ahmed. (2004) mentioned that the measure of firm efficiency consist of two component: technical efficiency, which reflects the ability of a firm to obtain the maximal output from a given set of inputs, and the allocative efficiency, which reflects the ability of the firm to use the inputs in optimal proportion, given their respective prices. These two measures combined to provide a measure of the total economic efficiency. The function can be estimated from sample data using non-parametric piece-wise-linear technique or a parametric function such as in the Cobb-Douglas form.

The model is defined by:

$\ln(y_i) = x_i \beta - u_i \quad , i = 1,2,....,N,$ (1)

$\ln(y_i)$ is the logarithm of the (scalar) output of the i^{th} firm;

x_i is a (k+1) row vector whose first element is "1" and the remaining elements are the logarithms of the K-input quantities used by the i^{th} firm;

$\beta = (\beta_0, \beta_1 \ldots \beta k)$, is a (K+1) - column vector of unknown parameters to be estimated; and the u_i is a non–negative random variable, associated with the technical inefficiency in production of firms in the industry involved.

The ratio of the observed output for the i^{th} firm, relative to the potential output defined by the frontier function, given the input vector x_i, is used to define the technical efficiency (TE_i) of the i^{th} firm:

$$TE_i = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \qquad (2)$$

Aigner, Lovell and Schmidt and Meeusen and van den Broeck (1977) Model proposed the stochastic frontier production function in which an additional random error, v_i, is added to the non-negative random variable, u_i, in equation (1) to provide:

$\ln(y_i) = x_i \beta + v_i - u_i \qquad i = 1,2,....,N,$ (3)

The random error, v_i, accounts for the measurement of error other random factors such as the effects of weather, strikes, luck, etc. and effects of unspecified input variables in the production function on the value of the output variable.

ALS (1977) assumed that the vi's were independently and identically distributed (i.i.d.) normal random variables with zero mean and constant variance, δ_v^2 , independent of the u_i's, u_i's were assumed to be (i.i.d), exponential or half-normal random variables. The model defined by equation (3) is called the stochastic frontier production function, because:

The output values are bounded by the stochastic (random) variable exp (x_i β + v_i). The random error, v_i, can be positive or negative.

The stochastic frontier output varies from the deterministic part of the frontier model, exp (x_i β).

ALS 1977 derived the log likelihood function for the model, defined by equation (3), in which the u_i's are assumed to be i.i.d. N(0, δ^2) random variables, independent of the vi's, v_i's are assumed to be N(0, δ^2_v).

They also expressed the likelihood function in terms of two variance parameters, $\sigma_s^2 = \sigma_v^2 + \sigma^2$. Battes & Corra (1977) suggested the parameter $\gamma = \sigma^2 / \sigma_s^2$ be used because it has a value between zero and one, the parameter γ could be of any non-negative value. A value of γ of zero indicates that the deviations from the frontier are entirely due to noise or uncontrollable factors while a value of one would indicate that all deviations are due to the technical inefficiency.

The γ-parameterization has advantages in obtaining the Maximum Likelihood (ML) estimates because the parameter space for γ can be searched by a suitable iterative maximization algorithm. The log-likelihood function, in terms of this parameterization is equal to

$$\ln(L) = -\frac{N}{2}\ln(\pi/2) - \frac{N}{2}\log(\partial_s^2) + \sum_{i=1}^{N}\ln[1-\Phi(Z_i)] - \frac{1}{2\delta_s^2}\sum_{i=1}^{N}(\ln y_i - x_{i\beta})^2 \quad (4)$$

Where: $$Z = \frac{(\ln y_i - x_i\beta)}{\partial_s}\sqrt{\frac{\gamma}{1-\gamma}}$$

(Φ.) is the distribution function of the standard normal random variable.

The ML estimates of β, δ^2 and γ are obtained by finding the maximum of the log-likelihood function (Ahmed,2004).

4.2.3 The Stochastic Frontier Cost Functions

Tim Coelli (1996**)** all of the above specifications have been expressed in terms of a production function, with the U_i interpreted as technical inefficiency effects, which cause the firm to operate below the stochastic production frontier. If we wish to specify a stochastic frontier cost function, we simply alter the error term specification from:

(Vi - Ui) to (Vi + Ui). For example, this substitution would transform the production function defined by (1) into the cost function:

$Y_i = x_i\beta + (V_i + U_i)$,i=1,...,N, (5)

Where

Y_i is the (logarithm of the) cost of production of the i^{th} firm;

x_i is a k×1 vector of (transformations of the) input prices and output of the i-th firm;

β is a vector of unknown parameters;

The V_i are random variables which are assumed to be iid $N(0,\sigma_V^2)$, and independent of the

U_i which are non-negative random variables which are assumed to account for the cost of inefficiency in production, which are often assumed to be iid $|N(0,\sigma_U^2)|$.

In this cost function the U_i now defines how far the firm operates above the cost frontier. If allocative efficiency is assumed, the U_i is closely related to the cost of technical inefficiency. If this assumption is not made, the interpretation of the U_i in a cost function is less clear, with both technical and allocative inefficiencies possibly involved. The exact interpretation of these cost efficiencies will depend upon the particular application.

Rahman. (2002) stated that productive efficiency is generally defined as the ability of a production organization to produce at well-specified out put at minimum cost. To attain minimum cost the production organization must utilize its inputs in the most efficient manner (technical efficiency) and choose a combination of inputs which recognizes relative input prices and marginal products (allocative efficiency). As Schmidt and Lovell (1979) have shown, deviations from the frontier cost function can be a mixture of technical and allocative mistakes. The stochastic frontier cost function is the dual function of the stochastic frontier production function and with this stochastic cost frontier we can simultaneously estimate both the technical and allocative efficiency from single equation.

4.2.4 Stochastic Production Frontier in Applied Studies

Ibrahim (2007) stated that age of farmers, main occupation, family size, and educational level are significance in explaining technical inefficiency for both sorghum and sesame crops production. Hussein (2008) found that insufficient irrigation, working time in field are significance in explaining technical inefficiency in the Rahad scheme, while the gender, tenant's age, educational level, marital status, tenants experience and family are not significance for wheat production in the Rahad Scheme. Yousif (2008) found the farm location, age of farmers, family size, and educational level are significance in explaining technical inefficiency in White Nile Pump Schemes, except the gender and insufficient irrigations. Rahman (2002) found that farm size and educational level has a negative effect on rice production, older farmers had smaller technical inefficiency than younger one, farmer with more experiences had greater technical efficiencies than farmers with less experiences, farmers with more extension contact are technically more efficient than farmer with less extension contact and owner operators are technically more efficient than sharecroppers. Herdt and

Mantac (1981) and kalirajan (1984) found that technical efficiency increased with the increase in farmers' experiences.

Coelli and Battese (1996) found that the technical efficiency increases with the increase in age of farmer.

Ahmed (2004) stated that number of contacts with extension agents, differences between the cash advances for cotton weeding and harvesting and their actual cost, credit constraints, total area planted with other crops and number of visits by inspectors are the main factors behind The tenant's technical inefficiency.

4.2.5 Stochastic Frontier Production Function:

The explicit Cobb-Douglas stochastic frontier production function is given below:

$$\ln y_i = \beta_0 + \sum_{j=1}^{8} \beta_j \ln x_{ij} + v_i - u_i \qquad (3.1)$$

Where:

ln = the natural logarithm;

Y_i = Total output of sorghum (sacks), sesame (kantar) and sunflower (kantar);

X_1 = Area under sorghum, sesame and sunflower crops (feddan);

X_2 = Sowing date;

X_3 = Number of weeding;

X_4 = Rainfall distribution (dummy variable; 1= if the farm received good rainfall distribution and 0 = if the farm did not received good rainfall distribution)

X_5 = Total quantity of fuel gasoline (galloons);

X_6 = Total quantity of (seeds/kg/feddan);

X_7 = Harvesting cost;

X_8 = Off-farm income.

β_0 and β_1 are unknown parameters to be estimated for variables, respectively.

v_i represents the statistical error and the other factors which are beyond the farmers control such as weather, topography and others factor which are not included and may be positive , negative or zero. u_i is a non-negative random variable,

4.2.5.1Inefficiency Effect Model

The u_i in the stochastic production frontier model is a non-negative random variable, associated with the farmers technical inefficiency in production and assumed to be independently distributed, such that the technical inefficiency effect for the i^{th} farmers, u_i, will be obtained by truncating (at zero) of the normal distribution with mean, μ_i, and variance, δ^2, such that

$$\mu_i = \delta_o + \sum_{s=1}^{8} \delta_s Z_{si} \quad (3.2)$$

Z_{1i} = Age of farmers respondent;

Z_{2i} = Main occupation of farmers;

Z_{3i} = Educational level of farmers;

Z_{4i} = Credit;

Z_{5i} = Extension services (dummy variable; 1 = if the farm had contact with extension agents and 0 = if he did not have any contact with extension agents)

δ_o and δ_s coefficient are unknown parameters to be estimated, together with the variance parameters which area expressed in terms of

$\sigma^2 = \sigma^2 u + \sigma^2 v$ and

$\gamma = \sigma^2 u / \sigma^2$

Where, the γ-parameters have value between zero and one. The parameters of the stochastic frontier production function model are estimated by the method of maximum likelihood, using the computer program, FRONTIER Version 4.1

4.2.5.2 Part two: Results and discussion

4.3 Socio-economics Characteristics

The socio-economics characteristics studied here were gender, age, education level, marital status, and family size the farmers in the study area. According to Elgozouli (1998) the production, consumption pattern and decision making are partially affected by size, age and sex distribution of producer household members.

4.3.1 Gender

World Bank (2001) stated that the gender prefers to socially constructed roles and socially learned behaviors and expectations associated with female and male. It can be defined as more than biological differences between men and women. It includes the way in which those differences, whether real or perceived, have been valued, used and relied upon to classify women and men and to assign roles and expectations to them (MWANZ, 1996).

Table 4.3.1 Farmers' Efficiency in Mechanized and Traditional sector According to Gender

	Mechanized sector		Traditional sector	
Gender	Percentage	Mean Efficiency	Percentage	Mean Efficiency
Male	98%	64	86	67
Female	2%	62	14	65

Source: Field survey, season (2007/2008).

Table (4.3.1) showed that, the majority of farmers in both the mechanized (98%) and traditional (86%) sectors are male. Although female farmers were small no numbers compared with men but their mean efficiency was almost the same (with men). Likewise the mean efficiencies in the two were almost equivalent, but the traditional were somehow more efficient. This might be attributed to contribution of the family members in the farms work and management.

4.3.2 Age

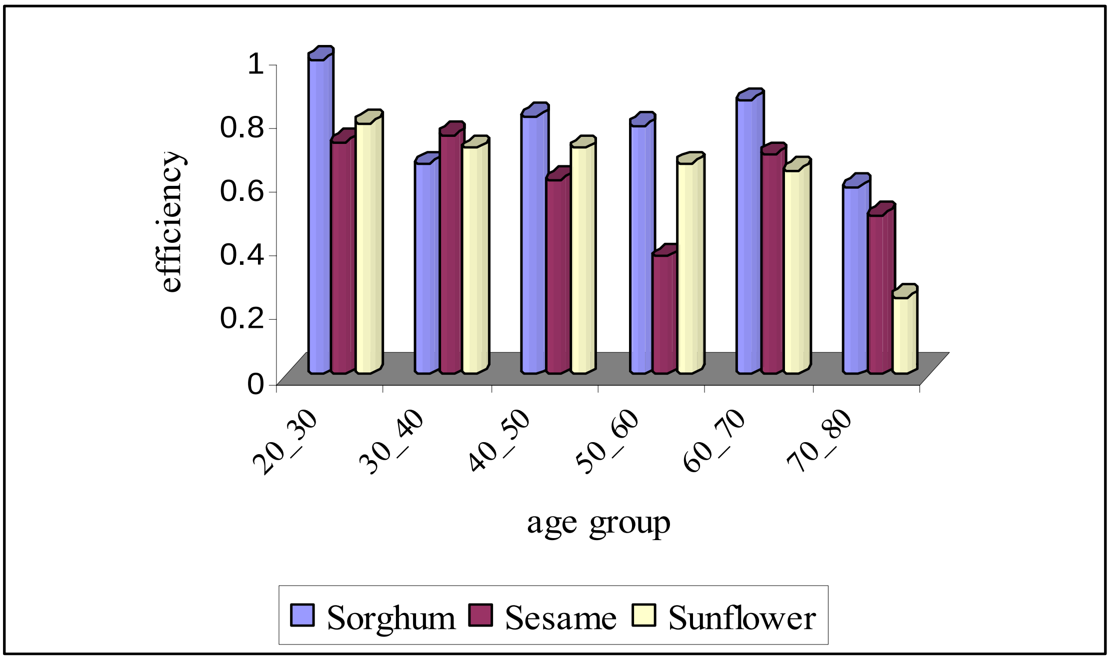
Siddig (1999) cited that a farmer's age is one of his demographic characteristic which influences his decision and his attitude toward accepting new ideas. Table (4.3.2), Table (4.3.2.1), Figure (4.3) and Figure (4.4) showed that the highest percentage of the farmers in Mechanized was in the age group of more than 40 years old (86.43%). This could attribute to the fact that, this sector are fully mechanized and needs experience mangers and money to operate which were found in the hands of the farmers in such age. The efficiency of sorghum production was more than all other crops, as sorghum represents the major crop produced in this sector. Sesame was the second crop grown in the study area, hence came second in terms of efficiency for the farmers in the age group of less than forty and more than sixty. But for most of the farmers particularly those of the age group (30-50) sunflowers came second in terms of efficiency. The reasons behind that might be due to the additional costs incurred in sesame production in terms of losses at harvest. On the other hands, the majority of the farmers in the traditional sector were in the age group of less than fifty, because traditional sector depends mainly on physical works (hand work) which provide mainly by the family member. Generally, groundnut was the main crop grown in this sector, according farmers' efficiencies was somehow better than the other grown crops. Although, sorghum is the second crops cultivated in the traditional sector, but farmers efficiencies were less compared with sesame.

Table 4.3.2 Distribution of Mechanized sector Farmers according to age

Age	%	Crop Efficiency			
		Sorghum	Sesame	Sunflower	Mean efficiency
20-30	3.19	0.99	0.73	0.79	0.67
30-40	10.38	0.66	0.75	0.71	0.71
40-50	33.1	0.81	0.61	0.71	0.71
50-60	35	0.78	0.37	0.66	0.60
60-70	14.1	0.86	0.69	0.64	0.73
70-80	4.23	0.59	0.50	0.24	0.44

Source: Field survey, season (2007/2008)

Fig 4.3 Distribution of Mechanized sector Farmers according to age



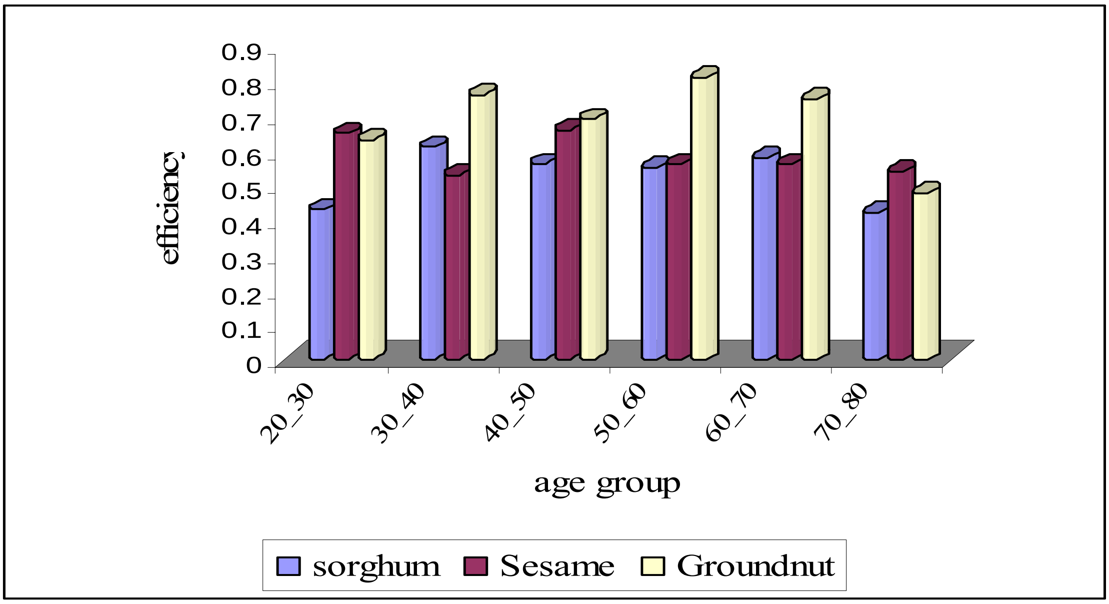
Source: author calculation from field survey data 2008.

Table 4.3.2.1 Distribution of Traditional sector Farmers according to age

Age	%	Crop Efficiency			
		Sorghum	Sesame	Groundnut	Mean efficiency
20-30	9.34	0.43	0.65	0.63	0.50
30-40	24	0.61	0.53	0.76	0.63
40-50	22.67	0.56	0.66	0.69	0.64
50-60	18.67	0.55	0.56	0.81	0.59
60-70	12	0.58	0.56	0.75	0.61
70-80	13.3	0.42	0.54	0.48	0.45

Source: Field survey, season (2007/2008)

Fig 4.4 Distribution of Traditional sector Farmers according to age



Source: author calculation from field survey data 2008.

4.3.3 Education

Education in general can be defined as accumulation of knowledge and experience to prepare an individual for live (Ahmed, 1996 and Siddig, 1999). Education of farmers plays pivotal role in the production process by combining and managing inputs in an efficient way. Education of farmers helps to increase farm production. Phillips and Marble (1986) observed that farmers with four or more years of schooling caused an increase in productivity.

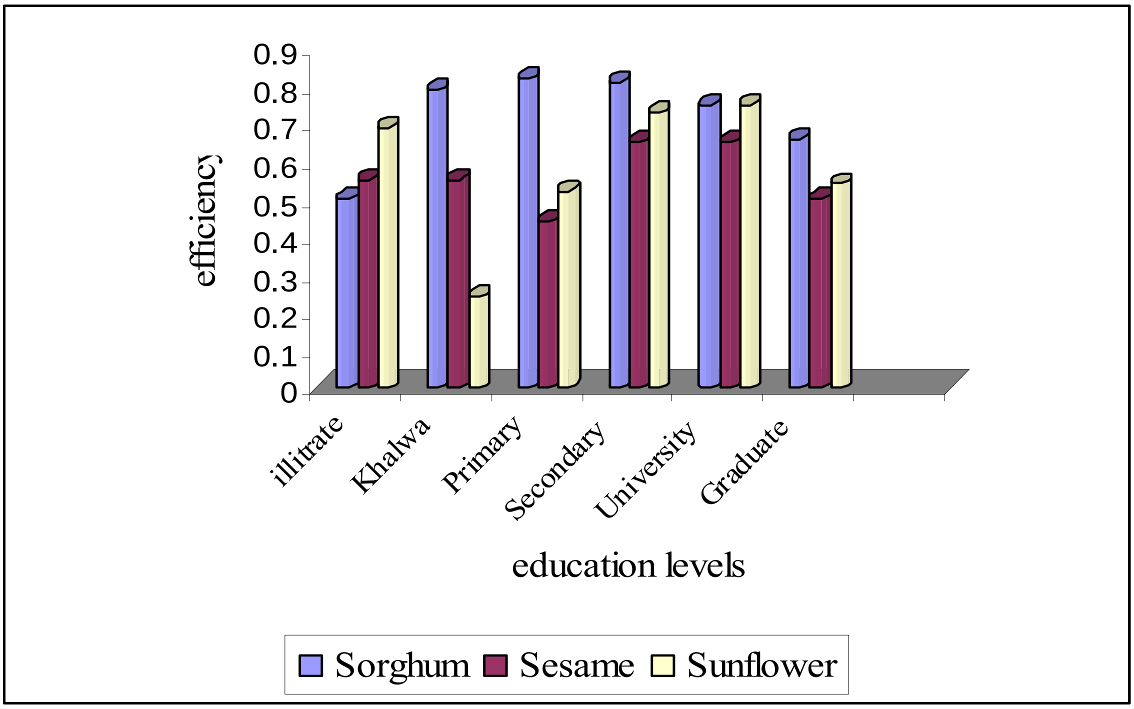
The survey showed that the farmers in mechanized and traditional sectors whom attained at least the have primary education were 92%, 39% respectively (Table 4.3.3) and (Table 4.3.3.1). This level of education indicates that the farmers' level of awareness, their abilities to take the right decisions on how and what to produce, and adopting new agricultural technologies, and manage inputs in the traditional sector were weak. Education enhances a farmer's ability to seek, decipher and make good use of information about production inputs (Kebede, 2001). Mean efficiency of crop production in the two sectors shows fluctuating pattern with the increasing level in educational (Figure 4.5) and (Figure 4.6).

Table 4.3.3 Distribution of Mechanized sector Farmers according to Education

Education level	Percentage	Crop Efficiency			
		Sorghum	Sesame	Sunflower	Mean efficiency
Illiterate	2.1	0.5	0.55	0.69	0.58
Khalwa	5.6	0.79	0.55	0.24	0.53
Primary	21	0.82	0.44	0.52	0.59
Secondary	45.4	0.81	0.65	0.73	0.73
University	21	0.75	0.65	0.75	0.72
Graduate	4.9	0.66	0.50	0.54	0.65

Source: author calculation from field survey data 2008.

Fig 4.5 Distribution of Mechanized sector Farmers according to Education level



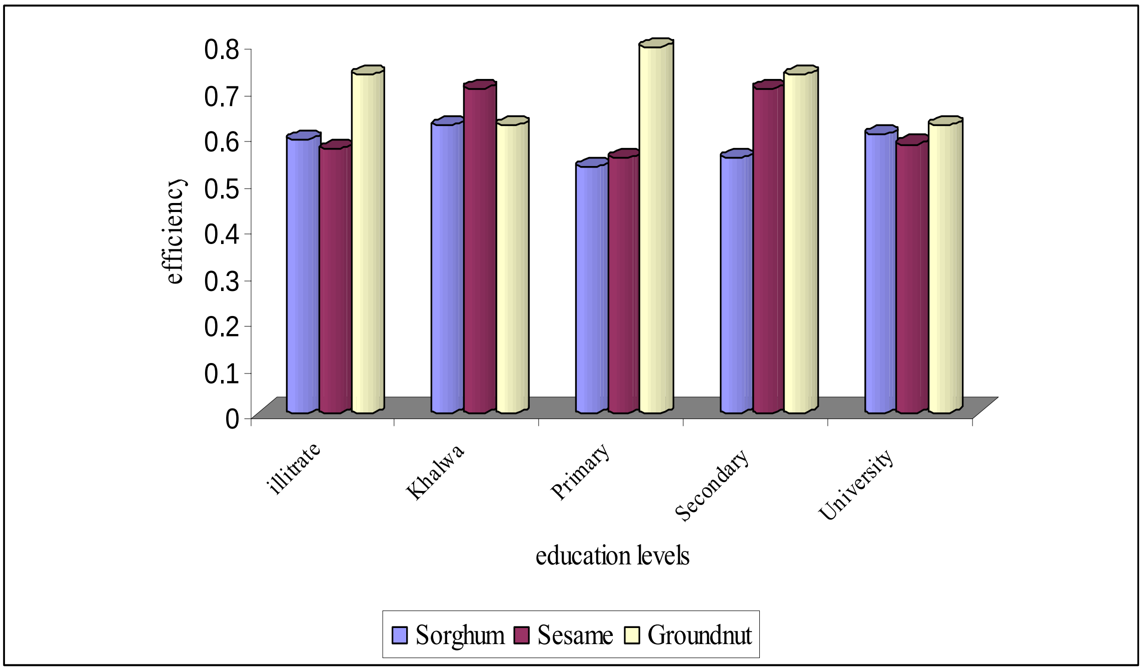
Source: author calculation from field survey data 2008.

Table 4.3.3.1 Distribution of Traditional sector Farmers according to Education level

Education level	Percentage	Crop Efficiency			
		Sorghum	Sesame	Groundnut	Mean efficiency
Illiterate	49.33	0.59	0.57	0.73	0.63
Khalwa	12.00	0.62	0.70	0.62	0.65
Primary	20.00	0.53	0.55	0.79	0.62
Secondary	17.33	0.55	0.70	0.73	0.66
University	1.33	0.60	0.58	0.62	0.85

Source: Field survey, season (2007/2008

Fig 4.6 Distribution of Traditional sector Farmers according to Education level



Source: author calculation from field survey data 2008.

4.3.4 Marital status of the farmers in the study area

Table (4.3.4) illustrates that the majority of farmers in mechanized and traditional sector were married (90% and 75%) respectively. The efficiency of married is greater than that of single. The reasons behind that were: married farmers can benefits from the family members in their farms works which is the one of the feature of the developing countries, besides he is some how more stable. Since the family activity of traditional sector is labor

Table 4.3.4 Distribution of the Farmers According to Marital Status in Mechanized and Traditional sector

Marital status	Mechanized sector		Traditional sector	
	Percentage	efficiency	Percentage	efficiency
Marriage	90	70	75	66
Single	10	64	25	62

Source: Field survey, 2008).

intensive, availability of labor determines the level of output that can be obtained from the farm (Kebede, 2001).

4.3.5 Family Size

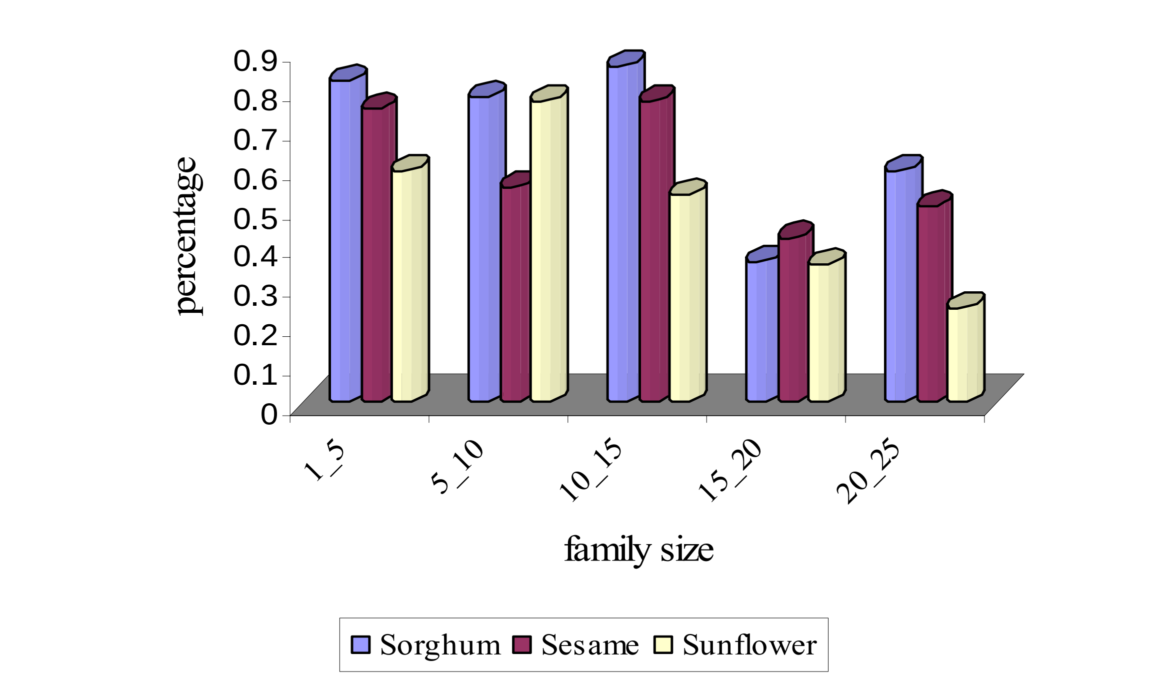
Family can be defined as all members living within a household having a blood relationship and who are supported by an income known as the family income (Siddig, 1999). Beside, that family plays a vital role in the agricultural economic and development. Table (4.3.5), table (4.3.5.1),figure(4.7) and figure(4.8) shows that the family size in the mechanized and traditional sectors ranged between (1 and 25) members and the largest family size ranged between 5 and 10 members for the two sector (66% and 53.33%), respectively. Generally we can say that, the mean efficiencies in the two sectors were not affected with family size.

Table 4.3.5 Distribution of Mechanized sector Farmers according to family size

Family size	Percentage	Crop Efficiency			
		Sorghum	Sesame	Sunflower	Mean efficiency
1-5	17.2	0.82	0.75	0.59	0.72
5-10	66	0.78	0.55	0.77	0.70
10-15	9.5	0.86	0.77	0.53	0.72
15-20	3.19	0.36	0.42	0.35	0.38
20-25	4.12	0.59	0.50	0.24	0.44

Source: Field survey, season (2007/2008).

Fig (4.7.Distribution of Mechanized sector Farmers according to family size



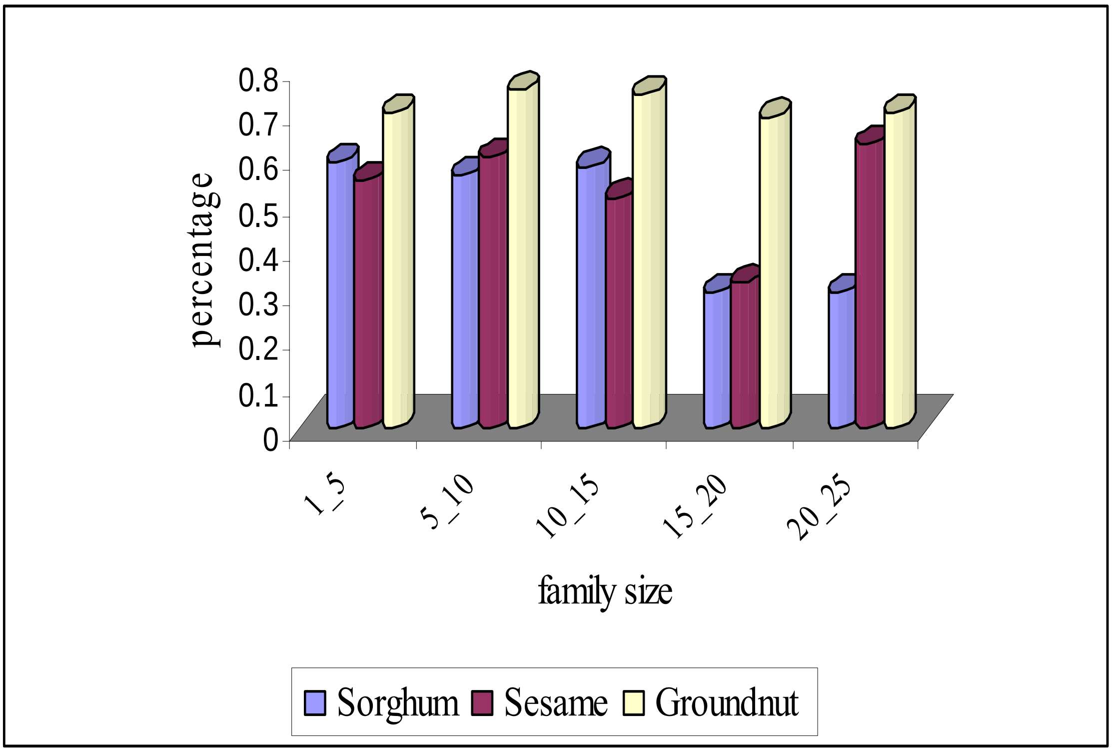
Source: author calculation from field survey data 2008.

Table 4.3.5.1 Distribution of Traditional sector Farmers according to Family size

Family size	Percentage	Crop Efficiency			
		Sorghum	Sesame	Groundnut	Mean efficiency
1-5	33.33	0.59	0.55	0.70	0.61
5-10	53.33	0.56	0.60	0.75	0.64
10-15	10.67	0.58	0.51	0.74	0.61
15-20	1.33	0.30	0.32	0.69	0.44
20-25	1.33	0.30	0.63	0.70	0.54

Source: Field survey, 2008.

Fig (4.8) Distribution of Traditional sector Farmers according to Family size



Source: author calculation from field survey data 2008.

4.4 Stochastic Frontier Production Function Analysis

Economic Efficiency is intended to show how and why the farmers or firm operate above the cost frontier. Stochastic Frontier version 4.1 programs (Coelli, 1996) was used to estimate the level of technical efficiency for sorghum, sesame, sunflower and groundnut crops.

4.4.1 Sorghum production efficiency in mechanized sector

As shown in Table (4.4.1), the mean technical efficiency of sorghum production in mechanized sector is 0.79 in the sorghum model, with a minimum of 23% and maximum of 99%. This means that, the mechanized sector produced an average of 79 percent of sorghum output, given the current level of production practice, inputs and technology. This implies that the respondent can increase their sorghum output by 21 percent from a given mix of production inputs if the farmers are technically efficient.

4.4.2 Sesame production efficiency in mechanized sector

As shown in Table (4.4.1), the mean technical efficiency of sesame production function is 0.58 in the mechanized sector, with minimum efficiency of 11%, and maximum efficiency 99%. This means that on average, the mechanized sector produced 58percent of sesame output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondent can increase their sorghum output by 42 percent from a given mix of production inputs if the farmers are technically efficient.

4.4.3 Sunflower production efficiency in mechanized sector

As shown in Table (4.4.1), the mean technical efficiency of sunflower production in mechanized sector is 0.67 in the sunflower model, with a minimum of 24% and maximum of 98%. This means that on average, the mechanized sector produced 67 percent of sunflower output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondent can increase their sunflower output by 33 percent from a given mix of production inputs if the farmers are technically efficient.

Table 4.4.1 Summary Statistics of Efficiency Estimate from the Stochastic Frontier Model of Mechanized sector crops

Statistic	Efficiency score		
	Sorghum	Sesame	Sunflower
Mean	0.79	0.58	0.67
Minimum	0.23	0.11	0.24
Maximum	0.99	0.99	0.98

Source: calculated by the author from field survey data season 2008.

4.4.4 Sorghum production efficiency in traditional sector

As shown in Table (4.4.2), the mean technical efficiency of sorghum production in traditional sector is 0.58 in the sorghum model, with a minimum of 23% and maximum of 99%. This means that on average, the farmers in traditional sector produced 58 percent of sorghum output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondent can increase their sorghum output by 42 percent from a given mix of production inputs if the farmers are technically efficient.

4.4.5 Sesame production efficiency in traditional sector

As shown in Table (4.4.2), the mean technical efficiency of sesame production in traditional sector is 0.57 in the traditional sector model, with a minimum of 22% and maximum of 99%. This means that on average, the farmers in traditional sector produced 57 percent of sesame output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondent can increase their sorghum output by 43 percent from a given mix of production inputs if the farmers are technically efficient

4.4.6 Groundnut Production Efficiency in Traditional sector

As shown in Table (4.4.2), the mean technical efficiency of groundnut production in traditional sector is 0.73 in the sorghum model, with a minimum of 20% and maximum of 95%. This means that on average, the farmers in traditional sector produced 73 percent of groundnut output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondent can increase their sorghum output by 27 percent from a given mix of production inputs if the farmers are technically efficient

Table 4.4.2: Summary Statistics of Efficiency Estimate from the Stochastic Frontier Model of Traditional sector crops

Statistic	Efficiency score		
	Sorghum	Sesame	Groundnut
Mean	0.58	0.57	0.73
Minimum	0.23	0.22	0.20
Maximum	0.99	0.99	0.95

Source: Author calculation

4.5 Factors Affecting Crop Technical Efficiency

Results of the Maximum-likelihood (ML) estimates of stochastic frontiers production function for sorghum, sesame and sunflower and the inefficiency model for Mechanized sector were presented in Tables (4.5), (4.5.1) and (4.5.2).

Most of the estimated β co-efficient of the stochastic frontier model for all crops have the expected sign. The coefficient of area has a positive sign and insignificant for sorghum, negative sign and significant (99% level of significant) for sesame and negative sign and insignificant for sunflower crop. This means that farmers have not fully used their available land for sesame and sunflower production, (although sunflower was not significant). This could be a kind of risk aversion measures adopted by the farmers, as sesame crop needs huge money for harvest (characterized by seed shattering) which not usually available in hands of farmers at the specified time. Besides that, one of the most critical periods for labors availability is usually associated with the period of sesame harvest (labor intensive crop). The estimated coefficient of sowing date for sorghum, sesame and sunflower has negative signs and significant (95%, 99% and 95% level of significant, respectively). Negatively significant parameter of sowing date means that the rate of output decreases with the dalliance of sowing date. The main reasons were; postponing sowing date makes the crop vulnerable to pests and diseases.

Table (4.5): Maximum-likelihood Estimate for the Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Effect Model for Sorghum Mechanized sector crops

Variable	Parameters	Coefficient	Standard error	T-ratio
Constant	β_0	1.87	0.668	2.7974 ***
Area under crops (X_1)	β_1	0.065	0.069	0.9420
Sowing; (X_2)	β_2	-0.919	0.466	-1.9721*
Weeding (X_3)	β_3	-0.862	0.422	-2.0427*
Rainfall distribution (X_4)	β_4	0.590	0.107	5.5140***
Fuel (X_5)	β_5	0.078	0.073	1.069
Seeds/kg (X_6)	β_6	-0.188	0.059	3.186***
Harvesting (X_7)	β_7	0.011	0.045	0.244
Off farm income (X_8)	β_8	0.019	0.005	3.8***
Inefficiency model:				
Age (Z_1)	δ_1	-0.188	0.059	-3.186***
Main occupation (Z_2)	δ_2	-0.858	0.072	-11.917***
Educational level (Z_3)	δ_3	-0.146	0.143	-1.021
Family size (Z_4)	δ_4	-0.266	0.158	-1.684
Credit (Z_5)	δ_5	-0.226	0.470	-0.481
Extension services (Z_6)	δ_6	-0.315	0.250	-1.260
Sigma-squared	$\sigma_s^2 = \sigma_v^2 + \sigma^2$	0.097	0.014	6.92***
Gamma	$\gamma = \sigma^2 / \sigma_s^2$	0.98	0.013	75.38***
Mean efficiency			0.79	
Log likelihood function			24.684	

***,** and * asterisks on the value of the parameters indicates it is significance at 1, 5 and 10 percent level respectively

Table (4.5.1): Maximum-likelihood Estimate for the Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Effect Model for Sesame Mechanized sector crops

Variable	**Parameters**	**Coefficient**	**Standard-error**	**T-ratio**
Constant	β_0	8.303	3.186	2.514**
Area under crops (X_1)	β_1	-0.374	0.114	-3.281***
Sowing; (X_2)	β_2	-1.768	0.450	-3.929***
Weeding (X_3)	β_3	-0.248	0.086	-2.884***
Rainfall distribution (X_4)	β_4	1.298	0.123	10.553***
Fuel (X_5)	β_5	-0.134	0.110	-1.218
Seeds/kg (X_6)	β_6	0.096	0.080	1.200
Harvesting (X_7)	β_7	-0.357	0.291	-1.227
Off farm income (X_8)	β_8	0.011	0.032	0.344
Inefficiency model				
Age (Z_1)	δ_1	0.550	0.329	1.672*
Main occupation (Z_2)	δ_2	-0.480	0.150	-3.2**
Educational level (Z_3)	δ_3	-0.256	0.151	-1.695*
Family size (Z_4)	δ_4	-0.903	0.351	-2.573**
Credit (Z_5)	δ_5	0.191	0.355	0.538
Extension services (Z_6)	δ_6	0.285	0.786	0.363
sigma-squared	$\sigma_s^2 = \sigma_v^2 + \sigma^2$	0.097	0.014	6.92***
gamma	$\gamma = \sigma^2 / \sigma_s^2$	0.96	0.05	19.2***
Mean efficiency			0.58	
Log likelihood function			36.21	

***,** and * asterisks on the value of the parameters indicate it is significance at 1, 5 and 10 percent level respectively

Table (4.5.2): Maximum-likelihood Estimate for the Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Effect Model for Sunflower Mechanized sector crops

Variable	Parameters	Coefficient	Standard-error	T-ratio
Constant	β_0	-0.085	1.038	-0.082
Area under crops (X_1)	β_1	-0.242	0.198	-1.22
Sowing; (X_2)	β_2	-0.372	0.262	-1.420*
Weeding (X_3)	β_3	-0.903	0.351	-2.573**
Rainfall distribution (X_4)	β_4	2.283	0.381	5.992***
Fuel (X_5)	β_5	0.246	0.174	1.414*
Seeds/kg (X_6)	β_6	-0.480	0.313	-1.534*
Harvesting (X_7)	β_7	-0.733	0.306	-2.395**
Off farm income (X_8)	β_8	-0.002	0.023	-0.087
Inefficiency model				
Age (Z_1)	δ_1	0.096	0.216	0.444
Main occupation (Z_2)	δ_2	-0.904	0.354	-2.554**
Educational level (Z_3)	δ_3	-0.919	0.466	-1.972
Family size (Z_4)	δ_4	0.012	0.033	0.364
Credit (Z_5)	δ_5	-0.002	0.023	-0.087
Extension services (Z_6)	δ_6	-0.132	0.881	-0.150
sigma-squared	$\sigma_s^2 = \sigma_v^2 + \sigma^2$	0.067	0.068	4.431***
gamma	$\gamma = \sigma^2 / \sigma_s^2$	0.97	0.05	19.4***
Mean efficiency	-	-	0.67	
Log likelihood function			24.106	

***,** and * asterisks on the value of the parameters indicate it is significance at 1, 5 and 10 percent level respectively

The estimated coefficient of sowing date for sorghum, sesame and sunflower has negative signs and significant (95%, 99% and 95% level of significant, respectively). Negatively significant parameter of sowing date means that the rate of output decreases with the dalliance of sowing date. The main reasons were; postponing sowing date makes the crop vulnerable to pests and diseases.

The coefficient of the number of weeding for all crops is significantly different from zero, with negative signs for all crops. This implies that increasing weeding numbers beyond certain levels negatively affect farmers' returns. The negative sign of weeding numbers with respect to production reflect farmer's inability to finance this operation due to his insufficient credit, high cost of weeding particularly in the study area which characterized by a heavily rainy season.

The coefficient of rainfall distribution has a positive sign and high significantly difference from zero for all crop. That means rainfall distribution is one of the main determinants of crops production in rain fed sector.

The coefficient of fuel (gasoline) got negative signs for sesame and sunflower (although it is insignificant for sesame), and positive but insignificant for sorghum. The negative sign means that increasing the quantity of fuel reduces the output. This may reflect the negative relationship between fuels availability, accessibility and prices (high prices) and crops production.

The estimated coefficient of seed/kg has a negative sign and significant at 1 percent and 10 percent for sorghum and sunflower respectively, while for sesame crop the coefficient seed rate has a positive sign and not significant. This means that the quantity of seeds has negative significant impact for increasing sorghum and sunflower output, and positive but not significant impact for sesame output.

The coefficient of harvesting is positive sign for sorghum and negative sign for sesame and sunflower, and it is significant for sunflower at 5 percent of the level of significant and not significant for both sorghum and sesame output. This coefficient is contrary due to high cost of harvesting for sunflower and sesame crops, lack of labor or untimely labor for harvesting, length of harvesting period and the conflicts between pastoralists and farmers may affects sorghum , sesame and sunflower output.

The coefficient for off-farm income used in agricultural processes is positive and significance at 1 percent of the level for sorghum, positive but not significant for sesame, and negative and not significant for sunflower. The possible explanation of these results are that the major part of the off-farm income might go directly towards purchasing food crops and/or education expenses rather than the production practice of sorghum, sesame and sunflower crops.

The mean technical efficiency models in the mechanized sector crops (sorghum, sesame, and sunflower) indicates that the respondent operate at 0.79, 0.58, and 0.67 level of technical efficiency for the three crops respectively. Results also revealed that, the variance ratio parameters γ for sorghum, sesame, and sunflower was large and significant at 0.98, 0.96 and 0.97 percent, respectively. These results express that about 98% of sorghum, 96% sesame and 97% sunflower output deviation are caused by differences in farmer's level of technical efficiency as opposite to the conventional random variability. The significant estimates of the hypothesis γ and δ2s imply that, the assumed distribution of u_i and v_i is accepted (Tables 4.5.3).

Table (4.5.3): Sorghum, sesame and sunflower models, Test of hypothesis for the parameters of stochastic frontier production function

	Model			Decision
	Sorghum	Sesame	Sunflower	
H_0: $\gamma = \mu = 0$	75.38***	19.137***	19.4***	H_0: Rejected
LR H_0: No technical inefficiency	29.74***	36.48***	20.79***	H_0: Rejected

***,** and * asterisks on the value of the parameters indicate it is significance at 1, 5 and 10 percent level respectively

As shown in Table (4.5.3) the test of hypothesis of sorghum, sesame and sunflower likelihood ratio test (LR), which tests the null hypothesis for the technical inefficiency effect for crops production in Mechanized sector are rejected.

The value of the test is calculated as:

$LR = -2\{\ln[L(H0) / L(H1)]\} = -2\{\ln[L(H0)] - \ln[L(H1)]\}$

Where L(H0) and L(H1) are the values of the likelihood function under the null hypothesis and alternative hypothesis, respectively (Rahman, 2002 & Ahmed, 2004).

4.5.1 Inefficiency Model for Sorghum, Sesame and Sunflower:

Results of the inefficiency model for sorghum, sesame and sunflower were shown in Tables (4.5), (4.5.1) and (4.5.2) respectively. The factors study in the in the mechanized sector inefficiency models were age, main occupation, educational level, credit, and extension services. The age of farmers has negative and significant (1% level of significance) effects on sorghum production inefficiency, positive and significant on sesame (10% level of significance) and positive but not significant on sunflower crop. These results indicates that, there were negative and significant effects of farmers age on sorghum inefficiency model, that is, sorghum production efficiency increases with increasing level of farmers' age (older farmers have smaller inefficiency than younger farmers, or the older farmers are technically more efficient than younger one). The negative sign might attribute to the fact that, older farmers are more experience in agricultural management, as the mechanized sectors need good management rather than physical efforts.

Main occupation of farmers has significantly negative effects for all crops cultivated in the mechanized sector (Table 4.5). These significant relationships might be due to the increasing skills of farmers who practice agricultural as a sole proficiency. Those farmers whose agriculture represents their main proficiency are more experience in agricultural practices than others.

The coefficient of educational levels of farmers inefficiency models were negative significant for both sesame and sunflower (10% and 1% level of significance respectively), and negative but not significant for sorghum. Negatively significant parameter of educational level means that, the technical inefficiency of sorghum, sesame and sunflower decrease with the increasing level of farmers' education. The reasons might be that, the educated farmers were more aware and able to adopt new agricultural technologies able to manage their farms perfectly, and work towards achieving their goals of maximizing the profits.

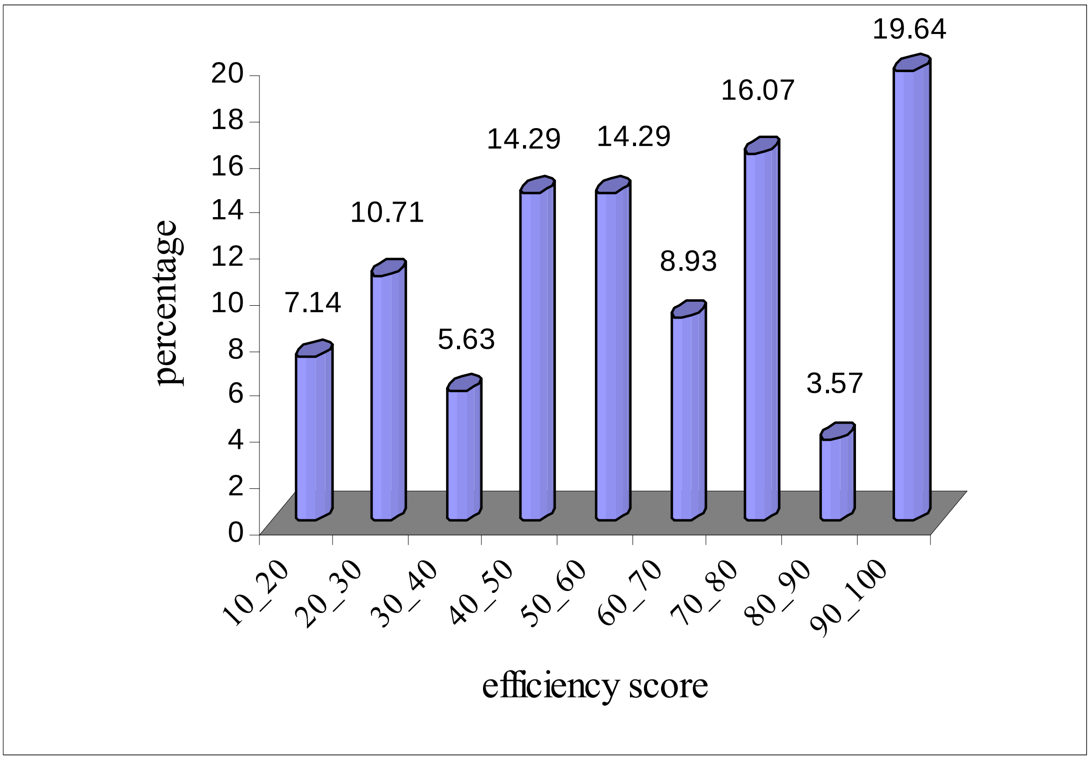
The coefficients of credit in the inefficiency models were found to be insignificant for all crops studied in the mechanized sector (sorghum, sesame and sunflower). This is due to the fact that, most farmers do not receive their credits on the correct time and amount.

The coefficients of extension services in inefficiency models were found to be insignificant for all studied crops in the mechanized sector (sorghum, sesame and sunflower). These inefficiency effects of extension service are due to absence of extension contact of farmers with extension agents. Previous studies affirmed that farmers with more extension contact with extension agents are more technically efficient than farmers with less extension services contact. This reflects the important of extension services in improving farmers' production and technical efficiencies and enhancing the sustainability of agricultural efficiency in the mechanized sector.

4.5.2 Frequency Distribution of farmers Technical Efficiency

The farmers in Mechanized and Traditional sector have a wide range of technical efficiency. The frequency distribution of the efficiency estimates obtained from the stochastic frontier model was calculated by summing up all the percentage of the efficiency score till the mean technical efficiency. In this study the mean technical efficiency for sesame in mechanized sector were 58 (see Table (4.5.1, accordingly, about 51.79 percent of farmers operate within the efficiency range (10-60) and 48.21 percent operate within efficiency range (60-100) (Figure 4.9). This implies that, on average, the sesame farmers in mechanized sector achieved almost 58 percent of the potential sesame production level, given their current level of production inputs and technology used. About 51.79 percent of them operate below the mean technical efficiency (58 percent) of sesame production, and about 48.21 percent operated above the mean technical efficiency.

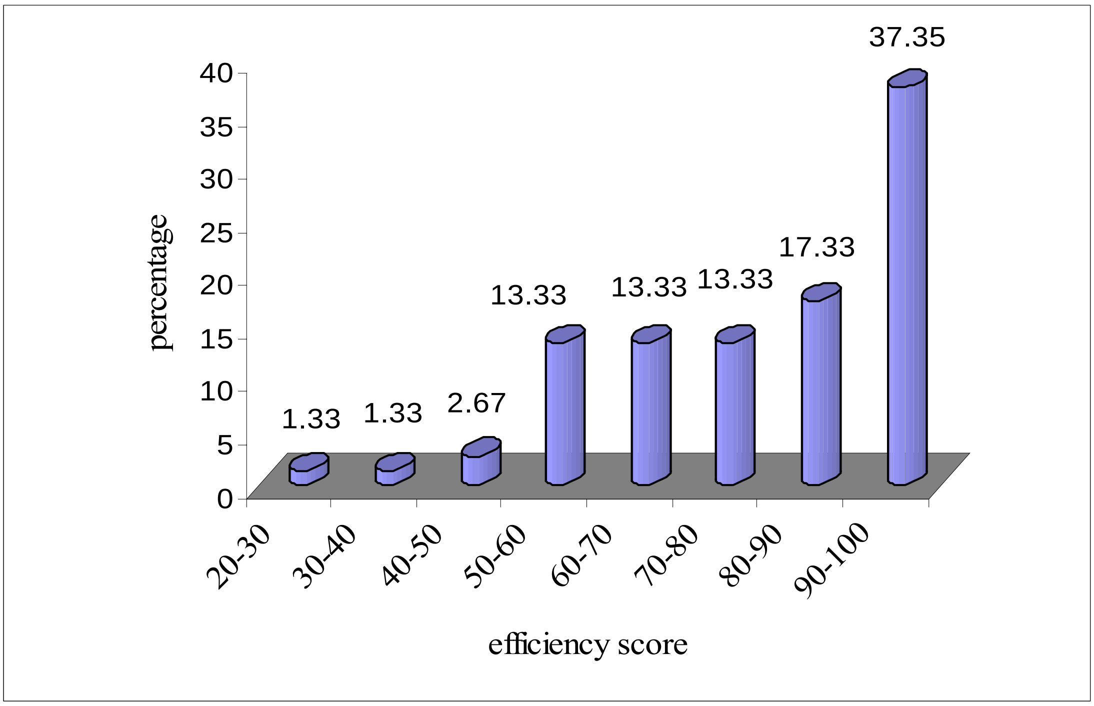
Fig 4.9: Technical Efficiency score of sesame in mechanized sector



Source: author calculation from field survey data 2008.

The farmers in Mechanized sector have a wide range of technical efficiency ranging from 23 percent up to 99 percent for sorghum crop. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for sorghum (Figure 4.10) shows that 45.32 percent of farmers operate with efficiency ranged between (20-80) and 54.68 percent operate with efficiency ranged between (80-100) This implies that on average, the farmers producing sorghum in mechanized sector achieved almost 79 percent of the potential stochastic frontier sorghum production level given their current level of production inputs and technology used. 45.32 percent of sorghum production model farmers in mechanized sector operated below 79 percent of the maximum sorghum production, obtained by the fully efficient and only 54.68 percent operated above the 79 percent level of technical efficiency in the sorghum model.

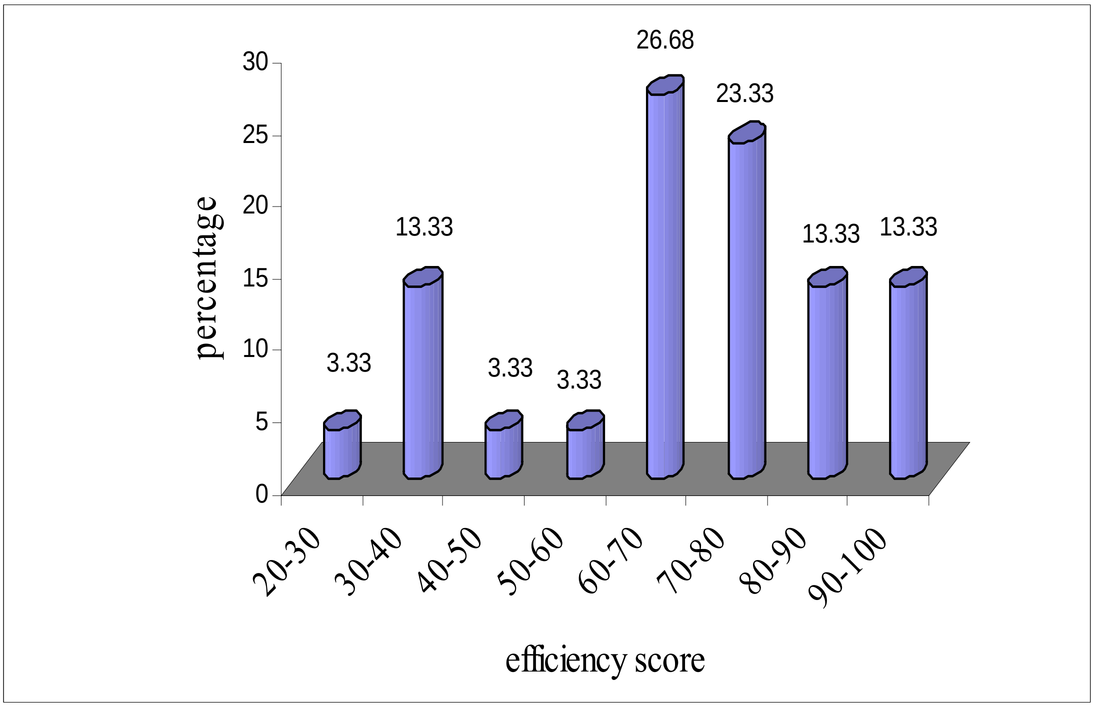
Fig 4.10: Technical Efficiency score of sorghum in mechanized sector



Source: author calculation from field survey data 2008.

The farmers in Mechanized sector have a wide range of technical efficiency ranging from 24 percent up to 98 percent for sunflower crop. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for sunflower (Figure 4.11) shows that 50 percent of farmers operate with efficiency ranged between (20-70) and 50 percent operate with efficiency ranged between (70-100) This implies that on average, the farmers producing sunflower in Mechanized sector achieved almost 67percent of the potential stochastic frontier sunflower production level given their current level of production inputs and technology used. 50 percent of sunflower production model farmers in Mechanized sector operated below 67percent of the maximum sunflower production, obtained by the fully efficient and only 50 percent operated above the 67 percent level of technical efficiency in the sunflower model.

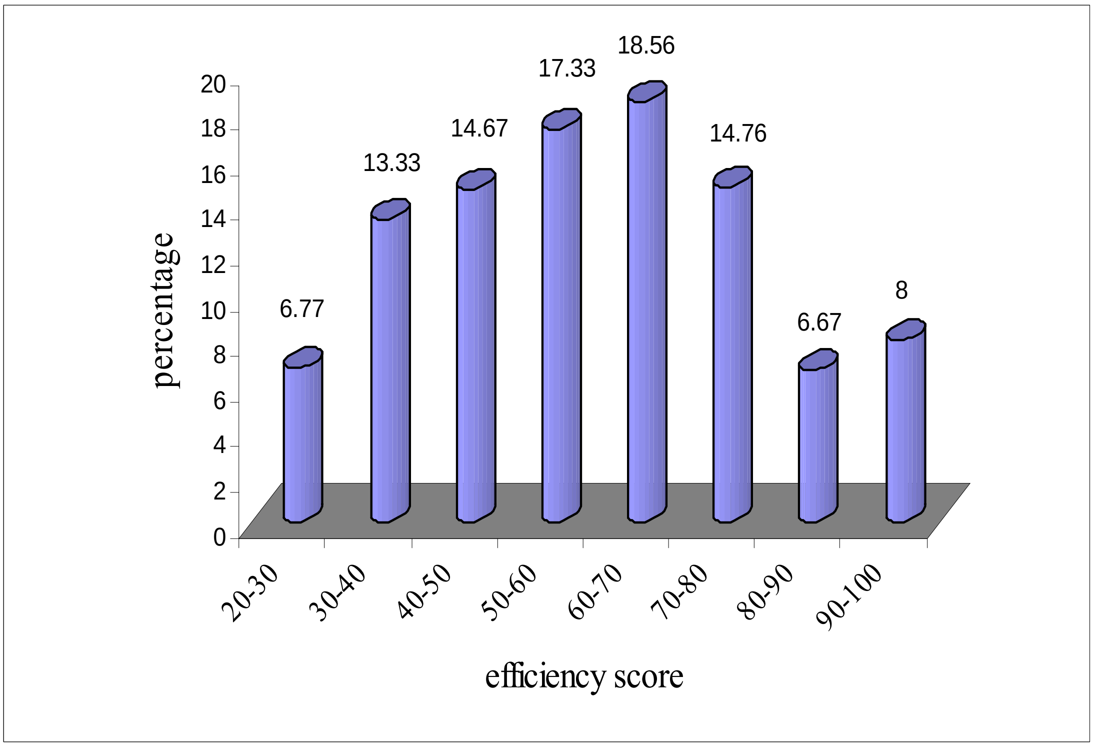
Figure 4.11: Technical Efficiency score of sunflower in mechanized sector



Source: author calculation from field survey data 2008.

The farmers in Traditional sector have a wide range of technical efficiency ranging from 23 percent up to 99 percent for sorghum crop. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for sorghum (Figure 4.12) shows that 52.1 percent of the farmers operate with efficiency ranged between (20-60) and 47.9 percent operate with efficiency ranged between (60-100) This implies that on average, the farmers producing sorghum in Traditional sector achieved almost 58 percent of the potential stochastic frontier sorghum production level given their current level of production inputs and technology used. 52.1 percent of sorghum production model farmers in Traditional sector operated below 58 percent of the maximum sorghum production, obtained by the fully efficient and only 47.9 percent operated above the 58 percent level of technical efficiency in the sorghum model.

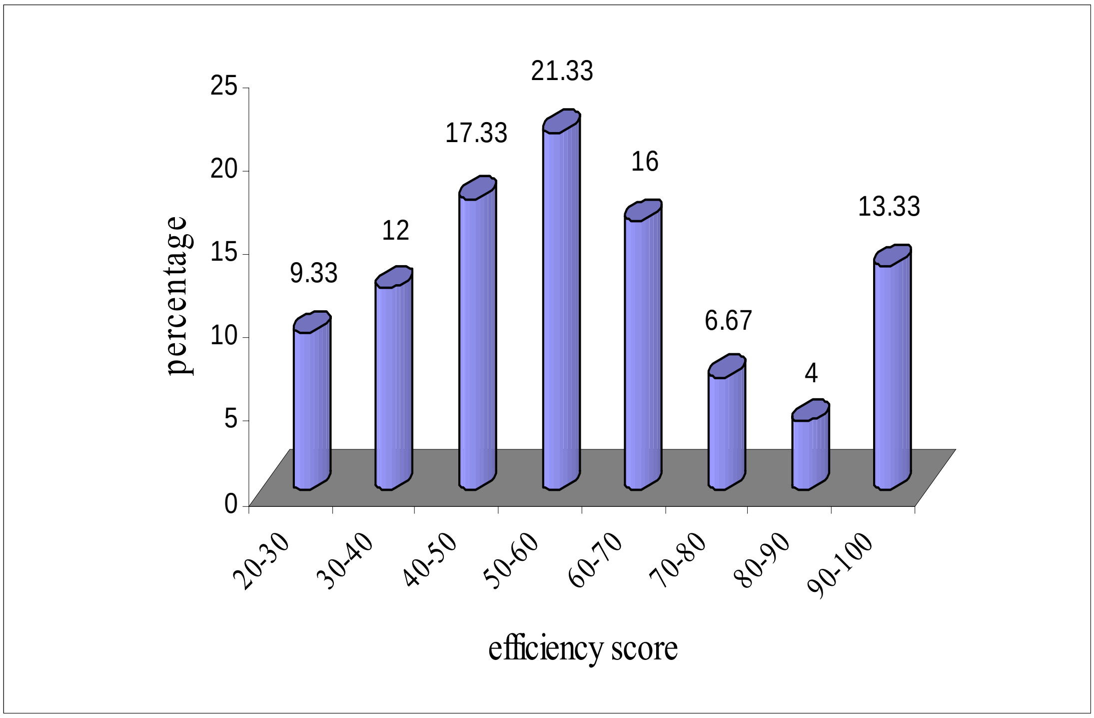
Fig 4.12: Technical Efficiency score of sorghum in traditional sector



Source: author calculation from field survey data 2008.

The farmers in Traditional sector have a wide range of technical efficiency ranging from 22 percent up to 99 percent for sesame crop. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for groundnut (Figure 4.13) shows that 60 percent of the farmers operate with efficiency ranged between (20-60) and 40 percent operate with efficiency ranged between (60-100) This implies that on average, the farmers producing sorghum in Traditional sector achieved almost 57 percent of the potential stochastic frontier sesame production level given their current level of production inputs and technology used. 60 percent of sesame production model farmers in Traditional sector operated below 57 percent of the maximum groundnut production, obtained by the fully efficient and only 40 percent operated above the 57 percent level of technical efficiency in the sorghum model.

Fig 4.13: Technical Efficiency score of sesame in traditional sector

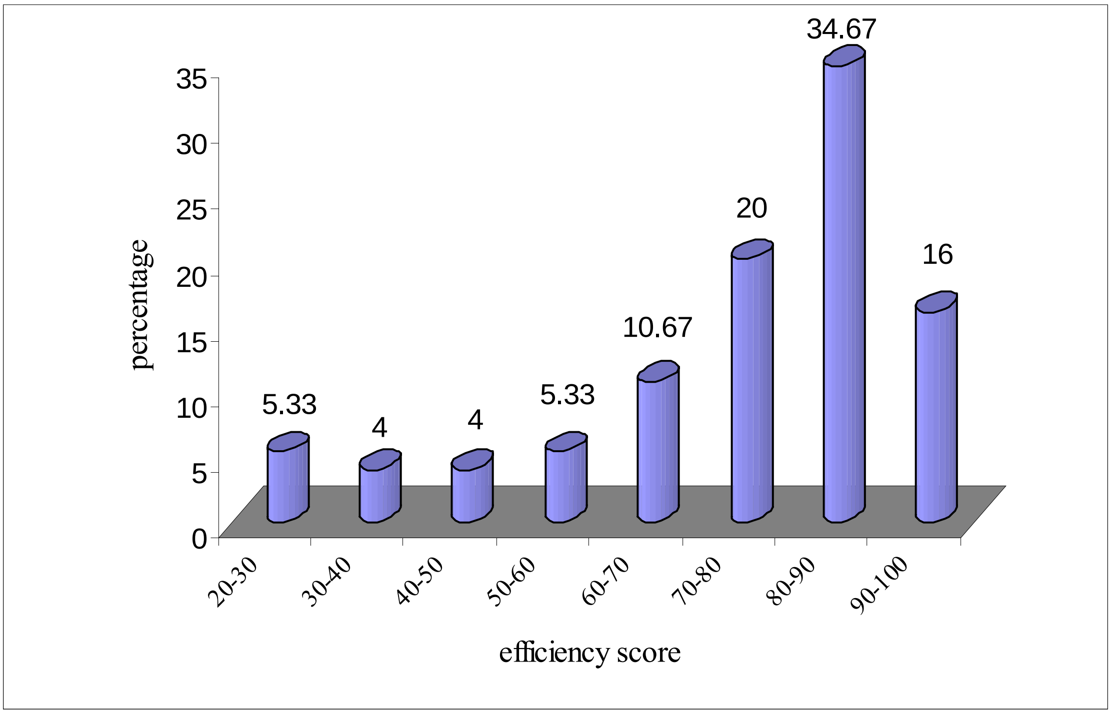


Source: author calculation from field survey data 2008.

The farmers in Traditional sector have a wide range of technical efficiency ranging from 20 percent up to 95 percent for groundnut crop. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for groundnut (Figure 4.14) shows that 49.33 percent of the farmers operate with efficiency ranged between (20-80) and 50.67 percent operate with efficiency ranged between (80-100) This implies that on average, the farmers producing sorghum in Traditional sector achieved almost 73 percent of the potential stochastic frontier groundnut production level given their current level of production inputs and technology used. 49.33 percent of sesame production model farmers in Traditional sector operated below 73 percent of the maximum groundnut production, obtained by the fully efficient and only

50.67 percent operated above the 73 percent level of technical efficiency in the groundnut model.

Fig 4.14: Technical Efficiency score of groundnut in traditional sector



Source: author calculation from field survey data 2008.

CHAPTER FIVE

Specification of the Linear Programming Model

This chapter discusses the linear programming model development and its specification.

5.1 Theoretical framework

5.1.1 Economic choice concepts

Factors of production are the inputs: land, labor and capital. The quantities of available resources are limited. We can not produce every thing we want in the quantities we desire. Resources are scarce relative to desire, because our resources are services. Opportunity costs exist in all situations where available resources are not abundant enough to satisfy all our desire. In all such situation, we must make hard decisions about how to allocate our scarce resources among competing uses. Our ability to alter the mix of output depends in parts on the capability of factors of production to move from one industry to another. Two issues arise, first, can the resources be moved, second, and how efficient will the resources be in a new line of production, (Schiller, 1991). The opportunity cost is define as, the most desirable goods and services that are forgone in order to obtain something else. The opportunity cost of a product is measured by the most desirable goods and services that could have been produced with same resources.

Dent, Harrison and Woodford (1986) defined the shadow price of the activity as a measure of its true profitability after taking account of both cash returns and opportunity cost. The terms shadow price, opportunity cost and marginal value product are often used when referring to resources. Beneke and Winterboer (1973) reported that shadow prices for production activates indicate how value if the program would change (how much income would penalized). If an additional unit of the activity were forced into the final plan. They will be referred to frequently as income penalties. Shadow prices for the disposable activities provide information concerning the productivity of added resources (relation of restraints).

5.1.2 Linear programming model

5.1.2.1 General overview

Linear programming (LP) is considered as an efficient and effective method of determining the optimum plan that maximizes the farm profit or minimizes production cost in existence of alternative enterprises or processes and restrictions. A linear programming problem has three quantitative components, an objective, alternative methods or processes for attaining the objective and resources or restrictions (Heady and Candler 1973).

Linear programming is the name of a branch of applied mathematics that deals with solving optimization problems of a particular form. Linear programming problems consist of a linear cost function (consisting of a certain number of variables) which is to be minimized or maximized subject to a certain number of constraints. The constraints are linear inequalities of the variables used in the cost function. The cost function is also sometimes called the objective function. Linear programming is closely related to linear algebra; the most noticeable difference is that linear programming often uses inequalities in the problem statement rather than equalities. (G. Strang 1988). James Aspnes, (2004), reported that linear programs are a class of combinatorial optimization problems involving minimizing or maximizing a linear function of some real-valued variables subject to constraints that are inequalities on additional linear functions of those variables. We will not discuss the details of the standard algorithms for solving linear programs much, for reasons that will be explained in more detail later. However, linear programming is a very powerful tool for representing a wide variety of optimization problems, and it is important to be able to recognize when a problem can be formulated in terms of a linear program so that it can be solved using these standard tools.

Programming is the one of techniques, which is used in allocation problems. Mathematically, linear programming is defined as the analysis of problems in which a linear function of a number of variables is to be maximized (or minimized) when those variables are subjected to a number of restraints in the form of linear equalities (Dorfman, Samuelson and Solow (1958). Linear programming generally refers to computational method used in prescribing production patterns which maximize profit of firms, minimizing cost of producing a specific commodity or related types of aggregative analysis. The term linear refers to the fact that straight line relationships are employed in linear programming. A more precise mathematical definition of linear programming is that, linear programming techniques involve the maximization of a linear function, subject to linear inequalities (Heady and Candler, 1973). Another definition reported by Dent, Harrison and Woodford (1986) is that linear programming is one of a class of operations research methods referred to as mathematical programming; the linear programming technique is a general methodology that can be applied to a wide range of problems. While Hazell and Norton (1986) see linear programming as a method of determining a profit maximization combination of farm enterprises that are feasible with respect to a set of fixed farm constraints. Mohamed (1986) reported that, LP provides a means to find the level of decision variable(s) that would maximize the objective function subject to a set of constraints. A linear programming problem is a special case of a mathematical programming problem. From an analytical perspective, a mathematical program tries to identify an extreme (minimum or maximum) point of a function which furthermore satisfies a set of constraints i.e., linear programming is the specialization of mathematical programming to the case where both, function and the problem constraints are linear (Kourouma, 1982). A linear programming problem has three quantitative components, an objective, alternative methods or processes for attaining the objective and resources or restrictions (Heady and Candler 1973).

5.1.2.2 Assumptions of LP:

Several assumptions are used in linear programming. If these assumptions do not apply to the problem under consideration, linear programming may not provide a sufficient precise solution. These assumptions are explained below:

Additive and linearity:

The activities must be additive in the sense that when two or more are used, their total product must be the sum of their individual products. An equivalent statement is that, the total amount of resources used by several enterprises must be equal to the sum of the resources used by each individual enterprise. Thus no interaction is possible in the amount of resources required per unit of output regardless of whether activities are produced alone or in various proportions.

Divisibility:

It is assumed that factors can be used to produce commodities that can be produced in quantities which are fractional units. That is, resources and products are considered to be continuous to be infinitely divisible.

Finiteness:

It is assumed that there is a limit to the number of alternative activities and to the resource restrictions which need to be considered.

Single-value expectations:

In general, the linear programming method used widely to date employs the standard linear programming assumption that resources supplies, input-output coefficients, and prices are known with certainty. (Heady and Candler, 1973).

Other assumptions summarized by Hazel and Norton (1986) are:

Optimization:

It is assumed that an appropriate objective function is either maximized or minimized.

Fixedness:

At least one constraint has a non-zero right hand side coefficient.

Homogeneity:

It is assumed that all units of the same resource or activity are identical.

Proportionality:

The gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used.

5.1.2.3 Why use LP:

The great advantage of programming is that it allows one to test a wide range of alternative adjustments and to analyze their consequences thoroughly with a small input of managerial time (Beneke and Winterboer, 1973). Linear programming is a powerful tool of analysis which can be used to look at several budgets of a farm at a time and depict the optimal enterprises in a profit-maximization or cost minimization context (Kourouma, 1982). Emphasize that the simplex method of linear programming enjoys wide acceptance because of 1) its ability to model important and complex management decision problems and 2) its capability for producing solutions in a reasonable amount of time. Malik (1994) sees the most important advantages of linear programming is the flexibility in stating objectives that will satisfy the consumption requirements of the household. Furthermore, the by-product of the solution provides rich information on economic issues like shadow prices and average productivities.

One should be careful in utilizing linear programming results in explaining farmer's behavior, because of the normative nature of LP analysis and due to its dependence on the degree of accuracy of the coefficients and assumptions which were used in the model formulation. Nevertheless, LP still provides an essential indicator of the degree to which farmers are market-oriented and gives an adequate analysis of input-output relationships (Malik, 1994).

5.1.2.4 Limitations of the LP model:

Elhouri (2008) reported that LP technique suffers from several limitations which can be stated as follows:

1) Programming can not help the manager in the difficult task of formulating price expectations.

2) Activities that involve decreasing costs cannot be treated adequately with programming methods.

3) Restraints are sometimes difficult to specify.

4) LP is of little help in estimating input-output relationship. It can only specify data needed. But the planning must supply estimates of the amount and distribution of labor, land and capital needed to produce crop. Estimates of such type are difficult to make.

5) LP proceeds as if the price and input-output expectations we have formulated were equally reliable for all farm products and the result is that a farm treated as they were equally without risk i.e risk preference of the operator does not take into consideration.

6) One of the assumptions of the LP is that each additional unit of the output requires the same quantity of the input. But if you recall the law of diminishing return to scale, the amount of crop output declines as more fertilizer is used per feddan.

***5.1.2.5*LP in Applied Studies:**

Abdalla (2005) found that, the land use in optimal solution was very different from the current use.

Babiker and Osman (2002) found that the net farm income increased in the optimal solution by about 18% over the observed.

El nour, (1996). Found that labor and capital are limited in Rahad Scheme.
a linear programming sector model was employed by Faki et al (1994) . The objective function was to maximize the total gross margins of standard farms in each of the Sudan's irrigated schemes, namely, tenancies in Gezira, Rahad and New Halfa, and average scheme in White Nile, Blue Nile and Northern. Production activities were derived from a set of three crops: wheat, groundnut, and sorghum. Resource constraints comprised monthly supplies of land, irrigation water and family labor. Different scenarios were developed: Land utilization and returns to producers: under a free cropping pattern, full land utilization was achieved in all schemes, except for Blue Nile and White Nile where water limitation was the main constraint.
Saeed (2008) reported that The net farm income in the optimal models are over the current situation by 121%, 77.3%, 49.4% and 73% in Merawe, Dongola, Halfa and Al-Debba respectively.Land, labor and capital are a constraining factors in Al-Debba and Halfa, while land, labor, capital and water availability are a constraining factors in Dongola and Merawe.

5.1.2.6 The objective function

The objective function is maximization of the farm income after satisfying food security of main food crop (sorghum). The positive values of the objective function (Table 5.1a) reflect returns that are the prices per unit of output. While the negative values of the objective function include the costs of crop production, labour hiring, borrowed capital from the bank and prices per unit of purchased consumed sorghum.
The zero values in the objective function include the produced millet and sorghum for consumption and transferred capital from one period to another.

5.2 Specification of the model structure:

The objective function of the representative farm model maximizes net farm income after satisfying family requirements of the main food crop in traditional sector which is sorghum. The mathematical form of the model used is as follows:

Max $z = \Sigma^{n}_{t=1}$ Cj Xj

Subject to $\Sigma^{n}_{t=1}$ aij xj <= bi

And

xj >= 0, all j = 1 to n

Where:

Z = objective function value

Cj= gross margin per feddan of the jth farm activity i.e input/output coefficients.

Xi = the level of the jth farm activity

aij = the quantity of the ith resource required to produce one unit of the jth activity i.e input/output coefficients

bi = vector of resource availability .

The above structure was then formulated into a matrix that gives the model's technical input-output coefficients and resource endowments as shown in Table (5.1a). and table (5.1b).

The first row of matrix represents the procedure's objective function. The objective function is maximization of gross farm income after satisfying consumption requirement from sorghum. The positive signs in the objective function are the prices per unit of output (G1…G4). The negative signs in

the objective function include the cost of production of crops (CRP1…CRP4), cost of labor hiring (HL1….HL8), morabaha margin of capital borrowed (BC1…BC8) and the prices per unit of sorghum brought from the market. The zero value in the objective function is given to sorghum produced for consumption since it does not involve cash transactions. On the other hand, capital transfers are assigned a zero value since they do not involve any actual expenditure of funds but are rather a capital transfer from one period to another.

In the constrain row, demand supply of resource are represented by negative and positive coefficients. The positive coefficients in the left hand side indicate the resource requirement per unit of activity. The level of activity times the coefficient gives the total derived demand by that activity. The sum of total derived demands for all crops should not exceed the right hand side of constraints inequalities.

The first constrain row (land) represents land availability and stated that the total land allocation to cropping activities is bounded by farm size (total land). A set of constraints indicate the availability of labor by month (lab1, Lab8). These constraints insure that labor demand by crop production is bounded by supply each period. Labor is supplied by family labor and labor hiring. A set of operating capital constraints (OC1, OC2, etc) insures that cash demanded by crop production in each month should not exceed the available capital. Cash is available from the farmer's own funds and the amount borrowed from the banks. The credit limit constraints states that the money borrowed should not exceed the amount provided by the banks. A crop balance insures that what is produced is what is sold plus the domestic consumption.

A consumption constraint insures that the household consumption of sorghum is being met by either farm production and/or market purchase.

5.3 Empirical specification of the model

As discussed in chapter three the data was collected by field survey season 2008. Two sectors were selected in the North Upper Nile State according to the existing administrative structure. These two sectors are Mechanized and Traditional sectors. They reflect different resource endowments, different resource use and different production relations. Representative farm model were build for each farming in the two sectors.

5.4 The activity set:

The activity set in the model includes the following:

i. Crop production activities.

ii. Hired labor activities.

iii. Sorghum consumption and buying activities.

iv. Crop selling activities.

v. Borrowing activities.

vi. Transfer activities.

Table 5.1 An LP tableau of a representative farm in the North Upper Nile State Mechanized Sector

5.4.1 Crop production activities

Tables 5.2a and 5.2b represent portions of the LP matrix of the crop production activities in Mechanized and Traditional sectors. The crop production activities in Mechanized sector are sorghum, sesame, sunflower and millet, in Traditional sector the crop production activities are sorghum, sesame, groundnut and cowpea.

The objective function coefficients for the production activities represent the total cost of production per feddan excluding the cost of hired labor and capital. The cost carry negative signs since they draw from the value of the objective function.

Averages from the selected sample were used to estimate the labor coefficients. The labor input-output coefficients were calculated on per feddan basis which is the unit of the production activities. The production activities are linked with production balance equations and their respective yields per feddan are shown as negative figures in these equations, meaning supply with that level per feddan .

5.4.2 Hired labor activities:

The mechanized sector farmers use only hired labor, while, traditional sector use both family labor (F.L.) and Hired labor (H.L.) in conducting their field crop production activities

Tables 5.3a and 5.3b show the portions of the matrix representing H.L. activities. The labor hiring activities were introduced in the models to supplement the family labor on monthly basis. The unit of the activity is one manday (8 hours of work/day). A standard man day was taken as the effort exerted by a healthy adult in the age of 15-65 years in working day A one day labor input was assumed to be 0.75 standard manday for women and 0.5 for children and old person (Abdel-Aziz, 1999).

The objective function coefficient of each of the hired labor activities represents average monthly wage rates estimated from the field survey. The coefficients carry negative sign since they draw from the value of the objective function.

Table 5.2a Crop production activities in Mechanized sector

Activities		Sorghum	Sesame	Sunflower	Millet		
Objec fun		-77.8	-132	-120	-88		
constraints	unit					**Dir.**	**RHS**
Total land	Fed.	1	1	1	1	<=	1604
Sorgland	"	1				>=	0
Sesland	"		1			>=	0
Sunflland	"			1		>=	0
Milletland	"				1	>=	0
Junelab	"	0	2	2	0	<=	48
Julylab	"	3.2	7	6	4.2	<=	48
Augulab	"	3.3	3.5	2.3	3.1	<=	48
Septlab	"	3	0	0	2.3	<=	48
Octlab	"	0	6	0	0	<=	48
Novlab	'	0	6	0	8	<=	48
Declab	"	5	0	6	2.5	<=	48
Janlab		3	0	3	0	<=	48
Junecpt	SDG/fe	0	11.5	13.79	0	<=	35000
Julycpt	''	16.76	36	38.28	22.67	<=	0
Augustcpt	"	13.17	20.13	15.86	16.73	<=	40000
Septcpt	"	11.97	0	0	12.29	<=	0
Octcpt	"	0	34.51	0	0	<=	0
Novcpt	"	0	30.26	0	43.18	<=	0
Deccpt	"	23.94	0	31.38	13.5	<=	0
Jancpt	"	11.97	0	20.69	0	<=	0
Cptrep	SDG	0	0	0	0	<=	35000
Cptend	SDG	0	0	0	0	>=	75000

Source: Constructed from survey data season 2008.

Table 5.2b Crop production activities in Traditional sector

Activities		Sorghum	Sesame	Groundnut	Cowpea		
Objective function		-65	-120	-200	-167		
constraints	unit					Dir.	RHS
Total land	Fed.	1	1	1	1	<=	34
Sorgland	"	1				>=	0
Sesameland	"		1			>=	0
Grounland	"			1		>=	0
Cowland	"				1	>=	0
Maylab	m.d/fed.	1.05	1	2	2	<=	42
Junelab	"	0	1.45	2	2	<=	42
Julylab	"	1	8	1	1	<=	42
Auglab	"	8.5	3	9	6	<=	42
Seplab	"	0	2	1	1	<=	42
Octlab	"	0	5	2	0	<=	42
Novlab	'	5.55	7	5	3	<=	42
Declab	"	3.5	1	3	3	<=	42
Maycpt	SDG/fed.	4.1	3	20	20	<=	235
Junecpt	"	0	5	25	24	<=	235
Julycpt	''	11.40	48.37	30	20	<=	0
Augcpt	"	13.35	0	40	20	<=	0
Septcpt	"	0	0	0	0	<=	0
Octocpt	"	0	40	30	20	<=	0
Novcpt	"	21.85	14.25	30	37	<=	0
Decrcpt	"	15.30	0	25	26	<=	0
Cptrep	SDG	0	0	0	0	<=	235
Cptend	SDG	0	0	0	0	>=	470

Source: Constructed from survey data season 2008.

Table 5.3a Hiring labor activities in Mechanized sector

Activities		H.L May	H.L June	H.L July	H.L Aug	H.L Sept	H.L Oct	H.L Nov	H.L Dec		
Obj. func.		-8	-8	-8	-8	-8	-8	-8	-8		
Constraint	Unit									**Dir.**	**RHS**
Maylab	md.	-1								<=	48
Junelab			-1							<=	48
Julylab				-1						<=	48
Augustlab					-1					<=	48
Septlab						-1				<=	48
Octlab							-1			<=	48
Novblab								-1		<=	48
Declab									-1	<=	48
Maycpt		8								<=	48
Juncpt			8							<=	35000
Julycpt				8						<=	0
Augustcpt					8					<=	0
Septcpt						8				<=	0
Octcpt							8			<=	0
Novecpt								8		<=	0
Dececpt									8	<=	0

Source: Constructed from survey data season 2008.

Table 5.3b Hiring labor activities in Traditional sector

Activities		H.L May	H.L June	H.L July	H.L Aug	H.L Sept	H.L Oct	H.L Nov	H.L Dec	H.L May		
Obj. func.		-7	-7	-7	-7	-7	-7	-7	-7	-7		
Constraint	Unit										**Dir.**	**RHS**
Maylab	md.	-1									<=	42
Junelab			-1								<=	42
Julylab				-1							<=	42
Augustlab					-1						<=	42
Septlab						-1					<=	42
Octlab							-1				<=	42
Novblab								-1			<=	42
Declab									-1		<=	42
Maycpt		7									<=	42
Juncpt			7								<=	235
Julycpt				7							<=	0
Augustcpt					7						<=	0
Septcpt						7					<=	0
Octcpt							7				<=	0
Novecpt								7			<=	0
Dececpt									7		<=	0

Source: Constructed from survey data season 2008.

5.4.3 Consumption and buying activities:

Consumption activities include meeting consumption requirements through production and/or buying. Sorghum consumption activity is included in the model with a zero objective function coefficient

(No cost) and is linked to the sorghum consumption constraint and sorghum production balance equation.

The buying activities are permitted to allow households to satisfy sorghum consumption constraint in case model production could not satisfy this constraint. The objective function value for this buying activity represents the average price household pays for purchased sorghum (tables 5.4a and 5.4b).

5.4.4 Selling activities:

The selling activities include sales of crops. The objective function coefficients for the selling activities represent average price per unit of sale. The objective function coefficients of selling activities also appear as supplying the operating capital stream in the month where selling takes place (tables 5.5a and 5.5b).

Table 5.4a Crop selling, activities in Mechanized sector

Activities		**Sorgh Selling**	**Sesa Selli**	**Sunfl Selli**	**Millet Selling**		
Objective function		88	105	50	90		
Constraint	Units					**Dir**	**RHS**
June cpt	SDG					<=	35000
July cpt	"					<=	0
Aust cpt	"					<=	0
Sept cpt	"					<=	0
Oct cpt	"					<=	0
Nov cpt	"					<=	0
Dec cpt	"		-105	-50		<=	0
Jan cpt	"	-88			-90	<=	0
Sorg prod	Sack	1				<=	0
Sesa prod	"		1			<=	0
Sun prod	"			1		<=	0
Mill prod	"				1	<=	0

Source: Constructed from survey data season 2008.

Table 5.4b Crop selling, consumption and buying activities in Traditional sector

Activities		**Sorgh Sellin**	**Sesa Selli**	**Grou Selli**	**Cowp Sellin**	**Sorgh Cons**	**Sorgh buyi**		
Objective function		82	105	45	88	0	95		
Constraint	Units							Dir	RHS
May cpt	SDG							<=	230
June cpt	"							<=	0
July cpt	"							<=	0
Aust cpt	"							<=	0
Sept cpt	"							<=	0
Oct cpt	"							<=	0
Nov cpt	"		-105					<=	0
Dec cpt	"	-82		-45	-88			<=	0
Sorg cons	Sack					1		=	8
Sorg prod	"	1				1	-1	<=	0
Sesa prod	"		1					<=	0
Sun prod	"			1				<=	0
Mill prod	"				1			<=	0

Source: Constructed from survey data season 2008.

5.4.5 Borrowing activities:

Tables 5.5a and 5.5b show the portions of the matrix representing borrowing activities. Borrowing activities are used to supplement the amount of cash owned by the farmers, and include formal sources of finance mainly the Agricultural Bank of Sudan (ABS). The bank lending terms depend on Morabaha system, where the Morabaha margin for the year 2008 was 10%. This rate appears as a negative coefficient in the objective function.

5.4.6 Transfer activities:

Tables 5.6a and 5.6b show the portions of the matrix representing transfer activities in Traditional and Mechanized sector. These activities were used in the models to indicate that cash, which was not completely used in a specific month, was transferred to the next one. The coefficients of capital transfer in the objective function carry zero values since it does not involve money transactions.

5.5 Constraints set:

The constraints set of the model includes the following:

i Land .

ii Labor .

iii Operating capital and credit constraint .

iv Consumption .

v The crop balance constraint .

Table 5.5a Borrowing capital activities in Mechanized sector

Activities		BC June	BC July	BC Aug	BC Sep	BC Oct.	BC Nov	BC Dec	BC Jan	Cpt rep	Cpt end		
Obj. function		-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10		0	0		
Cons.	unit											Dir	RHS
Junecpt	“	-1										<=	35000
Julycpt	“		-1									<=	0
Augtcpt	“			-1								<=	0
Septcpt	“				-1							<=	0
Octocpt	‘’					-1						<=	0
Novecpt	‘’						-1					<=	0
Dececpt	‘’							-1				<=	0
Jancpt									-1		1	<=	0
Cptrep	‘’	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	-1		<=	40000
Cptend	‘’										1	>=	75000

Source: Constructed from survey data season 2008.

Table 5.5b Borrowing capital activities in Traditional sector

Activities		BC May	BC June	BC July	BC Aug	BC Sep	BC Oct.	BC Nov	BC Dec	Cpt rep	Cpt end		
Obj. function		-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	0	0		
Cons.	unit											Dir	RHS
Macpt	SD	-1											
Juncpt	"		-1										
Julycpt	"			-1									
Augcpt	"				-1								
Septcpt	"					-1							
Octcpt	''						-1						
Novcpt	''							-1					
Deccpt	''								-1		1		
Cptrep	''	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	-1			
Cptend	''										1		

Source: Constructed from survey data season 2008

Table 5.6a Capital transfer activities in Mechanized sector

Activities		TC June/ July	TC July/ Aug	TC Aug/ Sep	TC Sep/ Oct	TC Oct/ Nov	TC Nov/ Dec	TC Dec/ Jan		
Objective function		0	0	0	0	0	0	0		
Cons.	Unit								DIR	RHS
Junecpt	SDG	1							<=	35000
Julyecpt	"	-1	1						<=	0
Augtcpt	"		-1	1					<=	40000
Septcpt	"			-1	1				<=	0
Octocpt	"				-1	1			<=	0
Novecpt	"					-1	1		<=	0
Dececpt	"						-1	1	<=	0
Janucpt	"							-1	<=	0

Source: Constructed from survey data season 2008.

Table 5.6b Capital transfer activities in Traditional sector

Activities		TC May/ June	TC June/ July	TC July/ Aug	TC Aug/ Sep	TC Sep/ Oct	TC Oct/ Nov	TC Nov/ Dec		
Objective function		0	0	0	0	0	0	0		
Cons.	Unit								**DIR**	**RHS**
Maycpt	SDG	1							<=	235
Junecpt	"	-1	1						<=	230
Julycpt	"		-1	1					<=	0
Augtcpt	"			-1	1				<=	0
Septcpt	"				-1	1			<=	0
Octocpt	"					-1	1		<=	0
Novecpt	"						-1	1	<=	0
Dececpt	"							-1	<=	0

Source: Constructed from survey data season 2008

5.5.1 Land

The amount of the available land per farm was calculated and the averages obtained were 1604 and 34 feddans in Mechanized and Traditional sectors respectively. The values of these lands represent the right hand side of the corresponding equation as shown in tables 5.2 and 5.3.

5.5.2 Labor

Labor is a classical input assumed to affect the output of the different crops. Elfeil (1993) stated that although the labor is assumed to be abundant and sometimes of negative marginal value in the developing countries, but still there are times when labor may become a constraining factor of production. This happens during the time weeding, harvesting and such operations that demand large amounts of labor in just limited time. So, it is actually the limited time of the operations rather than any thing else.

The amount of labor available in the four localities was calculated as follows:

1. The unit of analysis is the household head.
2. Family labor supply was measured using standard mandays.
3. The labor requirement of the permanent crops from the average of the available family labor supply in each month, plus possible hired labors in the respective month of the model represents the right hand side of the equation as shown in Tables 5.3a and 5.3b.

5.5.3 Operating capital and credit constraints

The available working capital required to finance purchases of agricultural inputs can be an important constraint on farm plan. Some working capital may be available from the farm's family own savings, but this can often be supplemented by borrowing (Hazel and Norton, 1986). The available capital to finance the agricultural production in the North Upper Nile state may be available from farmer’s own funds and are often supplemented by borrowing. The available cash at the beginning of the season represents the farmer's own funds. It includes sales of his own animal, off-farm activities, saving from farm and assistance from relatives. The average amount of cash available at the beginning of the season was found to be SDG 35000 and SDG 235 in Mechanized and Traditional sectors respectively. A credit limit is imposed reflecting the amount of credit provided by the ABS to each farmer per year. The average limits of credit obtained from the results of the survey were SDG 40000 and SDG 230 in the two sectors respectively.

5.5.4 Consumption:

A consumption constraint of sorghum in traditional sector is imposed. The results of the survey showed the average annual consumption per average family was 8 sacks in traditional sector.

5.5.5 The crop balance constraint:

This refers to the fact that the crop produced is used through sales and /or consumption.

CHAPTER SIX
Results and Discussion of The Linear Programming Model

6.1 Introduction:

This chapter presents and discusses the results of the basic models and presents the different scenarios by changing their parameters. The results of the basic models are compared with the actual situation. The information compared includes, the value of the objective function, the optimum cropping pattern, the level of resources used and their respective marginal productivities. The results of the basic models were validated by comparing the results to the real situation in the County as shown by the results of the field survey conducted in the year 2008.

6.2 The basic solution:

6.2.1 Cropping pattern:

The basic solution of the basic LP model is given in Table 6.1. Further calculations were made on the results for estimating resource utilization.

Tables 6.1a show that in Mechanized rain fed sectors most of the land is allocated to sorghum crop (1596.6 feddans), followed by sesame (8 feddans), while sunflower and millet did not enter the plan. In the actual situation Sorghum crop occupied the largest area (587.2 feddans) followed by sesame (246 feddans) and then sunflower (240 feddan) and Millet (120 feddan). In Traditional sector, Table 6.1b groundnut crop came first in allocated area (18.36 feddans), followed by sorghum (15.19 feddan), sesame (1.05 feddan) and then cowpea did not enter the plan. In the real situation groundnut occupied the largest area (12 feddan), followed by sorghum (11 feddan), and then cowpea (3 feddan), and sesame (2 feddan).

6.2.2 Resource use:

Labor use in the basic models compared to real situations. From table 6.2 the total labor mandays required for the basic solutions are (352 m.d.) and (310.72 m.d.) in mechanized sector and traditional sector respectively, compared to (384 m.d.) and (295 m.d.) actually utilized in the same respective sectors. In mechanized sector all hired labor in the basic solutions and in the real situation were required. The percentage of the available labor utilized to the total available labor in mechanized sector model was (91.77%) compared to 100% in the real situation. In traditional sector the percentage of the available hired labor to the total available labor were (23.52%) and (20.65%) in the basic model and in the real situation respectively, while the percentage of the available family labor to the total available labor were (76.48%) and (67.15%) in the basic model and in the real situation respectively at the same sectors. The percentage of the available labor utilized to the total available labor in Traditional sector model was (92.48%) compared to (87.80%) in the real situation.

Table 6.2 shows the number of labor mandays required per month in the basic models in comparison to reality. The peak of labor utilization in Mechanized sector model is in all months except June, and in the actual situation the peak is in all months. In Traditional sector there is no different between model and the actual situation for the peak of labor utilization.

6.2.3 Credit use of the basic models in comparison to reality:

The results of the basic models in table 6.3 show the problem of cash during May to September in all sectors. In September, the marginal value productivities of capital decrease in all sectors while in December and January no problem of cash in two sectors. These results show the need for cash to meet different agricultural operations, and after some crops are harvested, some cash is reinvested and the need for cash is decrease.

Table 6.1a Optimum solutions of the basic models of Mechanized sectors in comparison with the actual situation

	Mechanized sector	
	Model	actual
Total land	1604.6 fed.	1193.6 fed.
Sorghum “	1596.6 “	587.6 “
Sesame “	8 “	246 “
Sunflower “	0 “	240 “
Millet “	0 “	120 “
Total labor	352 m.d.	384 m.d.
Family labor	0.0 “	0.0 “
Hired labor	352 “	384 “
% of utilized H.L./T.L.	100%	100%
% utilized T.L/T.L.	91.77%	100%
Net farm income	58.4million SDG	9.8 million SDG

Source: analysis of survey data 2008.

6.2.4 Net farm income:

From tables 6.1a and 6.1b the net farm income in the optimum solution of the LP model of Mechanized sector is (58.4million SDG) which is higher than the actual situation by (498.97%). In Traditional model the net farm income is (1.5 million SDG) which is higher than the actual achieved by (51.23%).

Table 6.1b Optimum solutions of the basic models of Traditional sectors in comparison with the actual situation

	Traditional sector	
	model	actual
Total land	34.6 fed.	28 fed.
Sorghum "	15.19 "	11 "
Sesame "	1.05 "	2 "
Groundnut "	18.36 "	12 "
Cowpea "	0 "	3 "
Total labor	310.72 m.d.	295 m.d.
Family labor	237.65 "	225.63 "
Hired labor	73.07 "	69.37 "
% of utilized F.L./T.L	76.48%	67.15%
% of utilized H.L./T.L.	23.52%	20.65%
% utilized T.L/T.L.	92.48%	87.80%
Net farm income	1.5 million SDG	0.96 million SDG

Source: analysis of survey data 2008.

Table 6.2 The monthly average number of man-days required in the basic solutions compared to observed in the two sector 2008

	Mechanized sector		Traditional sector	
Month	model	observed	model	observed
May	-	-	42	42
June	16	48	32	38.25
July	48	48	42	42
Augustus	48	48	42	42
September	48	48	19	20.47
October	48	48	34	34
November	48	48	42	42
December	48	48	42	42
January	48	48	-	-

Source: analysis of survey data 2008.

Table 6.3 Marginal value productivities of credit (SDG/unit) in the basic solution in two sector season (2007/2008)

Month	Mechanized sector	Traditional sector
May	-	0.10
June	0.10	0.10
July	0.10	0.10
Augustus	0.10	0.10
September	0.10	0.10
October	0.10	0.10
November	0.10	0.10
December	0	0
January	0	-

Source: analysis of survey data 2008.

6.3 Sensitivity analysis:

In this part of the chapter the basic solutions of the LP models are developed by changing their parameters to present different policy analysis scenarios. These scenarios examine the impact of cost of production, prices, productivities, and adoption of improved technologies on the crop mix and net farm income of the basic solutions.

6.3.1 The impact of crops productivities:

6.3.1.1 Increase of sorghum productivity by 25% in two sectors:

Increasing the sorghum productivity by (25%), in Mechanized sector all of the area is confined to the sorghum crop, other crops did not enter the plan, and the net farm income increased to (155.8 million SDG). In the model of Traditional sector the crop mix is change all of the area is confined to the sorghum crop, other crops did not enter the plan, and the net farm income increased to (3.2 million SDG). Table (6.4).

Table 6.4 The net farm income (in SDG) and crop mix (in feddan) of increase the sorghum productivity by 25% in two sectors

	Mechanized sector	Traditional sector
Total land	1604.6	34.6 fed.
Sorghum "	1604.6	34.6 "
Sesame "	0	0
Sunflower "	0	-
Millet "	0	-
Groundnut "	-	0
Cowpea "	-	0
Net farm income	155.8 million SDG	3.2 million SDG

Source: analysis of survey data 2008.

6.3.1.2 Increase of sesame productivity by 25% in two sectors

Increasing the sesame productivity by (25%), in Mechanized sector in general did not change the crop mix, but the net farm income increase to

(58.9 million SDG). In the model of Traditional sector, increase of the sesame crop productivity by 25% did not change the crop mix, but the net farm income increased to (1.5 million SDG) (4.61% lower). Table(6.5).

Table 6.5 The net farm income (in SDG) and crop mix (in feddan) of increase the sesame productivity by 25% in two sectors

	Mechanized sector	Traditional sector
Total land	1604.6 fed.	34.6 fed.
Sorghum "	1596.6 "	15.19 "
Sesame "	8 "	1.05 "
Sunflower "	0 "	-
Millet "	0 "	-
Groundnut "	-	18.36 "
Cowpea "	-	0
Net farm income	58.9 million SDG	3.2 million SDG

Source: analysis of survey data 2008.

6.3.1.3 Increase of sesame productivity by50% in two sectors

Increasing the sesame productivity by 50% in Mechanized sector most of the total area distributed to the sesame crop 1588 feddans and sorghum 16 feddans while sunflower and millet did not enter the plan. The net farm income increased to (73.4 million SDG). In Traditional sector model, an increasing of sesame productivity by 50% the total land decreased from 34.6 feddans to 26.21 feddans, and the crop mixed is change while the net farm income increased to 1.6 million SDG, Table (6.6).

Table 6.6 The net farm income (in SDG) and crop mix (in feddan) of increase the sesame productivity by 50% in two sectors

	Mechanized sector	Traditional sector
Total land	1604.6 fed.	26.21 fed.
Sorghum "	16.4 "	8.59 "
Sesame "	1588 "	2.26 "
Sunflower "	0 "	-
Millet "	0 "	-
Groundnut "	-	15.36 "
Cowpea "	-	0
Net farm income	73.4 million SDG	1.6 million SDG

Source: analysis of survey data 2008.

6.3.1.4 Increase of sunflower productivity in Mechanized sector by 25%

In this scenario sunflower entered the plan by (1604.6 fed) while other crops did not entered the plan. The net farm income increased to 111 million SDG.

6.3.1.5 Increase of millet productivity in Mechanized sector by 25%

By 25% increase in millet productivity the net farm income increased to (58.5 million SDG). Sorghum occupied the largest area (1597.7 fed), millet entered the plan by (6.9 fed), while sesame and sunflower did not enter the plan.

6.3.1.6 Increase of groundnut productivity in Traditional sector by 25%

With (25%) increase in groundnut productivity in traditional sector, the net farm income increased from (1.5 million SDG) to (4.4 million SDG). Groundnut occupied the total area, sorghum, sesame and cowpea did not enter the plan.

6.3.1.7 Increase of cowpea productivity in Traditional sector by 25% and 50%

Increasing the cowpea productivity by (25%) and (50%) in traditional sector millet crop did not enter the plan and the crop mixed did not change and the net farm income did not change.

6.3.1.8 Increase of all crops productivity in Mechanized and Traditional sectors by 25%

Increasing the all crops by (25%) in mechanized sector model the net farm income increased to (1555.8 million SDG) and the crop mix did not change. In Traditional sector model, most of the area is confined to the groundnut crop (32.8fed) followed by sorghum (1.74 fed), while sesame and cowpea did not enter the plan. The net farm income increased to (4.4 million SDG).

6.3.2 The impact of prices:

6.3.2.1 Increase in sorghum price by 25% in Mechanized and Traditional sectors:

Increasing the sorghum price by (25%) in Mechanized sector, increase the net farm income from (58.4 million SDG) to (155.4 million SDG) (by 166.1%), while in Traditional sector the increase of sorghum price by 25%, increase the net farm income from (1.45 million SDG) to (3.1million SDG) by (110.64%), sorghum occupied the total area (34.6 fed) others crops did not enter the plan. (Table 6.7)

6.3.2.2 Increase in sesame price by 25% in Mechanized and Traditional sectors:

With (25%) increase in sesame price in Mechanized sector. The net farm income increased from (58.4 million SDG)to (58.9 million SDG) (by 0.87%), and the crop mix did not change, while in Traditional sector the increase of sesame price by 25%, increase the net farm income from (1.45 million SDG) to (1.52 million SDG) (by 4.57%), and the crop mix did not change .(Table 6.8).

Table 6.7 the net farm income (in SDG) and crop mix (in feddan) of increase the sorghum price by 25% in Mechanized and Traditional sector

	Mechanized sector	Traditional sector
Total land	1604.6	34.6 fed.
Sorghum "	1604.6	34.6 "
Sesame "	0	0
Sunflower "	0	-
Millet "	0	-
Groundnut "	-	0
Cowpea "	-	0
Net farm income	155.8 million SDG	3.2 million SDG

Source: analysis of survey data 2008.

6.3.2.3 Increase in sunflower price by 25% in Mechanized sectors:

With 25% increase in sunflower price in Mechanized sector, the net farm income increased from (58.4 million SDG) to (111.1 million SDG) (by 90.15%) sunflower occupied the total area (1604.6 fed) others crops did not enter the plan.

6.3.2.4 Increase in groundnut price by 25% in Traditional sectors:

By 25% increase in groundnut price in Traditional sector, the net farm income increased from (1.45 million SDG) to (5.45 million SDG) (by 274.72%), and the crop mix did not change

6.3.2.5 Increase in millet price by 25% in Mechanized sectors:

With (25%) increase in millet price in Mechanized sector, the net farm income increased from (58.4 million SDG) to (58.5 million SDG) (by 0.17%) sorghum occupied the largest area (1597.74 fed) millet enter plan (by 6.86 fed) others crops did not enter the plan.

Table 6.8 The net farm income (in SDG) and crop mix (in feddan) of increase sesame price by 25% in Mechanized and Traditional sector

	Mechanized sector	Traditional sector
Total land	1604.6 fed.	34.6 fed.
Sorghum "	1596.6 "	15.19 "
Sesame "	8 "	1.05 "
Sunflower "	0 "	-
Millet "	0 "	-
Groundnut "	-	18.36 fed.
Cowpea "	-	0 "
Net farm income	58.9 million SDG	1.5 million SDG

Source: analysis of survey data 2008.

6.3.2.6 Increase in cowpea price by 25% in Traditional sectors:

By 25% increase in cowpea price in Traditional sector, the net farm income and the crop mix did not change.

6.3.2.7 Increase in prices of all crops by 25% in Mechanized and Traditional sectors

With increasing prices of all crops by (25%) in Mechanized sector the crop mix did not change but the net farm income from (58.4 million SDG) to (155.5 million SDG) (by 166.23%). While in Traditional sector an increase of all crops prices by (25%) the net farm income increase from (1.45 million SDG)to (4.30 million SDG), groundnut occupies the largest area (21) fed followed by sorghum (13.6) fed and then sesame and cowpea did not enter the plan.(Table 6.9).

Table 6.9 the net farm income (in SDG) and crop mix (in feddan) of increase prices of all crops by 25% in Mechanized and Traditional sector

	Mechanized sector	Traditional sector
Total land	1604.6 fed.	34.6 fed.
Sorghum "	1596.6 "	13.6 "
Sesame "	8 "	0 "
Sunflower "	0 "	-
Millet "	0 "	-
Groundnut "	-	21 fed.
Cowpea "	-	0 "
Net farm income	155.52 million SDG	4.30 million SDG

Source: analysis of survey data 2008.

6.3.3 The impact of production cost:

6.3.3.1 The impact of lowering the production cost by 25% in Mechanized and Traditional sectors.

With decreasing of production cost of all crops by (25%) in Mechanized sector, the net farm income increased from (58.4 million SDG) to (94.6million SDG) (by 61.95%), the crop mix did not change, while in Traditional sector, the net farm income increased from (1.45 million SDG) to2.83 million SDG), groundnut occupied the largest area (32.4 fed) followed by sorghum (2.2 fed) sesame and cowpea did not enter the plan. Table (6.7).

Table 6.10 The net farm income (in SDG) and crop mix (in feddan) of lowering the cost of production of all crops by 25% in two sectors.

	Mechanized sector	Traditional sector
Total land	1604.6 fed.	34.6 fed.
Sorghum "	1596.6 "	2.18 "
Sesame "	8 "	0 "
Sunflower "	0 "	-
Millet "	0 "	-
Groundnut "	-	32.42 fed.
Cowpea "	-	0 "
Net farm income	94.6 million SDG	2.83 million SDG

Source: analysis of survey data 2008.

CHAPTER SEVEN

Summary, Conclusions and Recommendations

7.1 Summary:

The Northern Upper Nile (Renk Area) lies between latitude 10o27' N and 12o45' N, and longitude 28o 5' and 35o E at an elevation of 380m above the sea level .Its area is approximately (165.1thousand hectare). It borders Blue Nile to the northeast, southern Kordofan to the west and northwest, and the White Nile state to the North. Generally, the area extends from the Joda (Wanthaw and Kuak in the north to Melut and Kaka in the south. Administratively it is divided into five piaum Jalhak, Geiger, North Renk, Shumudi and South Renk. Each piaum divided into a number of administrative units. The area lies in the arid and semi-arid zone. According to the last census in 2008 the population of the Renk County is (0.964 million persons). The total cultivable area of the Renk is (1.58 million ha) (3.8 million fed). Northern Upper Nile State is lies in central rain lands; the extreme northern part of the Renk has a (5) month rainfall of 450 –655mm per annum, while the southern part receives 700 –780mm that spread over (6–7) months. According to Renk and Goz Rom meteorological stations, rainfall starts from May and end at October with annual average precipitation rains between 450 to 550 mm. p.a. The main agricultural crops grown are sorghum, sesame, sunflower, millet, groundnut, and cowpea. The study area is one of the most important agricultural productions in North Upper Nile State; it contributes in food production beside cash crops. Despite the above mentioned importance, the agricultural production in Mechanized and Traditional Rain Fed suffers many problems (economical, technological, environmental and social problems) that hinder its development and success resulting in low yield and low income.

The main objective of the study is to evaluate and analyze the rain-fed sub-sector in Renk County, north part of the Upper Nile State, in order to improve the livelihoods of farmers via improving their agricultural returns, (income). with specific objectives to investigated the socio-economic characteristics of farmers, estimate productivity and profitability of producing crops under different rain-fed sector, identify and evaluate farmers technical efficiency of resources used between different rain-fed sector, investigate the main factors behind farmer's technical inefficiency for crops production, determine the optimum cropping combination, that will maximize the farmer's net return and to draw some conclusions and recommendation from the analysis for improving yield in Rain fed sector.

The main source of the data was the primary data through a primary field survey conducted in season 2007-2008. The secondary data was collected from relevant institutions. A multi-stage stratified random sampling technique was used. The actual number of farmers interviewed was 150 distributed as 75 farmers in Mechanized sector and 75 respondents for Traditional sector. The study depended mainly on primary data for 2007/2008 agricultural season which was collected by direct interviewing of respondents through a multi-stage stratified random sampling technique using a structured questionnaire. The study also used secondary data collected from the relevant institutional sources. To deal with the objectives of the study, Descriptive statistics, gross margin analysis, Stochastic Frontier Production function and linear programming (LP) were used.

7.2 Summary of the main results

The descriptive statistic of socio-economics characteristics result showed that the average age of farmer were 50.4 and 47.9 years in Mechanized and Traditional rain-fed sector respectively. The percentages of illiterate farmers were 1.3% and 49.33% and educated one were 98.7% and 50.67% in the two sectors respectively. The average family size was found to be 7.5 and 6.43

persons in Mechanized rain-fed sector and Traditional rain-fed sector respectively. The holding size in Mechanized sector, (feddans/farmer) averagely is about (1194) while, the farm size, (feddans/farmer) in Traditional sector, is about (28). In Mechanized sector sorghum occupied the largest area (66.12%) followed by sesame (20.68%), sunflower (7.21.62%), and millet (5.99%). In Traditional sector also sorghum occupied the largest area (57.35)6% followed by sesame (23.23%), groundnuts (14.36%), and cowpea (5.06%).

The study reveals that, about (68%) of Mechanized sector farmers and (47%) of the farmers in traditional sector delay the sowing date of Sesame till starting of August, while 30% of the farmers in mechanized sector and (22%) of the farmers in traditional sector delay the sowing date of sorghum till the end of August. The survey results show that the quantity of seeds is under the optimum level by (10%), (10.28%) and (31.88%) in Mechanized sector for sorghum, sesame and sunflower respectively, while the actual seed rate for millet the level of seed rate is over optimum level by (9.1 %).In traditional sector The survey results show that the quantity of seeds rate is over the optimum level by (8.33%), (14.28%), (20%) for sorghum, sesame and cowpea respectively, while the actual seed rate for groundnut is under the optimum level by (11.2%).

The results of the survey conducted by the author for the season 2008 showed that most of sesame, sorghum, sunflower and millet growers in mechanized sector applied one weeding during the season, while those in traditional sector applied two weeding during the season. Weeding method is dominated by hoe. Herbicides are rarely applied for weed control because for difficulties in get and use them.

The results of the survey conducted by the author for the season 2008 shows that, most of the sesame growers in the two sectors were harvested in November. Sorghum crop was harvested in December by most of the farmers in two sectors. Sunflower, groundnut and cowpea were harvested in December.

The marginal gross analysis revealed that sesame and groundnut had high cost of production followed by sunflower and sesame in mechanized and traditional sector respectively. The average gross returns per feddan for sorghum, sesame, sunflower and millet per feddan were found to be (SDG 122), (SDG 71), (SDG 147.5), (SDG 45)and (SDG 68) respectively in mechanized sector while in traditional sector the average gross returns per feddan for sorghum, sesame, groundnut and cowpea per feddan were found to be (SDG 115.5), (SDG 79), (SDG 147.5)and (SDG 9) respectively.

Farmers in rain fed sector facing many problems such as high production cost, low net returns, lack of credit, irregular rainfall distribution and weakness of extension services and supervision.

The Stochastic Frontier Production function analysis revealed that the mean technical efficiency in mechanized sector is (79%), (58%), and (67%) for sorghum, sesame and sunflower, respectively were achieved by farmers while, the mean technical efficiency in traditional sector is (58%), (57%), and (73%) for sorghum, sesame and groundnuts, respectively were achieved by farmers . This shows that there is a scope for increasing sorghum, sesame and sunflower production by (21%), (42%), (27%) and (33%) respectively in mechanized sector with present technology .and increasing Sorghum, sesame and groundnut production by (42%), (43%) and (37%)respectively in traditional sector. An analysis of the determinants of technical efficiency indicated that the sowing, weeding, labor and off-farm income for producing sorghum, sesame and sunflower are both significant variable for improving technical efficiency. Also most of the estimated δ variables such as age of operating farmers, main occupation, educational level, family size, and marital status are significant variable.

The facilitates credit and extension services are not available for farmers and not significant.

The study showed the results of the LP models in Mechanized sector basic model, most of land was allocated to sorghum crop (1596.6 feddans), followed by sesame (8 feddans) , while sunflower and millet did not enter the plan. The total labor required in the basic solution was 352 m.d, which was represented 100% of the available total labor. Capital was a constraining factor during May to September. The net farm income was (9.75 million SDG) in the real situation compared to (58.4 million SDG) (498.97%). in the basic solution. while in traditional sector basic model most is allocated to groundnut crop (18.36 feddans), followed by sorghum (15.19 feddans), sesame (1.05 feddans) and cowpea did not enter the plan. In the real situation sorghum occupied (11 fed), sesame occupied (2 fed), groundnut occupied (12 fed) and cowpea occupied (3 fed).The total labor required in the basic solution was 310.72 m.d , which was represented (91.77%) of the available total labor. Capital was a constraining factor during May to September.

7.2.1 Sensitivity analysis:

Sensitivity analysis was used to show the impact of the changes in the coefficients of the objective function, amount of the resources available (right hand side, RHS) and the coefficients matrix, on the optimum plan.

The effect of increase of productivity of all crops in mechanized sector the net farm income increased to (1555.86 million SDG) but crop mix did not change. An increase of productivity of all crops in Traditional sector most of the area is confined to the groundnut crop (32.8fed) followed by sorghum (1.74 fed), while sesame and cowpea did not enter the plan. The net farm income increased to (4.4 million SDG). Increase in sorghum price by 25% in Mechanized and Traditional sectors due to increasing of sorghum price at world level as the result of using sorghum for biogas production, in Mechanized sector, increase the net farm income from (58.4 million SDG) to

(155.4 million SDG) (by 166.1%), while in Traditional sector the increase of sorghum price by 25%, increase the net farm income from (1.45 million SDG) to (3.1 million SDG) (by110.64%) ,sorghum occupied the total area others crops did not enter the plan. With decreasing of production cost of all crops by 25% in Mechanized sector, the net farm income increased from (58.4 million SDG) to (94.6 million SDG) (by 61.95%), the crop mix did not change, while in Traditional sector, the net farm income increased from (1.45 million SDG) to (2.83 million SDG) (by 94.45%), groundnut occupied the largest area (32, 42 fed) followed by sorghum (2, 18 fed) sesame and cowpea did not enter the plan.

7.3 Conclusions

Based on the results of Descriptive Statistic, Stochastic Frontier Production function, a gross margin analysis and linear programming in this study the following conclusions can be drawn:

1. Most of the farmers in the Rain fed sector are within the active age group.

2. Most surveyed farmers are managed by males, and most of them are married and educated.

3- In Mechanized sector sesame had high cost of production followed by sunflower, millet and sorghum respectively. While in Traditional sector groundnuts had high cost of production followed by sesame, cowpea and sorghum respectively.

4- In Mechanized sector the sorghum crop yields a higher gross margin per feddan followed by sesame, millet and sunflower respectively. While in Traditional sector the groundnut crop yields a higher gross margin per feddan followed by sorghum, sesame and cowpea respectively.

5. Rain fed sector farmers facing many problems such as high production cost, low net returns, lack of credit, irregular rainfall distribution and weakness of extension services and supervision.

6. Labor and capital factors are limiting in the Rain fed sector.

7- Farmer’s in Rain fed sector are technically efficient; the mean technical efficiency in mechanized sector is 79%, 58%,and 67% for sorghum, sesame and sunflower respectively while in traditional sector the mean technical efficiency is (58%), (57%) and (73%) for sorghum, sesame and groundnut respectively .This shows that there is a scope for increasing sorghum, sesame and sunflower in mechanized sector production by (21%), (42%), and (33%) respectively, and increasing sorghum, sesame and groundnut in traditional sector production by (42%), (43%) and (37%) respectively, with present technology.

8. In this study educational level of farmer’s found to have a negative significant impact on production in rain fed sector.

9. The study found that an extension service has no significant impact for sorghum sesame and sunflower crops. To enhance the production technical efficiency and agricultural growth, government could extent agricultural extension services to all farmer’s, and make relationship and contact between farmers and extension agent.

10. Agricultural credit has no significant influence for efficiency. To purchase production inputs and improve production efficiency, the government must provide a credit at time and correct, and provide credit to smallholders' farmers.

11. Most of the land in mechanized sector is allocated to sorghum crop (1596.6 feddans), followed by sesame (8 feddans), sunflower and millet did not enter the plan while in traditional sector; groundnut occupied the largest area of 18.36 fed. and then sorghum 15.19 fed., while sesame entered the plan by 1.05 fed. and cowpea did not enter the plan.

12. The results of LP models reveal that the net farm income in the optimal models in mechanized sector is over the current situation by (498.97%).while in traditional sector model is over the current situation by (51.23%).

13- There was a problem of cash in Rain fed sector during May to September.

14- There was a problem of cash in Rained sector during May to September.

7.4 Recommendations:

The principle recommendation is enhancement of the overall system of incentives of agricultural production in the Northern Upper Nile State through price and non-price policies. The specific recommendations embrace the following items:

1. Establishment of a well-equipped Agricultural Extension Unit in order to improve farmers' skills via enlightening them on the recommended cultural practice and optimal use of the accessible resources. This could be done through using mass media campaigns, administrative farms.
2. Boosting the benefits of the surface water in farming by adopting water harvest techniques to promote water infiltration (soil conservation).
3. Agricultural finance should channeled at right and appropriate time and quantity, besides, agricultural banks should change his policies towards medium and long term credit system rather than the short one. Enlightening the small, traditional farmers about the importance of micro-credit could also improve production efficiencies.
4. The government should supply the farmers with their requirement of herbicides and combined harvesters at subsidized rate, as allowed by the WTO convention.
5. Generally the farmers in the study area sell their products at harvest time at relatively low prices, while the prices increase after harvest. To reconcile this complication and to increase the farm income, the study suggests the following actions:

a. Government should intervene to protect farmers from price decreases through activation of the strategic store.

b. Dissemination of market information.

c. Encouragement of farmers to establish farmers' institutions (cooperatives)

6. Enacting the law of allocating 10-20% of the agricultural land in the rain-fed sectors to forest cultivation.

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Appendix 1. Gross margin (SDG per feddan) of the main crops grown in Mechanized sector (Renk County season 2007-2008)

1.1 Sorghum

Average yield sack/fed	2.75
Average price (SDG/sack)	88
Total revenue of production(SDG)	242
Production costs:	
Land preparation:	
Land cleaning	-
Ploughing	10
Agricultural operation:	
Sowing	10
Weeding	15
Harvesting	28
Transportation	8
Inputs used:	
Seeds	7
Empty Sacks	6
Other costs	
Taxes	8
Camp	4
Nazir and khafir	5
Food ratio	4
Zackat	15
Total	120
Gross margin (SDG/fed.)	122

Source: author's survey, 2008

1.2 Sesame

Average yield kuntar/fed	2.2
Average price (SDG/kuntar)	105
Total revenue of production(SDG)	231
Production costs:	
Land preparation:	
Land cleaning	10
Ploughing	10
Agricultural operation:	
Sowing	10
Weeding	15
Harvesting	55
Transportation	6
Inputs used:	
Seeds	5
Empty Sacks	5
Other costs	
Taxes	14
Camp	4
Nazir and khafir	5
Food ratio	6
Zackat	15
Total	160
Gross margin (SDG/fed.)	71

Source: author's survey, 2008

1.3 Sunflower

Average yield sack/fed	4
Average price (SDG/sack)	50
Total revenue of production(SDG)	200
Production costs:	
Land preparation:	
Land cleaning	-
Ploughing	10
Agricultural operation:	
Sowing	10
Weeding	8
Harvesting	30
Transportation	12
Inputs used:	
Seeds	30
Empty Sacks	10
Other costs	
Taxes	10
Camp	2
Nazir and khafir	3
Food ratio	4
Zackat	16
Total	145
Gross margin (SDG/fed.)	45

Source: author's survey, 2008

1.4 Millet

Average yield sack/fed	2.2
Average price (SDG/sack)	90
Total revenue of production(SDG)	198
Production costs:	
Land preparation:	
Land cleaning	-
Ploughing	10
Agricultural operation:	
Sowing	10
Weeding	15
Harvesting	47
Transportation	5
Inputs used:	
Seeds	3
Empty Sacks	6
Other costs	
Taxes	5
Camp	2
Nazir and khafir	5
Food ratio	4
Zackat	8
Total	120
Gross margin (SDG/fed.)	68

Source: author's survey, 2008

Appendix 2 Gross margin (SDG per feddan) of the main crops grown in Traditional sector (Renk county season 2007-2008)

2.1 Sorghum

Average yield sack/fed	2.75
Average price (SDG/sack)	82
Total revenue of production(SDG)	225.5
Production costs:	
Land preparation:	
Land cleaning	15
Ploughing	-
Agricultural operation:	
Sowing	10
Weeding	30
Harvesting	22
Transportation	4
Inputs used:	
Seeds	6
Empty Sacks	5
Other costs	
Taxes	8
Zackat	10
Total	110
Gross margin (SDG/fed.)	115.5

Source: author's survey, 2008

2.2 Sesame

Average yield sack/fed	1.1
Average price (SDG/sack)	168.70
Total revenue of production(SDG)	174.57
Production costs:	
Land preparation:	
Land cleaning	15
Ploughing	
Agricultural operation:	
Sowing	10
Weeding	30
Harvesting	57
Transportation	4
Inputs used:	
Seeds	6
Empty Sacks	5
Other costs	
Taxes	10
Zackat	15
Total	152
Gross margin (SDG/fed.)	79

Source: author's survey, 2008

2.3 Groundnut

Average yield sack/fed	7.21
Average price (SDG/sack)	40.19
Total revenue of production(SDG)	289.77
Production costs:	
Land preparation:	
Land cleaning	25
Ploughing	-
Agricultural operation:	
Sowing	23
Weeding	49
Harvesting	54
Transportation	12
Inputs used:	
Seeds	36
Empty Sacks	10
Other costs	
Taxes	10
Zackat	16
Total	235
Gross margin (SDG/fed.)	147.5

Source: author's survey, 2008

2.4 Cowpea

Average yield sack/fed	2
Average price (SDG/sack)	88
Total revenue of production(SDG)	176
Production costs:	
Land preparation:	
Land cleaning	20
Ploughing	-
Agricultural operation:	
Sowing	23
Weeding	40
Harvesting	48
Transportation	4
Inputs used:	
Seeds	8
Empty Sacks	5
Other costs	
Taxes	4
Zackat	15
Total	167
Gross margin (SDG/fed.)	9

Source: author's survey, 2008