TECHNICAL EFFICIENCY OF WHEAT PRODUCTION
IN RAHAD SCHEME, SUDAN.

By

Hassan Hussein Ibrahim Hassan
B. Sc. (Honors, 2003), Agricultural Economics,
Faculty of Agricultural Sciences, University of Gezira.

Supervisor
Dr. Amel Mustafa Mubarak

A Thesis Submitted in Partial Fulfillment for the Requirement
of the Degree of Master Science in Agricultural Economics

Department of Agricultural Economics
Faculty of Agriculture
University of Khartoum

November, 2008
Dedication

I dedicate this little effort with all my respect and deep love

To

My Mother and the soul of my Father

To my brother

To my friends

With my love

Hassan
Acknowledgement

Firstly I am fully thank to the Almighty Allah for the good health and live he gave me through the study and research.
I am greatly indebted to my supervisor Dr. Amal Mustafa Mubarak for her valuable guidance, wise counsel and encouragement, and advice throughout this study.
My thanks extending to Dr. Adam Elhag Ahmed for his advice throughout this study.
I would also like to thanks the staff members of the department of Agricultural economics, Faculty of Agricultural Sciences, University of Khartoum for their unlimited helps and support. And the staff members of the Department of Agricultural Economics, Faculty of Agricultural Sciences, University of Gezira
My thanks are also extending to all tenants in Rahad scheme, colleagues, Mohammed Elfatih, Ohaj, and all friends.
ABSTRACT

This study was carried out as a part of program to estimate wheat technical efficiency in Sudan for the agricultural season 2007-2008 supervised by the department Agricultural Economic, Faculty of Agriculture, University of Khartoum. In Rahad scheme. The main purposes of the study are to measure technical efficiency of producing wheat, to determine main factors behind technical inefficiency, and to identify the socio-economic factors that affecting the level of efficiency of farmers.

The study used primary and secondary data. Primary data were collected through a field survey carried out in Rahad scheme in December 2007 covering the season 2007-2008 using structured questionnaire, 54 tenants interviewed in the 5th and 10th agricultural sector of the scheme that represent all tenants cultivating wheat in this season, and it covers the socio-economics characteristics of tenants, and the different inputs quantities used in agricultural practices. Secondary data collected from different institutional sources including Bank of Sudan, Ministry of Agriculture and Forests, Rahad agricultural corporation, using their reports, records, journals, etc.

The Stochastic Production Frontier (SPF) analysis was used to estimate the technical efficiency of producing wheat in the scheme, and to determine the factors behind inefficiency such as gender, age, educational level, marital status and family size. Also, descriptive statistics were used to analyze the socio-economic characteristics of farmers.

The result showed that most of the estimated $\beta$ co-efficient of the stochastic frontier model for wheat production model have the expected signs. The mean technical efficiency is 70% for wheat crop. This means that the tenants can increase their output by 30% through the better use of
available resources if the tenants are technically efficient. The insufficient irrigation, working time in field are significant in explaining technical inefficiency in the Rahad scheme, while the gender, tenant’s age, educational level, marital status, tenants experience and family size are not significant in affecting technical in-efficiency for wheat production in the scheme.

The descriptive statistic of socio-economics characteristic result showed that most tenants in the study are male (98.1%) with technical efficiency of 70%. The age distribution ranged between (25-70) years with (48.1%) of the tenants their age distributed between (25-35) and (29.6%) of the tenants in the age group of (35-45) with the highest technical efficiency. About 3.7% of the respondents received no education with the least mean efficiency of 61% while 51.8% of the tenants got secondary education with the highest technical efficiency level of 74% in producing wheat. About 63% of farmers are married, 37% single with the same level of technical efficiency of 70%. The highest efficient tenants have family size of (3-6) members and lowest efficient tenants have family size of (7-9) members.

Lastly, the study recommended that improvement in educational level, maintain the irrigation channels and increasing the working time in the field, for improve technical efficiency for wheat production in the area,
الخلاصة

دراسة

هذة أجرت في السودان في القمح لإنتاج الكفاءة لتدريب برنامج الأحسن الزراعي في موسم الزراعي 2007-2008 الزراعي الإقتصادي قسم الإشراف تحت م، الزراعة الكلية، جامعة الخرطوم بمشريعة الزراعة.

القياسية هذه من الأساسي الهدف اللفة القمح محلة، عوامل تحديد للفة الإقتصادية، خصائص المجتمعية الإنتاجية.


وحسبت نسبة 98.1 معلومة التي استندت على تحليل في الدوال الاجتماعية الإنتاجية ، وتواتر هذه 10 حسب 70% من الزراعة الإجمالية لفهنة الفلاحين.
يسعى الشباب في العمر (35-25) لتحسين الوضعية الفلاحية، حيث %39.4 من الشباب في الفئة العمرية (45-35) يسعون لتحسين الوضعية الفلاحية. يُلاحظ أن نسبة %36 من الأشخاص في سن 48-12 عاماً تشتركون في اتخاذ قرارات تأثرها بالعوامل الاجتماعية والاقتصادية. ومن بين الأشخاص الذين يسعون لتحسين الوضعية الفلاحية، %29.6 من الشباب مرتبطون بالزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة. يُلاحظ أن نسبة %39.1 من النساء في الزراعة، %48.1 من الذكور في الزراعة، %48.1 من النساء في الزراعة، %39.1 من الذكور في الزراعة.
# LIST OF CONTENTS

## CHAPTER ONE

| Dedication | i |
| Acknowledgement | ii |
| English Abstract | iii |
| Arabic Abstract | v |
| List of Contents | vii |
| List of Tables | xi |
| List of Figure | xii |
| List of Appendices | xiii |

1. INTRODUCTION

1.1 Background

1.2 Problem Statement

1.3 Objectives Of The Study

1.4 Hypotheses

1.5 Organization Of Study

## CHAPTER TWO

2. THE LITERATURE REVIEW

2.1 Wheat

2.1.2 Background

2.1.3 Wheat in Sudan

2.2 Efficiency

2.2.1 Efficiency Concept

2.2.2 Production Efficiency

2.2.3 Production Possibility Frontier
CHAPTER THREE
3. STUDY AREA AND RESEARCH METHODOLOGY ............... 23
3.1 Study Area ......................................................... 23
3.1.1 Rahad Scheme ..................................................... 23
3.1.1.1 Background Information ............................................. 23
3.1.1.2 Objective of the Scheme .............................................. 24
3.2 Research Methodology ............................................. 25
3.2.1 Sources of Data ................................................... 25
3.2.2 Data Analysis ...................................................... 25
3.2.2.1 Efficiency Model .................................................... 25
3.2.2.3 Inefficiency Effect Model ......................................... 26

CHAPTER FOUR
4. RESULTS AND DISCUSSION ........................................ 28
4.1 Social Characteristics ............................................... 28
4.1.1 Gender, Age, Educational Level, Marital Status And Family Size .............. 28
4.2 Stochastic Frontier Production Function Analysis ............................ 32
4.2.1 Wheat Production Efficiency ...................................... 32
4.2.2 Hypotheses Test of Wheat Production ................................ 33
4.2.3 Frequency Distribution of Farmers Technical Efficiency .................. 36
4.2.4 Inefficiency Model for Wheat ..................................... 38
CHAPTER FIVE

5. SUMMARY CONCLUSIONS AND ECOMMENDATIONS

5.1 Summary

5.2 Conclusions

5.3 Recommendations

REFERENCES
LIST OF TABLES

Table (2.1): Distributional assumptions allowed by the software ………… 19
Table (4.1): Summary Statistics of Efficiency Estimate from the Stochastic Frontier Model of Wheat…………………………. 32
Table (4.2): Test of hypothesis for the parameters of stochastic frontier production function of wheat………………………………. 33
Table (4.3): Maximum-likelihood Estimates for the parameters of the Stochastic Frontier Production Function and Technical Inefficiency Effect Model for Wheat……………………… 34
Table (4.4): Inefficiency model .......................................................... 39
LIST OF FIGURES

Figure (1.1): The average wheat yield (Kg/fed) in Rahad Scheme, Gezira & Managel, New Halfa Scheme and Northern State (89/1990-98/1999)……………………………………………………………………………… 4

Figure (1.2): The average wheat yield in Rahad scheme (89/1990-98/1999)………………………………………………………………………………….. 4

Figure (4.1): Distribution of Sample Farmers According to Gender ………….. 28
Figure (4.2): Distribution of Sample Farmers According to Age ………………… 29
Figure (4.3): Distribution of Sample Farmers According to Education ………… 30
Figure (4.4): Distribution of sample farmers According to Marital Status …… 31
Figure (4.5): Distribution of Sample Farmers According Family Size ………… 31
Figure (4.6): Efficiency Score of Wheat………………………………………………
LIST OF APPENDICES

Appendix (1): The average wheat yield (Kg/fed) in Rahad Scheme, Gezira & Managel, New Halfa Scheme and Northern State (89/1990-98/1999) ................................................................. 50

Appendix (2): The planted, harvested area, production and yield of wheat in Rahad scheme (89/1990-98/1999) ................................................................. 51

Appendix (3): Distribution of Sample Farmers According to Gender ................. 52

Appendix (4): Distribution of Sample Farmers According to Age .................... 52

Appendix (5): Distribution of Sample Farmers According to Education .......... 52

Appendix (6): Distribution of sample farmers According to Marital Status ......... 53

Appendix (7): Distribution of Sample Farmers According Family Size ............. 53
CHAPTER ONE
1. INTRODUCTION

1.1 Background:

Sudan is the largest country in Africa, with a total area of about (2.5) million Km², it has a population of 37.239,000, about 37.6% of them live in the urban area and the rest in the rural area with agriculture as the main activity (Central Bureau of Statistics, 2007). The arable land represents approximately one third of the total land, 88 million hectares (200 million feddans), and about 22% of it is currently cultivated. Agriculture in Sudan depends on two sources of water: direct rainfed and irrigation principally from the Nile and it's tributaries. There are also flood irrigation schemes fed by seasonal rivers in the east of the country in the Gash and Tokar deltas. The area of irrigated sub-sector is about 4 million feddan. The irrigated sub-sector contributes 27% of agricultural GDP and it produces most of the cotton, sugar, legumes and cereal crops in Sudan (Central Bureau of Statistics, 2007). The major components of this sub-sector are: large scale schemes, which are Gezira, Rahad and New Halfa.

Rahad scheme is one of the important national schemes in Sudan, it is extending on the eastern bank of Rahad river, between longitudes 22°-34" and 35°-55" east and latitudes 14°-35" and 13°-43" north. The area of the scheme is 353 thousand feddan, 38% of it in Gadarif State and 62% in Gezira state. The scheme headquarter is at Elfau town which lies about 260 Km south-east of Khartoum. The climate is semi-desert; rain fall is between 400mm north and 600mm south of the scheme. Rahad scheme irrigated from Rahad river, using 11 pumps in the dry season. The first phase of the Rahad scheme was
modeled on the same pattern of Gezira Scheme with a central management, the tenant farmers, and the same crop mix, with one exception; there is no fallow in the rotation, yielding a 100% cropping intensity. Like other national corporations, the core of the scheme is the farmer’s plot with a standard area of 21 feddans (10 ha) equally divided among the four field crops, cotton, wheat, sorghum and groundnuts. Eventually the scheme stopped wheat production at season 98/1999, but in this Season 2007/2008 more than 900 feddans has been planted with wheat in the 5th and 10th Agricultural sector, as 500 feddans and 400 feddans respectively (Planning and research unit, Rahad Agricultural Scheme).

On a world production and utilization basis, wheat is the world’s single most important food crop and wheat trade represents a significant component of the balance of trade of national economies (Henry and Kettlewell, 1996; Gooding and Davies, 1997). Wheat is used and processed for many products because of the large quantity produced by people of diverse cultures and socioeconomic groups. The global success of wheat as a food crop not only derives from its geographical range of climate and soil tolerance, but also its adaptability for many different food products, thousands of which are produced worldwide (Faridi and Faubion, 1995).

In most years, the Sudan has a surplus of sorghum and a balance of millet, but has a great wheat deficit (Osman, 1989). During the period 1961-95 mean annual wheat consumption increased by 14 percent. Most of the increase was met by imports. In the Sudan, wheat imports increased by 15 percent annually during the same period. Wheat imports have exerted a heavy burden on the Sudan's meager and deteriorating foreign exchange resources and involved a worsening of its negative trade balance (Hassan and Faki,
Therefore, there is a great incentive to expand the utilization of domestic resources in wheat production.

1.2 Problem Statement:

Wheat is one of the most important food crops, in Sudan 37.6% of the population live in urban area, their main food is wheat and 68% of the population lives in rural area with sorghum and millet was the main food for them, but they are presently changing from a traditional local based consumption pattern to an increased use of domestically produced and imported wheat products, because many traditional wild food products are increasingly difficult to find and wheat products are becoming available from urban areas and fashionable to eat. Wheat normally produced in the northern Sudan for thousands of years but the production is not enough accompanied by increasing consumption that was met by increasing imports. The import bill of wheat and wheat flour represents 5.7% and 4.2% of total imports in 2005 and 2006 respectively. So government encourages wheat production in the national irrigated schemes. Wheat production started in Rahad Scheme in season 89/1990. In this season yield is very low compared with other schemes (Fig.1). There was fluctuation in the yield till season 98/1999 when the scheme stopped wheat planting (Fig.2). Due to the high cost of cultural operation most of the tenants get negative profit from wheat. The break even point exceeded the average yield in most seasons. In season 96/1997, the break even point was 4.89 sack/fed. while the average yield was 4.83 sack/fed. But in this Season 2007/2008 about 900 feddan has been planted with wheat in the 5th and 10th Agricultural sector. So wheat production in Rahad scheme must be investigated by studying the factors that may affect wheat production such as:

1. Irrigation problems.
2. Insufficient finance and agricultural extension.

3. Also, the factors that affect wheat productivity:
   Is the tenants is efficient in producing wheat?
   Is there any other factors behind this low yield or productivity?
Fig (1.1): The average wheat yield (Kg/fed) in Rahad Scheme, Gezira & Managel, New Halfa Scheme and Northern State (89/1990-98/1999).

Source: General Administration of Planning and Agricultural Economics, Ministry of Agriculture and Forests.

Fig. (1.2): The average wheat yield in Rahad scheme (89/1990-98/1999).

Source: General Administration of Planning and Agricultural Economics, Ministry of Agriculture and Forests.
1.3 Objectives of the Study:

The overall objectives of this study are to measure and evaluate the technical efficiency of wheat producing tenants in the Rahad scheme. This study is also aimed to achieve the following specific objectives:
1. To identify and measure the tenant technical efficiency.
2. To determine the major factors that affecting the technical efficiency of wheat production in Rahad scheme.

1.4 Hypotheses:

1. The main factors that affect the tenant's technical efficiency in Rahad scheme are tenant’s experience, level of education, financial ability, area under wheat, etc.
2. The differences in wheat productivity among the tenants in the Rahad scheme are assumed to be mainly due to the tenant's in-efficiency.

1.5 Organization of the Study:

This study consists of five chapters:

Chapter one contains an introduction to the agriculture, the importance of wheat to Sudan economy, the research problems, justification, hypotheses and the objectives of study. The literature review which related to efficiency and wheat production in Sudan was presented in chapter two. The study area and research methodology which include data collection and model specification are presented in chapter three. The empirical result are presented and discussed in chapter four. Lastly chapter five present the summary, conclusions and recommendations.
CHAPTER TWO

2. THE LITERATURE REVIEW

2.1 Wheat

2.1.2 Background

Cereals are crucial to human survival and are the main components of human diets (Henry and Kettlewell, 1996). Cereal grains provide a major source of energy, protein, and dietary fiber in human nutrition. For example, wheat can provide more than half of the calorie requirements in a healthy daily diet. Wheat is also a major source of protein compared with other foods and contributes more than 25 percent of the protein consumed in the human diet. The protein contents in sorghum and millet are nearly equal and are comparable to that of wheat and maize (FAO/ICRISAT, 1996). New mineral-enriched varieties could reinforce nutritional benefits in grain, particularly in developing countries (Gooding and Davies, 1997).

2.1.3 Wheat in Sudan

Sudan has been cultivating wheat in the north for thousands of years. Although the area never exceeded 15,000 ha until the 1950’s, yields were high enough to cover consumption needs in northern Sudan and the main towns. The rest of the population was dependent either on sorghum in central and eastern Sudan or cassava in the south. All of Sudan’s grains, with the exception of wheat, were produced without irrigation. In January 2003, the price of sorghum-Sudan’s food staple-rose steeply, prompting the government to remove grain import taxes until September 30. At the same time, the Board of Strategic Commodity Reserves announced an allocation of 5000 SDG to purchase grains for redistribution to deficit areas. Contracts
were also concluded to purchase 100,000 tonnes of wheat. Despite food distributions and the injection of cereals into the market from Sudan’s strategic reserve, food prices have remained high in many areas. In June, grain prices were twice as high as the same period last year and still were rising. (Tyler; 2003)

The optimum time for planting wheat is November, though temperatures during this period remained higher than average. Although in the Gezira this did not result in significant delays in planting (90% planted in the optimum period) in the north planting spanned November to the beginning of January. Had these high temperatures continued, it is conceivable that the overall wheat crop would have been severely affected. However, uncharacteristically below-normal temperatures in the period mid-January to March greatly assisted crop development. The overall weather situation was therefore favorable for production. (FAO; 1997).

With urbanization, in the past 50 years, food traditions have changed, and wheat consumption has soared to about 1 million tonnes per year. To meet this demand, wheat cultivation was introduced into central Sudan, where temperatures generally, exceed the optimum for the crop and the winter season is relatively short.

Despite these limitations, Sudan’s wheat area was expanded by 600% between 1984 and 1994 to as much as 357,000 ha in 1994. Production subsequently increased from fewer than 100,000 tonnes in 1984 to 875,000 tonnes in 1992, the peak harvest year. However, due to economic reforms and policy liberalization in the mid-1990’s and the resulting inflation, the cost of production became prohibitive, and wheat area has slipped by one-third. Consequently, imports, which had dropped to a low of 200,000 tonnes is 1992, have climbed to about 700,000 a year in the past three years.
Currently, the Gezira area produces more than 50% of Sudan’s total wheat production, with the remainder grown in the northern and Nile States and specified areas in the Rahad and New Halfa projects. However, there are plans to construct Hamdab and Kajbar dams to facilitate expansion of the northern state’s wheat production and for attaining self-sufficiency as well as export. Wheat production is expected to expand in the irrigated areas of central Sudan by heightening the Roseires Dam. Sudan is one of the fastest growing wheat markets in the world, therefore the emphasis on expanded wheat output.

Unlike Egypt, The Sudanese government is not involved in wheat, flour or breadstuffs in a direct way. There is no subsidized bread, flour or wheat, and price is strictly dependent on competition. Wheat consumption in Sudan is low when compared to other Middle Eastern countries, but high in comparison to other African countries. The main type of bread that is consumed is a unique baguette-type that is long and somewhat oval shaped with points on the end. Very little flat bread or toast bread is consumed in Sudan. Competition among wheat exporters to Sudan has become intense in recent years. Some millers are dealing exclusively with the Australian Wheat Board while others are dealing exclusively with the Canadian Wheat Board. However, Australia has become the top supplier of wheat to Sudan. An annual supply agreement was signed between Australian Wheat Board (AWB) and one of the largest flourmills in Sudan (SAYGA). It supplies 100% of the mill’s needs. (Tyler; 2003).

The effectiveness of irrigation is determined by the availability and supply of fuel for pump irrigation and the degree of siltation in canals for larger schemes. In general both of these were not constraining in 1997 and farmers were able to provide crops between five and eight irrigations.
The fertilizer situation was also satisfactory throughout the country, though a slight shortage of super-phosphate in Gezira reduced applications to 0.8 units of phosphate instead of the recommended 1 unit per unit area. Nonetheless, this did not appear to have a significant impact on yields.

No significant outbreaks of pests and diseases were reported and what little occurred were comfortably controlled by limited use of pesticide.

The favourable weather and input situation overall, therefore, resulted in a noticeable gain in productivity this year. Average yields are estimated at around 825 kg/fd or roughly 1.96 tons/ha. In comparison to 1996 and the average this represents an increase of 11 percent and 18 percent respectively.

As a result of these factors a bumper wheat crop is expected this year, second only to the record crop produced in 1991/92. Aggregate output is estimated at 650 000 tons, which is slightly higher than estimated by the Food and Agriculture Organization (FAO)/World Food Program (WFP) mission in December last year and 24 percent higher than both the 527 000 tons produced in 1996 and an average of 526 000 tons respectively. (FAO; 1997).

FAO reported that in season 1996/97 in Rahad scheme 40 000 feddans (16 800 ha) of wheat were cultivated in Rahad in 1996/97, similar to last year. The crop is cultivated in 8 out of the 9 administrative units within the scheme. Although the supply of urea was adequate, there was some shortage of super-phosphate. Irrigation supplies were reported to be satisfactory throughout the season. Almost the entire area was planted with the Kandour variety.

Due to a lack of finance and the late arrival of fertilizers at the beginning of the season, planting was delayed somewhat. However, like
other parts of the country cool temperatures in the later stages generally favoured crop development.

Harvesting began in the last week of March and is expected to be completed by the end of April. No shortage of combine harvesters was reported. In the first week of April, an estimated 40 percent of crop area had been harvested at an average yield of 586 kg/fd. The overall yield is expected to be around 525 - 530 kg/fd (1 250 - 1 260 kg/ha), giving an output of around 21 000 tons from the scheme. The average yield this year is estimated to be some 10 -11 percent lower than in 1995/96, which is attributed to the shortage of finance at planting which restricted fuel supplies and consequently led to late sowing in some areas. (FAO; 1997).

2.2 Efficiency:

2.2.1 Efficiency Concept

Efficiency is a very loose term indeed; to an engineer efficiency may mean the ratio of output / input or output/ theoretical capacity, percent. While the cost account use the ratio standard cost / actual cost, percent, or its inverse to measure the productive efficiency of a firm. The economist, when he refers to the efficiency of a firm generally means one of two ratios, the first concerns the firm’s success in producing as large as possible an output from a given set of inputs; or what amounts to the same thing, producing a given output with the least inputs; this called productivity, or technical efficiency.(Amey; 1969).

2.2.2 Production Efficiency

One of the three conditions necessary for an economy to be economically efficient is that it be on its production-possibilities frontier. If it is not on the production-possibilities frontier, more could be produced with the given resources and technology. Because greater production would
increase value, any position below the production-possibilities frontier is inefficient. Notice that a great many points satisfy this condition of production efficiency every point on the production-possibilities frontier is production efficient.

This requirement that resources must be used properly can be stated more technically. Production efficiency requires that an equimarginal principle be satisfied. It requires that the ratio of marginal products for any two resources be the same for all products. The table presents a case in which this condition is not met. Here the ratio of the two marginal products for the production of widgets is \((5/5)\) or 1 and the ratio of the two marginal products for getwids is \((6/4)\) or 1 1/2.

<table>
<thead>
<tr>
<th>Production Inefficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal product of capital is:</td>
</tr>
<tr>
<td>5 widgets or 6 getwids</td>
</tr>
<tr>
<td>Marginal product of labor is:</td>
</tr>
<tr>
<td>5 widgets or 4 getwids</td>
</tr>
</tbody>
</table>

To show that the situation in the table is not production-efficient, consider what happens if a getwid producer trades a unit of labor to a widget maker for one unit of capital. The widget maker will have no change in output as a result. Reducing capital by one unit cuts output by five, but this is offset by the five widgets the extra labor adds. However, there will be more getwids. The extra unit of capital adds 6 getwids, whereas the loss of a unit of labor subtracts 4 getwids. There is a net gain of two getwids. Because the amount of production after the exchange of resources was more than the original amount, the economy could not have been on the production-possibilities frontier originally. Further, because more output has more value to consumers, the original use of resources was less efficient than the use of resources after the trade.
As a result of the trade of resources, marginal products should change. Because more capital is being used in producing getwids, its marginal product in getwid production should drop (by the law of diminishing returns). Because more labor is being used in producing widgets, its marginal product in widget production should drop. Hence some exchange of resources should bring the ratios of marginal products to equality (http://ingrimayne.com/econ/efficiency/overview11mi.html).

2.2.3 Production Possibility Frontier

The 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 labour 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 (http://tutor2u.net/economics/content/topics/introduction/production_possibility_frontiers.htm).

2.2.4 Economic Efficiency

Economic efficiency is a general term in economics describing how well a system is performing, in generating the maximum desired output for given inputs with available technology. Efficiency is improved if more output is generated without changing inputs, or in other words, the amount of "friction" or "waste" is reduced.

**Economic Efficiency** = *Technical Efficiency* x *Allocative Efficiency*

Economic efficiency is used to refer to a number of related concepts. A system can be called economically efficient if:

* No one can be made better off without making someone else worse off.
* More output cannot be obtained without increasing the amount of inputs.
* Production proceeds at the lowest possible per unit cost.

These definitions of efficiency are not exactly equivalent. However, they are all encompassed by the idea that nothing more can be achieved given the resources available.

An economic system is more efficient if it can provide more goods and services for society without using more resources. Market economies are generally believed to be more efficient than other known alternatives. The first fundamental welfare theorem provides some basis for this belief, as it states that any perfectly competitive market equilibrium is efficient (but only if no market imperfections exist).
Microeconomic reforms is policies that aim to reduce economic distortions, and increase economic efficiency. However, there is no clear theoretical basis for the belief that removing a market distortion will increase economic efficiency. The Theory of the Second Best states that if there is some unavoidable market distortion in one sector, a move toward greater market perfection in another sector may actually decrease efficiency.

There are several alternate criteria for economic efficiency, these include:

- Pareto efficiency
- Kaldor-Hicks efficiency
- X-efficiency
- Allocative efficiency
- Distributive efficiency
- Productive efficiency
- Optimization of a social welfare function
- Utility maximization

(http://www.economicsentwork.ac.uk/copyright.html).

### 2.2.5 Allocative and Technical Efficiency

Technical efficiency is just one component of overall economic efficiency. However, in order to be economically efficient, a firm must first be technically efficient. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (i.e. be technically efficient), use the right mix of inputs in light of the relative price of each input (i.e. be input allocative efficient) and produce the right mix of outputs given the set of prices (i.e. be output allocative efficient) (Kumbhaker and Lovell 2000). These concepts can be illustrated graphically using a simple example of a two input \((x_1, x_2)\)-two output \((y_1, y_2)\) production process (Figure 1). Efficiency can be considered in terms of the optimal combination of
inputs to achieve a given level of output (an input-orientation), or the optimal output that could be produced given a set of inputs (an output-orientation).

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 isoquant associated with the minimum level of inputs required to produce \((y_1^*, y_2^*)\) (i.e. \(\text{Iso}(y_1^*, y_2^*)\)). The input-oriented level of technical efficiency \((\text{TE}_I(y,x))\) is defined by \(0B/0A\). 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 \((\text{CE}(y,x,w))\) is therefore defined by \(0D/0A\). The input allocative efficiency \((\text{AE}_I(y,w,w))\) is subsequently given by \(\text{CE}(y,x,w)/\text{TE}_I(y,x)\), 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 \((\text{TE}_O(y,x))\), can be given by \(0A/0B\). 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, a 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 maximise 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 ($RE(y,x,p)$) is given by $0A/0D$. Output allocative efficiency ($AE_o(y,w,w)$) is given by $RE(y,x,w)/TE_1(y,x)$, or $0B/0D$ in Figure 1(b) (Kumbhaker and Lovell 2000).
Figure 1: Input (a) and output (b) oriented efficiency measures
2.2.6 Stochastic Production Frontier Software

Stochastic frontiers can be estimated using a different range of multi-purpose econometric software which can be adapted for the desired estimation. This software includes known statistical packages such as LIMDEP, TSP, Shazam, GAUSS, SAS, etc. The two most commonly used packages for estimating of stochastic production frontiers and inefficiency are FRONTIER 4.1 (Coelli 1996a) and LIMDEP (Greene 1995). A recent review of both packages is provided by Sena (1999).

FRONTIER 4.1 is a single purpose package specifically designed for the estimation of stochastic production frontiers (and nothing else), while LIMDEP is a more general package designed for a range of non-standard (i.e. non-OLS) econometric estimation. An advantage of the former model (FRONTIER) is that estimates of efficiency are produced as a direct output from the package. The user is able to specify the distributional assumptions for the estimation of the inefficiency term in a program control file. In LIMDEP, the package estimates a one-sided distribution, but the separation of the inefficiency term from the random error component requires additional programming.

FRONTIER is able to accommodate a wider range of assumptions about the error distribution term than LIMDEP (Table 2.1), although it is unable to model exponential distributions. Neither package can include gamma distributions. Only FRONTIER is able to estimate an inefficiency model as a one-step process. An inefficiency model can be estimated in a two-stage process using LIMDEP. However, this may create bias as the distribution of the inefficiency estimates is pre-determined through the distributional assumptions used in its generation.
Table 2.1: Distributional assumptions allowed by the software

<table>
<thead>
<tr>
<th>Distribution</th>
<th>LIMDEP</th>
<th>FRONTIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time invariant firm specific inefficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Half-normal distribution</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>· Truncated normal distribution</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>· Exponential distribution</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Time variant firm specific inefficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Half-normal distribution</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>· Truncated normal distribution</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>One step inefficiency model</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: Sena (1999)

2.2.7 FRONTIER 4.1

The most commonly used package for estimation of stochastic production frontiers in the literature is FRONTIER 4.1 (Coelli, 1996a). This incorporates the maximum likelihood estimation of the parameters. The estimation process consists on three main steps. At the first step OLS is applied to estimate the production function. This provides unbiased estimators for the $\beta$'s (except for the intercept term and the variance estimate). The OLS estimates are used as starting values to estimate the final ML model. First, the value of the likelihood function is estimated for different values of $\gamma$ between 0 and 1 given the values for the $\beta$'s derived in the OLS. Finally an interative Davidon-Fletcher-Powell algorithm calculates the final parameter estimates, using the values of the $\beta$'s from the OLS and the value of $\gamma$ from the intermediate step as starting values.
FRONTIER 4.1 has been created specifically for the estimation of production frontiers. As such, it is a relatively easy tool to use in estimating stochastic frontier models. It is flexible in the way that it can be used to estimate both production and cost functions, can estimate both time-varying and invariant efficiencies, or when panel data is available, and it can be used when the functional form have the dependent variable both in logged or in original units.

FRONTIER solves two general models. The error components model can be formulated as

\[ Y_{it} = X_{it} \beta + (V_{it} - U_{it}) \]

Where \( Y_{it} \) is the (logged) output obtained by the i-th firm in the t-th time period; \( X_{it} \) is a (kx1) vector of (transformation of the) input quantities of the i-th firm in the t-th time period; \( \beta \) is a (kx1) vector of unknown parameters; and \( V_{it} \) are assumed to be iid N(0, \( \sigma_v^2 \)) random errors, and \( U_{it} = U_i \exp(-\eta(t-T)) \), where \( U_i \) are assumed to be iid as truncations at zero of the N(\( \mu_i, \sigma_u^2 \)).

This is the Battese and Coelli (1992) model. However some other models can be summarized as special cases of this one and can also be solved using FRONTIER. Setting \( \eta=0 \), the time invariant model of Battese, Coelli and Colby (1989) is obtained. The Battese and Coelli (1988) model results from the previous one for the particular case of problems in which balanced data is available. If we add \( \mu=0 \) to the aforementioned assumptions, the Pitt and Lee (1981) model results. And if we finally set \( T=1 \) in the Pitt and Lee model, we obtain the original cross-sectional data model of Aigner, Lovell and Schmidt (1977).

If \( \eta>0 \), the inefficiency term, \( U_{it} \), is always decreasing with time, whereas \( \eta<0 \) implies that \( U_{it} \) is always increasing with time. That could be
one of the main problems when using this model, technical efficiency is forced to be a monotonous function of time.

The second model included in the FRONTIER package is the Technical Efficiency (TE) effects model (Battese and Coelli 1995). It can be expressed as \( Y_{it} = X_{it} \beta + (V_{it} - U_{it}) \), where \( Y_{it}, X_{it}, \beta \) and \( V_{it} \) are as defined earlier and \( U_{it} \sim N(m_{it}, \sigma_u^2) \), where \( m_{it} = Z_{it} \delta \), \( Z_{it} \) is the vector of firm-specific variables which may influence the firms' efficiency. FRONTIER offers also the solution of the model of Stevenson (1980) which is a particular case of the previous model that can be obtained for the cases in which \( T \) is equal to 1 (for cross-sectional data).

There are two approaches to estimating the inefficiency models. These may be estimated with either a one step or a two step process. For the two-step procedure the production frontier is first estimated and the technical efficiency of each firm is derived. These are subsequently regressed against a set of variables, \( Z_{it} \), which are hypothesised to influence the firms' efficiency. A problem with the two-stage procedure is the inconsistency in the assumptions about the distribution of the inefficiencies. In the first stage, the inefficiencies are assumed to be independently and identically distributed (iid) in order to estimate their values. However, in the second stage, the estimated inefficiencies are assumed to be a function of a number of firm specific factors, and hence are not identically distributed unless all the coefficients of the factors are simultaneously equal to zero (Coelli, Rao and Battese, 1998). FRONTIER uses the ideas of Kumbhakar, Ghosh and McGuckin (1991) and Reifschneider and Stevenson (1991) and estimates all of the parameters in one step to overcome this inconsistency. The inefficiency effects are defined as a function of the firm specific factors (as in the two-stage approach) but they are then incorporated directly into the
MLE. This is something that should be taken into consideration when programming in some of the general statistical packages.
FRONTIER offers a wide variety of tests on the different functional forms of the models that can be conducted easily by placing restrictions on the models and testing the significance of the restrictions using the likelihood ratio test. The FRONTIER program is easy to use. A brief instruction file and a data file have to be created. The executable file and the start-up file can be downloaded from the Internet free of charge at the CEPA (University of New England) http://www.uq.edu.au/economics/cepa/frontier.htm.
CHAPTER THREE  
3. STUDY AREA AND RESEARCH METHODOLOGY

3.1 Study Area:
3.1.1 Rahad Scheme:

3.1.1.1 Background Information:

The Rahad Scheme is one of the schemes through which the government chooses to expand the production. The scheme started production in the season 1977/78 with the aim of raising the living standard of the population in its area and increasing cash crops exports, namely cotton and groundnuts. It lies east of the Blue Nile, on the eastern bank of the Rahad River, between longitudes 22°-34" east and 35°-55" east and latitudes 14°-35" and 13°-43" north. It extended for 160 Km from Mafaza village in the south to Abu Haraz village near Wad Medani in the north. On average it covers a width of 5.26 Km across the eastern part of the central clay plain of the Sudan. The scheme headquarter is at Elfau town which lies about 260 Km south-east of Khartoum. The area of the scheme is 353 thousand feddan, 38% of it in Gadarif State and 62% in Gezira state. The climate is semi-desert; rainfall varies between northern and southern parts of the scheme. the northern and southern parts has an annual rainfall of 400mm and 600mm in average respectively. The core of the scheme is the farmer’s plot with a standard area of 21 feddans. (10 ha) equally divided among the four field crops, cotton, wheat, sorghum and groundnuts. All in all there are 14 thousand farmers organized in a union and through the union the farmers do participate in the management board and the various production councils at all levels of the scheme. Another characteristic of the scheme is that there
are tarmac roads all across the area and all parts are reachable during the rainy season, unlike all other schemes. The scheme is also connected by highways to the sea ports and to the capital; an advantage that can facilitate specialization in export crops, especially horticultural crops and animal production. The scheme draws water for irrigation from the Blue Nile using 11 giant electric pumps situated at Miena near Singa town in Blue Nile into a siphon across River Dinder to the scheme main canal. Also water is diverted from the Rahad seasonal River to the scheme main canal. The arrangement is that from July up to the end of October, water for irrigation is to be delivered from the Rahad River and from November to the end of June the necessary irrigation water is to be pumped out of the Blue Nile. (planning and research unit, Rahad Agric. Scheme).

3.1.1.2 Objective of the Scheme

El-sammani (1990) summarized the scheme objectives as follows:

1. Utilize government investments in water diversion and storage works at El-roseires dam in crop production by developing the Rahad Scheme.
2. Generation of additional values from cotton and groundnuts contribute to the GNP.
3. Offer an opportunity to improve further upon irrigation and agricultural technologies.
4. Increase the quantity, quality and value of domestically consumed crops.
5. Improve the welfare of an economically marginal population, through the increase of their income, standard of living, housing, nutrition, health, education and corresponding changes in attitudes and value.
6. Provide employment for a national agricultural wage labour force.
3.2 Research Methodology:

3.2.1 Sources of Data:

Primary and secondary data were used to fulfill the objective of the study. Primary data collected by mean of a questionnaire following complete census, 54 tenants were interviewed of the Rahad tenants in the 5th and 10th Agricultural sector. The primary data included basic information about the socio-economic characteristic, area of the tenancy, location of the tenancy, agricultural practices for wheat and the other crops, etc.

Secondary data collected from different institutional sources including Bank of Sudan, Ministry of Agriculture and Forests, Rahad agricultural corporation, using their reports, records, journals, etc.

3.2.2 Data Analysis:

The objectives of this study were achieved by using the Stochastic Frontier Production (SFP) model. Stochastic frontier production analysis is method of estimating frontier function involving the use of econometric and thereby measuring the efficiency of production. Economic efficiency is generally defined as the ability of a production organization to produce a well-specified output at the minimum cost. In our study two models will be used:

3.2.2.1 Efficiency Model:

This model includes the tenant’s factors affecting the tenant technical efficiency for wheat production. Stochastic production frontier model of the Cobb-Douglas form was used. The model is written as follows:
\[ \ln y_i = \beta_0 + \beta_1 D_1 x_{i1} + \sum_{j=1}^{7} \beta_j \ln x_{ij} + v_i - u_i \]

Where:
\( \ln y_i \) = the natural logarithm of wheat yield in sack/feddan;
\( X_1 \) = Agricultural income;
\( X_2 \) = Non-agricultural income;
\( X_3 \) = Planted area under wheat crop;
\( X_4 \) = Working time in field hr/day;
\( X_5 \) = Pest infestation;
\( D_1 x_{i6} \) = dummy variable for sowing date which has value of one if the sowing is done at the optimum time and zero, otherwise;
\( X_7 \) = Varieties;
\( \beta_1 \) and \( \beta_j \) are unknown parameters to be estimated for the dummy and continuous variable, respectively.
\( v_i \) represent the statistical error and the other factors which are beyond the tenants control such as weather, topography and other factors which are not included and may be either positive, negative or zero.
\( u_i \) is non negative random variable, associated with the tenants technical inefficiency in production and assumed to be independently distributed. For the technical inefficiency effect for the \( i^{th} \) tenants, it will be obtained by truncation (at zero) of the normal distribution with mean, \( \mu_i \) and variance \( \sigma^2 \).

3.2.2.2 Inefficiency Effect Model:
As mentioned above in the tenants model, \( u_i \) in the stochastic production frontier model is anon negative random variable, associated with the tenants' technical inefficiency in production and assumed to be independently distributed, such that the technical in efficiency effect for the \( i^{th} \) tenant, \( u_i \), will
be obtained by truncating (at zero) of the normal distribution with mean, $\mu_i$, and variance, $\delta^2$, such that
\[
\mu_i = \delta_0 + \sum \delta_s Z_s
\]
Where:
$Z_{1i} = \text{Gender}$;
$Z_{2i} = \text{Tenants age}$;
$Z_{3i} = \text{level of education}$;
$Z_{4i} = \text{Marital status}$;
$Z_{5i} = \text{Tenants experience}$;
$Z_{6i} = \text{Family size}$;
$Z_{7i} = \text{Number of insufficient irrigation}$;
$Z_{8i} = \text{Location of the farm}$;
$\delta_s$ and $\delta_s^2$ are unknown parameters to be estimated;
CHAPTER FOUR
4. RESULTS AND DISCUSSION

This chapter presents the empirical results of study. Namely the socio-economics characteristics of the tenants, stochastic production frontier and inefficiency model using the data of growing season 2006/07.

4.1 Social Characteristics

4.1.1 Gender, Age, Educational Level, Marital Status and Family Size

World Bank (2001) stated that the gender refers to socially constructed roles and socially learned behaviors and expectations associated with females and males. It can be defined as more than biological differences between men and women. It includes the ways 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).

Figure (4.1): Distribution and Efficiency of Sample Farmers According to Gender
Figure (4.1) shows that most of the farmers are male with 98.1% of total respondent’s distribution and with mean technical efficiency of 70% in the Rahad scheme and 71% for female.

**Figure (4.2): Distribution and Efficiency of Sample Farmers According to Age**

![Age distribution and efficiency chart](chart.png)

Age has an important effect on productivity and output of the individual as it affects the mental and the manual abilities. Many writers reported that, age has a positive effect on productivity until a certain level beyond which it would have a negative effect. Figure (4.2) shows the age distribution in the tenant sample. As we see in the figure, the age distribution ranged between (25-70) years with (48.1%) of the tenants their age distributed between (25-35) and (29.6%) of the tenants in the age group of (35-45) with the highest technical efficiency.
In developing countries, where technological change is radically altering life style, education is necessary for survival; it helps people to understand and benefit from change and obtain their economic rights (World Bank 1980). Figure (4.3) shows that about 3.7% of the respondents received no education with the least mean efficiency of 61%, 5.6% received some khalwa, 37% received primary education, about 51.8% of the tenants got secondary education with the highest efficiency level of 74% and only 1.9% of them have university degree. From this table we found that the technical efficiency increases with increasing in education level. At the university levels the efficiency declines. This declining can be resulted from the fact that the tenant who has a high education practices agriculture as a second job and he didn’t spend enough working time in the field.
Figure (4.4): Distribution and Efficiency of Sample Farmers According to Marital Status

Figure (4.4) shows that the majority of sample respondents (63%) are married and (37%) single, with the same technical efficiency of 70%.

Figure (4.5): Distribution and Efficiency of Sample Farmers According to Family Size

Figure (4.5) shows that the family size ranged between (1 and 11) members, 48%of the respondents have family size group ranged between 1 and 3 members. The large family size represents smaller percentage of the
respondents. The highest efficient tenants have families of 4-6 members and lowest efficient tenants have families of 7-9 members.

4.2 Stochastic Frontier Production Function Analysis

Stochastic Frontier version 4.1 program (Coelli, 1996) was used to estimate the level of technical efficiency for Wheat production. The maximum likelihood (MLE) estimate of Cobb-Douglas stochastic production frontier model with the assumption of half-normal for wheat production efficiency, and technical in-efficiency were presented in Tables (4.8), (4.9), respectively.

4.2.1 Wheat Production Efficiency


<table>
<thead>
<tr>
<th>Statistic</th>
<th>Wheat Efficiency score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.70</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.25</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.98</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Source: Author calculation

As shown in Table (4.1), the mean technical efficiency of wheat production is 0.70, with a minimum of 25% and maximum of 98% as shown in the table. This means that on average, the tenants in the scheme produced 70 percent of wheat yield attainable by the best practice. This result implies that the tenants can increase their wheat output by 30 percent using the same mix of production inputs if the tenants are technically efficient.

An important result is that the variance ratio parameters $\gamma$ is large and significant and has a value of 0.99. This result express that about 99 percent
of wheat output deviation are caused by differences in tenant’s level of technical efficiency as opposite to the conventional random variability. The significant estimates of $\gamma$ and $\delta^2$ imply that the assumed distribution of $u_i$ and $v_i$ is accepted (Tables 4.3).

4.2.2 Hypotheses Test of wheat Production Model

Table (4.2): Test of hypothesis for the parameters of stochastic frontier production function of wheat.

<table>
<thead>
<tr>
<th></th>
<th>Wheat Production Model</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0: \gamma = \mu = 0$</td>
<td>40.09 ***</td>
<td>$H_0$: Rejected</td>
</tr>
<tr>
<td>LR $H_0$: No technical inefficiency</td>
<td>54.42 ***</td>
<td>$H_0$: Rejected</td>
</tr>
</tbody>
</table>

Source: Author calculation.

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

As shown in Table (4.2) the test of hypothesis of wheat likelihood ratio test (LR), which tests the null hypothesis for the technical inefficiency effect for wheat production in Rahad scheme is rejected. The value of the test is calculated as:

$$LR = -2\{\ln[L(H_0) / L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}$$

Where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null hypothesis and alternative hypothesis, respectively (Rahman, 2002 & Ahmed, 2004).

Table (4.1) reveals that there are significant technical inefficiency effects in wheat production, because the null hypotheses $H_0$ are fully efficient given the specification of (SPF) in Cobb-Douglas form. Then the ($H_0: \gamma = \mu =0$): null hypothesis are rejected.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameters</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$B_0$</td>
<td>1.122 ***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.404)</td>
</tr>
<tr>
<td>Agricultural Income (X₁)</td>
<td>$B_1$</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.019)</td>
</tr>
<tr>
<td>Non- Agricultural Income (X₂)</td>
<td>$B_2$</td>
<td>-0.0045</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0154)</td>
</tr>
<tr>
<td>Planted Area (X₃)</td>
<td>$B_3$</td>
<td>0.0265</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0468)</td>
</tr>
<tr>
<td>Working Time in field/Hr (X₄)</td>
<td>$B_4$</td>
<td>0.510</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.158)</td>
</tr>
<tr>
<td>Pest Infestation(X₅)</td>
<td>$B_5$</td>
<td>-0.0363</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0955)</td>
</tr>
<tr>
<td>Sowing Date (X₆)</td>
<td>$B_6$</td>
<td>-0.0213</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0797)</td>
</tr>
<tr>
<td>Varieties (X₇)</td>
<td>$B_7$</td>
<td>0.0302</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0343)</td>
</tr>
</tbody>
</table>

\[
\sigma^2_s = \sigma^2_\nu + \sigma^2 \\
\sigma^2_s = \sigma^2_\nu + \sigma^2 \\
\gamma = \frac{\sigma^2}{\sigma^2_s} \\
\gamma = \frac{\sigma^2}{\sigma^2_s} \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameters</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.0397***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0128)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.999***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0249)</td>
</tr>
<tr>
<td>Mean Efficiency</td>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td>Log likelihood function</td>
<td></td>
<td>19.653</td>
</tr>
</tbody>
</table>

Source: Author calculation.

*** asterisks on the value of the parameters indicate its significant at 1 percent level of significance. The estimated standard errors are presented in parenthesis bellow the corresponding parameter estimate.
Table (4.3); present Maximum-likelihood estimates (ML) of wheat stochastic frontiers for Rahad scheme. Most of the estimated $\beta$ coefficients of the stochastic frontier model for wheat production model have the expected sign.

The coefficients of agricultural and Non-agricultural income have a negative sign. However it is not significantly different from zero. A possible explanation of the negative sign is that the major part of the agricultural and non-agricultural income may be directed toward other crops and to satisfy their other needs such as food supplies, school fees for students, etc. Moreover, the high non-agricultural income means that the tenant have another job, so he has no enough time to look after his crops cultural practices.

The coefficient of area under wheat is expected to have significant negative effect because of the shortage of labor, difficulties in land preparation and agricultural practices, but it has a positive signs and it is not significantly different from zero. This result could be due to that all agricultural practices and land preparation are done by the agricultural bank.

The estimated coefficient of Working Time in field, Hrs/day for wheat has positive signs and significantly different from zero at 1, 5 and 10 percent level of significant. Working time in field is very important to supervise the wheat activities and it captures all cultural practices for producing wheat, specially the irrigation process; it leads to increase the yield of wheat.

The coefficient of the pest infestation has a negative sign. However, it is not significantly different from zero. The negative sign reflects the harm effect of infestation on the wheat production level.
The coefficient of sowing date has negative signs and not significantly different from zero. The negative sign means that the latest sowing date reduces the yield of wheat.

The planted wheat varieties in the scheme are Imam, Bohain, Nelain, Kondor and Khaleifa. The estimated coefficient of wheat varieties has a positive sign, but it is not significantly different from zero. This means that the varieties have no effect on wheat output.

4.2.3 Frequency Distribution of Tenants Technical Efficiency

The tenants in Rahad scheme have wide range of technical efficiency ranging from 25 percent up to 98 percent for wheat production. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for wheat production Figure (4.6) shows that 24.1 percent of the tenants operate with efficiency ranged between 61-70 level of efficiency for wheat. This implies that on average, the farmers producing wheat in Rahad scheme achieved 70 percent of the potential stochastic frontier wheat production level given their current level of production inputs and technology used.
Figure (4.6): Efficiency Score of Wheat

Efficiency score of wheat

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-50</td>
<td>7.4</td>
</tr>
<tr>
<td>51-60</td>
<td>22.2</td>
</tr>
<tr>
<td>61-70</td>
<td>24.1</td>
</tr>
<tr>
<td>71-80</td>
<td>14.8</td>
</tr>
<tr>
<td>81-90</td>
<td>20.4</td>
</tr>
<tr>
<td>91 Above</td>
<td>11.1</td>
</tr>
</tbody>
</table>
4.2.4 Inefficiency Model for Wheat

As shown in Table (4.4) for wheat inefficiency, the estimated $\delta$ coefficient associated with explanatory variable in the model for inefficiency effects. The farmer’s sex has a positive sign and has no significant effect upon the inefficiency model for wheat production.

The age of farmers has positive sign, but it is not significant from zero. Positive sign of coefficient of farmers’ age for wheat means that the inefficiency effects increases and decreases with increase and decrease in age of farm’s operator, respectively. That means the older farmers have higher inefficiency than younger farmers, or the older farmers are technically less efficient than younger farmers.

The coefficient of educational levels of farmers is negative, but not significant different from zero Negative sign of the parameter of education means that technical inefficiency of wheat decrease with the increase in education level of farm operators. The reasons may be that the educated farmers were found to have alternative income sources (functionary or employee). Also level of education of farmers are indicators of the farmers’ awareness and their abilities of taking decision on how and what to produce, approaching credit, allocating their available resources and adopting new agricultural technologies.

The marital status has negative sign and not significant. Negative sign means that the increasing of number of farmers who married reduces inefficiency but not in statistically significant amount. The coefficient of experience of farmers has a positive sign but not significantly different from zero. That means the technical inefficiency of the tenants increase with increase in experience of farmers’. This result is very strange, but there is an explanation for it, in the Rahad Scheme
cultivation of wheat started in season 89/1990 and last for ten seasons, at season 98/1999 the scheme stopped wheat cultivation till seasons 2007/2008. So expert tenants in cultivating wheat are the oldest tenants so they can not operate the farm efficiently.

**Table (4.4): Inefficiency Model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameters</th>
<th>Estimate</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\delta_0$</td>
<td>0.541</td>
<td>(0.876)</td>
</tr>
<tr>
<td>Gender (Z₁)</td>
<td>$\delta_1$</td>
<td>-0.110</td>
<td>(0.477)</td>
</tr>
<tr>
<td>Age (Z₂)</td>
<td>$\delta_2$</td>
<td>0.0017</td>
<td>(0.0072)</td>
</tr>
<tr>
<td>Educational level (Z₃)</td>
<td>$\delta_3$</td>
<td>-0.0431</td>
<td>(0.113)</td>
</tr>
<tr>
<td>Marital status (Z₄)</td>
<td>$\delta_4$</td>
<td>-0.139</td>
<td>(0.236)</td>
</tr>
<tr>
<td>Experience (Z₅)</td>
<td>$\delta_5$</td>
<td>0.0057</td>
<td>(0.0356)</td>
</tr>
<tr>
<td>Family size(Z₆)</td>
<td>$\delta_6$</td>
<td>0.0151</td>
<td>(0.0542)</td>
</tr>
<tr>
<td>Insufficient irrigation (Z₇)</td>
<td>$\delta_7$</td>
<td>0.359***</td>
<td>(0.0776)</td>
</tr>
<tr>
<td>Location (Z₈)</td>
<td>$\delta_8$</td>
<td>-0.0257</td>
<td>(0.0966)</td>
</tr>
</tbody>
</table>

Source: Author calculation.

***asterisks on the value of the parameters indicate its significant at 1 percent level of significance. The estimated standard errors are presented in parenthesis bellow the corresponding parameter estimate
The coefficient of family size of farmers in the model for inefficiency effects is estimated to be positive and not significant for wheat production; this indicates that farmers with large family size tend to have higher inefficiency effects than farmers with smaller family. This may be due to that the tenants with large family spend most of their income their living expenses and their other needs.

The coefficient of the insufficient irrigation in the model of inefficiency effects is estimated to be positive and significant for wheat production. This means that inefficiency increase in statistically significant amount with the increase of number of insufficient irrigation.

The location parameter has negative sign but it is not significantly different from zero. The negative sign means that the farm far away from the irrigation canals has large inefficiency.
CHAPTER FIVE
5. SUMMARY CONCLUSIONS AND ECOMMENDATIONS

In this chapter summary of the results and some recommendations were presented.

5.1 Summary

This study was carried out in Rahad Agricultural Scheme. The main objective of this study is to measure and evaluate the technical efficiency of wheat production which is practiced in the Rahad scheme. The specific objective are to identify the main factors behind the tenants technical inefficiency, to identify the socio-economic factors affecting the level of efficiency of tenants, to develop specification and estimations of stochastic frontier econometric models for producing wheat and to draw policy recommendations.

The study used primary and secondary data. Primary data were collected using structured questionnaire for all tenants producing wheat in the scheme in the 5th and 10th agricultural sector of the scheme, and it covers the socio-economics characteristics of tenants, and the different inputs quantities used in agricultural practices. Secondary data collected from different institutional sources including Bank of Sudan, Ministry of Agriculture and Forests, Rahad Agricultural Corporation.

The Stochastic Production Frontier (SPF) analysis was used to estimate the technical efficiency of producing wheat in the scheme, and to determine the factors behind inefficiency such as gender, age educational level, marital status, family size. Also, descriptive statistics were used to analyze the socio-economic characteristics of farmers.
The result showed that most of the estimated $\beta$ co-efficient of the stochastic frontier model for wheat production model have the expected signs. The mean technical efficiency is 70% for wheat crop. This means that the tenants can increase their output by 30% through the better use of available resources if the tenants are technically efficient. The 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 scheme.

The descriptive statistic of socio-economics characteristic result showed that most tenants in the study are male (98.1%) with technical efficiency of 70%. The age distribution ranged between (25-70) years with (48.1%) of the tenants their age distributed between (25-35) and (29.6%) of the tenants in the age group of (35-45) with the highest technical efficiency. About 3.7% of the respondents received no education with the least mean efficiency of 61% while 51.8% of the tenants got secondary education with the highest technical efficiency level of 74% in producing wheat. About 63% of farmers are married, 37% single with the same level of technical efficiency of 70%. The highest efficient tenants have family size of (3-6) members and lowest efficient tenants have family size of (7-9) members.

Lastly, in order to improve technical efficiency for wheat production in the area, the study recommended improvement in educational level, maintenance of the irrigation channels and increasing the working time in the field.
5.2 Conclusions

The conclusions of this study based on the results of stochastic production frontier for wheat crop, in this study the following conclusions can be drawn:

1- Tenants in Rahad scheme are technically efficient; the average technical efficiency is 70%. This indicates that tenants can increase output by 30% under existing inputs and technology.

2- Working time in the field have a significant impact on production in Rahad scheme.

3- The planted area of wheat has no significant impact for wheat production.

4- Agricultural income and non agricultural income has no significant influence for efficiency. To purchase production inputs and improve production efficiency, the Agricultural Bank must provide a credit at time.

5- Sowing date has a negative impact on the efficiency but it is not significant. That means wheat must be planted at the optimum sowing date.

6- The varieties have no significant impact for the technical efficiency of wheat production.

7- Gender, age of tenant’s, tenant’s experience and family size has no significant impact on wheat production technical efficiency.

8- The tenants in the age group of (35-45) have the highest technical efficiency and the oldest tenants have the lowest technical efficiency.

9- The highest efficient tenants have families of (3-6) members and lowest efficient tenants have families of (7-9) members.
5.3 Recommendations

This study examined the technical efficiency of producing wheat in Rahad scheme. The study recommended that improving technical efficiency of wheat production of the tenants can be through:

1- Increasing the working time in the field for the better application of recommended cultural packages.
2- Maintenance of the irrigation channels.
3- Performing the cultural practices in the optimum time.
4- Improvement in educational level and increase awareness of tenants by extension services.
REFERENCES


(http://www.economicsentwork.ac.uk/copy right.html).

(http://tutor2u.net/economics/content/topics/introduction/production_possibility_frontiers.htm).
Appendices

Appendix (1): The average wheat yield (Kg/fed) in Rahad Scheme, Gezira & Managel, New Halfa Scheme and Northern State (89/1990- 98/1999).

<table>
<thead>
<tr>
<th>Season</th>
<th>Rahad</th>
<th>Gezira &amp; Managel</th>
<th>New Halfa</th>
<th>Northern</th>
</tr>
</thead>
<tbody>
<tr>
<td>89/1990</td>
<td>444</td>
<td>599</td>
<td>700</td>
<td>1196</td>
</tr>
<tr>
<td>90/1991</td>
<td>476</td>
<td>546</td>
<td>585</td>
<td>1160</td>
</tr>
<tr>
<td>91/1992</td>
<td>955</td>
<td>939</td>
<td>710</td>
<td>1289</td>
</tr>
<tr>
<td>92/1993</td>
<td>536</td>
<td>560</td>
<td>585</td>
<td>857</td>
</tr>
<tr>
<td>93/1994</td>
<td>407</td>
<td>530</td>
<td>355</td>
<td>907</td>
</tr>
<tr>
<td>94/1995</td>
<td>538</td>
<td>599</td>
<td>511</td>
<td>1200</td>
</tr>
<tr>
<td>95/1996</td>
<td>590</td>
<td>650</td>
<td>590</td>
<td>1200</td>
</tr>
<tr>
<td>96/1997</td>
<td>487</td>
<td>701</td>
<td>574</td>
<td>1301</td>
</tr>
<tr>
<td>97/1998</td>
<td>563</td>
<td>867</td>
<td>702</td>
<td>1300</td>
</tr>
<tr>
<td>98/1999</td>
<td>150</td>
<td>272</td>
<td>391</td>
<td>898</td>
</tr>
</tbody>
</table>

Source: General Administration of Planning and Agricultural Economics, Ministry of Agriculture and Forests
**Appendix (2):** The planted, harvested area, production and yield of wheat in Rahad scheme (89/1990- 98/1999)

<table>
<thead>
<tr>
<th>Season</th>
<th>Area (000) Feddan</th>
<th>Production (000)ton</th>
<th>Yield Kg/Fed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planted</td>
<td>Harvested</td>
<td></td>
</tr>
<tr>
<td>98/1990</td>
<td>9</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>90/1991</td>
<td>67</td>
<td>63</td>
<td>30</td>
</tr>
<tr>
<td>91/1992</td>
<td>66</td>
<td>66</td>
<td>63</td>
</tr>
<tr>
<td>92/1993</td>
<td>62</td>
<td>56</td>
<td>30</td>
</tr>
<tr>
<td>93/1994</td>
<td>61</td>
<td>59</td>
<td>24</td>
</tr>
<tr>
<td>94/1995</td>
<td>47</td>
<td>39</td>
<td>21</td>
</tr>
<tr>
<td>95/1996</td>
<td>41</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td>96/1997</td>
<td>40</td>
<td>39</td>
<td>19</td>
</tr>
<tr>
<td>97/1998</td>
<td>17</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>98/1999</td>
<td>21</td>
<td>20</td>
<td>3</td>
</tr>
</tbody>
</table>

**Source:** General Administration of Planning and Agricultural Economic, Ministry of Agriculture and Forests.
Appendix (3): Distribution of Sample Farmers According to Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Efficiency</th>
<th>Percentage</th>
<th>Efficiency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>70%</td>
<td>98.1%</td>
<td>71%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author calculation

Appendix (4): Distribution of Sample Farmers According to Age

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Percentage</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>25–35</td>
<td>48.1%</td>
<td>70%</td>
</tr>
<tr>
<td>35–45</td>
<td>29.6%</td>
<td>74%</td>
</tr>
<tr>
<td>45–55</td>
<td>14.8%</td>
<td>66%</td>
</tr>
<tr>
<td>55–65</td>
<td>5.6%</td>
<td>63%</td>
</tr>
<tr>
<td>65 and up</td>
<td>1.9%</td>
<td>57%</td>
</tr>
</tbody>
</table>

Source: Author calculation

Appendix (5): Distribution of Sample Farmers According to Education

<table>
<thead>
<tr>
<th>Educational Level</th>
<th>Percentage</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illiterate</td>
<td>3.7%</td>
<td>61%</td>
</tr>
<tr>
<td>Khalwa</td>
<td>5.6%</td>
<td>66%</td>
</tr>
<tr>
<td>Primary</td>
<td>37.0%</td>
<td>67%</td>
</tr>
<tr>
<td>Secondary</td>
<td>51.8%</td>
<td>74%</td>
</tr>
<tr>
<td>University</td>
<td>1.9%</td>
<td>70%</td>
</tr>
</tbody>
</table>

Source: Author calculation
Appendix (6): Distribution of Sample Farmers According to Marital Status

<table>
<thead>
<tr>
<th>Marital Status</th>
<th>Efficiency</th>
<th>Percentage</th>
<th>Efficiency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marriage</td>
<td>70%</td>
<td>63.0%</td>
<td>70%</td>
<td>37.0%</td>
</tr>
<tr>
<td>Single</td>
<td>70%</td>
<td>37.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author calculation

Appendix (7): Distribution of Sample Farmers According to Family Size

<table>
<thead>
<tr>
<th>Family Size</th>
<th>Percentage</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>48.1%</td>
<td>72%</td>
</tr>
<tr>
<td>4-6</td>
<td>37.1%</td>
<td>76%</td>
</tr>
<tr>
<td>7-9</td>
<td>11.1%</td>
<td>49%</td>
</tr>
<tr>
<td>10 and up</td>
<td>3.7%</td>
<td>68%</td>
</tr>
</tbody>
</table>

Source: Author calculation