PRODUCTION FRONTIER OF SMALL SCALE PEARL MILLET FARMERS UNDER CONSERVATION AGRICULTURE IN NORTHERN NAMIBIA

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DECLARATION

I, Bonolo Pontsho Montle, hereby declare that the work contained in the thesis, entitled ***Production Frontier of Small Scale Pearl Millet Farmers Under Conservation Agriculture In Northern Namibia*** is my own original work and that I have not previously in its entirety or in part submitted it at any university or other higher education institutions for the award of a degree.

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Bonolo Pontsho Montle **Date**

DEDICATION

"*If a man is called to be a street sweeper, he should sweep streets even as Michelangelo painted, or Beethoven composed music, or Shakespeare wrote poetry. He should sweep streets so well that the hosts of heaven and earth will pause to say, here lived a great street sweeper who did his job well*"

Martin Luther King Jr.

This work is dedicated to:
My dearest family

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ABSTRACT

Pearl millet is a major staple food crop of Northern Namibia dominantly produced by small scale farmers. This paper examines technical efficiency of smallholder pearl millet farmers under Conservation and Traditional Agriculture as well as their willingness to pay for extension services. The data was collected using a structured questionnaire administrated to 100 randomly selected small-scale pearl millet farmers in Omusati, Ohangwena, Oshikoto, Oshana and Kavango regions. Data was analysed by descriptive statistics, stochastic frontier production function approach as well as the probit regression model. The estimated stochastic frontier Cobb-Douglas production function showed that land availability, the level of fertilizer use and tractor power explains variations in the production of pearl millet. The efficiency analysis results show that farm level technical efficiency for Conservation Agriculture and Traditional Agriculture were 32% and 33% respectively. This indicates that overall, there is a potential to improve efficiency in pearl millet production among smallholder farmers in the study area by 68% through the efficient use of Conservation Agriculture. Furthermore, on Traditional Agriculture, there is a potential to improve efficiency by about 67% utilising existing farm resources better and adopting improved technology and techniques. Based on this result, the study recommends that Conservation Agriculture should be continued and over a long period of time so that the impact can be felt. The results of the inefficiency model indicate that under Conservation Agriculture, farming experience has a significant positive effect on efficiency. While on Traditional Agriculture, farm experience, farm size, training had a significant and positive effect on efficiency. The policy implications with regards to the technical efficiency are that to improve farm efficiency, efforts should focus on capacity building, training, extension services, information on agronomic practices and farmer's education. On farmer's willingness to pay for extension services, the predicted probability of getting farmers willing to pay is 60%. The model showed that farm size, Income < 2000, cooperative membership and household size are significant determinants of farmers' willingness to pay. The study recommends that these key parameters are given proper policy consideration in the design and the implementation of a workable policy, for example, improving extension services through privatization.

Keywords: Technical efficiency; Conservation Agriculture; Pearl millet, Willingness to pay

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

CA	Conservation Agriculture
C.A.N	Conservation Agriculture Namibia
CCAP	Comprehensive Conservation Agriculture Programme
CES	Creative Entrepreneurs Solutions
CLUSA	Cooperative League of the United States of America
CONTILL	Conservation Tillage
CRS	Constant Return to Scale
DCPP	Dryland Crop Production Program
DEA	Data Envelopment Analysis
EU	European Union
GDP	Gross Domestic Product
Ha	Hectare
Kg	Kilogram
MAWF	Ministry of Agriculture, Water and Forestry
NAB	Namibia Agronomic Board
NCAP	Namibia Conservation Agriculture Project
NGO	Non-Government Organisation
NNFU	Namibia National Farmers Union
NSCA	Namibia Specific Conservation Agriculture
NSCT	Namibia Specific Conservation Tillage
NRC	Namibia Resource Consultants
RSA	Republic of South Africa
SFA	Stochastic Frontier Analysis
TA	Traditional Agriculture
TE	Technical Efficiency
UNDP	United Nations Development Program
USAID	United States Agency for International Development
WTP	Willingness to Pay

CHAPTER 1

INTRODUCTION

1.1 Background to the Study

The importance of agriculture sector to the Namibian economy cannot be overemphasized. The sector plays an important role in providing food, employment and intermediate products for the agro-industries. It also contributes greatly to export earnings and to the gross domestic product of the country (GDP). In 2013, 2014 and 2015 financial years, it contributed 3.4%, 3.8%, 3.2% respectively to the GDP (Namibian Statistics Agency (NSA), 2015). About forty percent of all Namibia's export in 2008 was due to agricultural products. In 2015 the exports of agricultural products accounted for 43 percent of the total exports (NSA, 2015). Vast majority of the population directly or indirectly depend on agriculture. The Namibian population at large has a large number of people that are rural dwellers. About 70 percent of these rural dwellers depend on agriculture for sustenance (UNEP, 2012). The agriculture sector is a major contributor to employment. It employs about twenty-seven per cent of the country's work force and fifty-eight per cent of the workforces in the rural areas (UNEP, 2012). Nevertheless, there has been a declining trend in productivity and often the practice is seldom sustainable.

In 2013, a report by the World Food Programme on food security in Namibia indicated that crop production was threatened by continued drought. Consequently, a significant drop in cereal output was recorded in 2015. Maize production fell by 73% from the above average yield in 2014. Production of sorghum and millet also decreased by 60 and 65 per cent respectively (Food and Agriculture Organisation (FAO), 2015). This resulted in food shortages, leading to about 30% of households adopting survival strategy of reducing the number of their food ration to one meal per day (FAO, 2015). This led to reduced availability and reduction in dietary diversity to about 46% among the households (Emergency Food Assessment in Communal and Resettlement

Areas of Namibia (EFA), 2013). As a result, an estimated number of 330 925 people were found to be food insecure (EFA, 2013).

The major challenge in the new millennium is how to improve agricultural productivity. This is because the improvement of agricultural productivity is an important tool towards increasing household food security and alleviating rural poverty (Owour, 2000). Although Namibia has made great strides to achieve key milestones towards eradicating poverty and hunger as per the Millennium Development Goal, there are still challenges in terms of food insecurity and malnutrition (United Nation Partner Framework (UNPAF), 2014). More effort is required for total eradication of poverty and food insecurity. In this regard, the key area of intervention is to enhance efficiency and productivity growth, make land available to the poor through land reform and maximize the potential of available land through the use of improved soil fertility, and the adoption of technical innovations that enhance technical change (UNPAF, 2014).

These landmarks are currently not achieved under the Traditional Agricultural (TA) system where little available land is marginally utilized, resulting in soil degradation and decline in productivity. In the wake of this situation, there is a need to re-think about the best way of utilizing land potentially. Amongst other, agricultural practices that inculcate the principle of conservation have recently been adopted. This type of practice is called Conservation Agriculture (CA). It is a type of agricultural practice that aims to improve efficiency and productivity by virtue of preventing loss or damage to the soil and soil components, thereby enhancing the preservation and careful management of the environment and of natural resources such as land.

It is against this backdrop that this study adopts Conservation Agriculture (CA) in a small-scale pearl millet farming community in the Northern Communal Area of Namibia. This practice is adopted for this study because it is good to establish the real fact about low agricultural productivity; perhaps, the problem is not in the entire system but in the cultural practice itself. The CA method has been adopted in many countries for several years but is not widely adopted in most developing countries such as Namibia. It has been applied in some parts of Zambia and found to be useful in improving soil fertility and crop production as well as household food security (Haggblade, Tembo & Donovan, 2003). The main aim of this study is therefore, to test whether the application of CA is a better option compared to traditional way of farming in Namibia in the quest to improve productivity of rural farming communities. In this research, Pearl millet locally known as "*Mahangu*" will be used in the CA evaluation, particularly comparing its yield to that of the traditional method.

Pearl millet is a choice for this study because of its several attributes; (a) it is a major staple crop for the people residing in the study area constituting about 50% of the country's population, (b) it can adapt well in harsh climate, (c) it is high yielding and can produce larger yield for home consumption (Uno, 2005) and (d) it is tolerant to diseases (Uno, 2005). Pearl millet in its different processed forms is an important staple food providing significant amounts of nutrients particularly, calories, roughage and protein and is consumed by many households in Namibia as a thick porridge. It can be baked into bread as well as fermented for traditional drink (Ministry of Agriculture, Water and Forestry, (MAWF), 2009). Occasionally it is processed into finished products such as biscuit as part of promoting its use along the value chain. In other words, enhancing its value chain development might contribute to productivity increases and job creation. The question is how efficient are the farmers in the production of mahangu?

The measurement of farm efficiency is an important area of research both in the developed and developing world (Olayemi 2002, Kareem, Dipeolu, Aromolaran & Samson 2006). These researchers affirmed that at least 73% of all rural Africans are small-scale farmers. In spite of this, most of the food requirements are still not being met from local production, suggesting that policy interventions should focus on production efficiency. Increasing production efficiency is an important factor for productivity growth and it will be a viable option in the developing countries where resources are scarce (Kibaara, 2005).

While considering farmers' efficiency, one other element is to examine their willingness to pay for extension services because the CA techniques that are investigated in the study are currently offered by an Non Governmental Organisation (NGO) in the study area. In future farmers might be charged a premium for such service. Therefore, the study assesses the Willingness to Pay (WTP) for extension services to be offered in the future by CA service providers. The WTP is a strong research approach that involves the targeted clients for potential services in establishing the preferences of the services proposed and the value the respondents are ready to pay (Oladele, 2008). In agriculture, WTP studies have been used to evaluate demand and cost curves for extension services delivery through commercial agents (Oladele, 2008). A similar approach will be adopted in this study because the extent to which the farmers are willing to pay for extension services has not been conducted in this field of study in Namibia. The study is important because the outcome will aid policy makers and stakeholders towards the generation of pool of knowledge about farm practices that are optimal and can maximize land use. This will form important anecdote to the mandate of the national development plans (Mushunje, 2005).

1.2 Problem Statement

Pearl millet is the dominant staple crop grown in most parts of Namibia. It has good drought resistance characteristics, can survive high temperatures and does well in sandy soils (Uno, 2005). However, recurrent droughts and floods cause harvests to fail, in addition, other constraints such as out-dated agricultural techniques contribute significantly to low yield. As a result, production is steadily declining. During the period from 1990 to 2000 a low yield of 230 kg/ha of pearl millet was produced (Mallet and du Plessis, 2001). The six-year average cereal yield assessed in the period 2001 – 2008 did not show any significant improvement as the production was 265 kg/ha. Pearl millet yields in Namibia are considered to be the lowest in the world and have not risen above 400 kg/ha in twenty years (MWAF, 2013). Despite being the major crop grown in most parts in the northern regions, about 42,800 tonnes of it was imported in 2012 (NAB, 2013). The low pearl millet yield often results in the demand for food relief from the Namibian government. In 2008, the government provided six months of food relief to the value of N$ 228 million. In a similar situation, in 2013 more than 300,000 Namibians received food relief from the government (MAWF, 2015).

It is forecasted that progressively more erratic weather is eminent due to climate change, making rainfall events more uncertain with an overall reduction in precipitation of up to 30% (Midgley *et al.*, 2005; Rowswell and Fairhurst, 2011**)**. The uncertainty in the weather conditions increasingly puts farmers at risk, especially against the backdrop of already very low yields. Input subsidy schemes have failed to provide the needed leverage. For instance, the government attempts to subsidize inputs have not resulted in productivity growth as there has been low yields over years (MWAF, 2009). In spite of the government policy support programmes and the technological advancement in agriculture (such as breeding, seed development, machinery, pesticides etc.), agricultural productivity still remains constrained (Wall, 2007). It is argued that low agricultural productivity (besides the impacts of the erratic weather patterns) is due to the high reliance on use of traditional farming practices (FAO, 2009). These practices include, improper tilling, planting and fertilizing. Other practices include; farmers' adoption of disc ploughing thus, pulverising the soil and exposing it to adverse effects of degradation hence affecting soil fertility and crop yield (Uno, 2005). The other challenge is an inadequately funded extension service which is essential for the grass root delivery of agricultural services. Therefore, there is a very large scope and need for the CA method as a solution to low crop productivity.

1.3 Justification for the study

Conservation Agriculture is believed to offer a simple and effective solution to low crop yields and helps farmers cushion the effects of climate change therefore, it is worth investigating. There is need to understand how efficiency, productivity, and farm-specific benchmarks can be achieved by adopting CA. In-so-doing, comparisons can be made among the various benchmarks and the specific factors influencing their performance can be identified. This will be useful for policy makers in projecting growth and productivity target.

1.4 Research Objectives

The main objective of this study is to evaluate the performance of Conservation Agriculture (CA) in five regions in Namibia - particularly comparing productivity of Pearl millet under CA and traditional farming. The sub-objectives are:

- i To examine the socio-economic characteristics that influence technical efficiency of small scale pearl millet farmers.
- ii To examine farmers' willingness to pay (WTP) for extension services rendered through CA service providers.

1.5 Limitations of the study

The study was part of a short CA project operational in the study area; this resulted in the impact of CA not being experienced over a longer period of time. Furthermore, the measurement error was also a factor as fertiliser and seeds were administered or applied manually. The trials were threatened by unfavourable climatic conditions (continuous dry spell) which had impacted crop growth and yields.

1.6 Study Outline

The rest of the paper is structured as follows: Chapter two provides literature review on the subject of CA vs TA application. Chapter three presents the general overview of the agricultural sector in Namibia. Chapter four gives the data and methodology used in the study. This chapter also gives a detailed profile of the study area where the study was conducted. The fifth chapter presents the empirical results of the study and discussion. Chapter 6 provides the conclusions and recommendations based on the outcome of the study. The last section encompasses the list of references cited in the study as well as the appendices.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter introduces the reader to the basic and overall concept of Conservation Agriculture. In addition, it presents the key findings in the literature of studies that applied CA vs TA. The empirical findings on production efficiency are also reviewed. An assessment of farmer's willingness to pay for extension services is also reviewed in this section. This section also discusses the differences between CA and TA methods, the role of CA in sustainabe agriculture as well as the relationship between CA and farmers' livelihoods.

2.2 The concept of Conservation Agriculture

Conservation Agriculture (CA) is a set of cropping principles aiming at sustaining high crop yields with minimum negative consequences for the resource-base such as water, soil, and surrounding natural environment (Hobbs, Sayre & Gupta, 2008; Gowing & Palmer, 2008). It is defined as the simultaneous cultivation of crops with application of minimal soil disturbance, permanent soil cover through a mulch of crop residues or living plants, and crop rotations (online citation from www.fao.org/ca). The CA has received increasing attention in sub-Saharan Africa as a means to increase food security and minimizing environmental degradation, particularly in sub-humid and semi-arid areas that are characterized by frequent droughts and dry spells (Hobbs et al, 2008).

Conservation Agriculture is also referred to as conservation tillage, no-tillage, zero-tillage and direct seeding/planting (Hobbs et al., 2008). However it should be noted that, although the two concepts of conservation agriculture (CA) and conservation tillage (CT) are often used interchangeably, conservation tillage may include some of the principles of CA but has more soil disturbance resulting in the failure to maintain a permanent or semi-permanent soil cover (Hobbs, 2006). Most importantly, CA should not be viewed as meaning just less soil tillage but be understood as a holistic system with interactions among households, crops and livestock

(Hobbs, 2006). Each principle of CA is linked to a specific purpose. The two principles of permanent soil cover and minimal soil disturbance ensure soil and water conservation and the control of soil erosion (Hobbs et al, 2008). Increased soil biological activity, biodiversity and enhanced soil carbon sequestrations are facilitated by crop residues and cover crops that are also embedded in the permanent soil cover (Derpsch, 2005). The principle of minimum soil disturbance targets minimum soil aggregation (Hobbs, 2007). Crop rotation is another form of CA. It is associated with the promotion of soil structure thereby reducing pesticide and herbicide requirements, environmental pollution as well as complementing natural biodiversity (Derpsch, 2005; Hobbs et al., 2007).

2.3 Conservation Agriculture in Namibia

Conservation Agriculture was first introduced in Namibia by a project called Conservation Tillage (CONTILL) dating back to 2005 after the Ministry of Agriculture, Water and Forestry realized that something has to be done to improve national Pearl millet and other dry land crop yields (NAB, 2012). This project operational in Omusati region was jointly facilitated by the Namibia National Farmers Union (NNFU), Namibia Agronomic (NAB) and Namibia Resource Consultants (NRC). The trial project involved farmers who applied CA methods among others planting basins which emerged as the farmers' preferred choice. In 2008, the CONTILL project received financial assistance from the European Union (EU) and thus expanded its operations to other northern regions. Having left a number of beneficiaries aware of various CA methods, the project ended in 2011 (NAB, 2012).

The UNDP Community Based Adaptation Pilot Project of 2009 got involved in CA in collaboration with CONTILL to implement CA in climate vulnerable areas. However, a question of sustainability with continuation proceedings existed until the Namibia Conservation Agriculture project (NCAP) came on board and took over where CONTILL had left off to continue with CA promotion within northern communities in 2012 (UNPAF, 2014). The project was USAID funded and implemented by CLUSA International in collaboration with a local Non-governmental Organisation (NGO), Creative Entrepreneurs Solutions (CES) which operated in regions such as Oshikoto, Ohangwena and Omusati. This project utilized Self-Help Groups

(SHGs) to raise awareness and adoption of CA methods through peer-to-peer learning on both the NSCT and Hand-Hoe Basin methods. Moreover, they created a model of assisting private farmers to have access to financial assistance in the procurement of tractors and ripper implements (NCBA, 2012).

The NSCT method adopted under the initial CONTILL project was developed in conjunction with farmers, the University of Namibia and Baufi Agricultural Services who designed the tilling implements (National Cooperative Business Association (NCBA), 2012). The method draws on a specialized ripping attachment for tractors and animal drawn ploughs that were developed through the project to suit local conditions. From a random experiment, it was evident from the project that the national pearl millet yield of 230 kg/ha could be improved to 1500 kg/ha through the use of NSCT method (NCBA, 2012). It can be concluded that, out of these few projects no standard research study has been conducted with enough sample size to examine comparisons in yields on CA vs TA methods.

Lately in 2014/2015, an EU donor funded project implemented by Conservation Agriculture Namibia (C.A.N) in collaboration with Namibia Resource Consultants (NRC) piloted CA farm level trials in communal areas of Oshana, Omusati, Ohangwena, Oshikoto, Kunene, Kavango East and West (Shamathe, 2015). The project offered support to a reasonable number of 360 beneficiaries. They provided trainings to the first time CA participant farmers and offered each of the beneficiaries a courtesy of free 0.5 hectare land preparation services together with seeds and fertilizers (Shamathe, 2015). The beneficiaries of this ongoing project are the target population for this study hence the outcome will manifest in the expected results from this research. This project has adopted the converted NSCT which is now called Namibia Specific Conservation Agriculture (NSCA) and is based on the methodology outlined in Table 2.1 below (Namibia Resource Consultants, 2015).

Table 2.1: Namibia Specific Conservation Agriculture Methodology

Practice	Technique
Land preparation	Ripper furrowing which simultaneously rips to 30cm to shatter the hard plough pan for deeper root development whilst at the same time forming furrows for in-field water harvesting thus increasing moisture in the base of the furrow by 75% [300mm p/a to 525mm]
Fertility Management	Manure is applied in the furrow at the rate of 5ton/ ha or 20 kg per 10 metres Mono-ammonium phosphate can be applied as a top-dressing
Soil moisture conservation	The furrowing water harvesting element mentioned above also lengthens the season meaning that longer season and higher yielding indigenous millet varieties can be used and also that the effects of mid-season drought is mitigated
Land degradation control	The above measures serve in soil degradation reversal provided farmers can be persuaded not to allow crop residues to be removed by livestock
Crop associations	crop rotations, crop legumes
Use of appropriate seed varieties	For millet indigenous varieties are best in the NSCA system as is 402 short season drought resistant maize seed ex Zambia

Source: Namibia Resource Consultants (2015)

The role of the NGOs in CA projects is widely acknowledged as they provide technical and administrative support to the partner implementing agencies and farmers on these technologies (MAWF, 2015). Conservation Agriculture Namibia (C.A.N.) grant this kind of support to Agricultural Cooperatives while CES plays a role in linking farmers to financial institutions for buying tractor implements as well as trainings. Above all, this improves the socio–economic wellbeing of the vulnerable communities in the northern regions. The Government of Namibia also has a significant role in the support and the promotion of this intervention, having realized the importance of CA, the government included the promotion of CA in the related polices among them the "National Climate Change policy for Namibia" as well as developing the Comprehensive Conservation Agriculture Programme (CCAP) for 2015 – 2019 (MAWF, 2015). Through this programme, the government advocates for and encourages the implementation of CA through the Ministry of Agriculture, Water and Forestry (Government of the Republic of Namibia, 2015).

2.4 Advantages of Conservation Agriculture

Conservation Agriculture is relatively new to the southern Africa region, however, FAO, (2013) embarked on an evaluation of this technique and outlined its advantages and disadvantages as follows;

(a) The primary advantage is its yield potential. In Zimbabwe in 2005/06, Concern Worldwide, an Irish NGO, found that 133 farmers practicing Conservation Agriculture had an average maize yield of 2.8 tonnes/ha, with a range from 1.03 to 4.71tonnes/ha, while other farmers in the same area had average yields of 0.8 tonnes/ha.

(b) Building up the soil organic matter also retains nutrients and improves the micro-flora in the soil, a vital component of living soil.

(c) Soil organic matter can hold many times its weight in water, therefore building up the organic matter in the soil results in greater water retention. One farmer practising Conservation Agriculture in KwaZulu Natal in South Africa found that his field can withstand irrigation of up to 20mm per hour, whereas fields under conventional tillage absorb 4-5 mm per hour of irrigation water without run-off. This reduces labour and fuel-use and also reduces wastage of irrigation water.

(d) When soil organic matter is built up through Conservation Agriculture, applied fertilizers work better.

(e) Different crops have different root structures – some have deep tap roots and others have fibrous roots at the surface. Through crop rotation, organic matter is placed in different soil strata, thereby making the soil more fertile.

(f) Other benefits include reduced labour, time, farm power, lower production costs as well as diversified enterprises. These factors all lead to higher profits.

2.5 Disadvantages of Conservation Agriculture

According to FAO (2013), Conservation Agriculture is generally a win-win situation, but that does not mean there are no difficulties. It requires a major change in mind-set of farmers which under normal circumstances takes a long time. CA requires high initial costs of specialized planting equipment and the completely new dynamics of a conservation farming system, requiring high management skills and a learning process by the farmer.

2.6 Limitations of Conservation Agriculture

2.6.1 Challenges of practising Conservation Agriculture

(a) *Understanding the system:* Conservation agriculture is a much more complex system than Traditional Agriculture. Site specific knowledge has been the main limitation to the spread of CA system (Derpsch, 2001). Managing these systems efficiently will be highly demanding in terms of understanding of basic processes and component interactions, which determine the whole system performance.

(b) *Technological challenges:* The basic principles which form the foundation of conservation agriculture practices (that is, no tillage and surface managed crop residues), as adoption under varying farming situations is a key challenge (Hobbs, 2007). The major challenges of CA stem from development, standardization and adoption. Others are developing crop harvesting and management systems.

(c) *Site specificity:* The CA practices are highly site specific, yet learning from cross-section of sites is a powerful way of understanding why certain technologies or practices are effective in a set of situations and not effective in another (Derpsch, 2005). This learning process accelerates the building of a knowledge-base for sustainable resource management.

(d) *Long-term research perspective:* The CA practices, e.g. no-tillage and surface maintained crop residues result in resource improvement only gradually, and benefits come about only with time. Indeed in many situations, benefits in terms of yield increase may not come in the early years of evaluating the impact of conservation agriculture practices (Abrol and Sangar, 2006). Understanding the dynamics of changes and interactions among physical, chemical and biological processes is basic to developing improved soil-water and nutrient management strategies (Abrol et al, 2006). Therefore, research in conservation agriculture must have longer term perspectives.

2.6.2 Challenges of Conservation Agriculture in Namibia

(a) *The widespread use of crop residues for livestock feed and fuel:* Under rain fed situations, farmers face a scarcity of crop residues due to less biomass production of different crops (NAB, 2012). There is trade-off between the use of crop residue for CA practice and for livestock feeding. This is a major constraint for promotion of CA under rain fed situations.

(b) *Food preferences:* Farmers often would prefer monoculture in order to plant as much larger quantity of the preferred staple as possible, thereby ignoring crop rotation which is one of the principles of CA. As a result the CA may not be a popular option in such areas (MAWF, 2013).

(c) *Lack of knowledge about the potential of CA:* In areas where the concept of CA is not known, its practice is limited.

(d) *Skilled and scientific manpower:* Managing conservation agriculture systems, will call for enhanced capacity of scientists to address problems from a systems perspective and to be able to work in close partnerships with farmers and other stakeholders. Strengthened knowledge and information sharing mechanisms are needed (NAB, 2012).

(e) *Fencing:* Farmers in the region usually do not fence their land, which allows cattle and other livestock to roam freely, grazing and destroying crop residues. This makes it more difficult for farmers to meet the year-round potential soil cover for CA (MAWF, 2013).

2.7 Differences between Conservation and Conventional Agriculture

Conventional agricultural practices are the traditional way of crop production. In intensive production systems farmers do practise tillage which disturbs the soil without considering the soil fertility improvement strategies (Hobbs, 2007). The practice does not conform to the key principles of the conservation agricultural practice like minimum soil disturbance, permanent residue soil cover and crop rotation (Hobbs, 2007).

In conservation agricultural practices, the minimum soil disturbance is a key principle by which farmers do not disturb soil in their production systems. According to Kassam *et al.* (2009) the disturbed area must be less than 15 cm wide or 25% of the cropped area. The soil is covered throughout the year by mulching and the cover crops like lablab and beans. Also Conservation Agriculture systems demand the adoption of crop rotation as a way to reduce external inputs for increasing soil fertility and control of pests and diseases.

2.7.1 Role of Conservation Agriculture in Sustainable Agriculture

Food production needs to keep pace with demand and the productivity of the land. This will enable the preservation of land as a natural resource for future generations. According to Hobbs

(2007), crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources and with minimal impact on the environment. Conservation agricultural practice is essential in sustainable agriculture since it involves crop and soil management systems that help improve soil health parameters (physical, biological and chemical) and reduce farm costs (Thiefelder et al, 2010). The improvement of the soil nutrient enables farmers to produce more crops from the small piece of land (Hobbs et al, 2008).

2.7.2 Conservation Agriculture and sustainable farmers' livelihood

In northern Namibia, agricultural production has decreased due to unreliable rainfall and poor soil fertility leading to a decline in yields and growing food insecurity amongst communal farmers (MAWF, 2015). The decline in yields lead to negative impacts on the livelihoods of communal farmers including decreased food that can be taken by a person and a lack of income to invest in assets such as farm inputs, education for children and household improvements (MAWF, 2015). This limits a household's ability to improve their livelihoods and increase the level of poverty and vulnerability amongst communities.

2.7.3 Conceptual Model, theory and practice of Conservation Agriculture

A conceptual framework provides understanding of the theoretical relationships between important variables and the economic performance of the agricultural practices (Hobbs, 2007). In Fig. 1 the variables such as knowledge and information on agricultural practices, farmers' attributes and farm enterprises influence the perception on conservation agricultural practice. The perception on conservation agricultural practice leads either to the uptake or rejection of the conservation agricultural practice (Hobbs, 2007). The uptake of conservation agricultural practice may lead to increase in crop yields, increase in cost and labour savings, and improvement in soil fertility and diversification of enterprises. The non-uptake of it may lead to decrease in crop yield, decrease in cost and labour savings, decline in soil fertility and non-diversification of enterprises (Derpsch, 2005).

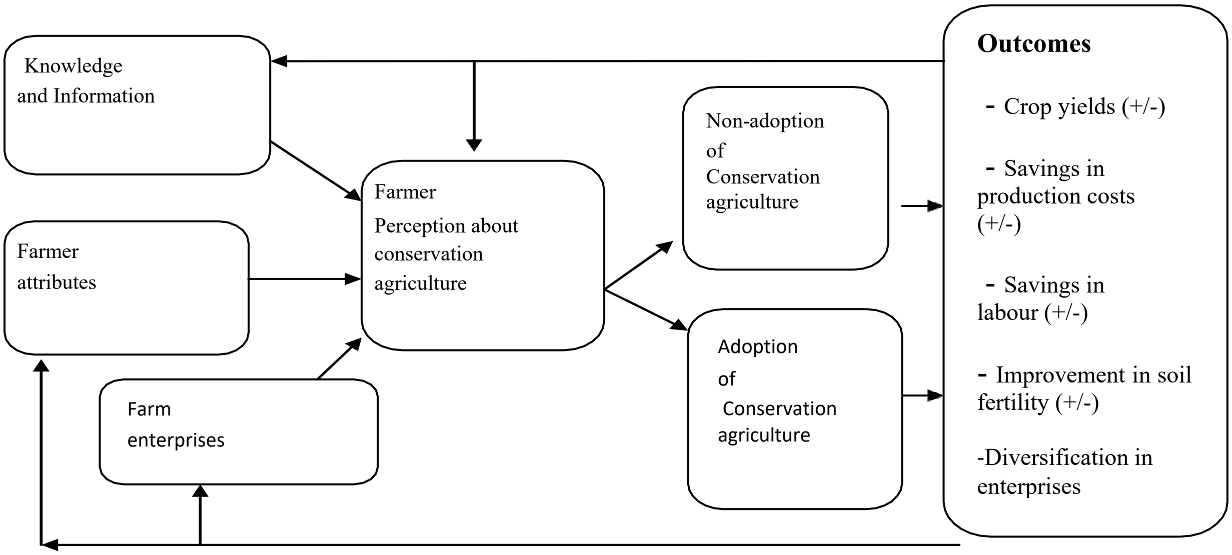

Figure 1: Conceptual framework for Conservation Agriculture practices (Hobbs, 2007)

2.8 Modelling of CA production efficiency

Efficiency is the ability to produce a given level of output at the lowest cost (Padilla-Fernandez and Nuthall 2001). Efficiency can be divided into two concepts, the technical and allocative efficiency. Technical efficiency is the ability of the farm to produce a maximum level of output given a similar level of production inputs. Allocative efficiency literally can be defined as generating of output with the least cost of production to obtain maximum profits (Chukwuji, Inoni, Ogisi & Oyaide, 2006). Economic efficiency is a product of both allocative and technical efficiency and it is achieved when the producer combines resources in the least combination to generate maximum output (Chukwuji, et al., 2006). Therefore, for increased productivity and profitability, farmers need to improve on the management practices through training and transfer of knowledge and skills from less to more efficient farmers or an increase on the adoption of new available technologies (Padilla-Fernandez and Nuthall, 2001).

Studies under review for Ghana and Nigeria indicate a negative relationship between small scale farmer's technical efficiency and extension service. Expectedly, it would be that an increase in access to extension would increase efficiency; however this may be attributed to the poor extension service rendered to farmers due to unqualified technical personnel (Sienso, Amegashie & Asuming, 2013; Jirgi, Jordaan, Viljoen & Nmadu, 2015). In a case study in Kenya, farmers with high education, smaller off-farm income, that are young and not using tractors were found to be technically efficient. While, in Uganda higher education, bigger household, group membership, location, improved varieties had a positive and significant impact on technical efficiency (Diiro, 2013). Other factors indicated to have a negative relationship on farmer technical efficiency include education, rotational practices, experience and seed type in Zambia and Ghana. This may be due to the fact that farmers take farming as a secondary activity. Among other factors showing a negative relationship are hired labour and rotation practices. However the importance of these two variables cannot be over-looked. This is because additional knowledge may be gained through shared experience from hired labour while intercropping may increase chances of pest/disease and weed control (Musaba & Bachwa, 2014).

Using Cobb Douglas production function, Musaba & Bwacha (2014) found out that land size and fertilizer were significant factors that affected production yield while seed quantity and labour gave opposite results. The results of this study are in agreement with the study done on small scale farmers of Gamothiba area in South Africa, where land and fertilizer exhibited a positive relationship with yield attained while capital, seed quantity and labour did negative influence (Baloyi, 2011). This study will similarly adopt the model and variables used in the Gamothiba study in modelling the production function in Namibia.

Table 2.2: Summary results of the empirical literature studies

Analyst	Year	Variables/Findings	Significance	Model	Country
Diiro	2013	1. Household size (+) 2. Production year (+) 3. Group membership (+) 4. Location (+) 5. Improved variety (+) 6. Education Level (+) 7. Gender (-) 8. Farm size (-) 9. Drought (-) 10. Market type (-)	1. Yes 2. Yes 3. Yes 4. Yes 5. Yes 6. Yes 7. No 8. No 9. No 10. No	SFA	Uganda
Geta, Bogale, Kassa & Elias	2015	1. Agro ecology (+) 2. Oxen holding (+) 3. Farm size (+) 4. Improved varieties (+)	1. Yes 2. Yes 3. Yes 4. Yes	DEA	Ethiopia
Musaba & Bwacha	2014	1. Age (+) 2. Cooperative member (+) 3. Farm size (+) 4. Seed type (-) 5. Rotation practices (-)	1. Yes 2. Yes 3. Yes 4. No 5. No	SFA	Zambia

		6. Education level (-) 7. Hired Labour (-)	6. No 7. No		
Kibaara	2005	1. Education (+) 2. Age (-) 3. Health (-) 4. Gender (-) 5. Tractor use (-) 6. Off farm income (-)	1. Yes 2. No 3. No 4. No 5. No 6. No	SFA	Kenya
Jirgi, Jordaan, Grové, Viljoen & Nmadu	2015	1. Education (-) 2. Credit (-) 3. Age (+) 4. Farm experience (+) 5. Extension (-)	1. No 2. No 3. Yes 4. Yes 5. No	DEA	Nigeria
Sienso, Amegashie & Asuming	2013	1. Improved variety (+) 2. Gender (-) 3. Experience (-) 4. Extension (-)	1. Yes 2. No 3. No 4. No	SFA	Ghana

The studies in Table 2.2 used both parametric and non-parametric methods to measure technical efficiency of farmers. Technical efficiency can be measured using both parametric (stochastic frontier estimation (SFA)) and non – parametric (Data Envelopment Analysis (DEA)). According to Ogundele and Okurwa (2006) stochastic frontier is where the deviation from the frontier is attributed to the random component reflecting measurement error and statistical noise and an inefficiency component. On the other hand, Kibaara, (2005) indicated that DEA is based on the notion that a production unit employing less input than another to produce the same amount of output is more efficient. The DEA approach applies the linear programming method where a series of equations are used to construct linear production frontiers.

The DEA gives allowance for comparing different production frontiers in terms of a performance index and also allows for freedom of determining efficiencies of the sub vectors. On the other hand, a major challenge faced by DEA is that it is a deterministic approach, meaning that it does not account for noise in the data; this means DEA efficiency scores are likely to be sensitive to measurements errors and random errors. The fact that in DEA no functional form for the frontier needs to be specified, has the disadvantage in that there is no definition of goodness of fit that would enable comparison of different models (Sarafidis, 2002). Moreover, in DEA, any deviation from the frontier is treated as inefficiency and there is no provision for random shocks. On the other hand, the SFA model explicitly allows the frontier to move up or down because of random shocks.

In this study, stochastic frontier analysis (SFA) was applied because of its advantages over the DEA. It is computationally simple and easy to interpret. The SFA specification separates the error component into technical inefficiency and stochastic effects. It is also able to estimate the production and technical inefficiency simultaneously (Ogundele et al, 2006). These models allow for technical inefficiency, but they also acknowledge the fact that random shocks outside the control of producers can affect output (Kumbhakar and Lovell, 2004). Moreover, farms are mainly small units, family-owned and subsistence, so farm records are not kept properly for example seed/fertiliser quantities. Thus available data has a high probability of having measurement errors.

The stochastic frontier approach (SFA) is based on the idea that an economic unit may operate below its production frontier due to pure errors and some uncontrollable factors (Margono and Sharma, 2004). Ogundele et al (2006) state that, SFA has a random term to account for statistical noise such as weather, in the production process which is beyond the control of the farmer. In particular, it requires separate assumptions to be made as to the distributions of the inefficiency and error components, potentially leading to a more accurate measure of relative efficiency. The main strength of the stochastic frontier function approach is its ability to measure efficiency in the presence of statistical noise and incorporate the stochastic error (Margono and Sharma, 2004). Sarafidis (2002) reported that SFA application is likely to be appropriate where random influences and statistical noise are perceived to heavily influence the data.

2.9 Production Functional forms

The commonly used functional forms for modelling production frontier are the Cobb- Douglas model, the Translog model, the Semi log model, and the quadratic forms (Musaba et al, 2014, Chiona, Kalinda & Tembo, 2014).

According to Delgado, Narrod, Tiongco & Baros (2008) a translog and quadratic forms has been widely because of the flexibility they offer in estimating parameters where it is not desirable to build in through model specification rigid assumptions about substitution relationships among inputs and factors. However, the translog and quadratic functional forms has a limitation when used in incidences of multicollinearity as experienced in Bahta & Baker (2015). The Cobb – Douglas production function has also been widely used by many researchers in production frontier studies including Bahta & Baker (2015), Musaba & Bwacha, (2014). This functional form has a number of limitations with major critics directed to the fact that it cannot represent all the three stages of Neo classical production function, signifying only one stage at a time. Secondly, the elasticities are constant irrespective of the amount of inputs used. However, despite this shortcoming the Cobb – Douglas function is used mostly for its mathematical simplicity and that it has a limited effect on the empirical efficiency measurement. It is also not exclusive to labour and capital but to other variables as well (Battese & Coelli, 1995). In addition, it is linear in its logarithm form, allows for incidences where multicollinearity may be experienced and also provides an adequate representation of the production technology. Based on its good features, this study adopts Cobb-Douglas model.

2.10 Modelling willingness to pay (WTP)

The phrase "willingness to pay (WTP)" connotes a research approach that involves the investigation of consumer preferences for a proposed service and the value they are ready to attach to the service (Oladele, 2008). This study used a probit model for the analysis of willingness to pay. According to Nagler (2002), probit model constrains the estimated probabilities to be between 0 and 1 and relaxes the constraint that the effect of the independent variable is constant across different predicted values of the dependent variable. This is normally experienced with the Linear Probability Model (LPM). The probit model assumes that while we only observe the values of 0 and 1 for the variable Y, there is a latent, unobserved continuous variable Y* that determines the value of Y. The other advantages of the probit model include moderate assumption about the error term distribution as well as realistic probabilities (Nagler, 1994).

Oladele (2008) examined the factors determining farmers' willingness to pay for extension services in Oyo state, Nigeria. Specifically the services farmers are willing to pay for were identified and how much farmers are willing to pay for such services were determined. Using frequency counts, percentages and Probit regression model for analysis, the results showed that 30 percent of the respondents are willing to pay for extension services and these services include providing information to women farmers, identifying rural problems, trainings and liaison with farm machinery. The Probit regression model showed that farmers' age, gender, educational level ,farm size, farming experience, land tenure, income, and proportion of crops sold are significant determinants of farmers willingness to pay for extension services. The study recommends that these variables are given proper policy consideration in the design and the implementation of a workable fashion of towards privatization of extension services.

In Uganda, Mwaura, Roland, Muwanika and Okoboi (2010) examined willingness to pay for extension services and factors that influence willingness to pay among crop farmers. Probit regression model was fitted to assess the factors that may be associated with willingness to pay (WTP) for the extension services stratified by agricultural activity. The results show that about 35% and 40% of the farmers were willing to pay on average Ugandan shillings 3,400 (US$ 1.8) for services. Key farmers' attributes that influenced willingness to pay included sex, age, education level, regions of residence and preferred means to receive the services. This study adopts the same modelling frame work used in these studies to evaluate factors that influence the willingness to pay of farmers.

2.11. Conclusion

In this study, stochastic frontier analysis model and decision choice probit model are adopted. The results will inevitably assist policy makers with information not only on the impact of CA on yields but also on the measurement of farmers' technical efficiency, and the CA adoption policy influenced by farmers' willingness to pay for improved technology. The identified models in this research are very suitable for reaching conclusions about resource usage at farm level and adoption of the right technology that enable deriving answers regarding production capacity over the long run.

The significant yield benefits under CA in Southern Africa are possible under different Conservation Agriculture management systems. Furthermore, the success of its implementation will however largely depend on addressing the challenges observed in the field, which will be an iterative participatory process with farmers to find local solutions and to adapt CA system to the site and farmer circumstances (Thierfelder and Wall, 2010).

CHAPTER 3

BACKGROUND OF THE INDUSTRY

3.1 Introduction

This section gives the general overview of the grain industry in Namibia that includes production, marketing system of the industry and contribution of the grain to the food security situation of the nation aligned to this study. In addition, limitations facing the industry are discussed.

3.2 Background on cereal production in Namibia

The commercial farming sector constitutes approximately about 4200 farmers and occupies 44% of the arable land, whereas communal farmers account for 41% of the agricultural land and are estimated to make up 67 % of the total population, 90% of whom are dependent on subsistence agriculture for their livelihood (Teweldemedhin and Kapimbi, 2012). Despite the fact that the cereal sub-sector on average contributes around 7% of the total agricultural output, it is important in terms of its contributions to food security and export earnings (Ministry of Agriculture Water and Forestry (MAWF), 2010). This sector is sensitive to climate variability and change whereby yield tends to oscillate accordingly. Only 2% of the country's total surface area is regarded as arable, whereas about 46% is suitable for permanent pasture, 22% is forest and the rest arid (Iita, 2012).

Crop farming takes place in communal and commercial areas, with the production largely dependent on rainfall. Even though the Northern part of the country receives higher rainfall, where majority of communal farmers reside, their productivity remains stagnant compared to the commercial sector. Average grain yields in communal agriculture are estimated at around the 0.5 - 0.55 t/ha while yields in the commercial sector which includes both dryland and irrigated cereals is on average estimated at 3.87t/ha and 12t/ha respectively (Ministry of Agriculture Water and Forestry, (MAWF) 2010).

Pearl millet and wheat are produced in the North east, west and central regions while dry-land maize is planted in the following areas: Maize Triangle (Otavi–Grootfontein–Tsumeb area), Otjizondjupa Region (Hochfeld, Otjiwarongo), Omaheke Region (Gobabis and Summerdown) and Zambezi and Kavango Regions, (Namibia Agronomic Board (NAB), 2011). Irrigation is possible only along the perennial rivers on the northern and southern borders and where dams feed irrigation schemes. Since Namibia is mainly characterized by summer rainfall, wheat as a winter crop is exclusively planted under irrigation and only small portions of land are cultivated each year (Iita, 2012).

3.3 Marketing of grain in Namibia

In Namibia, maize, millet and wheat are classified as controlled crops. This implies that the boarders are closed during the marketing of these products and no import permit are granted for grain imports during certain period of time (that is from June to October (NAB, 2011). This prevents domestically produced grain from competing with imports from countries where there are subsidies or low-cost production.

For the production period, 2012/2013 a total of 72,438 tonnes of maize was marketed locally, followed by Wheat and Millet at 14,819 and 1,136 tonnage respectively. In spite of this, Namibia still faces a challenge of shortages of local production leading to the import of the majority of food for consumption. Earlier in 2013 marketing period over 130,000 tonnes of maize were imported from South Africa followed by 3,863 tons of millet imported. Annually, Namibia needs about 185,000 tons of millet and maize to meet its consumption demands (NAB, 2013).

3.4 Challenges on Namibian grain industry

National Agricultural Policy aims to sustain and increase farm productivity to ensure food security in the nation yet years after adoption of the development strategies, there is still food shortages. The annual report of Namibian Agronomic Board (2006) listed the following challenges facing the grain industry in Namibia:

- Climatic condition: floods and droughts are of common occurrence that make the country depend more on importation for grain requirements.

- Poor crop varieties limit yields: farmers still adopt the local varieties used in the past. These local varieties have low yield potential which contribute to low grain production.

- Predominance of fragile ecosystems and low inherent soil fertility as well as poor farming methods. Also, pest and diseases infestation seriously affect grain production.

- High land use conflict between humans and wild life: Since government is promoting tourism, farmers are unable to expand their fields. For subsistence farmers, damage from wild life has become a big challenge, especially in Caprivi.

- High input cost: The commercial farmers are importing all the input materials from RSA. The strong rand makes the production cost very expensive.

3.5 Governement initiative on food security

Namibia's agricultural sector aims to become a more important part of the national economy, as a result the government came up with a number of initiatives to promote food security in the nation. That includes:

i. Dry Land Crop Production Programme (DCPP)
ii. National climate change policy (where Conservation Agriculture is incorporated)
iii. National Strategic Food Reserves programme
iv. Establishment of fresh produce marketing hubs

Dry Land Crop Production Programme (DCPP) aims at increasing crop production under rain-fed by adopting conservation agriculture (CA) practices. In addition, the government assisted the communal farmers by providing subsidised tractor ploughing services, provision of improved seeds, fertilizers, and weeding services under the Youth Employment Scheme. The Programme also aims at improving the level of productivity per unit household and to create employment opportunities (MAWF, 2010).

The second initiative is the National Policy on Climate Change which has Conservation Agriculture (CA) being recently added into its agenda after the government realised its importance as a responsive strategy to drought and rural food seurity (MAWF, 2015). The goal of this policy is to contribute to the attainment of sustainable development in line with Namibia's vision 2030 through strengthening capacities to reduce climate change risk and build resilience for any climate change shocks. The Policy requires a significant improved capacity in adaptation and mitigation measures. Namibia strives for excellence climate change by responding in a timely, effective and appropriate manner through exploring adaptation and mitigation approaches relevant to different sectors at local, regional and national level in order to improve the quality of life of its citizens (Ministry of Environment and Tourism (MET), 2011). In Namibia, economic and social development remain critical, thus the climate change policy seeks as far as possible to promote the primary government objectives, which include job creation, provision of basic services and infrastructure development, alleviation of poverty and provision of housing.

The third government initiative is National Strategic Food Reserves programme established for purposes of guaranteeing food security at national and household level in times of need. Through this, grain from local producers is procured, thereby providing a guaranteed market for local crop growers and storage facilities. These silos are found in cropping areas of Caprivi, Kavango and North central regions with a total storage capacity of 14 000 metric tonnes (Iita, 2012).

Lastly, the other initiative is to improve and strengthen the marketing system of the grain industry. In line with this, the government has developed two national Fresh Produce Business Hubs (FPBH) situated at Ongwediva and Rundu. The estimated total cost of the facility is N$217 million. It has 12 marketing agents facilitating the operational tasks of each site (MAWF, 2010). These two new efficient fresh produce hubs will support all producers, processors, traders as well as consumer needs (Amagola, 2010).

3.6 Conclusion

Considering that Namibia is relying heavily on importation of basic foods, there is a need to promote and intensify local production capacities. Support must be given to the vulnerable small scale farmers in the rural areas, though there is government support through the promotion among others, of Conservation Agriculture and dryland production support programmes channeled through the Ministry of Agriculture, Water and Forestry. More support is needed especially for the small-scale farmers who need to expand production capacity on sustainable agricultural input supply, increased efficiency and productivity.

CHAPTER 4

DATA AND METHODOLOGY

4.1 Introduction

This chapter provides a brief description of the overall methodology, overview of the study area, data collection and analytical techniques employed in the study. It also gives a description of parameters and justifications considered for the models used in the study.

4.2 Overview of the study area

The study was conducted in five administrative regions of Northen Namibia namely; Oshana, Omusati, Oshikoto, Ohangwena and Kavango regions (Figure 2). The selected regions are well suited for this study because their inhabitants derive their sustenance mainly from crop production especially pearl millet which is their major staple food. Drought occurrence in these regions is frequent with a resultant consequence of high vunerability, food shortages and poverty. Also, information regarding the CA practices in these regions is not known and has not been investigated before.

The North Central Namibia comprises of; Oshikoto, Oshana, Omusati and Ohangwena and it is the traditional area inhabited by the Owambo people. The region is characterised by relatively high annual rainfall between 400 and 550 mm during normal years, sandy and loamy soils, large flood plains called 'oshana' and open woodland and shrub land (Mendelsohn *et al.*, 2002; Le Roux and Mueller, 2009). It is among the most densely populated areas in the country. Apart from the urban centers of Ondangwa, Ongwediva, Oshakati and Eenhana most people live in rural homesteads and are reliant on extensive rain-fed agriculture and livestock rearing (Uno, 2005). On the other hand, Kavango (East and West) region is in the North-Eastern part of the country on the border to Angola to the north and in the south-east on the border to the North-West District of Botswana (Mendelson, 2006). The area has sandy soils with excellent drainage.

It has an average temperature of 22.4 degree Celsius and receives an average annual rainfall of about 577mm. Good rains are received during the period of February with an average of 147mm (Ministry of Agriculture, Water and Forestry, 2010).

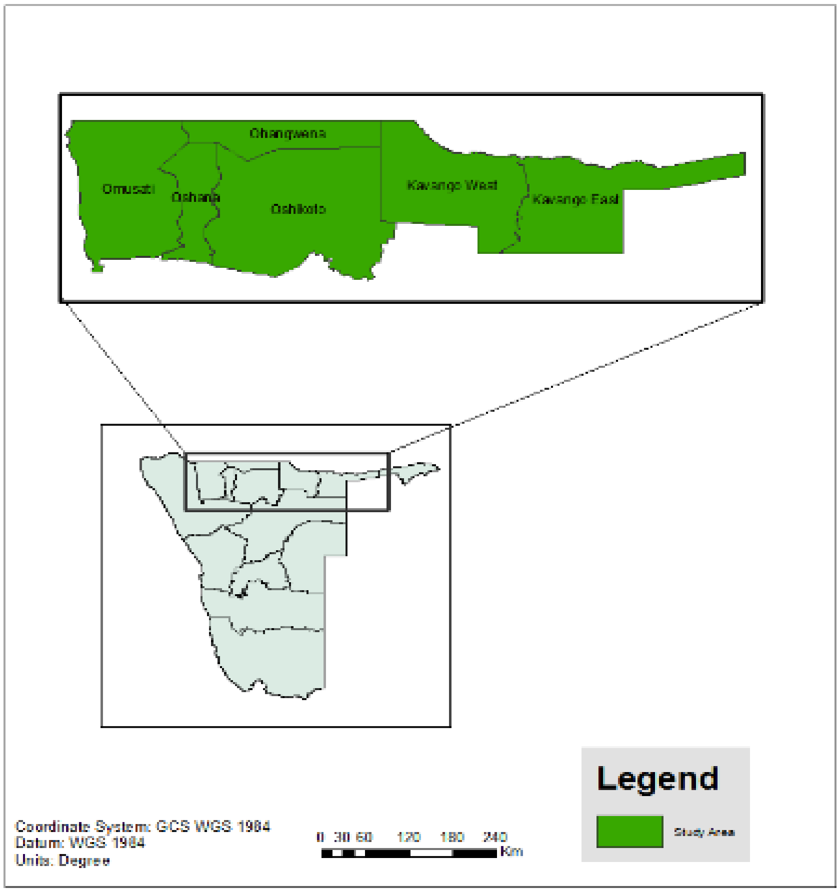

Figure 2: Study area, (Herman, 2016)

4.3 Data collection

Primary data was used in this study through field survey and household interviews using structured questionnaires. The first part of the questionnaire contains questions on the socio economic characteristics such as the age of the household head, household size, gender, farm size etc. The second part constitutes farmers' support program while the third part dealt with the on-farm operations such as fertilizer application, seeds and cropping practices. Yield estimations from both CA and traditional fields were observed using a separate document.

4.4 Ethical considerations

All respondents were briefed about the purpose of the research before administering the questionnaire. This was done to ensure that they provide the information voluntarily. The information collected was held strictly confidential to safeguard the privacy of the volunteers. Generalization was used when presenting the results i.e. no one was mentioned in the result's discussion and upon completion of the research the data was kept confidential.

4.5 Sampling technique and size

According to Leedy and Ormrod, (2005), sampling is a process of selecting units from a population of interest. The results obtained from the sample may be used to make inference about the population. Therefore, the characteristics obtained from the sample should at least reflect the same features as the whole population. The target populations for the study were the household heads in the region who are involved in decision making on food production. In this study, a simple random sampling procedure was employed to derive a sample from the population. The study survey was conducted amongst 100 respondents from the five selected regions with 20 respondents per region. The 100 farmers had two fields adjacent to each other, one for CA and one for TA.

4.6 Justification of variables used in the study

4.6.1 Input factors defining the production frontier

Literature from Baloyi (2011), Musaba and Bwacha (2014), Baha (2013) reveal that the immediate factors influencing the production frontier include; fertiliser, seeds, labour, land size and capital among others.

4.6.1.1 Fertiliser

According to Binam, Tonye and Wandi (2004), farmers who are farming in more fertile areas perform significantly better than those located in less fertile regions. Soil fertility is the ability of the soil to make plant nutrients available to the plant. This, therefore, reinforces the argument that improvement in soil fertility is a crucial element in increasing productivity. Findings by Tchale and Sauer (2007) also reveal that high levels of technical efficiency are obtained when farmers use integrated soil fertility options compared to the use of inorganic fertiliser only. Based on this notion, fertiliser appears to be the most important factor of production.

4.6.1.2 Labour

The traditional agricultural system is labour intensive. Labour is required during land preparation, weeding and harvesting among other practices (Tijani, 2006). Labour in agriculture can be classified into two categories; (i) hired and (ii) family labour. Hired labour is needed because of scarcity of labour due to increased urban migration. Labour is considered as one of the factors that influence the decision to adopt an agricultural technology as some new technologies are labour intensive while some are labour saving (Tijani, 2006). Some of the studies on the subject, Okurwa (2006) and Kibaara (2005) found out that the estimated coefficient for labour was positive and statistically significant, which implies that productive labour input contributes to the level of output produced. This result implies that the larger the family size, the more labour is available for farming operations. Contrary to these findings, Tchale and Sauer (2007) found that the labour coefficient was negative which shows that labour decreases production. This simply implies that under such circumstances the farmers are over-utilising the labour input.

4.6.1.3 Land (farm size)

Land in agricultural production is a heterogeneous resource in terms of soil size, soil type, associated soil characteristics and other productivity-related factors. It has been found in literature that land has a major influence on production since its estimated coefficient is positive in most studies. Fufa and Hassan (2003) found that the estimated coefficient of land is positive and significant. This indicates the positive influence of land on agricultural production. Furthermore, Kimhi (2003) found a positive relationship between the yield of maize and plot size, indicating that economies of scale are dominant throughout the plot size distribution.

4.6.1.4 Seeds

Seeds are a very important factor of crop production at which the level of production depends. Among others studies, Kibaara (2005) found that the estimated output elasticity of seeds is positive and could be attributed to the fact that enough seeds are sown so there is minimal competition for water, sunlight and nutrients. A study by Mushunje *et al*. (2003) gave a contrary finding on seed input coefficient being negative and thus implying a reduction in the level of production. This was attributed to sowing too much seeds or achieving poor germination and an indication that as the quantity sown increases, then so does reduction in yield.

4.6.1.4 Land preparation (Animal and tractor power)

Animal and tractor power are believed to be effective in production for their faster ability to ensure timely land preparation and planting when compared to manual labour which most communal farmers has traditionally adopted. Additionally, tractor and animal power enhance proper tillage through tilling the soil to a desirable depth for plant root penetration and moisture conservation. Kibaara (2005) found that mechanisation is important, households that used tractors for land preparation increased technical efficiency by 26% (4.41 bags). Against this background, animal and tractor power are more efficient than manual labour so they will increase the level of technical efficiency.

4.6.2 Socio – economic factors and efficiency

According to the literature, the socio-economic variables that influence the level of technical inefficiency are; group membership, age of household head, level of education, farming experience, family size, extension contacts, off-farm income, farm size, farm credit, soil quality, rainfall, planting date etc. (Kibaara, 2005; Musaba & Bwacha, 2014; and Diiro, 2013). It is important to note that a negative relationship means technical inefficiency decreases and therefore technical efficiency increases. A study by Tijani (2006) found that the estimated coefficient of age is negative and significant, implying that age reduces the level of technical inefficiency. Moreover, the negative coefficient for age indicates that older farmers tend to be more efficient than younger farmers because older farmers tend to be more experienced in agricultural production than young ones. Kibaara (2005) found that the estimated coefficient for level of education was negative indicating that an increase in the number of school years decreases technical inefficiency. This highlights the fact that farmers with more years of schooling tend to be more efficient in agricultural production since they respond more readily in using the new technology and produce closer to the frontier output.

According to Khairo and Battese (2005), the farming experience coefficient was negative and significant which means that farmers tend to decrease their technical inefficiencies as they become more experienced. This may be due to good managerial skills that they have learnt over time. Findings by Tijani (2006) show that the negative coefficient for age and farming experience implies that the aged farmers and the most experienced farmers are more efficient than the younger ones, meaning that as the age and farming experience of farmers increase, their inefficiency improves. Contrary to above findings, Chirwa (2003) found that the estimated coefficient for farming experience is positive, meaning it increases the level of technical inefficiency. This is attributed to the fact that experienced farmers may not be willing to try new innovations so are less efficient in the supervision of their farms.

In the study by Tijani (2006), the coefficient of family size was found to be positive. This implies that family size increases technical inefficiency, meaning it has a negative effect on technical efficiency. On the other side, Mushunje *et al*. (2005) study on relative technical efficiency of Zimbabwean communal farmers found the coefficient of family size to be positive but statistically insignificant. The family size coefficient can either be positive or negative, depending on members of the family who are actively involved in farming. With regards to extension, Mkhabela (2003) findings reveal that the estimated coefficients for extension contacts and farmers training class are negative. This indicates that increase in the extension visits and farm-training decrease the inefficiency level of farmers. Because of training, farmers' skills increase as well as their adoption of new technology for cultivation. Tchale and Sauer's (2007) results indicate that household income has a negative sign and therefore reduces technical inefficiency or in other words increases technical efficiency.

4.6.3 Socio economic factors and willingness to pay for extension services

A study by Tolera, Temesgen and Rajan (2014), found that farm size directly and significantly influence (at less than 5% probability levels) the willingness to pay for advisory services. The rationale behind this was that as the farm size increases, the probability of the willingness to pay for extension services also increases as farmers would tend to be commercially orientated. Tolera *et al*, (2014) further found that household size was significantly inversely related with WTP at less than 10% probability levels. Negative sign implies that smaller households were more willing to pay than larger households, as the family size increases by one person, the probability of willingness to pay for extension services decreases.

Household income was another important variable that was found to have a positive relationship with farmers WTP. Tolera *et al*, (2014) found that from the output of the model, the farmers who had better income are more willing to pay for extension services. The estimated marginal effect for this variable indicates that keeping the influences of other factors constant, the decision in favour of willingness to pay for extension services increases by a factor of 0.004 as farm income increases by thousand Birr. He further justified that, households at higher income levels are willing to pay for extension services since the budget constraint becomes less stringent and the households can afford it. On the other study, Oladele, (2008) found farming experience to have an inverse relationship with WTP for extension services. This indicates that an increase in this variable will lead to a decrease in the probability of willingness to pay for extension services. While on the other side, extension service, household structures were found to have a positive relationship with farmers' WTP. The argument was that, when farmers receive adequate extension service, they are better convinced to perceive a technology as an improvement within their farming system hence, encourages farmers' willingness to pay. Furthermore, educational level was found to have an insignificant influence on farmers' WTP. This was attributed to the notion that most educated farmers have jobs and hence engage in farming as part time subsistence activity (Oladele, 2008).

4.7 Variables included in the study

Four variables were used to estimate the stochastic production frontier model whereas twelve variables were selected for the technical inefficiency model. The WTP model was estimated with only 11 variables that were hypothesised to influence farmers' willingness to pay for extension services. Table 4.1 shows the production function and technical inefficiency variables to be fitted in the production frontier model as well as their expected signs. Table 4.2 shows the willingness to pay variables to be fitted in the probit model and their expected signs.

Table 4.1: Production and independent variables with expected signs

Variable	Measurement	Expected sign
Y_i = Pearl millet	The quantity of Pearl millet produced (kg/ha)	
Production function X_1 = Labour	The quantity of labour used	+
X_2 = Land	The area planted with pearl millet (ha)	+
X_3 = Fertiliser	The quantity of fertiliser used (kg/ha)	+
X_4 = Seed	The quantity of seed used (kg/ha)	+
X_5 = Tractor power	Land preparation method	+
Inefficiency model Z_1 = Farm experience	No. of years of farming experience	–
Z_2 = Education level	Dummy = 1 if the farmer has formal education, 0 = otherwise	-/+
Z_3 = Extension service	1 = yes, 0 = no	–
Z_4 = Non-farm income	1 = yes, 0 = no	-/+
Z_5 = Farm size	The total area of the farmers field	-/+
Z_6 = Household size	Number of people in a household	-/+
Z_7 = Coop member	Dummy = 1 if the farmer is a coop member, 0 = otherwise	–
Z_8= Household income (lte 2000)	If the farmers' household income is less than 2000	-/+
Z_9 = Household income (gt2000)	If the farmers' household income is greater than 2000	–
Z_{10} = Household status	Dummy = 1 if the household head is male, 0 = if the household head is female	–
Z_{11} = Training	1 = yes, 0 = no	–
Z_{12} = Farm credit	1 = yes, 0 = no	–

The variables used for the estimation of the stochastic frontier model are labour, fertiliser, seeds and area planted. These variables are expected to have positive influence on the production frontier of pearl millet *certeris paribus*. The technical inefficiency variables are farm experience, education, extension services, non-farm income, farm size, household size, cooperative membership, household income, household status, training and loan. The negative sign for a variable in the technical inefficiency model means that the variable reduces technical inefficiency, thus, have a positive effect on productivity while the positive sign indicates that the associated variable increases technical inefficiency.

Table 4.2: Willingness to pay and independent variables with expected signs

Variable	**Measurement**	**Expected sign**
P_i = Willingness to pay	Dummy = 1 if the farmer is willing to pay, 0 = otherwise	
X_1 = Farm experience	Number of years of farming experience	+
X_2 = Age	Years of the farmers	+
X_3 = Education level	Dummy = 1 if the farmer has formal education, 0 = otherwise	+
X_4 = Extension service	1 = yes, 0 = no	+
X_5 = Non-farm income	1 = yes, 0 = no	+
X_6 = Farm size	The total area of the farmers field	+
X_7 = Household size	Number of people in a household	_
X_8 = Coop member	Dummy = 1 if the farmer is a coop member, 0 = otherwise	+
X_9= Household income (lte 2000)	If the farmers' household income is less than 2000	+
X_{10} = Household income (gt2000)	If the farmers' household income is greater than 2000	+
X_{11} = Household status	Dummy = 1 if the household head is male, 0 = if the household head is family	_

For the estimation of willingness to pay, farming experience, age, education level, extension services, non-farm income, farm size, household size, coop membership, household income and household status were used. These variables are expected to influence the farmer's willingness to pay in the sense that a unit increase in one of the variables should increase the farmer's probability to pay, while the negative sign denotes that a decrease in probability to pay for extension services.

4.8 Analytical methods

4.8.1 Descriptive statistics

The purpose of using this type of analytical tool was to summarise the data by describing the basic features of the data in the study, and to provide simple summaries of the variables and measures.

4.8.2 Stochastic Frontier Analysis (SFA)

The Stochastic Frontier Analysis (SFA) takes into consideration measurement errors and noise in the specification of the production function. The stochastic frontier model can be presented as:

$$Y_i = f\left(X_i : \beta\right) \exp(V_i - U_i) \quad \text{.......} (1)$$

Where $i = 1, 2, \ldots n$

Y_i = Output of the i^{th} farm
X_I = Vector of input quantities used by the i^{th} farm
β = Vector parameters to be estimated
$V_i - U_i$ = Composite error term

V_i is the random error outside farmers control, assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ independent of U, which is the non-negative random variable associated with technical inefficiency. It is also independently distributed as a truncated normal, with truncations at zero of the normal distribution. Consistently following Battese and Coelli, (1995), U_i is given as:

$$U_i = \delta_0 + \delta_i Z_{ij} \quad \text{.......} (2)$$

Where Z_i represents the vector of farm-specific variables that may have an influence on the efficiency of the firm, and δ is the vector of parameters to be estimated.

In agricultural production, the technical efficiency (TE) of a farm is shown as the ratio of the observed output (Y_i) to the corresponding frontier output (Y*), conditioned on the level of inputs used by the farm. This equation is gives as:

$$TE = \frac{Y_i}{Y_i^*} = exp(X_i\beta + V_i - U_i)/exp(X_i\beta + V_i) = exp(-U_i) \quad \cdots\cdots (3)$$

It has been noted in Aigner et al. (1977) that in the stochastic frontier production function, it is advisable to utilise a likelihood function for two variance parameters, $\sigma^2 = \sigma_U^2 + \sigma_V^2$ and $\lambda = \sigma_U/\sigma_V$. More emphasis was given that values of λ must lie between zero and one with values of 0 indicating the deviation from the frontier while values of 1 gives an indication that all deviations are a result of technical inefficiency.

4.8.2.1 Production function frontier model

According to Alene and Hassan (2003), production frontier is specified to represent the maximum output from a given set of inputs and existing production technology. Failure to attain the frontier output implies the existence of technical inefficiency. STATA version 13.1. Software was used to fit both production frontier and technical inefficiency models. The frontier model specification was developed by Battese and Coelli (1995) who proposed a stochastic frontier model where technical inefficiencies can be expressed as a function of explanatory variables and a random error (Battese et al, 1995). The Cobb-Douglas stochastic frontier production function was specified as follows:

$$\text{Ln}\, Y_i = \beta_{0i} + \beta_1 \text{Ln} X_{1i} + \beta_2 \text{Ln} X_{2i} + \beta_3 \text{Ln} X_{3i} + \beta_4 \text{Ln} X_4 + V_i + U_i \quad \cdots\cdots (4)$$

Where;
Output (Y) is yield of pearl millet in kg;
X_1 is area of millet planted (ha)
X_2 is the fertilizer (kg)
X_3 is the seed quantity (kg)

X_4 is the total labour (man days)
X_5 is the tractor power

4.8.2.2 Technical inefficiency model

The technical inefficiency model was used to identify factors that impact the efficiency among pearl millet farmers in the study area, and the model was estimated as follows:

$$U_i = \delta + \sum_{n=1}^{12} \delta_n Z_i + \omega_i \text{ .... } (5)$$

Where;

Z_i = vector of explanatory variables associated with technical inefficiency effects, δ = vector of unknown parameters to be estimated, ω_i = unobservable random variables, which is assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown δ^2, such that U_j is non-negative. The inefficiency of production U_j was modelled in terms of the factors that are assumed to affect the technical efficiency of farmers. Empirically, the inefficiency model based on Battese and Coelli (1995) was specified as:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} \text{ .... } (6)$$

Where;

Z_1= farm experience; Z_2 = education level; Z_3= extension services; Z_4 = off farm income; Z_5 = farm size; Z_6 = cooperative membership, Z_7= household income (less than 2000), Z_8 = household income (greater than 2000), Z_9= household size, Z_{10} = household status, Z_{11} = farm training, Z_{12}= farm credit (loan).

4.8.3 Willingness to pay probit model

Probit regression model was fit to assess the factors that may be associated with willingness to pay (WTP) for the extension services. The independent variables used in this model include farm experience, age, education level, extension services, off farm income, farm size, cooperative membership, household income, and household. The dependent variable WTP is a dichotomous variable which takes the value of one if a farmer indicates that he/she is willing to pay, otherwise, zero. The aim is to identify the individual, household characteristics that influenced the farmers' WTP for ripper furrowing. The Probit model takes the form:

$$Pr\,(Y_1 = 1) = f(\beta_i X_i) + e_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where Y is a dichotomous dependent variable which can assume the value of 0 or 1. It measured the farmer's willingness to pay for extension services. X_i = n x k matrix of explanatory variables (farm experience, age, education level, extension services, off farm income, farm size, cooperative membership, household income, household status). β_i = k x 1 vector of parameters /coefficients to be estimated and e_i is the error term.

4.9 Conclusion

The positive sign of production function variables means that a unit increase in one of the variables will lead to an increase in the yield. With reference to the findings of the related studies, the expectation of this study is that technical efficiency should increase with increase in access to extension services and farming experience since extension services and farm experience are expected to be positively correlated to adoption of improved technology. This may be due to the fact that experienced farmers understand the techniques of production better than less experienced farmers. Other variables such as household income and off-farm income lead to improvement in technical efficiency and also influence willingness to pay for services. Area planted, fertiliser, seeds and labour are also important factors of production and hence the need to use them more efficiently in order to achieve the desired production frontier.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter discusses the results obtained from the stochastic frontier production analysis as well as the willingness to pay (WTP) estimated with probit model. The chapter is presented into three main sections. The descriptive statistics of the variables is given in Section 5.2, followed by the analysis of the results from the stochastic production frontier model in Section 5.3. The results of the technical inefficiency and its determinant are discussed in Sections 5.6 to 5.7. The chapter concludes with the analysis of the findings of willingness to pay results.

5.2 Descriptive statistics

The results from the descriptive statistics are presented in Table 5.1. As indicated in the previous chapter, the study used two models, the descriptive statistics include all the variables used in the technical inefficiency and willingness to pay models, irrespective of whether they are significant or not. The existence of multicollinearity was tested which was detected as some variables correlated with each other as shown in Table A.2 in appendices. The auto correlation was corrected allowing for the variance covariance matrix (VCE) estimation. This allowed for selection of suitable variables to run the model.

Table 5.1: Descriptive statistics of the respondents

Variable	Mean	Standard. Deviation	Min	Max
Wtp520	0.6	0.4923	0	1
Farmexp	31.07	12.4634	2	61
Age	61.16	13.3088	22	100
Edu	0.76	0.4292	0	1
Extserv	0.44	0.4988	0	1
NFI	0.66	0.4760	0	1

Farmsize	6.46	4.4041	1	25
HHsize	9.46	5.2308	1	28
Memcop	0.43	0.4975	0	1
Income < 2000	0.66	0.4760	0	1
HHstatus	0.76	0.4292	0	1

From the results, it can be deduced that the average farmer is more than sixty years old. The average farming experience is about 31 years, which means that most of the farmers have farmed for most part of their life. This is an indication that pearl millet production has been in existence for a number of years as the majority of the small-scale farmers have been in pearl millet production for more than 31 years. The age of the farmer is an important factor of production as older people tend to be too stereotyped always sticking to what they are used to (that is, they prefer to use old methods of planting than adopt new technology). It is assumed that older farmers are more experienced in farming activities and are in a better position to assess the risks involved in farming than younger farmers. The household size plays an important role in pearl millet production because most farmers depend on family labour. The data shows that the average household size is 9. Invariably, the large family size means that more labour will be available for farming. The average farm size for the farmers is 6.4 hectares. This indicates that the land of the sampled farmers is small; however, the aim of the study is to determine how efficient they are given their farm size and the introduction of conservation agriculture.

5.3 Maximum likelihood estimates of production frontier parameters

Table 5.3 presents the results of the Cobb Douglas production function for both methods (Conservation and Traditional Agriculture) as described in Chapter 4**.** In the case of Conservation agriculture, the estimated production function parameters indicated that the area planted, fertiliser and use of animal plough significantly affects the pearl millet yield. Labour and seed were found to be insignificant. In traditional agriculture, fertiliser and use of animal plough were shown to significantly affect yield while seed, area planted and labour were insignificant. These results are consistent with findings by Baloyi (2011) and Musaba and Bwacha (2014) in a study carried out in South Africa and Zambia respectively. The insignificant effect of seed quantity could imply that farmers in the study area do not use improved seeds hence; they resort to the indigenous varieties and the use of inappropriate seed rate. The insignificant effect of labour with negative sign is consistent with Musaba *et al* (2014), this could imply that there is abundant household labour in the study area and any increase in this labour will lead to a reduction in technical efficiency. The positive and significant coefficient for fertiliser indicates that pearl millet output increases with a unit increase in fertiliser input. The higher significance level under CA implies that farmers were advised well on the application of both basal and top dressing and application was also done in rows in close accessibility to a plant. While on TA, farmers mostly applied basal dressing fertilisers through broadcasting method which make this result acceptable. This is in agreement with a study by Tchale and Sauer (2007), which emphasised the essence of obtaining efficiency in more fertile areas. For CA, area planted was significant at 5% while on TA it was insignificant. The result shows that access to land is important in explaining the differences in yield of the farmers. This finding is supported by Kimhi (2003) who finds a positive relationship between maize yield and plot size, indicating that economies of scale are dominant throughout the plot size distribution.

The estimated coefficients for production parameters have shown the expected positive signs except labour, suggesting that labour had less influence in the production of millet; this is consistent with the study by Okurwa (2006). This scenario is expected as the level of pearl millet production depends largely on a number of factors including climate and not only limited to production inputs. However, all other variables for both technologies were positive, implying that the pearl millet in the study area is positively influenced by these factors. The seed quantity being insignificant is quite unexpected but given that farmers in the study area do not know the correct amount of seeds to be used in a unit area, the result is acceptable. With regards to land preparation, both in TA and CA the variable was significant, implying that using tractor power is much more efficient than manual labour as it speed up efficiency of operations. Most farmers have resorted to using machinery in attempt to cultivate bigger land and also do early land preparation. This is consistent with Kibaara (2005) who found that mechanisation is important, households that used tractors for land preparation increased technical efficiency by 26%.

Table 5.3: Maximum Likelihood Estimation of the Cobb Douglas stochastic production frontier for the comparison of Conservation & Traditional Agriculture

	Conservation Agriculture (CA)	Traditional Agriculture (TA)
Variable	**Coefficients**	**Coefficients**
Total labour	-0.0458 (0.5180)	-0.1279 (0.5290)
Land	0.1846** (0.0570)	0.1171 (0.2620)
Fertilizer	0.0592*** (0.0080)	-0.0551** (0.0120)
Seed	0.0410 (0.4020)	0.0253 (0.6250)
Tractor power	-0.2229** (0.0140)	-0.2309** (-0.0260)
Constant	6.5761*** (0.000)	0.1228 (0.6660)
$Ln\sigma_v^2$	-3.8945 (0.0000)	-3.6696 (0.0000)
$Ln\sigma_u^2$	-0.7741 (0.0000)	-0.7922 (-0.00060)
σ_v	0.1427 (-0.0370)	0.1596 (-0.0662)
σ_u	0.6791 (-0.0810)	0.6729 (-0.0973)
Wald Test: Joint Significance:		
Wald Chi-square(11)	20.030	15.650
Prob > Chi-square	0.001	0.008
LR Test: Sigma_u = 0	29.46 (0.0000)	7.02 (0.004)

Note: Figures in parenthesis are the p-values. The notation ***, **, and * denote statistical significance at the 1%, 5% and 10% level of significance.

5.4 Constant returns to scale (CRS)

For constant return to scale, the sum of the technical coefficients β must be equal to one (1), for increasing return to scale, it should be greater than one, and for decreasing return to scale it should be less than one (1). For the case of this study, the constant return to scale hypothesis was rejected indicating that the sum of the technical coefficients are not equal to one. This is an indication that the hypothesis is not supported by the data. Reasons attributed to this is that of shorter period of trials to examine the impact of CA, and that the labour input is not efficiently utilised by the farmers due to their communal set up of farming. Therefore, the output cannot double if inputs levels are doubled.

5.5 Hypothesis testing

The standard deviation of the two error components for the two models, σ_v and σ_u, and their log likelihood estimates $Ln\sigma_v^2$ and Ln_u^2 are respectively given in the post estimation Table 2. The result shows that they are all statistically significant. To test the presence of technically inefficiency effects, the log likelihood-ratio (LR) test was adopted. The null hypothesis of no technical inefficiency effects in pearl millet production was strongly rejected. The null hypothesis was rejected in favour of the alternative hypothesis because the estimated p-values for the two tests are zero. The Wald test statistics for joint significance of the variables in the two models are 20.03 and 15.65. The null hypothesis of joint zero coefficients was rejected. Based on result of the two tests, it can be concluded that the included variable contribute to explain production frontier and that technical inefficiency effects are present in the model, confirming the need to fit inefficiency model.

5.6 Technical inefficiency scores

This section discusses the technical efficiency estimates obtained from the stochastic frontier model. Table 5.4 presents summary statistics of the technical inefficiency scores based on two farming methods as well as by region. The technical inefficiency scores for individual farmer are found in Table A1 in the appendices section.

The mean technical efficiency of 32% under Conservation agriculture indicates that on average the respondents are able to obtain over 30% of potential output from a given mix of production inputs. The result is consistent with Diiro, (2013) and Kibaara, (2005). This implies that, in the longer term, there is a potential for pearl millet producers to increase their efficiency by about 68% by utilising existing farm resources better and following the appropriate principles of Conservation Agriculture so as to be on the optimal production frontier. While under TA, the mean technical efficiency of 33% indicate that on average there is a potential for pearl millet producers to increase their efficiency by about 67% utilising existing farm resources better and adopting improved technology and techniques. The regional analysis (Table 5.5) shows that Kavango region was the most efficient region in both technologies as evidenced by the farmers' inefficiency scores. The most inefficient was Oshikoto and Ohangwena regions for both methods of farming. The differences in efficiency levels between regions could be attributed to factors such as climate, soil fertility, availability of planting materials such as seeds, poverty prevalence, management and socio economic factors. The intra-region differences between CA and TA are also very small an indication that the effects of the CA cannot be realized in the short-run. Generally, the result indicates that there is a need to practice CA over a longer period of time in order to observe the desired impact.

Table 5.4: The summary statistics of Technical Inefficiency scores of sampled farmers

Farming method	Obs	Mean	Std. Dev	Min	Max
CA	100	0.6791	0.6285	0.0619	2.8432
TA	100	0.6729	0.5547	0.0641	2.7142

Table 5.5: Mean technical inefficiency scores by regions

	Oshikoto	Omusati	Oshana	Kavango	Ohangwena
CA	1.2171	0.5741	0.6439	0.2563	0.7038
TA	0.8824	0.5943	0.7511	0.3234	0.8136

5.7 Determinants of technical efficiency

The analysis of the estimated coefficients of the inefficiency model explains the contribution of the variables to technical efficiency in the study area. Using the SFA model, the sources of inefficiency were examined using the identified determinants of inefficiency effects. Table 5.6 shows the results for both Conservation and Traditional agriculture technical inefficiency model. As indicated in Chapter 4, the negative sign on the estimated parameters in the technical inefficiency model implies that an associated variable reduces inefficiency, meaning it has a positive effect on technical efficiency; as a result it increases productivity level. A positive sign indicates that the associated variables increase inefficiency or have negative effect on technical efficiency.

In the case of Conservation agriculture, household size, cooperative membership, income>2000, farming experience are significant at 5% and 10%. Although these variables are significant, they have positive signs except farming experience which implies that they have a negative effect on efficiency. This finding is consistent with studies carried out by Kibaara (2005), Mango, Makate, Lundy (2015) and Diiro (2013). The coefficient sign for farming experience is negative and significant; suggesting that this variable reduce technical inefficiency. This further entail that experienced farmers tend to be more efficient because of good managerial skills which they have learnt over time, and more efficient than younger ones. This result is supported by Khairo and Battese (2005) who found that the farming experience coefficient was negative and significant which means that farmers tend to decrease their technical inefficiencies as they become more experienced. The estimated positive coefficient of household size and significance at 5% implies that smaller families are efficient compared to larger ones that are said to exert pressure on the limited resources a farmer has (Mango et al, 2015).

Although the sign of the coefficient for education, extension service, non-farm income, farm size and training have negative sign, they are insignificant so their effect on the level of technical efficiency is of no effects. The rest of other variables, including farm credit (loan) and household status are not statistically significant. The insignificant level for extension service and training implies that extension sessions had no significant effect on the inefficiency levels which could be attributed to slow rate of adoption and understanding of the intervention by first time participants' farmers (Mkhabela, 2003). The positive coefficient sign for Income<2000 indicate that farmers who have a household income less than 2000 are inefficient compared to the ones earning more than this amount. This is because farmers with income<2000 will not have the financial power to purchase necessary inputs for farming that may increase their technical efficiency, this result is consistent with Oladimeji and Abdulsalam, (2013). Result on cooperative membership show that farmers who were non-cooperative members were efficient than the ones who are members. This could be due to the fact that members are not utilising the privilege of being attached to a cooperative.

Table 5.6: Determinants of technical efficiency for Conservation Agriculure vs Traditional Agriculture

	Conservation Agriculture (CA)	Traditional Agriculture (TA)
Variable	**Coefficients**	**Coefficients**
Farmexp	-0.0105*	-0.0122***
	(0.0952)	(0.0180)
Edu	-0.0845	0.0437
	(0.623)	(0.7730)
Extserv	-0.0029	0.1071
	(0.623)	(0.3390)
Nfi	-0.1512	-0.1537
	(0.381)	(0.2440)
Farmsize	-0.0128	-0.0210*
	(0.29)	(0.0700)
Hhsize	0.0319**	0.0263**
	(0.026)	(0.0230)
Memcop	0.2454*	0.1784
	(0.072)	(0.1470)
Income<2000	0.3508***	0.2207
	(0.016)	(0.1430)
Hhstatus	0.1802	0.1573
	(0.246)	(0.2140)
Training	-0.1789	-0.3505***
	(0.225)	(0.0140)
Loan	0.1783	0.3828**
	(0.357)	(0.0230)
Constant	0.4859	0.7711
	(0.266)	(0.0510)
F (12, 87)	5.88	6.84
Prob > F	0.000	0.000
R - Squared	0.139	0.1942
Root MSE	0.6219	0.5312

Note: Figures in parenthesis are the p-values. The notation ***, **, and * denote statistical significance at the 1%, 5% and 10% level of significance.

In traditional agriculture, the estimated coefficient sign of the variables from the inefficiency model shows that only farmers' training, farm experience and farm size are statistically significant with the correct signs. This indicates that these variables have positive influence on technical efficiency. With regards to training, the finding implies that farmers who have access to training classes are more efficient than the ones who do not. The training sessions farmers have received over time by the Ministry officials on production related information tend to increase efficiency, consistent with Mango et al (2015). Moreover, negative sign of farm size implies that farmers with large arable land tend to be efficient as they are able to diversify their activities, i.e. integrated farming that eventually increase their income hence improved efficiency, this result is supported by Mango (2015). Although household size, loan is significant, their coefficients are positive which implies their negative influence on technical efficiency. The rest of other variables are insignificant and have coefficients with positive signs, indicating that the associated variables led to a decrease in technical efficiency of farmers.

5.8 Factors influencing farmer's willingness to pay (WTP) for extension services

To identify determinants of willingness to pay for agricultural extension services, probit model was estimated. In total, 11 independent variables were estimated namely, farming experience, age, education level, extension service, non-farm income, farm size, household size, cooperative membership, household income (Income < 2000) as well as household status. Farm size, household income (Income < 2000), cooperative membership and household size have a significant relationship with farmer's willingness to pay. The results show that the predicted probability of getting farmers who are willing to pay for extension services is 60 %, (Table 5.7).

Table 5.7: Marginal effects test

	Delta method					
	Margin	Std. Err	z	P>|z|	[95% Conf. Interval]	
_cons	0.6008	0.0312	19.21	0.000	0.5395	0.6621

Table 5.8: Maximum likelihood estimates of the probit model

wtp520	Coef.	Robust Std. Err	z	P>|z|	[95% Confidence	Interval]
Farmexp	0.0185	0.0255	0.72	0.469	-0.0315	0.0685
Age	0.0050	0.0283	0.18	0.858	-0.0504	0.0605
Edu	0.4847	0.4044	1.2	0.231	-0.3080	1.2774
Extserv	-0.1653	0.3410	-0.48	0.628	-0.8337	0.5030
Nfi	0.5880	0.4284	1.37	0.17	-0.2516	1.4277
Farmsize	-0.0929	0.0430	-2.16	0.031	-0.1773	-0.0084
Hhsize	-0.1106	0.0378	-2.92	0.003	-0.1849	-0.0364
Memcop	-2.5604	0.3419	-7.49	0.000	-3.2307	-1.8901
Inc<2000	-2.0064	1.0036	-2.00	0.046	-3.9736	-0.0393
Hhstatus	0.1146	0.4137	0.28	0.782	-0.6963	0.9255
_cons	3.0895	1.6845	1.83	0.067	-0.2121	6.3911

Farm size was found to be significantly significant at 5% level with the willingness to pay for extension. Negative sign implies that farmers with small farm size are more likely to pay than those with larger farms. This could be attributed to the fact that farmers are in a communal farming set up and do not have resources to invest in larger hectares of land. If farm size increases they will pay more premium as the payment for extension is made per hectare, the realization of additional payment reduces their willingness to pay. Household size was significant at 1% level and has negative signs. The result is in agreement with the apriori expected sign because if household size increases, the cost of living increases and the purchasing power of the farmer decline. This finding is supported by Tolera *et al* (2014) who revealed that negative sign implies that small size households were likely to pay more than larger households.

Cooperative membership was significant at 1% level. A negative sign implies that farmers who were non-cooperative members are more likely to pay than unionized farmers. The finding is consistent with results by Oladele (2008). In most cases, most of the farmers were not cooperative members mainly due to several reasons. Some farmers are sparsely located in very remote areas and hardly get information from cooperatives that are located in towns. At the same time some farmers cannot afford cooperative member subscriptions and some do not understand the importance of being a cooperative member. Household income (< NAD 2000) is statistically significant but has negative signs. The result shows that household income does not influence the willingness to pay for extension service. As mentioned previously, these farmers have large family size and have high living expense; further expenditure on extension services would not be afforded.

Table 5.9: Marginal effects of the covariates

Variable	dy/dx	Std.Err.	z	P>|z|	[95% Confidence Interval]	
Farmexp	0.0066	0.0091	0.72	0.469	-0.0113	0.0245
Age	0.0018	0.0101	0.18	0.858	-0.0180	0.0217
Edu	0.1737	0.1450	1.20	0.231	-0.1106	0.4580
Extserv	-0.0592	0.1216	-0.49	0.626	-0.2976	0.1791
Nfi	0.2107	0.1525	1.38	0.167	-0.0882	0.5097
Farmsize	-0.0333	0.0152	-2.18	0.029	-0.0632	-0.0033
Hhsize	-0.0396	0.0131	-3.02	0.002	-0.0653	-0.0139
Memcop	-0.9175	0.1323	-6.93	0.000	-1.1770	-0.6580
Inc>2000	-0.7190	0.3616	-1.99	0.047	-1.4278	-0.0102
Hhstatus	0.0410	0.1481	0.28	0.782	-0.2492	0.3314

The result indicates that an increase in one unit of farm size will lead to a decrease in the willingness to pay for extension services by 3%. This is because an additional hectare cultivated will have to be paid for. Further, as the household size increases by one person, there will be a decrease in the farmer's willingness to pay by 4%. As the household enlarges, the farmer will have a huge responsibility of catering for the household and may not have extra resources to pay for extension services. If a farmer belongs to a cooperative, the likelihood that they will pay is lower by 91% compared to when they are not a member. This is because the farmer will expect the cooperative to subsidise and cater for a larger percentage of their extension service needs. Farmers with an income less than 2000 are less likely to pay for extension services than those that have higher. This is attributed to the fact that, farmers may be having a lot of responsibilities to cater for with their limited level of income, for example, paying school fees for children among others and thus paying for extension becomes a lesser priority.

5.9 Summary of the chapter

The study modelled production frontier of pearl millet using Cobb Douglas production frontier model. The aim was to compare two methods of farming system, Conservation and Traditional Agriculture. The result shows that fertiliser and tractor power had a significant effect in both farming methods with area planted only significant under CA. The result for the other farm inputs such as labour and seed are insignificant in both methods.

Further on technical efficiency scores, the respondents had almost the same technical efficiency levels from both farming methods. Farmers who applied CA exhibited 32% technical efficiency, while under Traditional agriculture the technical efficiency was at 33%. The result shows no significant difference between the two methods hence the need to further the practice of CA over a long period of time. In overall for both farming methods, variables that positively influenced efficiency were farming experience, farm size, farm training. These variables have the correct signs and were also statistically significant. With regards to factors influencing willingness to pay, four variables out of eleven were found to be statistically significant.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This paper investigated the stochastic production frontier of farmers that practised Conservation versus the Traditional Agricultural method of farming in the rural area of Northern Namibia. The aim was to determine the efficiency of pearl millet farmers under both practices; therefore, factors that affect their efficiency were investigated. The research is part of a pilot project administered free of charge by a non-governmental organisation (NGO). At the roll out of the major project, it is expected that the NGO extension services will be offered at farmer's cost; therefore, the study determines the willingness of the farmers to pay for the extension services at such a price to be determined by the NGO. The study used cross sectional data that was collected in February 2016 through personally administered and pre tested questionnaires from the communal farmers. The stochastic production frontier was estimated with Cobb Douglas production model whereas the willingness to pay was determined using a probit model. The findings of the research are discussed below.

6.2 Conclusions based on findings

6.2.1 Technical efficiency

The result of the production frontier under conservation agriculture shows that the area planted, tractor power and fertiliser significantly affect the pearl millet yield. On the other hand, fertilizer and tractor power influenced production under traditional agriculture method. No statistical significant effect was observed for seed and labour used for both method. The insignificant labour coefficient can be attributed to low labour productivity. Optimal labour use cannot be identified due to the use of family labour thus, output may be affected. Similar effects can be observed with regards to seed application. Non-optimal use of seed may result in negative effects on output. In addition, the use of the wrong seed variety that have low germination rate may affect output.

The results show that there is a technical efficiency of 32% under Conservation agriculture indicating that on average the respondents are able to obtain over 30% of potential output from a given mix of production inputs. While under traditional agriculture, the mean technical efficiency of 33% was calculated, indicating that on average there is a 67% allowance of efficiency improvement by addressing important constraints that affect farmers' levels of technical efficiency and productivity in the study area. The result revealed that Kavango region was the most efficient with the most inefficient being Oshikoto and Ohangwena. The study found out that the most probable factors attributed to differences in efficiency levels across regions could be climate conditions, soil fertility, poverty prevalence, management and other socio economic factors. Furthermore, an intra-region difference between CA and TA was noticed, even though it was at a small extent, it shows that Conservation Agriculture still need to be practised over a long run.

6.2.1 Determinants of technical efficiency

The findings revealed that in the case of conservation agriculture, the sign of the estimated coefficient for farming experience was negative and statistically significant. Additionally, training coefficient have a negative sign yet statistically insignificant. The result suggests that these variables reduce technical inefficiency, thus increasing technical efficiency. Other variables such as household size, cooperative membership, and household income were significant but have a positive sign which means that they increase inefficiency. With regards to traditional agriculture, the sign of the estimated coefficient for farm size, farm experience and training is negative and statistically significant, thus increasing technical efficiency. Generally, the study concludes that farmers are technically inefficient since there is an improper utilization of resources at farm level, and that farmers` technical efficiency can be improved through the interaction of the observed socio-economic factors.

6.2.3 Factors affecting farmer’s willingness to pay for extension service

The results show that variables such as farm size, cooperative membership, household size and household income were statistically significant but have unexpected signs. Farm size was found to have a significant influence on the willingness to pay for extension service. Negative sign of the coefficient for farm size implies that small farmers with small farm size are more likely to pay than those with large farms. Household size is statistically significant at 1% level with expected negative sign. The result is in agreement with prior expectation. This result is consistent with the finding by Tolera *et al* (2014) who revealed that negative sign implies that small size households are more likely to pay than larger households. Cooperative membership was significant at 1% level with negative sign. A negative sign implies that farmers who were non-cooperative members are more likely to pay than those who belong to cooperatives.

6.3 Recommendations and policy implications

Policy implications drawn from the result include a review of the national agriculture policy with regard to interventions towards improved small scale production infrastructure due to the fact that a number of factors that considerably affect agricultural production have been identified in this study hence, the need to consider it. There are already existing programs such as Dry land production which also need review to develop new areas such as irrigation farming schemes. Farmers should be exposed to credible extension services as an incentive to produce more and raise the current level of efficiency. Furthermore, farm training should be considered by policy-makers or institutions with the responsibility of designing programs towards pearl millet farming improvement in the studied area, if positive results are desired. The farmers should be encouraged to form farming groups/cooperatives where they will be able to have access to government assistance. Availability of farm training through qualified and trained extension staff empowers farmers with new innovations, methods and build-up of understanding.

Another policy issue to be considered is the need to strengthen the production system by using drought tolerant varieties and climate smart technologies. The climate change and resilience policy must also be looked into integrating comprehensive capacity building on CA to farmers; knowledge on the subject will build understanding that will ultimately contribute to adoption of the practice. Hosting farmer’s information days, demonstrations and input financing will play a significant role. Conservation Agriculture has been proposed to improve soil and water conservation, reduce soil erosion and increase pearl millet productivity. Practising CA may seem a process that will not bring about immediate effect as the result has shown, but as soon as the farmers develop a positive attitude for adoption, it will offer long time results. This study further recommend that Conservation Agriculture must be further practised over a long period of time so that its impact can be felt as an attempt to raise productivity in the northern communal areas.

The policy implication drawn from willingness to pay study include a detailed capacity building by government and other development agencies to farmers on the expected benefits of extension services to improve demand for the services and ensure the amount farmers dedicate for extension allows sustainable private sector engagement in the service. Extension services should be rolled out in these areas as farmers' livelihood is entirely centred on cropping.

To ensure that the willingness to pay for extension services is sustained, there is need to improve the extension contact with farmers. With this initiative, it is important to target small unit farmers with, low incomes, non-cooperative members and those with smaller households. Also, the privatization of extension services would improve production and their ability to pay for extension service. Therefore, the way out is a workable policy framework around the aforementioned issues.

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APPENDICES

Table A1: Technical inefficiency scores of sampled farmers

SN	CA	TA	SN	CA	TA	SN	CA	TA
1	1.4358	0.7098	41	0.0640	0.0769	81	0.7581	0.4086
2	2.8237	1.5893	42	0.3914	0.1155	82	0.2093	0.1265
3	1.8344	1.3416	43	0.0644	0.2243	83	0.1940	1.1080
4	1.2200	0.9730	44	0.1960	0.3093	84	0.1580	1.3072
5	1.0984	0.8694	45	0.3521	0.2452	85	2.1010	1.9082
6	1.1846	0.6622	46	0.4303	2.1828	86	1.1176	0.9821
7	1.7769	1.0147	47	1.1619	0.1657	87	1.1140	1.2610
8	0.9029	0.9245	48	0.2525	0.6349	88	0.5847	0.9086
9	1.1444	0.1100	49	0.1345	0.1295	89	1.6680	1.5685
10	1.0942	0.6768	50	0.8066	0.5696	90	1.9648	1.8727
11	0.5042	0.9629	51	1.2354	1.2239	91	0.1242	0.1846
12	1.2767	0.1457	52	1.7799	1.6129	92	0.2759	0.1409
13	0.9147	1.0901	53	0.3850	0.5691	93	0.0878	0.3751
14	0.3221	0.8175	54	1.8473	2.7142	94	0.2499	0.3892
15	2.8432	1.1612	55	0.3720	0.8193	95	1.3894	1.1034
16	0.7690	1.6439	56	0.0756	0.0641	96	1.2989	0.7382
17	0.8087	0.5940	57	0.3653	0.9445	97	0.2245	0.1239
18	0.5408	1.0405	58	1.4941	1.1415	98	0.1649	0.2127
19	0.7317	0.3737	59	1.2377	1.1169	99	0.1436	1.2274
20	0.0858	0.9471	60	0.2331	0.1612	100	0.2479	0.3243
21	0.8409	0.0673	61	0.0949	0.1001			
22	0.5651	0.8422	62	0.2839	0.2509			
23	0.1894	0.7429	63	0.1872	0.2054			
24	1.4719	1.4783	64	0.1254	1.0101			
25	0.7044	1.4262	65	0.4133	0.3778			
26	0.7532	0.5205	66	0.5105	0.3473			
27	0.1544	0.5178	67	0.0619	0.6669			
28	0.6430	0.1070	68	0.2652	0.4271			
29	0.2374	0.7483	69	0.2833	0.1786			
30	0.3851	0.2335	70	0.3194	0.3735			
31	1.5059	0.2323	71	0.2002	0.1180			
32	0.3248	1.4087	72	0.1587	0.1099			
33	1.9862	0.6025	73	0.2737	0.2709			
34	0.1947	1.8030	74	0.1450	0.1564			
35	0.1432	0.2084	75	0.3013	0.1857			
36	0.7387	0.2068	76	0.2401	0.2269			
37	0.0991	0.3273	77	0.1389	0.4102			
38	0.1988	0.1319	78	0.4250	0.2779			
39	0.2592	0.1028	79	0.3950	0.3940			
40	0.0640	0.1780	80	0.3034	0.3809			

Table A2: Correlation Matrix

Variable	wtp520	farmexp	age	edu	extserv	nfi	farmsize	hhsize	memcop	lte2000	gt2000	hhstatus
wtp520	1											
farmexp	0.0013	1										
Age	-0.1366	0.7779	1									
Edu	0.0191	-0.2895	-0.4689	1								
extserv	0.0658	-0.07	-0.0472	-0.0208	1							
Nfi	-0.112	0.0755	0.3004	-0.3045	0.0408	1						
farmsize	-0.2228	0.1638	0.253	0.0328	-0.1426	0.2591	1					
hhsize	-0.2808	0.3902	0.4235	-0.1753	-0.0125	0.0959	0.0731	1				
memcop	-0.6514	0.0016	0.1481	0.0151	-0.0374	0.2823	0.2371	0.1794	1			
lte2000	-0.0259	-0.0198	-0.0216	-0.0573	-0.2143	-0.2032	-0.2468	-0.2245	-0.2294	1		
gt2000	0.0177	0.0171	0.0572	0.0223	0.2335	0.2072	0.2103	0.2274	0.204	-0.9339	1	
hhstatus	0.1147	-0.0346	0.0386	-0.1513	-0.0208	0.0415	-0.0068	-0.1888	-0.0795	-0.0079	-0.0284	1