# ECONOMIC EFFICIENCY OF RAINFED MAIZE PRODUCTION IN THE SIPHOFANENI AREA OF SWAZILAND

**BY**

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# DEDICATION

The Master of Science in Agricultural and Applied Economics thesis is dedicated to the late Prof B.M. Dlamini and Prof M. Masuku for their mentorship and interest in my pursuit for continuing education. Dr. J.I. Rugambisa and Dr. D. Earnshaw were a source of encouragement towards finishing the MSc programme.

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**ECONOMIC EFFICIENCY OF RAINFED**
**MAIZE PRODUCTION IN THE SIPHOFANENI AREA OF SWAZILAND**

## ABSTRACT

*Government's intervention on improvement of rainfed maize production is through mechanization and input subsidy policy yet the production is still very low. This study compared the economic efficiency of rainfed maize production between no till and conventional tillage. Stratified random sampling was used to select 2 samples. A structured questionnaire was administered in three communities to collect the primary data. Descriptive statistics and stochastic production frontier model was used to analyze data. No till maize farmers in Siphofaneni are females with an average age of 50(±14.3) years while conventional tillage farmers are also 51 (±14.0) years. Educational experience was 7(±4.2) and 8(±4.5) years for no till and conventional tillage, respectively. Percentage of maize producers with no off-farm income was higher in conventional tillage than no till farming. Use of hybrid maize seeds was higher in no till than conventional tillage farming. Maize production under no till is more technically and economically efficient than conventional tillage. Economic efficiency of rainfed maize production in no till is statistically different from conventional tillage at 1% (p-0.0054). It is concluded that government investment in no till mechanization as an alternative to conventional tillage will improve maize production in rural rainfed agriculture in Siphofaneni area of Swaziland.*

Key words: rainfed maize production, Economic Efficiency, Stochastic Frontier Production Function, Soil Tillage.

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## ABBREVIATIONS

| | |
|---|---|
| **ACAT** | Africa Cooperative Action Trust |
| **AEZ** | Agro-ecological zone |
| **CA** | Conservation Agriculture |
| **CAADP** | Comprehensive Africa Agriculture Development Programme |
| **CASP** | Comprehensive Agriculture Sector Policy |
| **CSP** | Country Strategic Paper |
| **GAP** | Good agricultural practices |
| **GDP** | Gross Domestic Product |
| **FAO** | Food and Agriculture Organisation |
| **FDI** | Foreign Direct Investment |
| **NDS** | National Development Strategy |
| **RDA** | Rural Development Areas |
| **SPF** | Stochastic Production Frontier |
| **SWADE** | Swaziland Water & Agricultural Development Enterprise |
| **SNL** | Swazi Nation Land |
| **TDL** | Title Deed Land |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background to the Study

Comprehensive Agriculture Sector Policy (CASP) (2005) states that the National Development Strategy (NDS) provides a broad national vision on development. Swaziland's NDS underlines the need to define and strengthen sectoral policies and strategies geared towards food security and poverty alleviation. Government intervention always springs from a given policy hence development of the agriculture sector was guided by the sector-wide policy and strategy. Propounded policy statements present the intentions of government towards the overall development of the agriculture sector. Government policy statement on rainfed agriculture provides that the mechanization of rainfed agriculture should be improved and that the involvement of the private sector be promoted and facilitated (CASP,2005).

The objectives of CASP are to increase agricultural output and productivity; to increase the earnings for those engaged in agriculture by promoting adoption of diversification and sustainable intensification and use of appropriate technology; to enhance food security; to ensure sustainable use and management of land and water resources and to stabilize agricultural markets. These objectives have far reaching implications on the factors that directly contribute to agricultural productivity. Increased agricultural output and productivity by, but not limited to the use of appropriate technology and ensuring sustainable use and management of resources speaks to increased technical and allocative efficiency of rainfed agricultural production systems. The interest of agricultural economists then would be what is the total economic efficiency of rainfed agricultural system due the government's mechanization of rural agriculture programmes?

It is noteworthy that CASP's objectives aim at increasing productivity, which is generally viewed as the maximization of output by improving the use of given set of resources (CASP, 2005). These objectives are complementary to increasing agricultural output and productivity with appropriate technologies and methods. The outcomes of increased productivity include increased earnings for those engaged in agriculture, which is predominantly the rural population under rainfed agricultural production systems. Overall effects of productivity increase is the improvement of the status of food security. Programmes employed in the implementation of the policy on mechanization of rainfed agriculture are key in bringing the desired intention of the policy. While the objective might be to move closer to food security, the cost of realizing the objective with regards to negative externalities must be assessed.

Agriculture sector policy statements concerning rainfed crop production in the country, present an intention to mechanize farming processes in rural agriculture. National Policy supports mechanization of rainfed agriculture with involvement of the private sector. Mechanization involves a number of aspects which include but not limited to irrigation systems, use of farming implements and relevant technologies. A number of initiatives are evident and attest to progressive realization of the policy objective to mechanize agriculture in rural areas. Tractor services supplied through the Rural Development Areas (RDA) programme is evidence of the move towards mechanization rainfed agricultural production systems.

### 1.2 Development and Principles of Conservation Agriculture

Pimentel and Burgess (2013) asserted that humans worldwide obtain more than 99.7% of their food (calories) from the land and less than 0.3% from the oceans and aquatic ecosystems. The Food and Agriculture Organization - FAO's official definition of "Conservation Agriculture – CA" is defined as the Resource saving agriculture crop production concept that strives to achieve acceptable profits together with high and sustainable productivity levels while concurrently conserving the environment (The REOSA Technical Brief 01, 2010). The Technical Brief 01 presents three basic principles of CA as minimal soil disturbance, permanent soil cover and, crop association and rotation. Harrington (2008) states that CA is more than just the use of no-till implements but a complete system of farming. In his article on the history of Conservation Agriculture, he states that CA involves little or no disturbance of the soil, no burning, direct seeding into previously untilled soils and permanent soil cover. The development of no-till implements has been a technological and innovative response to the need for the mechanization of CA.

It is asserted that there are significant losses of soil due to wind and rainfall erosion. Agriculture plays a major role in creating a susceptible environment in which the soil is exposed to erosion. Cultivation of the entire field leaves the soil bare and exposed to agents of erosion. When the soil is cultivated it gets loose and then remains bare making it easy to have the soil particles blown away by wind or washed away by rain water. Pimentel and Burgess (2013) estimated worldwide losses of the most important agricultural resource at approximately 75 billion tons of fertile soil from world agricultural systems each year.

Agriculture brings the initial contribution towards food security through agricultural production. Surplus in food production becomes the springboard for economic development, leading to industrialisation. This suggests that while agriculture has the unfortunate contribution to land degradation and cannot be done away with, innovation and application of science should develop means by which land can be used for farming while there is little damage caused to the soil. Conservation agriculture seeks to address this problem through the application of Good Agriculture Practices – GAP (Africa Cooperative Action Trust -ACAT, 2014).

### 1.2.1 Principle 1: Minimal soil disturbance

The tenet of conservation agriculture aims at minimizing land degradation while maximizing the land resource's productivity for food production. An estimated 1.5 billion ha of world cropland now under cultivation for crop production is said to be almost equal in area to the amount of cropland (2 billion ha) that has been abandoned by humans since farming began (Pimentel & Burgess, 2013). More soil would be lost unless soil conservation practices are applied concurrently with agricultural practices. Conservation Agriculture promotes minimum tillage or no tillage in preparation of the soil reducing the damage of the physical properties of the soil.

Minimal soil disturbance allows the retention of soil organic matter. This not only provides nutrients but also stabilizes the structure of the soil, making it less vulnerable to crusting, compaction and erosion (Food and Agriculture Organization - FAO, 2010). The principle is while planting crops, there should be no unnecessary breaking (cultivation) of the soil where no planting shall take place. Only the part where crops shall be planted should be disturbed. Considering the size of a seed, in the case of maize, it has a very small diameter hence very minimal soil disturbance should take place when planting. By best horticultural practice, a seed planting depth is five (5) times its own diameter. Much of the depth of soil cultivation when using conventional tillage approached is not necessary. The environmental soil preserving benefit of no till is the protection of the soil by significantly reducing the planting depth. Minimal cultivation limits the extent of the damage of the soil structure.

Economic aspects of minimal soil tillage emanate from the reduced mechanization hours due to less time take in soil preparation. Less fuel is used due to reduced powered implements run time. Time saved can be used for other agricultural activities. The number of soil preparation operations is significantly reduced. Cultivation and breaking of clods are eliminated operations. No till soil preparation incorporates direct seed planting without or with minimal soil cultivating. This is a contribution to the technical efficiency of rainfed maize production of no till or CA with a high benefit on soil's productivity potential.

### 1.2.2 Principle 2: Permanent soil cover

Elimination of cultivation which is the direct cause for having the soil remaining bare after cultivation ensures continuous soil cover. Use of no till farming techniques ensures continuous soil cover in the fields. Crop residues are retained on the field as mulch and/or cover crop by reducing crop removal and allowing minimal animal access after harvesting. The cover crop protects the soil from exposure to agents of erosion by minimizing the effects of the physical impact of rain and wind while improving retention of soil moisture (FAO, 2010). Soil cover acts as mulch thus improving soil moisture conservation. Covering the soil implies that even with minimum rains the soil maximizes water conservation a property that is good for rainfed agriculture.

Microorganisms are agents of nutrients recycling by helping breakdown organic matter. Preserving the soil provides an intact habitat for microorganisms. Coupled with minimum or no tillage of the soil, there is minimal disturbance of the soil which is a habitat for the soil mesofauna. With a good microorganism habitat there is an increase in their population ensuring maximum decomposition of organic matter.

Minimal crop removal indirectly contributes to improved soil fertility from recycling of nutrients. Crop residues provide the material for microbial activity thus improve recycling of nutrients in the soil.

Economic benefit of prolonged use of CA is the builds up of the soil's own reservoir of nutrients. The accumulation of the natural reservoir of nutrients implies decreased need for the use of synthetic fertilisers which are also a direct cause of chemical soil problems. Natural fertility indirectly provides for the economic contribution of CA in that fertiliser is a major input in crop production. The reduced need of replenishing soil nutrients through application of synthetic fertilisers, leads to reduced cost of production resulting from reduced expenditure on this input. The reduced expense on fertiliser due to low quantities of fertiliser needed is a saving that could be redirected to finance other family needs indirectly contributing to poverty reduction. A logical deduction is that CA indirectly contributes to the allocative efficiency of rainfed maize production.

### 1.2.3 Principle 3: Crop association and rotation

Conservation encourages the use of crop association and crop rotation. While crop association is the mixture of crops planted on the same field, crop rotation is the planting of a different crop every planting season every after a few years. Crop association and crop rotation break the life cycle of pests, thus helping control pests (FAO, 2010). Both crop association and crop rotation improve availability of nutrients in the soil. Crop rotation involves planting of different crops in the field over a given period. Scientific evidence behind the principle lies in the different crop behaviour and use of different nutrients from the soil. While non-leguminous leafy crops use a lot of nitrates to maximize growth, rotation with a legume crop replaces the nitrates through the soil nitrification process. This ensures recycling of the nitrogen into the soil.

## 1.3 Global trends in Conservation Agriculture development

Harrington (2008) traces the propagation of modern CA back to a policy statement of the 1970s and 1980s by the Government of Brazil which intended to bring a shift from having sloping and high rainfall areas of Southern Brazil to soybean farming.

Implementation of the government policy led to a serious crisis as there was massive erosion of the soil and land degradation. A response to the land degradation was an introduction of a system of farming which had already been tested successfully in the US in the 1950s in which planting of crops was done without the tillage of soil. Early champions of CA in Brazil consulted with CA specialist in the University of Kentucky who facilitated access to early prototype no-till implements.

Huggins and Reganold (2008) stated that the US followed by Brazil is leading in terms of largest areas under no-till agriculture. About 85% of the global land under CA is in North and South America. Rosenberg (2016) presents statistics that show that Africa is the second largest continent at 30 244 049 sqkm after Asia which is the largest at 44 391 162 sqkm. South America occupies the $4^{th}$ position at 17 821 029 sqkm, making Africa 1.70 times larger than South America. Africa is sadly at 0.3% land occupation under CA while South America is at 46.8% followed by North America at 37.8%. Swaziland being a part of Africa, suffers slow adoption of the technologies associated with CA. It should be noted though, that there has been a development of no till advocacy structures with government receiving help from development partners and NGOs (ACAT, 2014; FAO, 2015)

## 1.4 Introduction to Conservation Agriculture in Swaziland

A study "Does Conservation Agriculture Matters in Swazis' Economy? Evidence from Maize Producing Farmers in Ngwempisi Rural Development Area of Swaziland" gives a brief history about CA in Swaziland (Oladeebo & Mkhonta, 2013). The study traced the introduction of CA back to the Shewula area in 2002. This was followed by the adoption of CA in 2002 by the Cooperation for the Development of Emerging countries (COSPE) and FAO. According to Oladeebo and Mkhonta (2013) there has been a change in the way people react towards the adoption of CA in the country.

Conservation Agriculture – CA, also referred to as no till was introduced in Swaziland in the year 2002 at Shewula, in the Lubombo Region (Oladeebo & Mkhonta, 2013). Food and Agriculture Organization has been instrumental in the promotion of the practice of Conservation Agriculture among rural farmers. Introduction of no till has involved households engaging portions of approximately 0.25ha of their family fields for the CA farming (ACAT, 2013). Rural farmers are allowed to experience the concept of CA in different approaches including but not limited to agro forest, no till which are forms of CA among many other farming methods.

Food and Agriculture Organization continues to engage rural farmers on CA. Several steps are being taken to introduce CA as an alternative to conventional soil tillage. A no till task force has been introduced in the country in which NGOs and government have joined forces to carry forward the mandate of CA to the rural communities. This task force is strategically developed to allow a propagation of a unanimous message on encouraging all maize farmers to embrace CA methodologies in rural agriculture. The Africa Cooperative Action Trust - ACAT trained 354 farmers, 139 were males and 215 females in the period 2012 - 2013 on Good Agricultural Practices – GAP (ACAT, 2013).

### 1.5 Mechanization of Rainfed Agriculture in Swaziland

MOAC has decentralised the provision of both technical and administrative agricultural assistance to rural communities. Swaziland Rural Development Project-II (SRDP-II) was a continuation of the Swaziland Rural Development Areas Programme (RDAP) when it was initiated in 1964. The programme was mainly concentrated in building rural infrastructures (dams, roads, and water supplies). After Swaziland's independence, a new RDA programme was launched in 1970, which concentrated mainly on four areas termed as maximum input areas (Futa & Aeppli, 1986).

Establishment of RDAs in all four regions of the country has ensured rural farming communities have access to services provided by the agriculture sector. The Ministry of Agriculture and Coopratives has RDAs in the four (4) administrative regions of the country (National Maize Corporation – NMC , 2010). Distribution of the RDAs is a strategic administrative programme in which the several rural communities could have access to the centres. RDAs play a significant role in the management of the implementation of the agriculture sector policies in rural rainfed farming. It is through the RDAs centres that farmers are equipped with agricultural skills and knowledge, resourced with input subsidies and offered customised service regarding individual farming activities.

Government initiatives to improve services provision to rural farming are implemented through the RDAs programme. Since the RDAs occur in rural farming communities, farmers are afforded easy access to government interventions. Tractor-hire service was created basically to provide mechanical power to Swazi farmers. Beginning as a pilot project, it was to demonstrate the benefits of mechanised farming. The pilot project was initiated with four RDAs namely Ludzeludze (Central) RDA, Northern RDA (Ntfonjeni), Mahlangatsha RDA and Southern RDA (Futa & Aeppli, 1986).

Low mechanization in rural rainfed agriculture leads to farmers relying on hand tool technology to complement the available but limited powered tools. Hand tools are powered entirely by human muscle, and in many cases, women's muscle (Mrema, Baker & Kahan, 2008). Food and Agriculture Organization/World Food Programme - WFP (2015) reported an average family size of 6.5 members; they are the source of farm labour. Rural mechanization of rainfed agriculture seeks to reduce such challenges of depending on human power. On the other hand there are concerns regarding demographic trends affecting the agricultural sector and productivity, including increasing urban populations. The ageing rural population consisting of ageing farmers makes up the farming population. The young and educated group migrates to urban areas to escape arduous and back-breaking hand tool agriculture (Mrema & Cruz, 2008).

Most TDL maize farming is under heavy mechanization. As opposed to SNL farmers, the issues of capital, farm land size are not constraints to the purchase of farming implements. Farming activities are sustained with the technical help from Extension officers in the SNL maize farming while commercial farmers rely on their own expertise in the production of maize. The Ministry of Agriculture and Cooperatives presented new tractors which were distributed to the RDAs (FAO/WFP, 2015). It was reported that there were 116 privately-owned tractors available for use in the

From 1997 to 2005 a total of 225 tractors were received by the Swaziland Government. FAO/WFP (2015) reported a fleet of 188 tractors, of which 118 of these were in good working condition. Subsidized tractor hire through the RDAs was at SZL 130 per hour for the 2014/2015 season; with an estimated turn-around-time conventional tillage of a hectare filed is between 2.2 and 2.5 hours. The 2015/2016 cropping season had subsidized tractor hire costs projected to vary between SZL 200 to SZL 300 per hour. Tractor hire programme ensures availability of conventional tillage mechanization to the farmers who may not have adequate resources to purchase their own tractors.

Provision of tractor services by the private sector is in keeping up with the involvement of the private sector in the mechanization of rural rainfed agriculture. Privately owned tractors are availed by their owners through registration with the RDAs and rural farmers register with the RDAs for the tractor services. Private tractor owners help government to reduce the shortage of tractors in rainfed maize production.

### 1.6 Rainfed Maize Production in Swaziland

Maize is a staple food for the Swazis and grown in both Swazi Nation Land (SNL) and Title Deed Land (TDL). Dlamini and Masuku (2011) stated that the total surface area for the country measuring 17, 364 sq km, 36% of the arable land is grown with maize. Sixty percent (60%) of the total surface area is Swazi Nation Land. Production of maize on TDL is market-oriented and uses modern technology and irrigation systems, while production on SNL is largely subsistence-oriented and rain-dependent. The SNL subsistence-oriented farming is characterised by low mechanization though the Ministry of Agriculture and Cooperatives provides tractor services and agricultural implements which are hired by rural communities through the RDAs.

Table 1.1 shows a five year period of maize production by each AEZ, between 2009/10 to 2014/15. The planting season 2014/2015 was below the five year period average on maize production despite the input subsidy availed to maize farmers. The trend in maize production indicates highs and lows in maize yield.

Table 1.1:

*Swaziland - AEZ Maize Production 2009/10–2014/15 (tonnes) with 2015/16 Production Forecast*

| | 2010/11 | 2011/12 | 2012/13 | 2013/14 | 2014/15 | 5-year average | 2015/16* | 2015/16 as % of 5 year average |
|---|---|---|---|---|---|---|---|---|
| Highveld | 36 437 | 31 315 | 31 440 | 38 821 | 32 887 | 32 814 | 17 208 | 52.4 |
| Middleveld | 33 127 | 32 056 | 32 738 | 48 097 | 39 548 | 35 733 | 13 602 | 38.1 |
| Lowveld | 12 532 | 9 273 | 12 994 | 19 081 | 6 646 | 13 176 | 1 741 | 13.2 |
| Lubombo | 2 589 | 2 774 | 4 762 | 12 872 | 2 542 | 5 472 | 908 | 16.6 |
| **National** | **84 685** | **75 418** | **81 934** | **118 871** | **81 623** | **87 195** | **33 460** | **38.4** |

**Source:** FAO/WFP Special Report July 2015
*AEZ maize production forecast

Figure 1.1 shows a decline in maize production in 2014/15 compared to the 2013/14 planting season. Food and Agriculture Organization /World Food Programme – FAO/WFP Special Report (2015) is on record that Ministry of Agriculture and Cooperatives reported a distribution of inputs to 3 723 rural farmers. Inputs other than the subsidised tractor services include subsidised inputs (20kg seeds, 6 x 50kg fertiliser and 4 x 50kg LAN) per household. For 2015/2016 a farmer paid SZL2000 for the same mix of farming inputs.

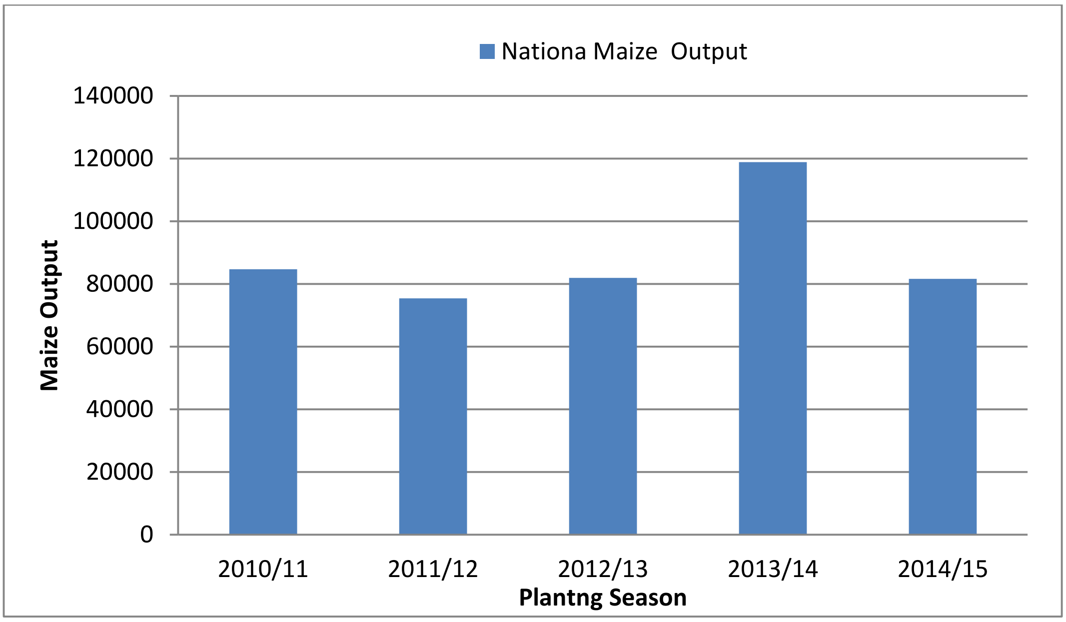


Figure 1.1: Swaziland – AEZ annual maize production 2009/10-2014/15
Source: Created by author 2017 from FAO/WFP Special Report July 2015

Table 1.2, shows an estimated total hectarage of 87 164ha that was planted with maize in 2014/2015 planting season, alongside the provision of rural mechanization through the tractor hire programme. An estimated hectarage of 69 874ha was harvested. The Lowveld agro-ecological zone together with the Lubombo Plateau experienced low planting/harvest ratio. Low planting/harvest ratio may be indicative of a high inefficiency in maize production or adverse weather conditions in these agro-ecological zones.

Table 1.2:

*Swaziland – harvested/planted area ratio by AEZ 2014/15*

| AEZ | Estimated area planted | Estimated area harvested | Harvest/planted area ratio |
|---|---|---|---|
| Highveld | 23 266 | 21 925 | 0.94 |
| Middleveld | 32 408 | 30 421 | 0.94 |
| Lowveld | 22 852 | 13 291 | 0.58 |
| Lubombo Plateau | 8 638 | 4 236 | 0.49 |
| **Swaziland** | **87 164** | **69 874** | **0.80** |

Source: FAO/WFP Special Report July 2015

Figure 1.2, shows a continuous increase in white maize export for the period 2011/2012 to 2014/15, indicating that maize production in Swaziland is not meeting the consumption demand.

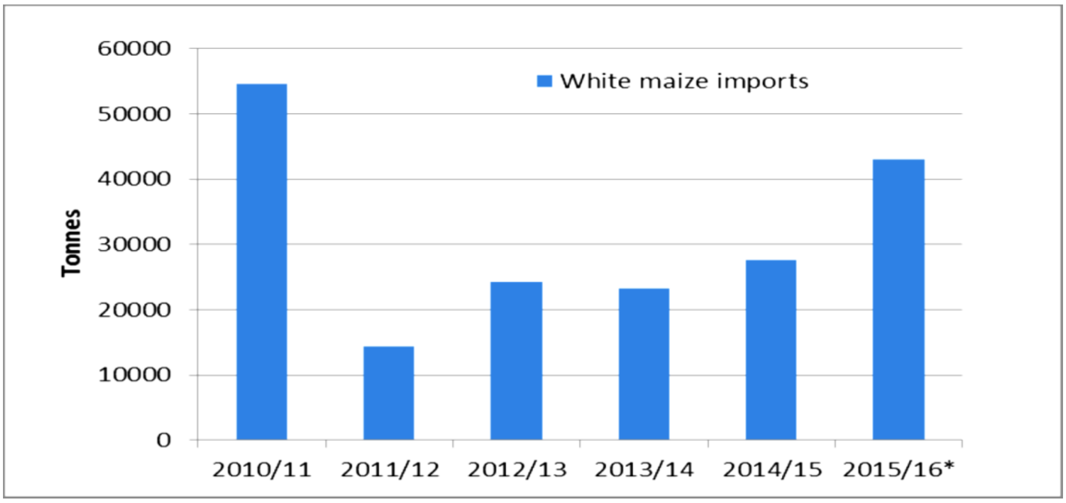


Figure 1.2: Swaziland – annual white maize imports 2009/10-2015/16

Source: FAO/WFP Special Report July 2015 from South African Grain Information Service (SAGIS) and CFSAM 2015 for 2015/16.
* Estimated white maize import requirement for 2015/16.

Figure 1.3 reveals that the Lowveld and the Lubombo Plateau are the least contributing in maize production. The joint percentage of the least contributing maize production AEZs was at 11% for the 2014/15 planting season. The two major contributing AEZs in maize production are the Highveld and Middleveld.

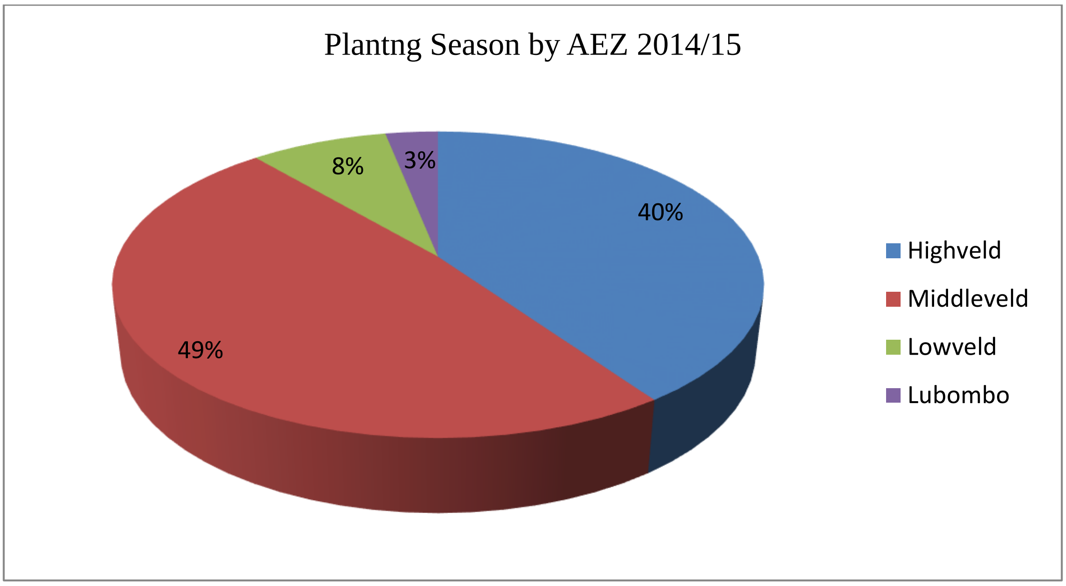


Figure 1.3: Swaziland – AEZ annual maize output 2014/15
Source: Created by author 2017 from FAO/WFP Special Report July 2015

## 1.7 Statement of the Problem

The National Maize Corporation reported that Swaziland had been importing maize from South Africa for the past 40 years (NMC, 2010). According to Mashinini *et al.*, (2006) 60% of the country's domestic maize requirement was imported from South Africa. FAO/WFP Special Report (2015) estimated a total of 81 623 metric tonnes of maize that was produced for the year 2014/2015. The Special Report estimated cereal imports requirements totalling 137 701 tonnes of which 87 547 was white maize. While the CASP aims to realize increased maize productivity, indications that women and child labour, use of hand tools and limited resources dominate rural agriculture, rainfed maize production might not be competitive. There is continued acute shortage of the staple food due low maize yield with increasing importation of maize to offset the gap in consumption demands.

The Government of Swaziland and her development partners have introduced several interventions to improve maize production in rural agriculture but productivity has not been improving. Some of the interventions include subsidised tractor hire, subsidised farming inputs and technical services through the extensions services. Maize production input subsidy policy includes but not limited to, subsidised tractor hire, subsidised farming inputs mainly fertiliser and seeds. These input subsidies focus on maize production as per national policy through mechanization of rainfed agriculture. In response to soil tillage mechanization of rainfed agriculture, conventional soil tillage implements take precedence over no till implements, yet a change to other soil tillage mechanization technologies exist with potentials for improving rural rainfed maize production. With the prevailing rainfed maize production environment, it is important to estimate the extent to which rainfed maize production is economically efficient to impact maize productivity towards levels of food security and reduce the importation of maize.

## 1.8 Objectives of the Study

The major objective of the study was to estimate and compare economic efficiency of rainfed maize production between no till and conventional soil tillage mechanization technologies in three farming communities (Hlute, Madlenya 1 and Vikizijula) in the Siphofaneni area of the Lubombo region.

The specific objectives of the study were to:

(i) describe the socioeconomic characteristics of maize farmers producing maize under rainfed rural agricultural production in the study area,

(ii) estimate and compare economic efficiency of maize production using no till and conventional tillage mechanization under rainfed agricultural production,

(iii) determine the factors affecting the economic efficiency of maize production under rainfed agricultural production in the study area.

## 1.9 Research Hypothesis

The following hypotheses were tested in the study:

i) There is no significant difference in the economic efficiency of rainfed maize production between no till and conventional soil tillage technologies.

ii) socioeconomic factors (such as age, farming experience, formal education, gender, household size, off-farm income, seed type and workshop attendance) do not influence the economic efficiency of rainfed maize production.

## 1.10 Significance of the Study

It is significant that adequate comparative research studies be conducted to establish the best alternative soil mechanization technology to improve maize production under rainfed agriculture. Research-based results are important for the selection of alternatives policy intervention in soil tillage technology. A Comparison of the economic efficiency of maize production using alternative soil tillage mechanization technologies will help inform government's choice of the best policy intervention for the mechanization of rainfed agriculture that is profitable and economically efficient for rural farming.

## 1.11 Definitions of Terms

**Mechanization** – shall refer to the use of soil tillage implements through powered machinery as inputs to achieve agricultural production.

**Decision Making Unit –** shall refer mainly to the maize farmers as decision makers on the choice of input used in the production of maize in rainfed agriculture.

**Conservation Agriculture (CA)** – shall be synonymous with minimum tillage, zero till and or no till.

**Conventional Tillage** – The use of soil disturbing (cutting) agricultural implements in crop production with refer to use tractor drawn cultivating implements.

## 1.12 Limitations of the Study

The area under investigation covered a maize farming community over a wide area of approximately a radius extending 17 ± 2km. There was also limited time available to complete the survey as the farmers were to individually respond to questions in the data collecting instrument at their homes. There enumerators were trained on the use of the instrument before being engaged for data collection. Private transport was availed to improve coverage of the maize producing homesteads. The enumerators were also incentivised for the task of collecting data.

# CHAPTER 2

# LITERATURE REVIEW

Chapter 2 presents the reported reviewed literature related to the study. The chapter is presented in 3 subtopics. Subtopic 2.1 theoretical review presents explores production a process of transforming inputs to output which is the basis of the study. Subtopic 2.2, Empirical review reports on methodologies, results and findings from related research studies including the recommendations. The subtopic 2.3 Methodological review presents methodologies employed in the estimation of parameters of the production and cost functions, and the determination of factors affecting efficiency. The chapter ends with reviewing the existing gaps and the approach this study shall follow developing from what other research studies have accomplished.

## 2.1 Theoretical Review

According to Parsons (2002) production is a process of transforming a set of inputs, $X_i$ into a set of output $Y_i$ in which the transformation process takes place in the context of a body of knowledge called a production function. In 1928, Charles Cobb and Paul Douglas concluded that there was a relationship between output, and inputs namely labour and capital (Blanchard, 2009). Their conclusion was represented in the function $Y = K^{\alpha}N^{1-\alpha}$ which gave a good description of the relationship between output, physical capital, and labour in the US from 1899 to 1922.The principal activity of any firm is turning inputs into outputs (Nicholson, 2005). According to Kalirajan, (1990) firms or economic agents also called decision making units –DMU, make decision on the use of inputs to produce output. Economists' interest in the choices of firms in which production goals are accomplish, led to the development of the structure of an abstract model of the production environment (Nicholson, 2005).

According to Dharmasiri (2009) improvement in agricultural productivity is generally considered to be a result of more efficient use of factors of production leading to economic growth. A better understanding of growth, if it leads to the design of policies that stimulate economic growth is that it should improve the standard of living (Blanchard, 2009). Productivity is output per unit input or the output per unit area. A point at which the Isocost line is at tangent to a given isoquant will model a production environment in which levels of maximum output can be achieved for a given least cost combination of inputs (Debertin, 2012). The more the farmer moves towards zero, then the farmer is becoming less efficient with the use of inputs at the given technology being used (Chiona, Thomson-Kalinda & Tembo, 2011). Technical improvements allow the DMU to produce a given output with fewer inputs by shifting total costs down if input prices remain the same (Nicholson, 2009).

Use of technology such as mechanization and scientific knowledge improves the DMU's efficiency of production. Agricultural mechanization has a wider scope than normally thought of as it covers the manufacturing, distribution, maintenance, repair, management, and utilization of agricultural tools, implements, and machines (Houmy *et al.,* 2013). Many rural Africans wait for governments which themselves have no resources due to low economic development to provide the means of mechanization (Mrema *et al*., 2008). According Mrema and Miranda-da-Cruz (2008) agricultural mechanization efforts shall succeed in Africa, if the urgent need for all concerned, which includes farmers, planners and policy-makers, together understand and contribute to agricultural mechanization efforts across the entire farming system and with a value chain perspective.

Application of agricultural mechanization includes but not limited to agricultural land development, crop production, harvesting, and preparation for storage, on-farm processing and rural transport (Houmy *et al.,* 2013). The importance of government's role in mechanization is that of identifying the correct strategies for increasing mechanization (Mrema & Miranda-da-Cruz, 2008). According to Mrema *et al*., (2008) a shift to tractor and other machine-powered equipment can be seen as a broader strategy to make agriculture attractive to the younger, energetic and innovative generation of farmers.

Production has two economically distinguishable random disturbances with different effects, DMU's errors and randomness due to factors outside the control of the DMU (Aigner, Knox Lovell & Schmidt, 1977). Variation in productivity may be attributed to DMU's inefficiencies and externalities which lead to inefficient allocations of resources because of market imperfections (Nicholson, 2005). The variation can be classified into conventional, inherent in the farmer's decision on inputs use and non-conventional factors related to market environment externalities, weather condition and natural disasters (Chiona *et al*., 2011). However, these disturbances could be minimized by improving the efficiency of production's two main components being technical and allocative efficiency (Parson, 2002). There is a relationship between the two components of randomness in productivity. A well-managed production firm in which the economic agents are technically efficient with their inputs operates closet to its production frontier and close to its least-cost expansion path (Schmidt & Lovell, 1980).

The presence of shortfalls in efficiency of production means that output can be increased by reducing these production process shortfalls without requiring additional conventional inputs and there may be no need for new technologies (Binam- Akoa *et al*., 2004). For a similar bundle of inputs and technology, an economic agent that uses the best possible practice methods achieves the maximum possible output than one who does not (Parsons, 2002). Pioneering works of Farrell of introducing the production frontier and ability to compare levels of efficiency across economic agents is still the major reason for estimating the frontier (Jondrow *et al*., 1982).

## 2.2 Empirical Review

Mignouna, *et al.*, (2010) investigated the adoption of new maize and efficiency of production in Western Kenya using the Tobit and Stochastic Production Frontier models. Technical efficiency was estimated at 70% for the population studied. To underscore the importance of new innovations, adoption of Imazapyr-resistant maize (IRM) significantly increased frontier maize output while household size decreased inefficiency. The results showed that the adoption of the Imazapyr-resistant maize was associated with high household income. Forty-one percent of the farmers were reported to have had at least one visit by an extension officer. Adopters of IRM variety were more literate than non-adopters. Exposure to Imazapyr-resistant maize through the visit by the extension officers significantly influenced farmers to adopt the technology in that 78% of the farmers visited adopted the IRM technology.

According to Chiona *et al*., (2011), there are two categories of factors affecting farmers' efficiency namely conventional and non-conventional factors. There are factors that are within the farmer's control including but not limited to amount of seed, fertilizer, pesticide, labour and all other farming inputs that the farmer decides to use commensurate to the scale of production. Non-conventional factors would include factors that are outside the farmer's control not limited to land productivity, export market stability and research.

Dlamini *et al*., (2012) investigated technical efficiency of maize production in Swaziland for 127 farmers. They reported a wide variability in terms of maize yield by farmers. It was reported that the average scale of production was 2.36ha of land per household. The study found that technical efficiency ranged from 14.5 to 93.3%. Results of the study estimated average maize yields at 598.93(±934.95) kg/ha. A range of 9740kg/ha was reported. Investigators reported averages of inputs usage as, 12.30(±11.2) kg/ha of seeds and 127.74(±86.70)kg/ha. Average labour usage was estimated at 30.59(±26.62) labour-days/ha. It was concluded that maize production was technically inefficient. Two major environmental challenges cited were lack of adequate rainfall and high temperatures. Lack of resources included unavailability of tractors and lack of income which was exacerbated by high costs of fertiliser. The study also revealed that individual farmers from the population studied, each could increase yield by 20% using the current input resources.

Grigoras *et al.*, (2012) conducted a study on "Conservation Agriculture versus Conventional Agriculture: Influence of an Agricultural System, Fertilizer, Plant Production on Wheat Yield" and found that wheat yield was 5001kg/ha in conventional tillage and 5272kg/ha no-till. Productivity increase was associated with preservation of water in the soil when using no-till.

Darko and Ricker-Gilbert (2013) estimated the "Economic Efficiency and Subsidized Farm Inputs: Evidence from Malawi Maize Farmers" using stochastic profit function models to estimate farm specific efficiency of maize farmers. The study found that maize farmers in Malawi were, on average, only 46.33% efficient in production, and that efficiency was positively affected by farm input subsidy, education and irrigation. Although the subsidy improves efficiency, efficiency among beneficiaries of the subsidy program is very low (about 47%). Although the subsidy program improves productivity, there was over 50% room for improvement in efficiency even among beneficiaries of the subsidy program. The study concluded that pursuing subsidy program alone was not very effective in improving agricultural productivity but to be implemented along with other programs like irrigation. It was also concluded that though there was the input subsidy in place, maize farmers were still at 47% efficient

Sessiz *et al*., (2013) in their study on “Conservation and Conventional Tillage Methods on Selected soils, Physical Properties and Corn Yield and Quality under cropping system in Turkey” found that fuel usage differed between the systems. They found that fuel consumption was six times more in Conventional Tillage than No till as there was a recorded consumption of 33.48L/ha and 6.6L/ha respectively. There was statistical difference in Protein, oil and ash content.

Xaba and Masuku (2013) in a studied the“Factors Affecting the Productivity and Profitability of Vegetables Production in Swaziland,’ found that access to credit increased the farm’s efficiency. A unit increase in credit access increased productivity by 0.231kg/ha.

Ngabitsinze (2013) conducted an analysis of Economic Efficiency of maize production from 65 maize farmers in Huye District in Rwanda using the stochastic frontier cost function. Total revenue (TR), Gross margin, net farm income (NFI) and return on Rwandan francs invested (ROI) per hectare were 2,611,000 Rwf, 492,830 Rw 475,830, Rwf and 0.22 Rwf respectively. Maize farming in the Huye District was not profitable and Diseconomics of Scale was obtained as 0.99 (ES<1), hence diseconomics of scale exists. Parameter of estimate indicated positive relationship and significance at 10% level for fertilizer and labour except maize output have negative relationship but significant at 10%. While improved seed have positive relationship but insignificant quantitative estimates obtained from the cost function shows mean cost efficiency index was 1.026, slightly above frontier cost indicating that an average maize farms from the study incurred about 2.6% costs above the frontier cost indication of inefficiency.

Krishna and Veetil (2014) investigated productivity and efficiency impacts of conservation tillage in Northwest Indo-Gangetic Plains. Results showed a significant cost savings of 14%, which was associated with the adoption of zero tillage. The results also showed a pronounced productivity increase of 5%. A small but significant improvement in the technical efficiency of productivity was reported. Sihlongonyane *et al*., (2014) studied the economic efficiency of maize production in Swaziland for 188 farmers. The Cobb-Douglas model was used to estimate the parameters of the production and cost functions of maize farmers from the quantities and costs of inputs used. Individual maize farmers' inefficiencies were estimated from the production function. The EE was computed as a product of the individual farmers' TE and AE scores. The study estimated a 64.7% technical efficiency for the target population of farmers.

An allocative efficiency of 99.52% was reported and economic efficiency was estimated at 64.3%. The Tobit model was used to determine which farmer's characteristics affecting efficiency. An investigation of the effects of inefficiency of maize producers found that education was positively related to technical efficiency. An additional one year of education increased technical efficiency of the farmer by 0.0056. Household size was found to be negatively related to technical efficiency. It was recommended that if farmers were to increase fertiliser application there would be improvement in the efficiency of maize production. Subsidized inputs and continued subsidized tractor hiring were two policy areas recommended for improved efficiency in maize production.

Ng'ombe and Kalinda (2015) measured technical efficiency under minimum tillage using the stochastic frontier analysis approach. Results showed that maize farmers faced increasing returns to scale (1.074) implying that there were opportunities for them to improve their technical efficiency. The half-normal and the exponential model distributions indicated average efficiency scores of 60 and 71.1 % respectively. Lowest scores were 9.3 and 8.5 respectively. Highest efficiency scores were 89.3 and 90.9% on the same half-normal and the exponential model distributions. It was found that characteristics of the farmers including marital status, level of education of the head of the household, household size, access to off farm income, in addition to agro-ecological zone, distance of vehicular road and access to loans were statistically significant factors affecting technical efficiency.

## 2.3 Methodological Literature Review

Agricultural productivity can be measured using parametric or non-parametric approaches. Early methodologies were based on deterministic models which attributed all deviation from maximum production to efficiency (Binam, 2004). Non-parametric methodologies include a set of mathematical programming. Econometric methodologies which are largely parametric, Cobb-Douglas and Stochastic Frontier production methodologies have the advantage of capturing statistical variability (Parsons, 2002). Stochastic frontier production function is able to capture the variation in production output of the individual economic agents. The variation due to the influence outside the control of the economic agent $v_i$ and variation due to technical inefficiencies of the economic agent, $u_i$ account for the production function error term (Schmidt & Lovell, 1980). Identification of the nature of the inefficiency of production and estimation of its magnitude allows structured approaches to correct for and improve productivity.

The Cobb-Douglas production function has been pivotal in further works in the field of estimation of productivity. Study of econometrics has introduced generalized forms like the exponential regression model which expands the Cobb-Douglas Production function by allowing inclusion of additional factors of production. Exponential regression model a development on the original Cobb-Douglas Production function measures rates of change (Gujarati & Porter, 2009). Economic relationships based on optimization behaviour define efficiency frontiers. Efficiency frontiers of minimum are estimated by the cost function while efficiency frontiers of maximum are estimated by the production function for the attainment of any set of relevant conditions (Stevenson, 1980).

Stochastic Frontier Production Function, $y_i = f(x_i;\beta) + \varepsilon_i,$ has gained much prominence in its ability to estimate the parameters of the production frontier, $f(x_i)$ with an ability to estimate the effects of variables influencing productivity outside the farmer's control (Chiona et al. 2011). Components of the production function consists of $y_i$ the observed output; $f(x_i)$ the production frontier in which $x_i$ is the vector of input for observation; $(\beta)$ the vector of the parameter and $\varepsilon_i$, error term for the observation (Jondrow, 1982). The $y_i$ is the maximum output obtainable from the $x_i$, a vector of input, which itself is non-stochastic (Aigner *et al*.,1977). An economic agent normally called a decision making unit (DMU), achieves maximum possible output with increased technical and allocative efficiency from a given set of resources (Parsons, 2002).

The model deals with stochastic noise, permits statistical tests of hypothesis and degree of inefficiency, $u_i$ (Chiona *et al*., 2011). Several studies have been conducted in Swaziland estimating technical, allocative and economic efficiency. Technical efficiency (TE) focuses on the ability of the economic agent to obtain the maximum output from a given set of resources. Technical efficiency is equal to 1 when the observed output achieves its maximum feasible value, otherwise TE provides a measure of the extent to which observed output falls short of maximum feasible output. Actual shortfalls indicate the magnitude of the opportunity for improvement (Parsons, 2002).

Technical efficiency is bounded by zero and one hence the OLS is not an appropriate technique to estimate the inefficiencies. There might be a need to transform the dependent variable or use a limited dependent variable technique. Tobit regression model is a limited dependent variable technique (Parsons, 2002). Tobit model originally developed by James Tobin is also known as censored regression model (Gujarati & Porter, 2009). Tobit regression estimates parameters of a regression function where there is a possibility of information available only for the regressor not the regressand. Information for the regressand may only be available for some observations.

Darko and Ricker-Gilbert (2013) stated that Battese and Coelli extended the stochastic production frontier model to capture inefficiencies. Inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. Estimation of the parameters of the stochastic production frontier has taken centre stage in the estimation of efficiencies.

Several SFA studies have been conducted estimating of TE, AE and EE of different production environments in Swaziland and worldwide. Most of the production efficiency measurement studies conducted in Swaziland have treated technology as a constant. These methodologies also treat efficiency as predicated on the DMU's inherent randomness. When technology is constant, variation in efficiency is assumed to result from the individual farmers unique inefficiencies. This study shall approach measurement of efficiency from a comparative research perspective. Economic efficiency of maize production in rainfed agriculture shall be estimated by comparing farmers' efficiency of production when using no till and conventional tillage technologies.

The SFA methodology used in several other studies as revealed in reviewed literature shall be used for the measurement of efficiency in this study. This study methodology shall introduce a variation in the technology employed in the production environment. A SFA comparative approach shall be used to estimate TE, AE and EE of maize production for the mechanization methods used in conservation agriculture and conventional agriculture. In the literature above, it was revealed that TE of maize production has been estimated in different studies (Mignouna, *et al.*, 2010; Grigoras *et al.*,2012). Varying the technology used in maize production under rainfed agriculture shall allow assessing the impact of each technology used, on the efficiency of maize production. These comparative results of the maize production efficiency of the farmers from the different technologies shall establish the technology under which the DMUs under investigation maximize their individual efficiencies. This comparison has not been achieved by previous studies as the is absence of literature (Dlamini *et al*., 2012; Xaba & Masuku, 2013; Sihlongonyane *et al*., 2014).

# CHAPTER 3

# METHODOLOGY

Chapter 3 presents the research methodologies employed in conducting the research. The chapter begins with the research design for the study presented in section 3.2. section 3.3 presents the study area in which a survey was conducted for data collection. Samples and sampling procedures are presented in sub-section 3.4. Data collection and data analysis are presented in section 3.5 and 3.6, respectively. The chapter ends with presentations on the analytical framework and summary, presented in sections 3.7 and 3.8, respectively.

## 3.1 Research Design

A quantitative research design using descriptive statistics and econometric multiple regression analysis methodologies was conducted for the purpose of estimating technical, allocative and economic efficiencies of rainfed maize production in the Siphofaneni area of Swaziland.

## 3.2 Study area

The study was conducted on rainfed maize famers in the Lowveld agro-ecological zone, which is one of the four (4) main agro-ecological zones in Swaziland. The targeted population consisted of farmers in three participating rural communities in the Siphofaneni area, which included Hlute, Madlenya 1 and Vikizijula all located in the Lowveld AEZ as shown in map, Figure 1.4. The Lowveld is at an altitude between 150-450m and receives the least amount of annual rainfall estimated at 400-55mm. The Lowveld records the highest average temperatures at $22^0$C and can reach a maximum of $40^0$C. (FAO, 2015)

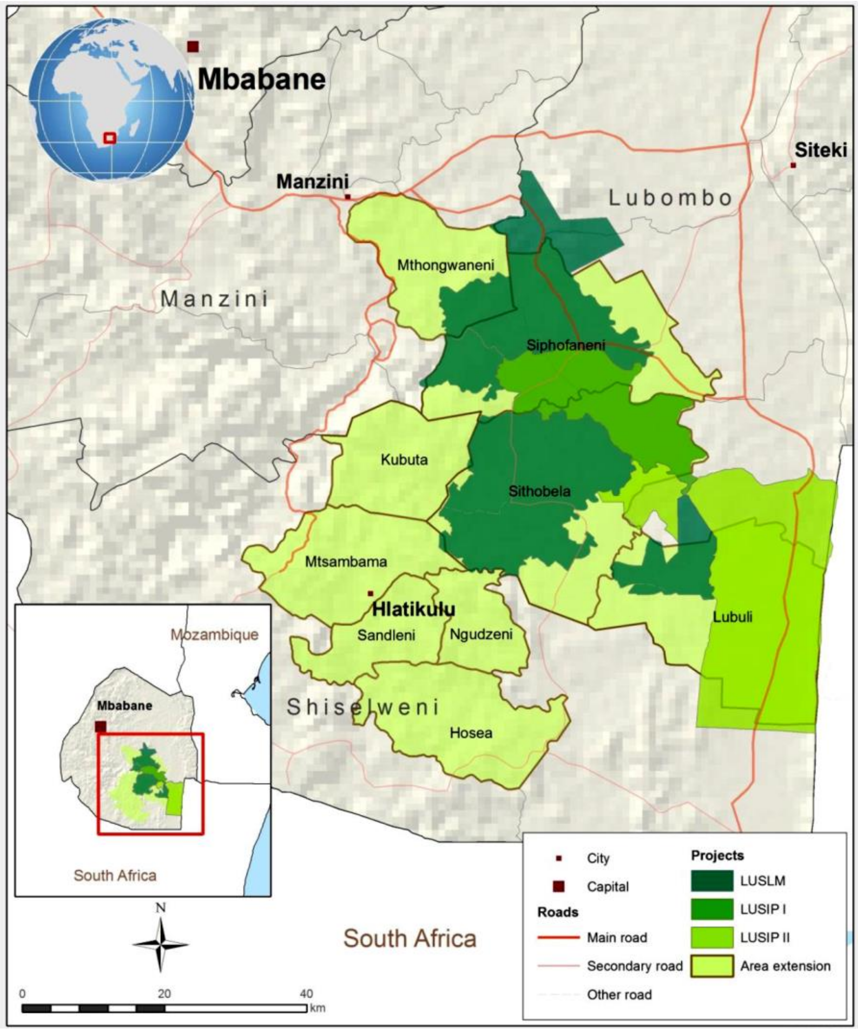


Figure 1.4: Swaziland and the Siphofaneni Project Development Area (LUSLM plus Area extension)
Source: International Fund for Agricultural Development - IFAD 2014

### 3.3 Sample and Sampling procedures

A multi-stage sampling technique was used to estimate the appropriate samples of farmers for the study. First stage sampling was the application of the stratified random sampling within the three preselected communities, Hlute, Madlenya 1 and Vikizijula. Geographical location was the stratification variable. Stratified random sampling was used to determine the representative sample sizes according to each community's participating population. SWADE provided a list of no till- based maize producing farmers from Hlute, Madlenya 1 and Vikizijula with a combined population totalling 341 households. Table 3.1 shows the samples distribution of the three communities in

Table 3.1

*Sample Sizes of the three Communities studied at Siphofaneni*

| AREA | $N_h$ | $N_h$ | $n_h$ | No till Farming | | Conventional Tillage | |
|---|---|---|---|---|---|---|---|
| | | | | Code | Sample size | Code | Sample size |
| Hlute | $N_1$ | 71 | 18 | $H_{Ni}$ | 20 | $H_i$ | 22 |
| Madlenya | $N_2$ | 87 | 22 | $M_{Ni}$ | 22 | $M_i$ | 26 |
| Vikizijula | $N_3$ | 183 | 46 | $P_{Ni}$ | 46 | $P_i$ | 46 |
| **TOTAL** | **341** | **341** | **86** | | **88** | | **94** |

Source: Source: Author's computations 2017

the Siphofaneni area. Three strata where a stratum was the number of households in rainfed maize production under each of three communities of Siphofaneni were determined.

Second stage sampling involved randomly picking every fourth farmer on the list provided by SWADE to select the actual number of respondents. Overall sample sizes of 88 no till-based maize producing farmers and 94 conventional tillage-based maize producing famers for the 2014/2015 planting season were selected.

### 3.4 Data Collection

Primary cross-sectional data on maize production for the 2014/2015 planting season were collected using a structured questionnaire developed for the study. The data were collected from maize producers using no till-based and conventional tillage methods of rainfed maize production. Section one included quantities and costs of the farming inputs input used by the maize producers. Section two consisted of variables on socioeconomic characteristics of the farmers and farm specific characteristics. Individual household maize yields in number of bags harvested were used as proxy for total output.

Three enumerators were trained on how they were to administer the questionnaire. There were given the list of communities and lists of sampled homesteads from which data would be collected. Enumerators were informed that respondents were not to be coaxed to give information. Giving information was to be voluntary and appreciation was to be extended for the time given to the interviews. The enumerators were deployed to the Siphofaneni area. Data collection was conducted in the month of December, 2016. All respondents availed themselves for the survey. The data collected were presented to the researcher for data analysis.

### 3.5 Data Analysis

Data were analysed using descriptive statistics included mean, standard deviation, frequency and range which were used to describe socio-economic characteristics of the maize producers using STATA 12.0 software. Stochastic Frontier Analysis was used to estimate the coefficients of the production and the cost function. The inputs to marginal productivity of rainfed maize production was determined by the vectors of production function parameters. Estimated coefficients from the cost function described the influence of inputs unit costs to marginal cost of rainfed maize production. The estimated inefficiencies were used to determine the farmers' technical, allocative and economic efficiencies. The Tobit regression analysis was conducted to determine factors affecting efficiency. Linear regression estimation of the socio-economic characteristics of the farmer and farm specific characteristics on the efficiencies estimated the effects of the socio-characteristics on the efficiencies.

### 3.6 Analytical framework

#### 3.6.1 Descriptive statistics of socio-economic Characteristics

Simple statistical variables were calculated to determine descriptive statistics of the collected data. Mean scores, frequencies, minimum and minimum values were determined for the farmers age, farming experience, educational experience, gender, household size, off-farm income, seed type and attendance of no till workshops. The statistical values were used to describe the socio-economic characteristics of the maize producers in the area of study.

#### 3.6.2 Estimation of the Stochastic Production Function Frontier

A firm's production environment (maize producing household) would be defined by the production function

$$Y = f(X) \quad \text{(eq. 1)}$$

Where: $f(X)$ is the production frontier

Output Y(maize yield in kilograms), which is the maximum possible output by a decision making unit (maize producing farmer) also referred to as a DMU that uses the best practices, is superior to output of a DMU who does not use best practices. Output can be at maximum or below its maximum defined by the production frontier, f(X). There cannot be an output magnitude above the frontier. The difference in the levels of output between two DMUs given the same bundle of inputs and technology would be their ability to employ best practices which define their efficiency of production.

Output however, is likely to be affected by random shocks, exp($V_i$) not under the control of the DMU. A production environment of the *i*th economic decision making unit, the DMUi can be estimated. Introducing the DMU's specific random shock, $V_i$ and technology parameter, $x_i$ of the production frontier, f($X_i$) for a given output $Y_i$, yields the stochastic frontier production function model.

The stochastic property of the production function derives from the introduction of the ($V_i$) which introduces randomness, otherwise the production function would be deterministic. Random shock is the basis of having varying outputs for the same bundle of resources and technology. Randomness does not only emanate from the random shocks outside the DMU's control, but also exists by reason of the very nature of human beings. Human beings are inherent with randomness hence $y_i = f(x_i; \beta) + \varepsilon_i$, where $\varepsilon_i \leq 0$. The disturbance term $\varepsilon_i$can be decomposed to two component of randomness yielding

$$\varepsilon_i = v_i - u_i$$

Where: $v_i$ represents the symmetric disturbance distributed as $N(0, \sigma_v^2)$

$u_i$ is assumed to be independently and identically distributed as $N(0, \sigma_u^2)$

Econometric production function model, Cobb-Douglas Stochastic Production Function frontier has several advantages as an estimation model. This model allows inclusion of all variables influencing production. It allows statistical testing of hypotheses made thus validating results. Since the Cobb-Douglas Stochastic Frontier model takes on the log-log functional form, it introduces estimation of elasticity of output to input used. Elasticity is an important phenomenon in production economics in that it estimates the magnitude of responsiveness of output to every additional unit input used. A DMU would be irrational in his/her decision to continue to increase inputs where the production function is exhibiting output that is inelastic. Practical interpretation would mean the DMU is no longer benefiting from the additional input used thus uneconomic in his/her decisions of inputs usage. Additional inputs may be used as long as the output is elastic.

The case scenario of maize production under rainfed agriculture in the Siphofaneni can be modelled using a stochastic frontier production function. A production function is modelled by taking the variables of the maize producing environment maize yield (kg), inputs used (fertiliser, seeds, herbicides, pesticides, labour and machine hours) and a disturbance term. Physical quantities of farming inputs used by an individual household in the production of maize provided the values of the independent variables (right hand side) of the production function. Maize yields harvested by individual households provided values of the dependent variable (left hand side) of the production function.

The general production function model is presented as

$$Y = F(X\beta)exp^{E} \qquad \text{(eq. 2)}$$

Where: Y = Maize Yield (kg) – dependent variable

β = Vector Parameters

X = Agricultural inputs – independent variables

E = Stochastic disturbance term ($V_i - U_i$)

can be expanded to introduce more frontiers and yield a specific stochastic frontier production function model that illustrates a particular production environment.

$$Y_1 = \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} X_3^{\alpha_3} X_4^{\alpha_4} X_5^{\alpha_5} X_6^{\alpha_6} exp^{E} \qquad \text{(eq. 3)}$$

Gujarati and Porter (2009) state that the OLS regression estimation model makes an assumption in that the regression model must be linear in parameters. Production function (eq. 3) above is not linear in parameters. Introducing the natural logs (ln) on both sides of the stochastic production function yields a functional form (log-log) that is linear in parameters (eq. 4). Equation 4, stochastic frontier production function is modelled as represented for purposes of estimating the rainfed maize production scenario of the Siphofaneni area.

$$lnY_1^* = \alpha_1 lnX_1^* + \alpha_2 lnX_2^* + \alpha_3 lnX_3^* + \alpha_4 lnX_4^* + \alpha_5 lnX_5^* + \alpha_6 lnX_6^* + (v_i - u_i) \quad \text{(eq. 4)}$$

Where: $lnY_i$ = Maize Yield in the $i^{th}$ farmer in (Kg/ha)

$lnX_1$ = Fertiliser (Kg/ha)

$lnX_2$ = Seeds (Kg/ha)

$lnX_3$ = Herbicides (L/ha)

$lnX_4$ = Pesticide (L/ha)

$lnX_5$ = labour (labour-days)

$lnX_6$ = mechanization (hrs/ha)

E = Random error-term $(v_i – u_i)$

Using the data collected from maize producing households, individual values of the dependent variable, output (maize yield in kilograms) per hectare per household, are regressed on the values of the inputs, the independent variables. Physical units of the output yield and farming inputs namely fertiliser, seeds, pesticides, labour, tractor hours and farm size are entries of the production function estimation.

Costs of the farming inputs used by the maize producers provided values of the independent variables (regressors) of the cost function. Aggregation of the costs of farming inputs per household provided the dependent variable (regressand), the total cost (C) of maize production of the individual household.

$$C = AX_1^{a_1}X_2^{a_2}X_3^{a_3}X_4^{a_4}X_5^{a_5}\, X_6^{a_6}\, exp^E \quad \text{(eq. 5)}$$

$$lnC_i^* = a_0 + a_1 lnX_{1i} + a_2 lnX_{2i} + a_3 lnX_{3i} + a_4 lnX_{4i} + a_5 lnX_{5i} + a_6 lnX_{6i} + (v_i – u_i) \quad \text{(eq. 6)}$$

Where $lnC^*_i$ = total cost

$lnX_1$ = cost of Fertiliser (Kg/ha)

$lnX_2$ = cost of Seeds (Kg/ha)

$\ln X_3$ = cost of Herbicides (L/ha)

$\ln X_4$ = cost of Pesticide (L/ha)

$\ln X_5$ = cost of human labour (labour-days)

$\ln X_6$ = cost of mechanization (hrs/ha)

E = random error term ($v_i - u_i$)

### 3.6.3 Estimation of Economic Efficiencies

Economic efficiency (EE) has two components: technical and allocative efficiency. Technical efficiency focuses on the ability to obtain the maximum output from a given set of resources for a given technology. Allocative efficiency is the DMU's ability to use the least-cost combination of inputs for maximum output for a given technology. Bravo-ureta and Pinheiro (1997) defines economic efficiency as the product of technical efficiency and allocative efficiency.

Therefore, the economic efficiency of each farmer is the product of the farmer's allocative and technical efficiency. Individual farmer's technical efficiency scores which were estimated from the production function were multiplied by the individual farmer's allocative efficiency scores which were estimated from the cost function. Specification of the model for economic efficiency is represented in the following function.

$$EE_i = AE_i \times TE_i \qquad \text{(eq. 7)}$$

Where $i = 1, 2..., n^{th}$ farmer

EE = Economic efficiency

AE = Allocative efficiency

TE = Technical efficiency

A system is economically efficient when all resources are allocated to it in the best way possible, such that there is minimization of both waste on inputs and inefficiency in the production system (Nicholson, 2005).

### 3.6.4 Determinants of Efficiency

Analysis of the determinants of efficiencies was conducted by regressing output, Y* on the socioeconomic characteristics of the farmer and farm's specific characteristics,

$P_{1i}$, $P_{2i}$, $P_{3i}$,...$P_{8i}$. Estimated parameters $a_{1,} a_{2,} a_{3,} \ldots a_{i,}$ give the magnitude of the units of change in the dependant variable, output Y* caused by a unit change in the independent variables being the socioeconomic characteristics of farmer or farm specific characteristics, $P_{1i}^{*}, P_{2i}^{*}, P_{3i}^{*}, \ldots P_{i}^{*}$. The variable occupation was omitted from the estimation as it was collinear with farm income.

The factors that cause variation of the efficiency variables would be identified through the investigation of the relationships between the calculated technical efficiency, allocative efficiency and the farmers' specific socioeconomic characteristics. Thereafter, the association between farmers' specific socioeconomic characteristics and efficiency can be established. The efficiency scores are regressed on the selected variables using Tobit model. Tobit model is specified as follows:

Efficiency ($u_i$) = f(age, farming experience, educational experience, gender, household size, off-farm income, seed type, workshop attendance)

$$u_i = X\beta_i + \varepsilon_i \quad \text{(eq. 8)}$$

$$u_i = a_0 + a_1P_{1i} + a_2P_{2i} + a_3P_{3i} + a_4P_{4i} + a_5P_{5i} + a_6P_{6i} + a_7P_{7i} + a_8P_{8i} + v_i \quad \text{(eq. 9)}$$

Where $u_i$* = efficiency

$P_1$ = Farmers age (in years)

$P_2$ = Years of farming experience

$P_3$ = Years of formal education

$P_4$ = Gender (female = 0, male =1)

$P_5$ = Household size (number)

$P_6$ = Off-farm income (no = 0, yes = 1)

$P_7$ = Seed type (hybrid =0, non-hybrid = 1, both = 2)

$P_8$ = Attendance of no till workshop (no = 0, yes = 1)

$v_i$ = disturbance term

Farmer's age was taken as a measure of the sample demographics in terms of age groups involved in farming. Rural farming largely consists of aged and poor individuals (FAO, 2015; Mrema, 2008). This group of the social strata engages in agriculture as a way of making a living in the absence of alternative gainful employment. An inverse relationship would be expected between age and the farmer's efficiency.  Younger energetic and innovative group who are most likely to be efficient, in many cases do not form part of the rural farming community.

Farmer's experience of farming in years was conceived as a measure of the accumulated of experience in planting maize under rainfed agriculture (Chiona, 2014). It would be expected that the more experienced the farmer is, the more improved the farming skill and more knowledge gained. Farming skills and knowledge would be expected to increase with more years of repeated farming. The more farming experience a farmer has the higher the expectation on improved farmer's efficiency in maize farming operation, correct use of inputs and carrying out farming operations with easy.

Farmer's years of formal education was used as a measure for literacy rate a proxy to human capital development. It would be expected that education enhances efficiency in human capital. Literacy rate increased farmer's assimilation and adaptation to new techniques. Literacy should increase ability to be self-critical, self-motivated, innovative and enable farmer to recognize or identify new farming techniques that work from the assessment of own farming operations. If the farmer develops new ways of farming through adapting to best farming practices, that should improve the farmer's efficiency.

There is gender bias in rural farming confirmed by literature which indicates that rural farming is most likely to be populated by females. Females are less likely compared to males to find employment in regular gainful employment. It would be expected that rural farming would be predominantly female.

Household size, that is the number of family members, was used to determine the dependency rate. Dependency rate could act as a proxy to socioeconomic status of the farmer. While big families would provide for farm labour in rural communities, it comes with the burden of sustainability. Household size of the farming family would pose competition on funding between domestic needs and investment capital for the farming operations. Large families would be expected to be less efficient in their farming operations imposed by the high demand for domestic funding depriving the farming operations of the same funding needs.

Farmers’ access to off-farm income was used as proxy to investment capital for farming. Off-farm income would allow the farmer through the disposable income to invest in improving farming operations. This would include but not limited to purchase of better inputs, procurement of more improved farming services, access to improved technology and to carry out improvement of farming infrastructure. Use of better farming inputs, use of improved technology and procurement of improved service should increase farmer’s services.

Farmers whose major occupation was full time farming were expected to be more efficient than farmers who did farming on part time basis. It would be expected that the farmer who is full time in farming would have more time to attend to the farming business operations. Time spent in the fields should help improve the farmer’s efficiency in the production of maize. Full time farming engagement would also be expected to make up for the other inefficiencies the farmer might have such as but not limited to illiteracy, lack of workshop attendance and inexperience in farming as the farmer is most likely to quickly gain the necessary experience and improve within a short time.

Choice of seed type used in the farming operations should also determine farmer’s efficiency. The role of science in plant breeding is to institute innovation in developing good characteristics of crop varieties. Good characteristics would include resistance to disease and to adverse weather conditions while hybrid seeds would be expected to exhibit better performance than indigenous varieties. Farmers who adopt the use of hybrid seeds were expected to be more efficient than those who did not use hybrid seeds.

The number of attendance at no till workshop was a measure of the farmer’s exposure to no till technology. Attendance at no till workshops should increase the farmer’s appreciation of the aims and contents of the workshop. A farmer exposed to a new concept would be most likely to adopt and apply the concept more than the farmer who is void of the same concept (Mignouna, *et al.*, (2010). Farmers who had attended a no till workshop were expected to be several times most likely to adopt the technology than those who were not exposed to no till training.

# CHAPTER 4

# RESULTS AND DISCUSSION

Chapter 4 presents the results of the econometric analysis of the cross sectional data collected from 182 maize producers in three communities of the Siphofaneni namely Hlutse, Madlenya 1 and Vikizijula. Subtopic 4.1 presents the results of the farm and farmers' socioeconomic characteristics are presented. Subtopic 4.2 is the estimation of the parameters of the stochastic frontier production function, the cost function, estimated technical, allocative and economic efficiency values. The chapter ends with subtopic 4.3 which presents the results of the analysis of factors affecting technical efficiency, allocative and economic efficiency.

## 4.1 Maize farmers' socioeconomic characteristics

Table 4.1 presents frequency distributions of the farmers' socioeconomic characteristics. Most of the no till maize producers (n=88) were females 57 (64.8%) and 31(35.2%) males while conventional tillage (n=94) had 48(51.1%) males and 46(48.9%) females. The mean age of farmers between 50 and 59years both no till (29.5%) and conventional tillage (27.7%) maize farmers was 54.4 ($\pm$2.6)years and 54.4 ($\pm$2.7) years . The overall number of female respondents was higher that male participants in the study. This indicate a that female presence is dominant in rural rainfed agriculture in the Siphofaneni communities. This result is supported by reviewed literature. Mrema *et al.,* (2008) stated women and children play a leading role in the tillage operations in developing communities. ACAT Report indicated observed high numbers of females who were attending lead farmer workshops in different communities (ACAT, 2013). IFAD (2014) reported that households headed solely by women and child-headed households are growing in number in Swaziland.

A majority of the farmers were below 7 years of educational experience, with 42.0% no till farmer spending 3.7 ($\pm$2.8) years and conventional farmers (46.8%) spent 4.5 (+3.0) years in forma educational. Most of the farmers (n=88) did not have tertiary education, only 2 (2.3%) have 15 – 20 years of educational experience. Descriptive

Table 4.1

*Frequency Distribution of socioeconomic characteristics Maize producing Farmers and farm specific characteristics*

| Dummy Variable | No till Farming = 88 | | | | Conventional Tillage = 94 | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | f | % | sd | Mean | f | % | sd |
| Age | | | | | | | | |
| 0 < 19 | 0 | 0 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0 |
| 20 < 29 | 22.8 | 5 | 5.7 | 2.1 | 29.0 | 1 | 1.1 | 2.0 |
| 30 < 39 | 35.1 | 14 | 15.9 | 3.4 | 35.8 | 19 | 20.2 | 2.0 |
| 40 < 49 | 45.2 | 22 | 25.0 | 2.9 | 45.9 | 20 | 21.3 | 2.5 |
| 50 < 59 | 54.4 | 26 | 29.5 | 2.6 | 54.4 | 26 | 27.7 | 2.7 |
| 60 ≤ | 68.9 | 18 | 20.5 | 7.3 | 66.0 | 28 | 29.8 | 5.6 |
| Educational Experience | | | | | | | | |
| ≤ 7 years | 3.7 | 37 | 42.0 | 2.8 | 4.5 | 44 | 46.8 | 3.0 |
| 8 < 14years | 10.4 | 34 | 38.6 | 1.5 | 10.6 | 41 | 43.6 | 1.5 |
| 15 < years | 15.0 | 2 | 2.3 | 0.0 | 15.9 | 9 | 9.6 | 0.3 |
| Gender | | | | | | | | |
| Female = 1 | | 57 | 64.8 | | | 46 | 48.9 | |
| Male = 2 | | 31 | 35.2 | | | 48 | 51.1 | |
| Off-farm income | | | | | | | | |
| No = 0 | | 49 | 55.7 | | | 74 | 78.7 | |
| Yes = 1 | | 39 | 44.3 | | | 20 | 21.3 | |
| Seed type | | | | | | | | |
| Non-hybrid = 0 | | 3 | 3.4 | | | 18 | 19.1 | |
| Hybrid = 1 | | 85 | 96.6 | | | 64 | 68.1 | |
| Both = 2 | | 0 | 0.0 | | | 24 | 25.5 | |
| At least 1 No till workshop | | | | | | | | |
| None = 0 | | 3 | 3.4 | | | 40 | 42.6 | |
| At least 1 = 1 | | 85 | 96.6 | | | 41 | 43.6 | |

Source: Author’s computations 2017 using EXCEL

statistics indicated low levels of education confirmed by investigations conducted in other developing countries in which it was noted that the young and educated migrate to urban areas and escape the arduous and back-breaking hand tool agriculture (Mrema *et al*., 2008).

Eighty-five (96.6%) no till maize producing farmers used hybrid maize seeds for maize production. Forty-nine (55.7%) farmers had no off-farm income while 39(44.3%) have alternative sources of income. Seventy-four (78.7%) farmers (n=94) who engaged in conventional tillage farmers had no off-farm income. IFAD (2014) reported that 84 per cent of the country's poor people live in rural areas, where per capita income is about four times lower than in urban areas. The Report further revealed that about 66 per cent of the population is unable to meet basic food needs, while 43 per cent live in chronic poverty. The high percentage of no off-farm income is consistent with reviewed literature.

Eighty-five (96.6%) of the no till farmers (n=88) attended at least 1 CA workshop while 40(42.6%) conventional tillage farmers (n=94) did not attend any workshop on CA technology. Hybrid seed adoption rate was high in no till-based maize production than conventional tillage at 85(96.6%) and 64(68.1%) farmers, respectively. Only 24(25.5%) conventional tillage farmers used both hybrid and indigenous maize seed varieties in their maize production.

Table 4.2 shows the descriptive statistics (mean, standard deviation and range) of farmers' characteristics. Output and inputs in maize production are also described. The average age of farmers in no till and conventional tillage maize production is 50(±14.3) year and 51(±14.0) years, respectively. The age range of 24 years to 85year for no till farmers was observed while conventional tillage farmers had an age range between 29years and 86years. There was no significant difference in the mean age value  between no till and conventional tillage farmers at 0.5% (p, -0.348). No till farmers were the least experience in their farming methodology at an average of 2 years while conventional had an average 19years in conventional tillage maize production. A t-test showed that no till farmers were significantly lower in experience compared to conventional tillage farmers in maize production at 1% (p-0.0000). The little experience of an average of two years in not till farming is associated with the fact that no till based mechanization in maize farming system is a newly introduced technology in Siphofaneni. The average educational experience was 7(±4.2) and

8(+4.5) years for no till and conventional tillage, respectively. Average household size of 7(+3.0) and 6(+28) people for no till and conventional tillage respectively, is comparable to the FAO estimated family size of 6.5 people (FAO, 2017).

Table 4.2

*Descriptive Statistics of Output, Inputs and Farmers Characteristics*

| Variables | no till farming = 88 | | | | conventional farming = 94 | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std D | Min | Max | Mean | Std D | Min | Max |
| Age (yr) | 50 | 14.3 | 24 | 85 | 51 | 14.0 | 29 | 86 |
| Farming Exp. (yr) | 2 | 3.6 | 1 | 25 | 19 | 11.1 | 2 | 41 |
| Education Exp (yr) | 7 | 4.2 | 0 | 15 | 8 | 4.5 | 0 | 16 |
| Household size | 7 | 3.0 | 0 | 22 | 6 | 2.8 | | 13 |
| Yield (Kg) | 203 | 179.9 | 0 | 800 | 408.5 | 350.6 | 0 | 1850 |
| Fertiliser (Kg) | 99 | 28.5 | 0 | 267 | 88 | 81 | 0 | 387 |
| Seeds (Kg) | 7 | 5.1 | 2.4 | 40 | 11.5 | 8.3 | 0.46 | 41 |
| Herbicide (L) | 0.7 | 0.6 | 0 | 2.1 | 1.1 | 1.0 | 0 | 10 |
| Pesticide (Kg) | 0.9 | 1.4 | 0 | 9.6 | 1.6 | 2.5 | 0 | 12 |
| Labour days | 13.7 | 14.5 | 2.3 | 109.8 | 32 | 25.9 | 9.2 | 131 |
| Mechanization (hr) | 0.45 | 0.3 | 0.2 | 1.5 | 2.2 | 2.1 | 0.6 | 11 |
| Farm size (ha) | 0.6 | 0.4 | 0.2 | 2.1 | 1.2 | 1.1 | 0.3 | 5.11 |

Source: Author's computation 2017 using STATA 12.0

The average maize yield for the no till farming was 203(+179.9) kg while the mean yield for the conventional tillage farming was 408.5 (+350.6) kg respectively. Yield for no till and conventional tillage farming had a range of 0 to 800kg and 0 to 1850kg respectively. Average maize yields estimates in high yielding agro-ecological zones were at 598.93 kg/ha (Dlamini *et al*., 2012). Low maize yield would be expected in low-yield agro-ecological zones of Swaziland where there is low rainfall and high temperatures (FAO, 2015). The zero output in maize yield can be explained by the high temperatures and drought during the 2014/2015 planting season. Some farmers abandoned their fields under the speculation that the crop would not survive the high temperatures and lack of moisture. The mean yield of rainfed maize production between no till and conventional tillage in Siphofaneni was significantly different at 1% (p-0.0000)

The average field size was estimated at 0.6(+0.4)ha for no till-based maize production per household, while conventional farming had a household field size of 1.2(+1.1) ha. Farm size range for no till farming technology was 0.2ha to 2.1ha while conventional farming had a field size range between 0.3ha to 5.1ha for conventional farming respectively. The small filed size in no till farming can be associated with the introduction of GAP project in which farmers were encouraged to reserve about 0.25ha for CA (ACAT, 2013). A t-test showed that there was no significant difference on the mean number of ha of filed size between no till and conventional tillage at 5% (p-1.000). Average amount of fertiliser application in no till (n=88) farming was 99(+28.5) kg and 88(+88.0%) kg for the conventional farming (n=94). Fertiliser quantities were estimated with a range of 27kg to 267kg. Conventional tillage farming had a range of fertiliser application between 27kg to 387kg. Seed application for no till farming (n=88) had an average mass of 7(+5.1) kg and a range of 2.4 to 40kg. Conventional tillage (n=94) had an average seed mass used at 11.5 (+8.3) kg with a range of 0.46kg to 41.0 kg.

Descriptive statistics indicated that in the conventional tillage farming the maximum field size was 5ha and the observed maximum amount of fertiliser was approximately 400kg. For no till farming the maximum field size was 2ha and the maximum quantity of fertiliser applied was approximately 250kg. These rates are not consistent with recommended fertiliser application rates of 400kg per hectare (FAO, 2105). Field size determines the quantity of fertiliser applied in the maize production farming activity.

Seed application was also not done according to recommended rates. Descriptive statistics revealed that while maximum field size was 5.1ha, the maximum quantity of seeds used was 41kg. It would be expected that the maximum amount of seeds to be recorded was supposed to be approximately 100kg if the standard recommended seed rate of 20kg/ha was used (FAO, 2105). The results indicate that farmers were at less than half of the recommended seed rate yet the farming input subsidy project by government was available to benefit farmers for the 2014/2016 planting season.

Subsidised farming inputs were supposed to alleviate the shortage of resources through the purchase of low price inputs.

Most of the farmers in no till-based maize production used a non-selective herbicide for controlling weeds. Herbicide application rate was at 4L/ha. The results indicate that while the maximum field size for no till farming was 2ha and 5ha for conventional tillage farming, the maximum herbicide quantities were 2L and 10L respectively. Observed herbicide application rates were approximately one litre to two litres per hectare corresponding to the observed average field sizes of 2ha and 5ha for no till and conventional tillage, respectively. The expected herbicide quantities for the observed average field sizes of 2ha and 5ha would be appropriately 8 and 20 litres, respectively. The results indicate that field size does not determine the quantity of herbicide to be used. Quantities of herbicides used by maize producers were determined by other than factors other application rates derived from field size.

The observed average labour-days for no till (n=88) maize production were estimated at 13.7 ($\pm$14.5) days while conventional tillage (n=94) had a comparable average of 32($\pm$25.9) labour-days to other studies. Dlamini *et al.*, (2012), in TE of maize production measurement an average labour usage estimated at 30.59 labour-days/ha was reported. The range in labour-days was 2.3 to 109.8 labour-days for the no till-based farming while 9.2 to 131 labour-days were observed for conventional tillage farming. Analysis of the data indicated that the average mechanical hours for no till were 0.45($\pm$0.3) hr per hectare.

In a comparative investigation on the effects of conservation agriculture and conventional tillage, no ill recorded the least usage of fuel (Sessiz *et al*., 2013). No till mechanization does minimum soil cutting and has fewer operations than conventional tillage hence less tractor run time resulting to the few mechanization hours (FAO, 2010). Average mechanical hours were estimated at 2.2($\pm$2.1) hrs for conventional tillage. The mechanisation hours in conventional soil tillage are equivalent to reported mechanical hours (FAO, 2015). A range of between 0.2 hours to 1.5 hours for no till-based farming and 0.6 to 11 hours for conventional tillage respectively was observed. There was a significant difference in mean number of mechanical hours between no till and conventional tillage at 1% (p-0.0000)

Table 4.3 presents the results on the total value of maize yields harvested, total costs of inputs used by both no till-based maize production and conventional tillage farming. Total costs of inputs used are also presented in Table 4.3. The average total costs incurred per household was estimated at E1 535(+858) and E 2 805(+2112) for no till-based maize production and conventional farming, respectively. An observed range of total cost of maize production per household was from E731 to E5 912 and E869 to E12 118, for no till and conventional tillage farming respectively. There were households that incurred losses in their maize production for the 2014/2016 as an output value of E0 was observed from the results.

Most of the farmers were using synthetic fertilisers. From Table 4.3, the average cost of fertiliser per household were E556(+159) and E509(+473) for no till-based farming

Table 4.3

*Total Revenue and Total Cost of rainfed maize production*

| Variables | no till farming = 88 | | | | conventional farming = 94 | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std D | Min | Max | Mean | Std D | Min | Max |
| Total output (E) | 1950 | 1727 | 0 | 7680 | 3811 | 3368 | 0 | 17 760 |
| Total cost (E) | 1535 | 858 | 731 | 5912 | 2805 | 2112 | 869 | 12 118 |
| Fertiliser (kg) | 556 | 159 | 0 | 1495 | 509 | 473 | 0 | 2310 |
| Seeds (kg) | 258 | 195 | 91 | 1520 | 400 | 297 | 14.6 | 1474 |
| Herbicide (L) | 30 | 24 | 0 | 91 | 12 | 88 | 0 | 774 |
| Pesticide (kg) | 65 | 359 | 0 | 387 | 59 | 94 | 0 | 540 |
| Labour days | 549 | 580 | 92 | 4392 | 1400 | 1115 | 414 | 5746 |
| Mechanization (hr) | 78 | 45 | 29 | 261 | 423 | 452 | 91 | 3406 |
| Farm size (ha) | - | - | - | - | - | - | - | - |

Source: Author's computation 2017 using STATA 12.0

and conventional tillage farming, respectively. Fertiliser costs ranged from 0 to E1 495 for no till farming and 0 to E2 310 for conventional tillage maize farming. Seeds cost farmers on average, amounts of E258(+195) for no till and E400(+297) for conventional tillage farming. The observed seed cost range was from E91 to E1 520 and E14.6 to E1 474 for no till and conventional tillage farming, respectively. Herbicide was most prevalent with the no till farmers than the conventional tillage farmers. Herbicide costs ranged from E12 to E387 for no till-maize production while it was E387 to E774 for the conventional tillage farmers. Average cost of pesticide was E65(±359) for the no till farmers and E59(±94) for the conventional tillage farmers. Pesticide costs ranged from E18 to E336 and E35 to E540 for no till-based maize production and conventional tillage farming, respectively.

The average cost of labour per household was estimated at E549 (±580) and E1 400 (±1115) for no till-based farming and conventional tillage respectively. Cost of labour ranged from E92 to E4 392 and E414 to E5 746 for no till farming and conventional tillage, respectively. Mechanization costs had a lower mean value for no till farming at E78(±45) compared to E423(±452) for conventional tillage farming. The range was E29 to E261 and E91 to E3 406 for no till farming and conventional tillage farming, respectively. Significantly low labour and mechanization costs in no till-based maize production were consistent with expectations. No till farming system uses herbicides for weed control which needs less human labour associated with mechanical weed control. Less soil preparation processes are undertaken in no till than there are in conventional tillage systems.

An average revenue of maize yield harvested per household in no till farming was estimated at E1 950(±1727) while E 3 811(±3368) was for the conventional tillage farming. Maize yield had a range in Emalangeni, from E0 to E7 680 and E0 to E17 760 for no till and conventional tillage farming respectively.

## 4.2 Estimation of the Stochastic Frontier Production Function Coefficients

Table 4.4 presents the estimated values of the production function parameters. Quantities of fertiliser, seeds and labour were significant input variables at level 5%, 10% and 1%, respectively in no till. All three variable farming inputs quantities namely seeds, herbicides and labour days, were significant at 1% to maize yield in conventional tillage. The SFA allows measurement of the rate of change, increase in production for an additional unit input used in the production environment (Gujarati & Porter, 2009).

Marginal product may be increase, decreasing or constant for an additional unit input used in production (Nicholson, 2005). For every unit increase fertiliser, observed marginal outputs in maize production increased by 0.55 units per hectare in no till technology. A unit increase in seeds used produced a marginal maize output of 0.35 and 0.27 units per hectare in no till and conventional tillage, respectively. For every unit increase in herbicide, observed marginal outputs in maize production increased by 0.41 units per hectare in conventional tillage. A unit increase in labour-days resulted to a maize marginal product of 0.66 and 1.08 units in maize yields in no till and conventional tillage respectively all other factors held constant.

Table 4.4

*Estimated coefficients of the Stochastic Production Function*

| Independent Variable | No till Farming | | | Conventional Tillage | | |
|---|---|---|---|---|---|---|
| | Coef. | Std error | z | Coef. | Std error | z |
| lnFertiliser | 0.5501** | 0.2701 | 2.04 | 0.0020 | 0.0271 | 0.07 |
| lnseeds | 0.3563* | 0.1824 | 1.95 | 0.2718*** | 0.0654 | 4.15 |
| lnHerbicides | 0.2620 | 0.3146 | 0.83 | 0.4123*** | 0.1568 | 2.63 |
| lnPesticides | 0.0295 | 0.9417 | 0.31 | 0.1086 | 0.0774 | 1.40 |
| lnLabour Days | 0.6651*** | 0.8752 | 7.60 | 1.0837*** | 0.1877 | 5.77 |
| lnMechanical hours | -0.1569 | 0.5588 | -0.28 | -0.1728 | 0.1317 | -1.31 |
| lnFarm Size | 0.1069 | 0.5201 | 0.21 | -01720 | 0.1509 | -1.14 |
| constant | 0.8240 | 1.305 | 0.63 | 2.0524 | 0.6111 | 3.36 |
| $\sigma_v^2$ | -2.4955*** | 0.4142 | -6.02 | -3.1166*** | 0.3825 | -8.15 |
| $\sigma_u^2$ | -0.8132*** | 0.3065 | -2.65 | -0.8521*** | 0.2612 | -3.26 |
| $\sigma_v$ | 0.2871 | 0.5947 | | 0.2104 | 0.0402 | |
| $\sigma_u$ | 0.6658 | 0.1020 | | 0.6531 | 0.0853 | |
| $\sigma^2$ | 0.5259 | 0.1246 | | 0.4708 | 0.1074 | |
| $\lambda$ | 2.3190 | 0.1390 | | 3.1025 | 0.1050 | |
| Wald chi2 (6) | 93.56 | | | 182.25 | | |
| Log-Likelihood | -82.589 | | | -79.995 | | |

Notes: *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level
Source: Author’s computation 2017 using STATA 12.0

The implication to production is that the DMU in both no till and conventional tillage are at the production stage where they can still increase fertiliser, seeds and herbicides to increase yield with all other factors remaining constant. Returns to scale for next unit of fertiliser, seeds and herbicide are decreasing at this stage of the production function while increasing returns to scale were noted for an additional unit of labour for conventional tillage (Viljoen, 2009). Increasing returns due to additional units of seed and herbicide rates used are consistent with the low input application rates far below the recommended rates as confirmed by the observed results above.

### 4.3 Estimation of the Cost function Coefficients

Table 4.5 presents results of the estimated coefficients of the cost function parameters in rainfed agriculture. Production economics principles are that profit maximization could be achieved through cost minimization approaches or productivity maximization, the input and output side, respectively (Debertin, 2012). A DMU in a maize producing firm may opt to keep the scale of production constant and employ cost minimization approaches to maximize profit. Alternatively a DMU may increase output for a given set of inputs (constant costs) by improving technical efficiency to arrive at the highest profitability potential of the same level of inputs used. Nicholson (2005) states that DMU intends to keep the difference between total revenue and total economic costs as larger as possible.

Estimation of the cost function parameters included the variable inputs namely fertiliser, seeds, herbicides, pesticides, labour and mechanisation. All input variables are significant to the total cost of maize production for both no till and conventional tillage at 1%. It can be inferred from the results that a unit decrease in cost of fertiliser, seeds, labour and mechanization would yield a 0.35, 0.16, 0.37 and 0.10 decrease in marginal cost in no till-based rainfed maize production, respectively. A lilangeni decrease in cost of herbicide and pesticide would yield a decrease in marginal costs of 0.01 and 0.02 respectively all other factors remaining constant; indicting that marginal cost is less elastic responsive compared to the above inputs costs. All the cost elements of the conventional tillage farming were significant at 1%.

A unit decrease in the cost of fertiliser, seed and herbicide would lower marginal cost by 0.05, 0.08 and 0.05, respectively. A unit decrease in labour cost would lower marginal cost of production by 0.68. DMUs source their inputs for different suppliers, an alternative supplier or a cost effective purchase should be considered to decrease costs of inputs to lower the total cost of production. It is noteworthy that marginal cost is highly responsive to labour in both no till and conventional tillage at 0.370 and 0.682, respectively. Cost minimization by the DMU could be achieved through application of effective managerial skills to managing labour costs at low levels.

Table 4.5

*Estimated coefficients of the Cost Function*

| Independent Variable | No till Farming | | | Conventional Tillage | | |
|---|---|---|---|---|---|---|
| | Coef. | Std error | z | Coef. | Std error | z |
| lnFertiliser | 0.3476*** | 0.0607 | 5.73 | 0.0468*** | 0.0053 | 8.82 |
| lnseeds | 0.1553*** | 0.0384 | 4.05 | 0.0812*** | 0.0119 | 6.80 |
| lnHerbicides | 0.0108*** | 0.0105 | 1.03 | 0.0548*** | 0.0123 | 4.45 |
| lnPesticides | 0.0202** | 0.0082 | 2.45 | 0.0182*** | 0.0051 | 3.56 |
| lnLabour Days | 0.3694*** | 0.0292 | 12.65 | 0.6822*** | 0.0248 | 27.49 |
| lnMechanical hours | 0.1018*** | 0.0304 | 3.35 | 0.0776*** | 0.0153 | 5.04 |
| constant | 1.5011 | 0.3610 | 4.16 | 1.7535 | 0.1469 | 11.93 |
| $\sigma_v^2$ | -4.1085 | 0.1516 | -27.10 | -4.4933*** | 0.1460 | -30.78 |
| $\sigma_u^2$ | -15.069 | 282.10 | -0.05 | -13.89 | 181.89 | -0.08 |
| $\sigma_v$ | 0.1282 | 0.0097 | | 0.1057 | 0.0077 | |
| $\sigma_u$ | 0.0005 | 0.0754 | | 0.0010 | 0.0874 | |
| $\sigma^2$ | 0.0164 | 0.0025 | | 0.0112 | 0.0016 | |
| $\lambda$ | 0.0041 | 0.0761 | | 0.0091 | 0.0881 | |
| Wald chi2 (6) | 663.52 | | | 28339.46 | | |
| Log-Likelihood | 55.27 | | | 77.809 | | |

Notes: *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level
Source: Author’s computation 2017 using STATA 12.0

## 4.4 Technical Efficiency

From the results in Table 4.6 it is evident that the technical efficiency scores range from 9.4 to 96.0 for the no till technology with a mean of 45.6%. The percentage of technical efficiency indicates the potential output gains without increasing input use. This means that if the maize farmer were to operate on the frontier, they would achieve a cost saving of 54.4%. On the other hand, if the average maize farmer in the sample was to achieve the technical efficiency level of its most efficient production, then the average maize farmer using the no till technology could realize a 52.5% cost saving that is [1 – (45.6/96.0)].

Table 4.6

*Frequency distribution of efficiency Scores: TE, AE and EE*

| Efficiency | Technical Efficiency | | | | Allocative Efficiency | | | | Economic Efficiency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | No Till | | Conventional | | No Till | | Conventional | | No Till | | Conventional | |
| | f | % | f | % | f | % | f | % | f | % | f | % |
| 90 – 100 | 7 | 8.0 | 1 | 1.1 | 2 | 2.3 | 93 | 98.9 | 6 | 6.8 | 1 | 1.1 |
| 80 – 89.99 | 5 | 5.7 | 3 | 3.2 | 85 | 96.6 | 1 | 1.1 | 3 | 3.4 | 2 | 2.1 |
| 70 – 79.99 | 6 | 6.8 | 3 | 3.2 | 0 | 0.0 | 0 | 0.0 | 8 | 9.1 | 3 | 3.2 |
| 60 – 69.99 | 7 | 8.0 | 4 | 4.3 | 0 | 0.0 | 0 | 0.0 | 8 | 9.1 | 5 | 5.3 |
| 50 – 59.99 | 11 | 12.5 | 10 | 10.6 | 0 | 0.0 | 0 | 0.0 | 11 | 12.5 | 9 | 9.6 |
| 40 – 40.99 | 4 | 4.5 | 10 | 10.6 | 0 | 0.0 | 0 | 0.0 | 3 | 3.4 | 11 | 11.7 |
| 30 – 39.99 | 16 | 18.2 | 13 | 13.8 | 0 | 0.0 | 0 | 0.0 | 17 | 19.3 | 12 | 12.8 |
| 20 – 29.99 | 15 | 17.9 | 25 | 26.6 | 0 | 0.0 | 0 | 0.0 | 13 | 14.8 | 26 | 27.7 |
| 10 – 19.99 | 17 | 18.2 | 25 | 26.6 | 1 | 1.1 | 0 | 0.0 | 19 | 20.5 | 25 | 26.6 |
| **Total** | **88** | **100** | **94** | **100** | **88** | **100** | **94** | **100** | **88** | **100** | **94** | **100** |
| Average | 45.6 | | 34.5 | | 98.1 | | 98.6 | | 44.0 | | 34.0 | |
| Maximum | 96.0 | | 95.1 | | 100 | | 100.0 | | 92.9 | | 92.8 | |
| Minimum | 9.4 | | 1.1 | | 92.7 | | 84.2 | | 3.7 | | 1.1 | |

Source: Author's computation 2017 using STATA 12.0

A similar calculation for the most technically inefficient maize farmer in the no till technology shows a cost saving of 90.2% that is [1 – (9.4/96.0)]. None of the respondents had a technical efficiency of 100%. The implication of this is that there is still room for improvement in maize production using no till in study area with the available technology and given resources. Low TE has been observed in other efficiency measurement studies (Dlamini et al., 2012; Xaba & Masuku, 2013; Sihlongonyane et al., 2014).

By extension, technical efficiency scores range from 1.1 to 95.1 for the conventional tillage technology with a mean of 34. 5%. The percentage of technical efficiency indicates the potential output gains without increasing input use. If the maize farmer were to operate on the frontier, they would achieve a cost saving of 65.5%. If the maize farmer in the sample was to achieve the technical efficiency level of its most efficient production farmer then the average maize farmer is the conventional tillage technology could realize a 63.7% cost saving that is [1 – (34.5/95.1)]. A similar calculation for the most technically inefficient maize farmer in the no till technology shows a cost saving of 98.8% that is [1 – (1.1/95.1)]. Like in no till technology, none of the respondents had a technical efficiency of 100%. There is still room for improvement the maize production using conventional tillage technology. Sihlongonyane *et al.,* (2014) estimated a 64.7% technical efficiency of maize production in high yield agro-ecological zones of Swaziland which is higher than the 45.6% and 34.5% technical efficiency in no till and conventional tillage respectively. Low yield agro-ecological zones, a case of Siphofaneni area shows that maize producers are less technically efficient in their maize production. A 54.4% room for improvement exists for no till-based maize producers while a 65.5% exists for conventional tillage farmers. Technical errors can be inferred from the descriptive statistics in that farmers used inappropriate fertilizer, seed and herbicide application rates with respect to recommended rates.

## 4.5 Allocative Efficiency

Individual farmers' allocative efficiency scores were determined from the cost function and are presented in Table 4.6. Average farmers allocative efficiency for no till-based maize production and conventional tillage were estimated at 98.1% and 98.6%, respectively. Allocative efficiency scores had a range of 92.7% to 100.0% for no till while a range between 84.2% and 100.0% was recorded for conventional tillage farming. Schmidt and Lovell (1980) questioned the possibility of having DMUs technical efficiency of production inversely related to their allocative efficiency. A well managed production firm operating close to its frontier is most like to also exhibit operations that are close to the least-cost expansion path. While the conventional tillage maize producers had a low technical efficiency, they exhibit a high allocative efficiency of maize production.

## 4.6 Economic Efficiency scores

Table 4.6 shows the frequency distribution of the individual farmers' economic efficiency scores. Estimated no till individual farmers' economic efficiency scores was 44.0% and 34.0% for conventional tillage. While the no till farmers recorded a minimum economic efficiency score of 3.7%, conventional tillage recoded a 1.1 percent minimum. Maximum economic efficiency scores of 92.9% and 92.8% were achieved for no till and conventional tillage farming, respectively. About 58% and 78.8% percent of the farmers had an economic efficiency of less than 40% for both no till and conventional tillage farming, respectively. Only a few, 6.8% of the farmers had an economic efficiency approaching 100.0% while 1.1% was recorded for conventional farming. Twenty-one percent of the farmers recorded economic efficiency scores of less than 19.99% and 26.6% was recorded for conventional tillage farming. On the average, no till farming had a higher economic efficiency than conventional tillage farming.

Conventional tillage farmers have even more room for improvement than no till farmers as presented in Table 4.7 which shows the summary of mean scores and the range of efficiency scores for the two farming system under investigation. Comparatively, technical and economic efficiency varied significantly between the two systems. Allocative efficiency of maize production was comparative and was also high for both farming systems. Technical efficiency may have contributed more on the variation of economic efficiency between the two farming technologies used for rainfed maize production in Siphofaneni.

Table 4.7

*Summary of the Mean and Range of the Efficiencies scores*

| Range | No till Farming | | | Conventional Tillage | | |
|---|---|---|---|---|---|---|
| | TE (%) | AE (%) | EE (%) | TE (%) | AE (%) | EE (%) |
| Average | 45.6 | 98.1 | 44.0 | 34.5 | 98.6 | 34.0 |
| Maximum | 96.0 | 100.0 | 92.9 | 95.1 | 100.0 | 92.8 |
| Minimum | 9.4 | 92.7 | 3.7 | 1.1 | 84.2 | 1.1 |

Source: Author's computation 2017 using STATA 12.0

Table 4.8 summarises average economic efficiency scores of maize production between no till and conventional tillage farming. Whilst the difference is the minimum economic efficiency between the farming systems was 2.6% the maximum economic efficiency showed very little difference (0.1%). The average economic efficiency of maize production under rainfed agriculture was 10% higher than conventional tillage farming. The 10% difference in economic efficiency between the farming systems can be attributed to the technical efficiency. Comparison between allocative efficiency indicated a 0.5%. Technical efficiency in no till was 11% higher than in conventional farming. Farmers in both systems need to focus improvement on their technical efficiency more than their allocative efficiency to improve economic efficiency. The was a significant difference in the mean economic efficiency of rainfed maize production between no till and conventional tillage in the Siphofaneni area of Swaziland at 1% (p-0.0054).

Table 4.8

*Summary of Economic Efficiency Scores*

| Alternative Technologies | Economic Efficiency % | Minimum % | Maximum % |
|---|---|---|---|
| No till Farming | 44.0 | 3.7 | 92.9 |
| Conventional Tillage | 34.0 | 1.1 | 92.8 |
| t = 2.820 p = 0.0054 | | | |

Source: Author's computation 2017 using STATA 12.0

Technology used in no till provides for better conditions for the maize producers to be technically efficient compared to the maize producers under conventional tillage farming. Maize producers under no till farming have 56.0% room to increase economic efficiency while conventional tillage farmers have 66.0% to increase economic efficiency. Results revealed that there was a generally low economic efficiency with a mean score of 39.0% for maize production in both tillage systems in the Siphofaneni area. There was a very high margin of the economic efficiency between the farmers themselves. Most of the farmers in Siphofaneni are not economically efficient in their maize production.

## 4.7 Socioeconomic factors affecting Efficiency of Rainfed maize production

Table 4.9 shows the results of the Tobit regression which estimates the effects of socio-economic characteristics of farmers and farm specific characteristics on the effects of maize production. Tables 4.9a and 4.9b indicate coefficients obtained in no till and conventional tillage farming, respectively. Three of the farmers' socio-economic characteristics age, gender and off-farm income were statistically significant at 1%, to no till-based farming technical efficiency whereas no socio-economic characteristics were significant in conventional tillage farming. An additional year in age will increase technical efficiency by 0.0144. Age can also be used as a proxy for farming experience. In rural communities where farming is a household practice, members of the family are exposed to farming as they grow. It would be consistent then, that age would have a positive influence on technical efficiency. Gender and off-farm income influenced technical efficiency. All other factors remaining constant, an additional Lilangeni increase in off-farm income will decrease technical efficiency by 0.3320.

Farmer's age, seed type and attendance of a no till workshop were statistically significant at 1%, to allocative efficient under no till-based maize production. Conventional tillage had age, farming experience and years of education as significant variables. Age was the common significant variable in both farming systems. An additional year of age would increase allocative efficiency by 0.0022 and 0.0008 in no till and conventional tillage respectively. Taking age as proxy to experience, farmers get more efficient as they grow older. Type of seeds used by farmers between hybrid

Table 4.9a

*Effects of Socio-Economic and Farm specific Characteristics on Efficiency:  No till farming*

| Factors | Technical efficiency | | | Allocative efficiency | | | Economic efficiency | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std Error | t | Coef. | Std Error | t | Coef. | Std Error | t |
| Age (yrs) | 0.0144*** | 0.0051 | 2.853 | 0.0022*** | 0.0006 | 3.638 | 0.0138*** | 0.0049 | 2.782 |
| Farming Experience (yrs) | -0.0150 | 0.0173 | -0.865 | 0.0002 | 0.0021 | 0.113 | -0.0133 | 0.0169 | -0.785 |
| Years of Education (yrs) | -0.0182 | 0.0171 | -0.059 | 0.0034 | 0.0021 | 1.654 | -0.0289 | 0.0168 | -1.129 |
| Gender (F = 1 or M = 2 ) | 0.3546*** | 0.1323 | 2.681 | 0.0221 | 0.0158 | 1.390 | 0.3364 | 0.1295 | 2.599 |
| Household size | -0.0223 | 0.0205 | -0.087 | 0.0040 | 0.0025 | 1.610 | -0.0195 | 0.0201 | -0.973 |
| Off-income (no = 1 or yes = 1) | -0.3320*** | 0.1218 | -2.725 | -0.0122 | 0.0146 | -0.834 | -0.3303*** | 0.1192 | -2.770 |
| Seed type (Non-hybrid = 0 or hybrid -1) | 0.4174 | 0.3579 | 1.166 | 0.2333*** | 0.0422 | 5.536 | 0.4102 | 0.3504 | 1.054 |
| No till workshop attendance (None = 0 or At least 1 = 1) | -0.2891 | 0.3623 | -0.798 | 0.2178*** | 0.0429 | 5.078 | -0.2544 | 0.3547 | -0.717 |
| Constant | 0.2456 | 0.4619 | 0.532 | 0.4775*** | 0.0510 | 9.008 | 0.2244 | 0.4528 | 0.496 |
| F-value | 0.0010 | | | 0.0000 | | | 0.0012 | | |
| Adjusted $R^2$ | 0.1545 | | | -0.6206 | | | 0.1560 | | |

Notes: *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level

Source: Author’s computation 2017 using STATA 12.0

Table 4.9b

*Effects of Socio-Economic and Farm specific characteristics on Efficiency: Conventional tillage farming*

| Factors | Technical efficiency | | | Allocative efficiency | | | Economic efficiency | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std Error | t | Coef. | Std Error | t | Coef. | Std Error | t |
| Age (yrs) | 0.0004 | 0.0030 | 0.128 | 0.0008*** | 0.0003 | 2.964 | 0.0060 | 0.0043 | 1.395 |
| Farming Experience (yrs) | -0.0005 | 0.0031 | -0.174 | 0.0008*** | 0.0003 | 2.985 | -0.0042 | 0.0044 | -0.952 |
| Years of Education (yrs) | -0.0030 | 0.0058 | -0.523 | 0.0034*** | 0.0005 | 6.930 | -0.0079 | 0.0083 | -0.956 |
| Gender (F = 1 or M = 2 ) | -0.0606 | 0.0442 | -1.369 | 0.0155** | 0.0038 | 4.121 | -0.0346 | 0.0633 | -0.547 |
| Household size | -0.0043 | 0.0088 | -0.492 | -0.0007* | 0.0007 | -0.956 | -0.0195 | 0.0126 | -1.548 |
| Off-income (no = 1 or yes = 1) | 0.0068 | 0.0560 | 0.122 | 0.0012* | 0.0048 | -0.249 | 0.0632 | 0.0800 | 0.789 |
| Seed type (Non-hybrid = 0 or hybrid -1) | 0.0531 | 0.0420 | 1.264 | -0.0106* | 0.0036 | -2.975 | 0.0908 | 0.0600 | 1.512 |
| No till workshop attendance (None = 0 or At least 1 = 1) | 0.0283 | 0.0446 | 0.633 | -0.0013* | 0.0038 | -0.349 | 0.0804 | 0.0638 | 1.260 |
| Constant | 0.3491 | 0.1463 | 2.386 | 0.9109 | 0.0124 | 73.219 | 0.1628 | 0.2092 | 0.778 |
| F-value | 0.8729 | | | 0.0000 | | | 0.5320 | | |
| Adjusted $R^2$ | -0.1319 | | | -0.1780 | | | 0.1731 | | |

Notes: *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level

Source: Author’s computation 2017 using STATA 12.0

and non-hybrid and attending a no till workshop influenced allocative efficiency in no till whereas it did not for conventional tillage.

Farmer's age and off-farm income were statistically significant to economic efficiency at % whereas none of the farmer and farm specific characteristics were significant to conventional tillage. An additional year in age would increase economic efficiency by 0.0138 in no till. Taking age as a proxy for experience, there is an increase in economic efficiency with an increase in age. It could be noted though that most of the maize producers in the Siphofaneni area were of an average age of above 50 years. A Lilangeni increase in off-farm income decreases economic efficiency by 0.022. It would be expected that increase in income should make the maize producers to be more economic efficient. Famers in Siphofaneni area indicated high dependency on farming as the only source of available income though the climatic condition is not favourable to gainful farming. With off-farm income farmers become less efficient in their farming activity. The decrease in efficiency may be attributed to the attention given to alternative engagements other than the farming activities.

# CHAPTER 5

# SUMMARY, CONCLUSION AND RECOMMENDATIONS

## 5.1 Purpose and Objectives

The purpose of the study was to estimate and compare economic efficiency of rainfed maize production between no till and conventional soil tillage mechanization technologies in three farming communities (Hlute, Madlenya 1 and Vikizijula) in the Siphofaneni area of Swaziland. Specific objectives were to: (i) describe socioeconomic characteristics of maize farmers producing maize under rainfed rural agricultural, production; (ii) estimate and compare economic efficiency of maize production using no till and conventional tillage mechanization under rainfed agricultural production; and (3) determine the factors affecting the economic efficiency of maize production under rainfed agricultural production.

## 5.2 Methodology

A quantitative research design was conducted to estimate the economic efficiency of rainfed maize production in the Siphofaneni area of Swaziland. Stratified random sampling was employed to determine three strata of maize producers from three farming communities of Siphofaneni namely Hlute, Madlenya 1 and Vikizijula. Study was conducted on farmers in the Lowveld AEZ. A structured questionnaire designed for the study was used to collect primary data from 182 cross sectional units. Three enumerators were trained and dispatched to administer the questionnaire. Data collected included quantities and costs of farming inputs used for maize production in the 2014/15 planting season and socioeconomic characteristics of maize producers. There were two samples where, n=88 for no till and n=94 for conventional tillage.

Descriptive statistics mean values, standard deviation, frequencies and percentages were used to describe the socio-economic characteristics of maize producers and specific farm characteristics. Econometric analysis was conducted using the SFA model on STATA 12.0. Stochastic Frontier Production Function was employed to estimate the parameters of the production and cost functions from quantities and prices of maize production inputs, respectively. Individual farmers' inefficiency scores were estimated from the production function, while allocative efficiency scores were derived from the cost function.

### 5.3 Summary of findings

Tables were used to present result of the analysis. No till maize production (n=88) had 57(±64.8%) females and 31(±35.2%) males while conventional tillage (n=94) had 48(±51.1%) males and 46(±48.9%) females. most of the no till maize farmers 37(42.0%) had an educational experience 7(±4.2). Conventional tillage maize farmers 41(±43.6%) had an educational experience of 8(s=4.5) years. About 49(±55.7%) no till farmers and 74(±78.7%) conventional maize farmers had no off-farm income. No till maize production inputs average costs were at E1535 (±858) and for conventional tillage is E2805 (±2112). No till maize production significant costs estimates for fertiliser E556 (±159), seeds E258 (±195) and labour E549 (±580). Conventional tillage had a high inputs cost were fertiliser 509(±473), seeds 400(297) labour 1400(±1115). Average maize yield 203(±179.9) kg/ha and 408(±350) kg/ha for conventional tillage.

For a unit increase in labour-days, marginal output in maize production increased by 0.66 in no till technology. A unit increase in seed quantity led to a marginal output of 0.27 in maize yield in conventional tillage. While a unit increase in herbicide quantity led to marginal output of 0.41, a unit increase in labour-days resulted to a marginal product of 1.11 maize yields in conventional tillage. A unit decrease in cost of fertiliser, seeds, labour and mechanization would yield a 0.34, 0.16, 0.37 and 0.10 decrease in marginal cost in no till-based rainfed maize production, respectively.

The farmers were 45.6% and 34.5% technically efficient in no till and conventional tillage, respectively. Economic efficiency was computed as a product of the TE and AE. Estimated EE for no till and conventional tillage was 44.0% and 34.0%, respectively. Further regression analysis was performed to determine the effects of farmer and farm's characteristics on technical, allocative and economic efficiencies. An additional 1 year in age was significant and increased TE and AE by 0.0144 and 0.0022 both at 1%, respectively. An additional Lilangeni decreased TE by 0.332 in no till farming. An additional workshop attended increased AE by 0.2178 in no till faming at 1%. Whereas socioeconomic characteristics were no significant TE in convention tillage, age education experience had significant effect on AE. An additional year in age and education increased AE by 0008 and 0034 at 1%.

## 5.4 Conclusion

It can be concluded that a typical maize producer in the Siphofaneni area is a female of an average age of 50 years with primary education without alternative source of income. A household in the Siphofaneni area has a family size of 6 members and highly dependent in maize production for livelihood due to lack of off-farm sources of income. Conventional tillage farming has two times as much land available for maize production as there is for no till farming. There is a high adoption rate of hybrid seeds in maize production with high herbicide usage among no till farmers. Farmers uses of fertiliser, hybrid seeds and herbicides in their farming operations but did not use recommended application rates.

Labour was the common significant input to marginal product under both no till and conventional tillage rainfed maize production. In addition to labour, fertiliser, seeds and herbicides were also significant in the production function of maize production. Though mechanization was not significant to the output, marginal output was negatively elastic to a unit change in mechanization. Under no till and conventional tillage farming, a significant cost generation input was labour with a marginal cost of 0.35 and 0.37, respectively. The marginal cost of production indicated high responsiveness to a unit increase in labour compared to fertiliser, seeds, herbicides and mechanization costs.

Estimation of efficiency yielded results indicating that technical and economic efficiency were significantly different between no till and conventional tillage farming. Allocative efficiency was not significantly different between the farming systems. The estimation results indicated that both technical and economic efficiencies were higher in no till more than conventional tillage. It may be concluded that maize producers under no till are more economically efficient than conventional maize producers.

Age is the only socioeconomic characteristic significant to technical, allocative and economic efficiencies in no till farming. While all the other socioeconomic characteristics were not significant to technical and economic efficiencies, age was significant to allocative efficiency in conventional tillage. Off-farm income was significant and negative to output in no till farming system.

## 5.5 Implications of the study

The Government of Swaziland plays a role in mechanization as state by Mrema and Cruz that the role of governments is to find strategies for correct mechanization. House hold size was estimated at an averages of 6 and 7 family members for conventional and no till maize production, consistent with FOA Fact file (2017) which estimated family size in Swaziland at 6.5 members. Dlamini *et al* (2012) on technical efficiency measurement, found that in maize yield in high agro ecological zones was 598kg/ha and seed application rate of 12.3kg/ha. This study found that maize farmers in the Siphofaneni area received 203kg/ha and 408kg/ha for no till and conventional tillage respectively. These results were consistent in that Siphofaneni area is in the low maize yield ecological zone. Farmers used on average 7kg/ha and 11.5kg/ha of seeds.

In this study technical efficiency was estimated at 45.6% and 34.5% for no till and conventional tillage, respectively. These findings indicated a lower technical efficiency compared to high maize yield agro-ecological zones. Sihlongonyane *et al* (2014) estimated a technical efficiency of 64.7% and 99.5% allocative efficiency. The Siphofaneni maize farmers were comparably allocative efficient in that they were at 98.6% in allocative efficiency. Siphofaneni is the low maize yield agro-ecological zones. The adverse weather condition of the low maize yield ecological zone may contribute to the farmers' low technical and economic efficiency

## 5.6 Recommendations

### 5.6.1 Recommendation for farmers

Based on the average age of 50 years of maize producers and low level of education of rainfed maize producers, households' heads should reinforce positive perception of maize farming to the young, innovative and energetic members of family units. Use of farming inputs by maize producers does not adhere to recommended application rates, yet fertilisers, seeds and herbicides are significant to efficiency. Maize producers must increase the applications of the inputs by adhering to recommended rates to improve their efficiency. The cost of maize production is highly responsive to labour input cost. Farmers need to employ cost saving measures in the use of labour. By minimizing labour costs, maize farmers can significantly reduce the cost of maize production in both no till and convention tillage.

### 5.6.2 Recommendations for Policy

The high frequency of above 50 years of age and less educated maize farmers in Siphofaneni scenario, implies that government should introduce incentives to attract the involvement of young and educated maize producers. There is need for the younger learned, innovative and energetic population to improve agricultural productivity.

The government of Swaziland should strength the subsidy policy on farming inputs, supply of fertiliser and herbicides to improve farmers' technical and allocative efficiency. Provision of subsidised farming inputs will also alleviate the lack of recourses to improve productivity which is currently low.

Introduction of no till mechanization should be improved in the RDAs as alternative to conventional tillage to improve both technical and economic efficiency of rainfed maize production.

## 5.7 Recommendations for further Research

A comparative research should be conducted on the economic efficiency of no till and conventional tillage farming in high yield agro-ecological zones. Research on high yielding agro-ecological zones will provide more insight on the best alternative for rural mechanization to improve productivity in maize production where climatologically conditions are even more favourable.

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# APPENDICES

**APPENDIX A: LETTER OF REQUEST TO CONDUCT A SURVEY (SWADE)**

# UNIVERSITY OF SWAZILAND

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Luyengo Campus
Faculty of Agriculture
P.O. Luyengo, M205
Swaziland,
SOUTHERN AFRICA.

Mr Norman Mavuso
SWADE-SIPHOFANENI

November 8, 2016

**RE: REQUEST FOR MR STANLEY M. NGQWANE TO BE ASSISTED TO COLLECT DATA FROM SMALLHOLDER SUGARCANE FARMERS**

This letter serves to request for permission on behalf of Mr Stanley M. Ngqwane to collect academic information from small holder farmers. He is currently a student ( ID # 103832) at the University of Swaziland pursuing a Masters degree in Agriculture and Applied Economics.

It is with the hope that you will cooperate with him and provide as much information as is necessary. Your assistance will be greatly a MAIZE FARMERS

UNIVERSITY OF SWAZILAND
DEPARTMENT OF AGRICULTURAL ECONOMICS & MANAGEMENT
08 NOV 2016
LUYENGO CAMPUS
P.O. LUYENGO, SWAZILAND
TEL: (+268) 2517 0593

Yours sincerely

J. Rugambisa
Head, Department of Agricultural Economics and Management

## APPENDIX B: LETTER OF REQUEST TO CONDUCT A SURVEY (SIPHOFANENI RDA)

# UNIVERSITY OF SWAZILAND


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Swaziland,
SOUTHERN AFRICA.


**TO WHOM IT MAY CONCERN**
**SIPHOFANENI RDA**

**November 8, 2016**

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This letter serves to request for permission on behalf of Mr Stanley M. Ngqwane to collect academic information from small holder farmers. He is currently a student ( ID # 103832) at the University of Swaziland pursuing a Masters degree in Agriculture and Applied Economics.

It is with the hope that you will cooperate with him and provide as much information as is necessary. Your assistance will be **MAIZE FARMERS**

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Yours sincerely

J. Rugambisa
Head, Department of Agricultural Economics and Management

## APPENDIX C: DATA COLLECTING QUESTIONNAIRE

# University of Swaziland

**Faculty of Agriculture, Luyengo**

**Agricultural Economics & Management, Department**

## Data Collecting Booklet

**A Comparison of Economic Efficiencies of**

**Maize Production using different Technologies under Rainfed Agriculture:**

**A Case of Siphofaneni Area**

**November/December 2016**

# University of Swaziland

**Faculty of Agriculture, Luyengo**

**Agricultural Economics & Management, Department**

**DATA COLLECTING INSTRUMENT**

A study is being conducted to compare the ***economic efficiencies*** of maize production using two different technologies. The questions are divided into two sections. **Section I** aims to collect data on the input (seeds & seed varieties, herbicides, fertilizer) quantities, related inputs costs incurred in your farming practice as well as farming mechanization used. **Section II** aims to collect data on your personal characteristics as a maize farmer. The information collected shall be used for this study. You are requested to provide information as accurately as you can possibly provide and as it applies to you.

The objectives of the study are stated below:

1. To compare the economic efficiencies of maize production using different technologies, No Till and Conventional tillage under rainfed agriculture.

2. To determine the factors affecting economic efficiency of maize production using different technologies, no till and conventional mechanization under rainfed agriculture.

| | |
|---|---|
| **SRL #:** 042 | |
| **Date:** Nov ☐ Dec ☐ | |
| **Hectares:** ☐ ha | |
| **Maize Crop** ☐ ha | |
| **Other Crops** ☐ ha | |

| | |
|---|---|
| Mandlenya 1 | ☐ |
| Phonjwane/Vikizijula | ☐ |
| Hlutse | ☐ |
| Other | ☐ |

| | |
|---|---|
| Farmer uses Conventional Tillage technology | ☐ |
| Farmer uses No Till technology | ☐ |

## SECTION I: Farming Inputs, Costs and Output

**Section I** deals with information on the farming inputs, costs of inputs as well as implements used for the farming system. You are requested to mark with an [**x**] in the box corresponding to implement and inputs used. Also fill in quantities and costs of inputs used.

| FARMING ACTIVITY | IMPLEMENT/INPUT USED (Please (√)) | QTY/AREA/TIME (HR) | | COST |
|---|---|---|---|---|
| Soil preparation | Mouldboard – 2 skaal ☐ 3 skaal ☐ Other ☐ | ☐ hrs | ☐ ha | E ☐ /hr |
| | Disc plough – 2 discs ☐ 3 discs ☐ Other ☐ | ☐ hrs | ☐ ha | E ☐ /hr |
| | Rigger – 2 tine ☐ 3 tine ☐ 4 tine ☐ Other ☐ | ☐ hrs | ☐ ha | E ☐ /hr |
| | Disc harrow ☐ | ☐ hrs | ☐ ha | E ☐ /hr |
| Seed planting | Seeds Variety [ ] ☐ | ☐ kg | ☐ bags | E ☐ |
| | Seeds Variety [ ] ☐ | ☐ kg | ☐ bags | E ☐ |
| | Seeds Variety [ ] ☐ | ☐ kg | ☐ bags | E ☐ |
| | Conv. Planter – 2-Row ☐ 3-Row ☐ 4-Row ☐ | ☐ hrs | ☐ ha | E ☐ /hr |
| | Direct seeder – 2-Row ☐ 3-Row ☐ 4-Row ☐ | ☐ hrs | ☐ ha | E ☐ /hr |
| | Hand tool (Jab planter) ☐ Ox-drawn ☐ | ☐ hrs | ☐ ha | E ☐ |
| Fertilizer application | Type 2:3:2 (22) ☐ (37) ☐ (38) ☐ Other ☐ | ☐ kg | ☐ bags | E ☐ |
| | Conv. Planter – 2-Row ☐ 3-Row ☐ 4-Row ☐ | ☐ hrs | ☐ ha | E ☐ |
| | Direct seeder – 2-Row ☐ 3-Row ☐ 4-Row ☐ | ☐ hrs | ☐ ha | E ☐ |
| | Hand tool (Jab planter) ☐ Ox-drawn ☐ | | | E ☐ |
| | LAN ☐ | ☐ kg | ☐ bags | E ☐ |
| | Kraal Manure ☐ | | | E ☐ |
| Weed control | Knapsack sprayer ☐ | ☐ pers | ☐ ha | E ☐ pers/day |
| | Mist blower ☐ | ☐ pers | ☐ ha | E ☐ pers/day |
| | Boom sprayer – 400L ☐ 600L ☐ Other ☐ | ☐ hrs | ☐ ha | E ☐ /ha |
| | Herbicide trade name (1) [ ] ☐ | ☐ Ltr | ☐ ha | E ☐ |
| | Herbicide trade name (2) [ ] ☐ | ☐ Ltr | ☐ ha | E ☐ |
| | Herbicide trade name (3) [ ] ☐ | ☐ Ltr | ☐ ha | E ☐ |
| Pests control | Knapsack sprayer ☐ | ☐ pers | ☐ ha | E ☐ pers/day |
| | Mist blower ☐ | ☐ pers | ☐ ha | E ☐ pers/day |
| | Boom sprayer – 400L ☐ 600L ☐ Other ☐ | ☐ hrs | ☐ ha | E ☐ /ha |
| | Pesticide trade name (1) [ ] ☐ | ☐ Ltr | ☐ ha | E ☐ |
| | Pesticide trade name (2) [ ] ☐ | ☐ Ltr | ☐ ha | E ☐ |
| | Pesticide trade name (3) [ ] ☐ | ☐ Ltr | ☐ ha | E ☐ |

**N.B.** ha = hectare Ltr = Litres pers = number of persons

**Maize Yield (2014/2015)** ☐ **Bags** ☐ **Kg or** ☐ **Tones**

Below you are given a space to comment about the type of technology used (No Till or Conventional Tillage Mechanization). You can express your observations on how the technology used has performed for you towards improving maize yields. What would be you suggestion to government to improve accessibility to the preferred technology.

.................................................................................................................................

.................................................................................................................................

.................................................................................................................................

## SECTION II: Characteristics of the Farmer

**Section II** deals with the characteristics of the maize farmer providing information. You are requested to mark with an [x] in the box corresponding to your situation. This information will be used for the purpose of achieving the objectives of the study. Information cannot be used anywhere else outside the purposes and objectives of the study being conducted. An example has been set for your use as reference and to guide you in responding to the questions.

Example: Do you own cattle: Yes [X] No [ ]

The box with a **Yes** has been marked. That means the respondent owns cattle

| CHARACTERISTICS | VARIABLE | COMMENTS |
|---|---|---|
| Years of farming experience | [ ] years | ........................ |
| Educational Experience | [ ] Yes [ ] No [ ] years | ........................ |
| Highest level of education | [ ] Primary [ ] Secondary [ ] Tertiary | ........................ |
| Number of family members | [ ] members | ........................ |
| Age | [ ] years | ........................ |
| Gender | [ ] Female [ ] Male | ........................ |
| Off-farming income | [ ] Yes [ ] No | ........................ |
| Occupation as a Farmer | [ ] Part-time [ ] Full-time | ........................ |
| Maize seed types used | [ ] hybrid [ ] non-hybrid | ........................ |
| Attended No Till workshops | [ ] At least 1 [ ] None | ........................ |
| Type of Implements used | [ ] No Till [ ] Conventional Implements | ........................ |

Date: [d] [d] [m] [m] [2] [0] [1] [6]

## THANK YOU

Thank you for taking your time to fill in the information in this questionnaire. The information collected will help contribute towards completion of the study being conducted.

## APPENDIX D: ESTIMATION OF THE STOCHASTIC FRONTIER PRODUCTION FUNCTION – NO TILL

```
. use "C:\Users\user\Desktop\DATA ANALYSIS SPREADSHTS 2017\Log NT_PROD_WK1.dta",

. frontier ln_Y ln_Fertiliser ln_Seeds ln_Herbicide ln_Pesticide ln_ManD ln_Mech
> al)

Iteration 0:   log likelihood = -85.668651
Iteration 1:   log likelihood = -82.842915
Iteration 2:   log likelihood = -82.591649
Iteration 3:   log likelihood = -82.589044
Iteration 4:   log likelihood = -82.589044

Stoc. frontier normal/exponential model          Number of obs   =         87
                                                 Wald chi2(7)    =      93.56
Log likelihood = -82.589044                      Prob > chi2     =     0.0000

------------------------------------------------------------------------------
        ln_Y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_Fertiliser |   .5500624   .2701188     2.04   0.042     .0206393    1.079486
    ln_Seeds |   .3562828   .1824539     1.95   0.051    -.0013203    .7138858
 ln_Herbicide |   .2619623   .3146083     0.83   0.405    -.3546585    .8785832
 ln_Pesticide |   .0295228   .0941711     0.31   0.754    -.1550492    .2140949
     ln_ManD |   .6651096   .0875221     7.60   0.000     .4935694    .8366497
     ln_Mech |  -.1568991   .5588011    -0.28   0.779    -1.252129    .9383309
    ln_FarmS |   .1068864   .5201207     0.21   0.837    -.9125314    1.126304
       _cons |   .8249608   1.305019     0.63   0.527     -1.73283    3.382751
-------------+----------------------------------------------------------------
    /lnsig2v |   -2.49552   .4142448    -6.02   0.000    -3.307425   -1.683615
    /lnsig2u |  -.8132466   .3065095    -2.65   0.008    -1.413994   -.2124989
-------------+----------------------------------------------------------------
     sigma_v |   .2871473   .0594746                      .1913382    .4309308
     sigma_u |    .665895   .1020516                      .4931228    .8992003
      sigma2 |   .5258697    .124619                      .2816209    .7701185
      lambda |   2.319002   .1390094                      2.046548    2.591455
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 17.44   Prob>=chibar2 = 0.000

. reg ln_Y ln_Fertiliser ln_Seeds ln_Herbicide ln_Pesticide ln_ManD ln_Mech ln_Fa

      Source |       SS       df       MS              Number of obs =      87
-------------+------------------------------           F(  7,    79) =    8.83
       Model |  32.5164511     7  4.6452073            Prob > F      =  0.0000
    Residual |  41.5581346    79  .526052337           R-squared     =  0.4390
-------------+------------------------------           Adj R-squared =  0.3893
       Total |  74.0745857    86  .861332392           Root MSE      =  .72529

------------------------------------------------------------------------------
        ln_Y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_Fertiliser |   .9354859   .3261592     2.87   0.005     .2862822     1.58469
    ln_Seeds |   .1848324   .2150633     0.86   0.393    -.2432403    .6129051
 ln_Herbicide |   .3682039   .4215763     0.87   0.385    -.4709226    1.207331
 ln_Pesticide |   .1081446   .1363764     0.79   0.430    -.1633058     .379595
     ln_ManD |   .6437556   .1278117     5.04   0.000     .3893528    .8981585
     ln_Mech |  -.5154373   .5819887    -0.89   0.378    -1.673857    .6429822
    ln_FarmS |   .3813432   .5626567     0.68   0.500     -.738597    1.501283
       _cons |  -1.410947   1.439225    -0.98   0.330    -4.275653    1.453758
------------------------------------------------------------------------------
```

# APPENDIX E: ESTIMATION OF COST FUNCTION COEFFICIENTS – NO TILL

```
. use "C:\Users\user\Desktop\DATA ANALYSIS SPREADSHTS 2017\Log NT_PROD_COST_WK1

. frontier ln_cost ln_Fert ln_Seed ln_Herb ln_Pest ln_Labour ln_Mech

Iteration 0:   log likelihood =   52.99877
Iteration 1:   log likelihood =  54.592632
Iteration 2:   log likelihood =  55.112893
Iteration 3:   log likelihood =   55.22728
Iteration 4:   log likelihood =  55.262781  (not concave)
Iteration 5:   log likelihood =  55.270465
Iteration 6:   log likelihood =  55.271953
Iteration 7:   log likelihood =   55.27278
Iteration 8:   log likelihood =  55.272896
Iteration 9:   log likelihood =  55.272914
Iteration 10:  log likelihood =  55.272933
Iteration 11:  log likelihood =  55.272933

Stoc. frontier normal/half-normal model          Number of obs   =         87
                                                 Wald chi2(6)    =     663.52
Log likelihood =  55.272933                      Prob > chi2     =     0.0000
```

| ln_cost | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ln_Fert | .347589 | .0606609 | 5.73 | 0.000 | .2286959 | .4664821 |
| ln_Seed | .1553225 | .0383672 | 4.05 | 0.000 | .0801243 | .2305208 |
| ln_Herb | .0108494 | .0105152 | 1.03 | 0.302 | -.0097601 | .0314589 |
| ln_Pest | .0202107 | .0082346 | 2.45 | 0.014 | .0040712 | .0363502 |
| ln_Labour | .3693656 | .0292051 | 12.65 | 0.000 | .3121246 | .4266066 |
| ln_Mech | .1018146 | .0304321 | 3.35 | 0.001 | .0421687 | .1614604 |
| _cons | 1.501176 | .3609924 | 4.16 | 0.000 | .7936439 | 2.208708 |
| /lnsig2v | -4.108524 | .1516307 | -27.10 | 0.000 | -4.405715 | -3.811334 |
| /lnsig2u | -15.069 | 282.0958 | -0.05 | 0.957 | -567.9667 | 537.8287 |
| sigma_v | .1281874 | .0097186 | | | .110487 | .1487234 |
| sigma_u | .0005343 | .0753659 | | | 4.7e-124 | 6.1e+116 |
| sigma2 | .0164323 | .002492 | | | .0115481 | .0213165 |
| lambda | .0041683 | .0761009 | | | -.1449868 | .1533235 |

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.00   Prob>=chibar2 = 1.000

. reg ln_cost ln_Fert ln_Seed ln_Herb ln_Pest ln_Labour ln_Mech
```

| Source | SS | df | MS |
|---|---|---|---|
| Model | 10.9029781 | 6 | 1.81716302 |
| Residual | 1.42959167 | 80 | .017869896 |
| Total | 12.3325698 | 86 | .143401974 |

```
Number of obs =      87
F(  6,    80) =  101.69
Prob > F      =  0.0000
R-squared     =  0.8841
Adj R-squared =  0.8754
Root MSE      =  .13368
```

| ln_cost | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ln_Fert | .347589 | .0632591 | 5.49 | 0.000 | .2216994 | .4734786 |
| ln_Seed | .1553225 | .0400105 | 3.88 | 0.000 | .0756991 | .234946 |
| ln_Herb | .0108494 | .0109656 | 0.99 | 0.325 | -.0109729 | .0326717 |
| ln_Pest | .0202107 | .0085873 | 2.35 | 0.021 | .0031215 | .0372999 |
| ln_Labour | .3693656 | .030456 | 12.13 | 0.000 | .3087562 | .429975 |
| ln_Mech | .1018146 | .0317356 | 3.21 | 0.002 | .0386587 | .1649704 |
| _cons | 1.500767 | .3711956 | 4.04 | 0.000 | .7620647 | 2.23947 |

# APPENDIX F: ESTIMATION OF STOCHASTIC FRONTIER PRODUCTION FUNCTION COEFFICIENTS – CONVENTIONAL TILLAGE

```
. use "C:\Users\user\Desktop\DATA ANALYSIS SPREADSHTS 2017\Log CM_PROD_WK1.dta",

. frontier ln_Y ln_Fertilizer ln_Seeds ln_Herbicide ln_Pesticide ln_Man_days ln_M
> on(exponential)

Iteration 0:   log likelihood = -107.72869  (not concave)
Iteration 1:   log likelihood = -104.09286  (not concave)
Iteration 2:   log likelihood = -85.530417
Iteration 3:   log likelihood =  -85.02745  (backed up)
Iteration 4:   log likelihood = -81.546127
Iteration 5:   log likelihood = -80.016539
Iteration 6:   log likelihood = -79.995268
Iteration 7:   log likelihood = -79.995164
Iteration 8:   log likelihood = -79.995164

Stoc. frontier normal/exponential model          Number of obs   =         94
                                                 Wald chi2(7)    =     182.25
Log likelihood = -79.995164                      Prob > chi2     =     0.0000
```

| ln_Y | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ln_Fertilizer | .0019681 | .0271395 | 0.07 | 0.942 | -.0512244 | .0551605 |
| ln_Seeds | .2718428 | .0654931 | 4.15 | 0.000 | .1434787 | .4002068 |
| ln_Herbicide | .4123848 | .1568075 | 2.63 | 0.009 | .1050478 | .7197218 |
| ln_Pesticide | .1085908 | .077402 | 1.40 | 0.161 | -.0431144 | .2602959 |
| ln_Man_days | 1.083741 | .1877458 | 5.77 | 0.000 | .715766 | 1.451716 |
| ln_Machnics | -.1727781 | .1316624 | -1.31 | 0.189 | -.4308316 | .0852755 |
| ln_Farm_size | -.1720647 | .1509278 | -1.14 | 0.254 | -.4678777 | .1237482 |
| _cons | 2.052434 | .6111036 | 3.36 | 0.001 | .8546931 | 3.250175 |
| /lnsig2v | -3.116616 | .3824996 | -8.15 | 0.000 | -3.866301 | -2.36693 |
| /lnsig2u | -.8521896 | .2612047 | -3.26 | 0.001 | -1.364141 | -.3402379 |
| sigma_v | .210492 | .0402565 | | | .1446916 | .3062158 |
| sigma_u | .6530544 | .0852904 | | | .505569 | .8435645 |
| sigma2 | .4707869 | .1073643 | | | .2603567 | .6812172 |
| lambda | 3.102515 | .1049879 | | | 2.896743 | 3.308287 |

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 68.34  Prob>=chibar2 = 0.000

. ref ln_Y ln_Fertilizer ln_Seeds ln_Herbicide ln_Pesticide ln_Man_days ln_Machni
unrecognized command:  ref
r(199);

. reg ln_Y ln_Fertilizer ln_Seeds ln_Herbicide ln_Pesticide ln_Man_days ln_Machni
```

| Source | SS | df | MS |
|---|---|---|---|
| Model | 91.1872756 | 7 | 13.0267537 |
| Residual | 62.4577748 | 86 | .726253196 |
| Total | 153.64505 | 93 | 1.65209732 |

```
Number of obs =       94
F(  7,     86) =   17.94
Prob > F      =   0.0000
R-squared     =   0.5935
Adj R-squared =   0.5604
Root MSE      =    .8522
```

| ln_Y | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ln_Fertilizer | -.0508093 | .0599418 | -0.85 | 0.399 | -.1699696 | .0683509 |
| ln_Seeds | .317171 | .1706514 | 1.86 | 0.067 | -.0220728 | .6564148 |
| ln_Herbicide | 1.216835 | .3329949 | 3.65 | 0.000 | .5548627 | 1.878807 |
| ln_Pesticide | -.0834581 | .157031 | -0.53 | 0.596 | -.3956254 | .2287092 |
| ln_Man_days | 2.84731 | .3697709 | 7.70 | 0.000 | 2.11223 | 3.58239 |
| ln_Machnics | -1.063297 | .3014358 | -3.53 | 0.001 | -1.662532 | -.4640628 |
| ln_Farm_size | -.7523516 | .3780461 | -1.99 | 0.050 | -1.503882 | -.000821 |
| _cons | -3.708644 | 1.169583 | -3.17 | 0.002 | -6.033698 | -1.383589 |

# APPENDIX G: ESTIMATION OF COST FUNCTION COEFFICIENTS – CONVENTIONAL TILLAGE

```
. frontier ln_cost ln_FertC ln_SeedC ln_HerbC ln_PestC ln_Labour ln_Mech

Iteration 0:   log likelihood =  76.646473
Iteration 1:   log likelihood =  77.362416
Iteration 2:   log likelihood =    77.6745
Iteration 3:   log likelihood =   77.74828
Iteration 4:   log likelihood =  77.790199
Iteration 5:   log likelihood =  77.797522
Iteration 6:   log likelihood =  77.805161
Iteration 7:   log likelihood =  77.805738
Iteration 8:   log likelihood =  77.808076
Iteration 9:   log likelihood =  77.808437
Iteration 10:  log likelihood =  77.808711
Iteration 11:  log likelihood =  77.808738
Iteration 12:  log likelihood =   77.80887
Iteration 13:  log likelihood =  77.808896
Iteration 14:  log likelihood =  77.808913
Iteration 15:  log likelihood =  77.808927
Iteration 16:  log likelihood =  77.808934

Stoc. frontier normal/half-normal model           Number of obs    =         94
                                                  Wald chi2(6)     =    2839.46
Log likelihood =  77.808934                       Prob > chi2      =     0.0000
```

| ln_cost | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ln_FertC | .0467658 | .0053036 | 8.82 | 0.000 | .036371 | .0571607 |
| ln_SeedC | .0812465 | .0119468 | 6.80 | 0.000 | .0578313 | .1046617 |
| ln_HerbC | .0548092 | .0123221 | 4.45 | 0.000 | .0306583 | .0789601 |
| ln_PestC | .0182952 | .0051461 | 3.56 | 0.000 | .0082089 | .0283814 |
| ln_Labour | .6822415 | .024822 | 27.49 | 0.000 | .6335913 | .7308918 |
| ln_Mech | .0776251 | .0153915 | 5.04 | 0.000 | .0474584 | .1077918 |
| _cons | 1.75358 | .1469382 | 11.93 | 0.000 | 1.465587 | 2.041574 |
| /lnsig2v | -4.493397 | .1459715 | -30.78 | 0.000 | -4.779496 | -4.207298 |
| /lnsig2u | -13.89436 | 181.8853 | -0.08 | 0.939 | -370.3829 | 342.5942 |
| sigma_v | .1057478 | .0077181 | | | .0916528 | .1220104 |
| sigma_u | .0009613 | .087427 | | | 3.74e-81 | 2.47e+74 |
| sigma2 | .0111835 | .0016347 | | | .0079795 | .0143876 |
| lambda | .0090909 | .0880523 | | | -.1634884 | .1816702 |

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.00    Prob>=chibar2 = 1.000

. reg ln_cost ln_FertC ln_SeedC ln_HerbC ln_PestC ln_Labour ln_Mech
```

| Source | SS | df | MS |
|---|---|---|---|
| Model | 31.7535006 | 6 | 5.2922501 |
| Residual | 1.05117483 | 87 | .012082469 |
| Total | 32.8046754 | 93 | .352738445 |

```
Number of obs =      94
F(  6,    87) =  438.01
Prob > F      =  0.0000
R-squared     =  0.9680
Adj R-squared =  0.9657
Root MSE      =  .10992
```

| ln_cost | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ln_FertC | .0467658 | .0055128 | 8.48 | 0.000 | .0358086 | .057723 |
| ln_SeedC | .0812465 | .012418 | 6.54 | 0.000 | .0565645 | .1059285 |
| ln_HerbC | .0548092 | .0128081 | 4.28 | 0.000 | .0293517 | .0802667 |
| ln_PestC | .0182952 | .0053491 | 3.42 | 0.001 | .0076633 | .0289271 |
| ln_Labour | .6822416 | .0258011 | 26.44 | 0.000 | .6309592 | .7335239 |
| ln_Mech | .0776251 | .0159985 | 4.85 | 0.000 | .0458263 | .1094239 |
| _cons | 1.752829 | .1344218 | 13.04 | 0.000 | 1.485651 | 2.020007 |

# APPENDIX H: HYPOTHESIS TEST OF SIGNIFICANT DIFFERENCE OUTPUT

```
. ttest EE_NT == EE_CM, unpaired unequal

Two-sample t test with unequal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| EE_NT | 88 | .4348812 | .0266594 | .2500871 | .3818928 | .4878697 |
| EE_CM | 94 | .3397821 | .0206417 | .2001284 | .2987919 | .3807724 |
| combined | 182 | .3857641 | .0170507 | .2300266 | .3521204 | .4194078 |
| diff | | .0950991 | .0337165 | | .0285324 | .1616658 |

```
    diff = mean(EE_NT) - mean(EE_CM)                              t =   2.8206
Ho: diff = 0                     Satterthwaite's degrees of freedom =  166.576

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9973         Pr(|T| > |t|) = 0.0054          Pr(T > t) = 0.0027
```

# APPENDIX I: EFFECTS OF SOCIOECONOMIC CHARACTERISTICS ON TE (NO TILL)

```
                  0 right-censored observations

. use "C:\Users\user\Desktop\DATA ANALYSIS SPREADSHTS 2017\Log NT_PROD_WK1.dta'

. tobit ln_Y Age Farming_Exp Educ_Exp Gender Household_Sz Off_Farm_Inc Seed_Tyr

Tobit regression                                  Number of obs   =         87
                                                  LR chi2(7)      =      23.92
                                                  Prob > chi2     =     0.0012
Log likelihood = -107.87945                       Pseudo R2       =     0.0998

------------------------------------------------------------------------------
        ln_Y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         Age |  -.0125055   .0083466    -1.50   0.138    -.0291157    .0041047
 Farming_Exp |   .0719237   .0264336     2.72   0.008     .0193191    .1245283
    Educ_Exp |   .0437455    .026736     1.64   0.106    -.0094608    .0969519
      Gender |  -.2037263   .2057534    -0.99   0.325    -.6131887    .2057361
Household_Sz |  -.0108927   .0309913    -0.35   0.726    -.0725673     .050782
Off_Farm_Inc |   .4641351   .1865632     2.49   0.015     .0928625    .8354077
   Seed_Type |  -.6237754   .6152748    -1.01   0.314    -1.848211    .6006604
       _cons |   5.608446    .836121     6.71   0.000     3.944512     7.27238
-------------+----------------------------------------------------------------
      /sigma |    .831122   .0648507                       .702065     .960179
------------------------------------------------------------------------------
  Obs. summary:          3  left-censored observations at ln_Y<=2.5257287
                        84     uncensored observations
                         0 right-censored observations
```

## APPENDIX J: EFFECTS OF SOCIOECONOMIC CHARACTERISTICS ON TE (CONVENTIONAL TILLAGE)

```
. tobit ln_Y Age Farmin_Exp Educ_Experience Gender Household_Size Income Seed_Type,

Tobit regression                                  Number of obs   =         91
                                                  LR chi2(7)      =      23.20
                                                  Prob > chi2     =     0.0016
Log likelihood = -99.140831                       Pseudo R2       =     0.1047
```

| ln_Y | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Age | -.0049569 | .0107268 | -0.46 | 0.645 | -.0262883 | .0163745 |
| Farmin_Exp | .0267075 | .0110207 | 2.42 | 0.018 | .0047916 | .0486234 |
| Educ_Experience | .0375243 | .02085 | 1.80 | 0.075 | -.0039383 | .0789869 |
| Gender | .199907 | .1541245 | 1.30 | 0.198 | -.1065865 | .5064006 |
| Household_Size | .0789047 | .032083 | 2.46 | 0.016 | .0151042 | .1427052 |
| Income | -.15641 | .2014846 | -0.78 | 0.440 | -.5570843 | .2442643 |
| Seed_Type | .0229795 | .149803 | 0.15 | 0.878 | -.2749201 | .3208791 |
| _cons | 4.662754 | .5260956 | 8.86 | 0.000 | 3.616555 | 5.708953 |
| /sigma | .7149445 | .0535053 | | | .6085433 | .8213457 |

```
  Obs. summary:          1  left-censored observation  at ln_Y<=3.2188759
                        90     uncensored observations
                         0 right-censored observations

.
```

## APPENDIX K: EFFECTS OF SOCIOECONOMIC CHARACTERISTICS ON AE (NO TILL)

```
. tobit ln_Cost Age Farming_Exp Educ_Exp Gender Household_Sz  Off_Farm_Inco Seed_

Tobit regression                                  Number of obs   =         87
                                                  LR chi2(7)      =      18.95
                                                  Prob > chi2     =     0.0084
Log likelihood = -30.732858                       Pseudo R2       =     0.2356

------------------------------------------------------------------------------
     ln_Cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         Age |  -.0007176   .0034163    -0.21   0.834    -.0075164    .0060811
 Farming_Exp |   .0382487   .0108396     3.53   0.001     .0166773    .0598201
    Educ_Exp |   .0018862   .0109513     0.17   0.864    -.0199077      .02368
      Gender |   .0746788   .0841521     0.89   0.378    -.0927892    .2421468
Household_Sz |  -.0136257   .0127405    -1.07   0.288      -.03898    .0117286
Off_Farm_Inco |   .0546964   .0764569     0.72   0.476    -.0974577    .2068506
   Seed_Type |  -.2361596     .25231    -0.94   0.352    -.7382724    .2659533
       _cons |   7.454799   .3428573    21.74   0.000     6.772491    8.137107
-------------+----------------------------------------------------------------
      /sigma |   .3409339   .0260738                      .2890454    .3928225
------------------------------------------------------------------------------
  Obs. summary:          1  left-censored observation  at ln_Cost<=6.5941534
                        86     uncensored observations
                         0 right-censored observations

.
```

## APPENDIX L: EFFECTS OF SOCIOECONOMIC CHARACTERISTICS ON AE (CONVENTIONAL TILLAGE)

```
. tobit ln_cost Age Farm_Exp Educ_Exp Gender HouseH_Size Off_Farm_Inc Occup Seed_

Tobit regression                                  Number of obs   =         94
                                                  LR chi2(8)      =      28.66
                                                  Prob > chi2     =     0.0004
Log likelihood = -70.824152                       Pseudo R2       =     0.1683
```

| ln_cost | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Age | .0009146 | .0076224 | 0.12 | 0.905 | -.0142381 | .0160674 |
| Farm_Exp | .0159367 | .0078764 | 2.02 | 0.046 | .0002789 | .0315945 |
| Educ_Exp | .0269432 | .0147275 | 1.83 | 0.071 | -.0023341 | .0562205 |
| Gender | .0196399 | .1087283 | 0.18 | 0.857 | -.1965048 | .2357847 |
| HouseH_Size | .0271299 | .0224388 | 1.21 | 0.230 | -.017477 | .0717368 |
| Off_Farm_Inc | -.1894696 | .5334541 | -0.36 | 0.723 | -1.249941 | .8710021 |
| Occup | -.0599599 | .5404291 | -0.11 | 0.912 | -1.134297 | 1.014378 |
| Seed_Type | .2630876 | .1070041 | 2.46 | 0.016 | .0503705 | .4758046 |
| _cons | 6.901049 | .6105863 | 11.30 | 0.000 | 5.687243 | 8.114854 |
| /sigma | .5098942 | .0375254 | | | .4352961 | .5844923 |

```
  Obs. summary:          1  left-censored observation  at ln_cost<=6.758791
                        93     uncensored observations
                         0 right-censored observations

.
```

## APPENDIX M: TEST OF SIGNIFICANCE OF THE MEANS, AGE, EDUCATIONAL EXPERIENCE, YIELD, MECHANIZATION HOURS, FILED SIZE

T-test of significance difference of the mean Age of the farmers

```
. ttest Age == Age_01, unpaired unequal

Two-sample t test with unequal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Age | 88 | 50.18182 | 1.523548 | 14.29215 | 47.1536 | 53.21003 |
| Age_01 | 94 | 52.02128 | 1.225443 | 11.88111 | 49.58779 | 54.45476 |
| combined | 182 | 51.13187 | .9709026 | 13.09819 | 49.21612 | 53.04761 |
| diff | | -1.839458 | 1.955226 | | -5.699175 | 2.020258 |

```
    diff = mean(Age) - mean(Age_01)                                t =  -0.9408
Ho: diff = 0                     Satterthwaite's degrees of freedom =  169.584

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.1741         Pr(|T| > |t|) = 0.3482          Pr(T > t) = 0.8259
```

T-test of significance difference of the mean Farming Experience

```
. ttest var1 == Farmin_Exp, unpaired unequal

Two-sample t test with unequal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| var1 | 88 | 2.375 | .3896896 | 3.655613 | 1.60045 | 3.14955 |
| Farmin~p | 94 | 19.54255 | 1.114541 | 10.80588 | 17.3293 | 21.75581 |
| combined | 182 | 11.24176 | .8783958 | 11.85021 | 9.508545 | 12.97497 |
| diff | | -17.16755 | 1.180703 | | -19.50624 | -14.82887 |

```
    diff = mean(var1) - mean(Farmin_Exp)                           t = -14.5401
Ho: diff = 0                     Satterthwaite's degrees of freedom =  115.286

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

## T-test of significance difference of the mean YIELD

```
. ttest Y_Bags == Y_Bags_01, unpaired unequal

Two-sample t test with unequal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Y_Bags | 88 | 203.1534 | 19.178 | 179.9056 | 165.0351 | 241.2718 |
| Y_Bag~01 | 94 | 397.0745 | 36.19242 | 350.8985 | 325.2035 | 468.9454 |
| combined | 182 | 303.3104 | 22.02218 | 297.0955 | 259.8572 | 346.7637 |
| diff | | -193.9211 | 40.95958 | | -274.8968 | -112.9453 |

```
    diff = mean(Y_Bags) - mean(Y_Bags_01)                      t =  -4.7344
Ho: diff = 0                     Satterthwaite's degrees of freedom =    140.7

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

## T-test of significance difference of the mean number of Mechanization Hours

```
. ttest Mech_Hours_nt == Mech_Hours, unpaired

Two-sample t test with equal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Mech_H~t | 88 | .4567045 | .0282282 | .2648041 | .4005979 | .5128112 |
| Mech_H~s | 94 | 2.301702 | .2097412 | 2.033517 | 1.885198 | 2.718207 |
| combined | 182 | 1.409615 | .1286701 | 1.735855 | 1.155729 | 1.663502 |
| diff | | -1.844998 | .2185249 | | -2.276198 | -1.413797 |

```
    diff = mean(Mech_Hours_nt) - mean(Mech_Hours)               t =  -8.4430
Ho: diff = 0                                   degrees of freedom =      180

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

## T-test of significance difference of the mean number of hectares – Field Size

```
. ttest Farm_Size == Farm_Size, unpaired unequal

Two-sample t test with unequal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Farm_S~e | 88 | .6122727 | .0414433 | .3887727 | .5298997 | .6946458 |
| Farm_S~e | 88 | .6122727 | .0414433 | .3887727 | .5298997 | .6946458 |
| combined | 176 | .6122727 | .029221 | .3876603 | .5546018 | .6699436 |
| diff | | 0 | .0586097 | | -.1156774 | .1156774 |

```
    diff = mean(Farm_Size) - mean(Farm_Size)                      t =   0.0000
Ho: diff = 0                        Satterthwaite's degrees of freedom =      174

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5000         Pr(|T| > |t|) = 1.0000          Pr(T > t) = 0.5000
```

## T-test of significance difference of the Economic Efficiency

```
. ttest EE_NT == EE_CM, unpaired unequal

Two-sample t test with unequal variances
```

| Variable | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| EE_NT | 88 | .4348812 | .0266594 | .2500871 | .3818928 | .4878697 |
| EE_CM | 94 | .3397821 | .0206417 | .2001284 | .2987919 | .3807724 |
| combined | 182 | .3857641 | .0170507 | .2300266 | .3521204 | .4194078 |
| diff | | .0950991 | .0337165 | | .0285324 | .1616658 |

```
    diff = mean(EE_NT) - mean(EE_CM)                              t =   2.8206
Ho: diff = 0                        Satterthwaite's degrees of freedom =  166.576

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9973         Pr(|T| > |t|) = 0.0054          Pr(T > t) = 0.0027
```