An evaluation of availability of traction power for tillage and its effects on food security of smallholder farmers' households in KwaZulu-Natal, South Africa

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DEDICATION

I dedicate this thesis to my mother, partner, brothers and daughter.

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ABSTRACT

Agricultural input availability remains an impediment to poverty reduction and achievement of food security in Sub-Saharan African countries. Timely availability of traction power is important in crop production, yet its availability is limited among smallholder farmers due to capital constraints, location bias of government traction power programmes and relatively small landholding. The circumstances facing households influence their traction power choice. An understanding of the determinants of their choices and the effect of traction power availability on crop productivity as well as food security can allow policy makers to develop appropriate strategies and programmes to enhance the productivity of smallholder farmers. This study aimed to contribute to the literature in two ways. The first objective of this study was to determine the factors influencing choice of alternative traction power source for tillage. Secondly, the study sought to evaluate the effect of traction power availability on maize productivity as well as household food security. The study focused on six villages from Okhahlamba Local Municipality, KwaZulu-Natal in South Africa. A Multistage probability sampling was used to select villages and households, whereby 207 households were surveyed. The study identified three main groups of tillage categories that smallholder farmers use, i.e., tractor, animal power, and a combination of the two sources. The multinomial regression results identified household characteristics significantly influencing the choice of traction power source for tillage.

The results from Cobb-Douglass production function and multinomial endogenous treatment effect model show that traction power availability affects maize productivity as well as food security. Using animal power and a combination of mechanical and animal power showed a positive effect on maize productivity as well as food security. The results suggest that the policies and programmes affecting traction power availability directly or indirectly through ownership, hire or government services should be improved as they affect crop productivity and food security. Also, there is need to enforce gender equity strategies in rural areas to ensure equal access to inputs and participation in government programmes. There is also a need to consider the introduction of tillage power suitable for the relatively small land sizes that smallholder farmers operate.

***Key words**: Smallholder farmers, Traction power source, Tillage, Food Security, Crop productivity, Multinomial endogenous treatment effect model.*

LIST OF ACRONYMS

AP	Animal Power
AIDS	Acquired Immune Deficiency Syndrome
ANOVA	Analysis of Variance
CASP	Comprehensive Agricultural Support Programme
COSMEC	Commonwealth Secretariat
DAFF	Department of Agriculture, Forest and Fisheries
DoA	Department of Agriculture
FAO	Food and Agricultural Organization
FSG	Farmer Support Group
GSA	Grain South Africa
Ha	Hectare
HIV	Human Immunodeficiency Virus
IIA	Independence of Irrelevant Alternatives
Kg	Kilogram
KZN	KwaZulu-Natal
MNL	Multinomial Logistic Regression Model
MP	Mechanical Power
MPAP	Mechanical and Animal Power
OLS	Ordinary Least Squares
PRB	Population Reference Bureau
SPSS	Statistical Package for Social Science
StatsSA	Statistics South Africa
SACU	Southern African Custom Union
SSA	Sub-Saharan Africa
US	United States
USEAP	Use Animal Power
USEMPAP	Use Mechanical and Animal Power
VIF	Variance Inflator Factor

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CHAPTER 1. INTRODUCTION

1.1 Background

The world is experiencing several developmental problems, including poverty and food insecurity (FAO, 2016). There is progress in the fight against poverty and food insecurity, but there continue to be many people who lack food and other basic needs to live a healthy and active life. According to Gonzalez (2015), food insecurity results from poverty rather than food scarcity. Globally, almost one billion people are experiencing food insecurity because they do not have enough money to buy food in the market or agricultural inputs to produce the food they need (Gonzalez, 2015). Rural populations suffer most from the developmental problems because of their substantial reliance on the underdeveloped agricultural sector (McGranahan and Beale, 2002; Muyanga and Jayne, 2014). According to FAO (2016), about 80% of the world's food insecure are rural people, ironically, who cultivate at least 70% of the world's food.

Rural populations in Sub-Saharan Africa (SSA) countries are more food insecure and poor than those in other countries within the African continent (World Bank, 2008). World Bank (2008) reported that three in every four people in SSA lives in rural areas, are disadvantaged, food insecure and depend directly or indirectly on agriculture for their livelihoods. Most of these SSA countries invest in improving agricultural productivity since it has a potential of addressing the developmental challenges through job creation, provision of food and raw materials. Regardless of these efforts, input availability remains an impediment to improved crop productivity, consequently food security (Baiphethi, 2009; Ramaila *et al.*, 2011).

In South Africa, the agricultural sector continues to be dominated by resource-poor farmers characterized by low-income, small landholdings, unavailability of traction power and lack of other improved inputs (Lahiff and Cousins, 2005; Maliwichi *et al.*, 2010; Oni *et al.*, 2011). As a result, attaining rapid growth in crop productivity and food security by these smallholder farmers remains a challenge. Household food insecurity persists in South Africa, and there has been minimal progress in reducing it (Hart, 2009; De Cock, 2013). Increase in area under cultivation and crop productivity, for household consumption and sale can enhance food security (Hart, 2009; Ambagna, 2012; Chitja, 2014). Several authors (Topps *et al.*, 1999; Yadav, 2003; Srivastava, 2004; Ajah, 2014; Mehta *et al.*, 2014; Sims and Kienzle, 2015; Takeshima, 2016) concur that availability of traction power has a positive impact on crop productivity. Traction power availability can allow the use of fallow and virgin arable land to increase the area under cultivation (Mudhara, 2010; Kansanga, 2016). Even though the South Africa government has introduced mechanization programmes to address traction power problems, timely availability remains a challenge. Timely available traction power for tillage is one of the most critical inputs in crop production, yet is not readily available to smallholder farmers due to capital constraints, location bias of government traction power programmes and relatively small landholding. As a result, farmers end up not planting at all in a particular season or planting late, hence realizing low productivity and food insecurity.

The circumstances that smallholder farmers face influence their choice and affordability of traction power source for tillage. Previous studies found that household characteristics and institutional factors significantly influence the choice of alternative traction power for tillage (Ghosh, 2010; Mabuza *et al.*, 2013; Manta and Aduba, 2013; Challa, 2014; Van Eerdewijk and Danielsen, 2015; Kansanga, 2016). For example, Ghosh (2010) and Challa (2014) found that relatively small farm size discourages farmers to use a tractor since it is not economically viable. Mabuza *et al.* (2013) indicated that households with relatively high income could invest in tractor purchases or hire for cultivation purposes. Manta and Aduba (2013) and Kansanga (2016) emphasized that institutional factors, especially government programmes regarding traction power services, influence the traction power availability and choice. Van Eerdewijk and Danielsen (2015) revealed that the gender of household head influences the choice of traction power source, especially in rural areas where gender equity is still a challenge.

A few studies (e.g.,Chisango, 2010; Rampokanyo, 2012; Tanaka *et al.*, 2013) proved that traction power availability has a significant effect on crop productivity. Although there is limited research on the effect of traction power availability on household food security, previous impact studies (e.g.,Cunguara and Darnhofer, 2011; Nkegbe *et al.*, 2017) found that traction power availability affects household food security. In this section of the study; problem statement, study objectives and organization of the study will be presented.

1.2 Problem Statement

Several studies show the importance of rural agricultural production in achieving food security and reducing poverty, but the productivity of this sector remains low. As a result, people abandon agricultural production and rely on limited non-farm income (Baiphethi and

Jacobs, 2009). Evenson and Gollin (2003) and Yengoh (2012) mentioned that the low productivity occurs due to limited availability of improved inputs. Increasing the availability and access of inputs can significantly increase crop productivity and food security. Several authors (Srivastava, 2004; Ajah, 2014; Mehta *et al.*, 2014; Sims and Kienzle, 2015; Takeshima, 2016) agree that traction power is the most crucial input in the agricultural crop production process. Studies conducted in different countries (including Bangladesh, China, Ethiopia, Ghana, Mozambique and Zimbabwe) shows that traction power availability significantly contributes to improved crop productivity as well as food security in smallholder farms (Beyene and Muche, 2010; Obi, 2010; Cunguara and Darnhofer, 2011; Bedeke, 2012; Abafita and Kim, 2013; Hossain, 2014; Yuyan *et al.*, 2015; Nkegbe *et al.*, 2017).

In South Africa, several impact studies have been conducted on the effect of the availability of improved seeds and fertilizer on crop productivity and food security (Baiphethi, 2009; Ramaila *et al*., 2011; Goldblatt, 2010; Fischer *et al.*, 2015). However, there has been limited/ no studies on the effect of timely availability of tillage power on crop productivity as well as food security. Traction power availability and its effect on crop productivity as well as food security have so far received little attention although it is the most critical input in most studies. Therefore, this study determines factors influencing the choice of traction power source for tillage and the effect of traction power availability on crop productivity as well as food security.

1.3 Study objectives

The main objective of the study was to evaluate traction power availability for tillage on smallholder farms and its effect on crop productivity, as well as food security.

a) To identify alternative traction power sources available for tillage and their relative uses by smallholder farmers.
b) To identify factors that determines the use of alternative traction power sources for tillage.
c) To determine the effect of alternative traction power sources on smallholder farmers' crop production as well as food security.

1.4 Organization of the study

The thesis is organized into six chapters. Chapter one provides the background of the study and the problem context, objectives. The second chapter presents the literature on factors influencing the choice of traction power source for tillage. Chapter 2 also provides a review of the effect of traction power availability on crop productivity as well as food security. Chapter 3 determine factors influencing the choice of alternative traction power source used for tillage by rural households. Chapter 4 evaluates the effect of traction power availability on maize productivity. Chapter 5 evaluates the effect of traction power availability on household consumption expenditure as a proxy of food security. Finally, chapter 6 presents the conclusion, policy recommendations and implications for further research.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Traction power is essential for pulling tools, equipment, and machinery in agricultural production. This chapter reviews the theoretical and empirical literature relating to the choice of traction power for tillage and the effect of its availability on crop productivity as well as food security. The chapter starts by defining some concepts of the study, namely, traction power source, tillage, crop productivity and food security. The chapter also reviews the literature on the factors influencing the choice of traction power source in developing countries. This is followed by a discussion of literature on the effect of traction power availability on crop productivity as well as food security.

2.2 Definition of concepts used in the study

2.2.1 Traction power sources

Tools, implements and powered machinery are needed to support production and productivity within the agricultural sector (Mandal, 2014). Traction power is the most crucial input that aids in the operation of tools, implements and powered machinery used during various farm operations (Sims, 2012). The source of power used on these tools and implements may be human, animals or mechanical. The power source used for tillage varies between households, depending on availability of alternative power sources and financial resources for hiring power externally. Sims (2012), indicate that in SSA, human power dominates by 65% as a source of power, then animal and mechanical power constitute 25% and 10%, respectively.

Animal power source is derived from domestic animal muscle to perform farming operations (Rijk, 1999). Using this power source requires less labour, is less time-consuming, and it reduces human drudgery (Karugia et al., 2007). Furthermore, animal power eases dependence on mechanical power and the reliance of agricultural production on limited petroleum products (Fuller and Aye, 2012). Different types of animals such as cattle's, buffaloes, horses, mules, donkeys, and camels are used as power sources in various parts of the world (Sims and Kienzle, 2006; Umaru et al., 2013). Animal power is renewable and easily accessible to smallholder farmers, who are the principal crop producers in developing countries. Although the use of animal power is cheap and reduces human drudgery, factors such hot weather, hard soil as disease and drought reduce their performance (Srivastava, 2004). Moreover, there may be shortage of feeds during dry periods making their active use during the farming season difficult.

On the other hand, mechanical power is the latest technology that encompasses all agricultural machinery which obtains its central power from sources other than muscles (Rijk, 1999). This power source ensures timely execution of farm operations and increases cropping intensity in case large land needs to be prepared (Srivastava, 2004; Manjengwa, 2011). The four-wheeled tractor is commonly used for pulling farming implements (Sharma and Soni, 2006; Sims and Kienzle, 2006).

2.2.2 Tillage

Tillage is amongst the fundamental and vital operations in crop production that influence soil properties and crop productivity (Sharma and Abrol, 2012; Alam *et al*., 2014). Apart from being the most crucial activity in crop production, it requires more power than other activities (Thierfelder *et al*., 2012). Mabuza *et al.* (2013) identified poor tillage as one of the factors causing low agricultural productivity in smallholder farms. Mannering and Fenster (1983) defined tillage as an activity that takes account of all the operations from seedbed preparation to enhance soil and environmental conditions for seed germination, seed establishment, and crop growth. Bajracharya (2001) and Anerua-Yakubu (2014) defined tillage as a form of soil disturbance aimed at creating favourable conditions for planting, germination, emergence, growth, and development of crops.

Previous studies (e.g. Akter and Gathala, 2014; Brouder and Gomez-Macpherson, 2014; Grabowski et al., 2014; Ngoma *et al*., 2015) identify two types of tillage, namely conservation and conventional tillage. These tillage types differ in the degree of soil disturbance, which then affects the rate of organic matter decomposition. Conservation tillage involves leaving at least 30% of the crop residue in the soil/field (Brouder and Gomez-Macpherson, 2014). This practice results in reduced power requirements for tillage, favourable soil temperatures, increased soil organic matter and conservation of soil moisture. It is also environmentally non-degrading, technically appropriate, economically viable and socially acceptable (Hobbs *et al.*, 2008). However, these benefits come at the cost of high weed management. (Hobbs *et al.*, 2008; Hoogmoed, 2009; Temesgen *et al.*, 2009; Chiputwa *et al.*, 2011; Mathew *et al.*, 2012; Bisangwa, 2013; Akter and Gathala, 2014; Grabowski *et al.*, 2014). Previous studies

(Kabamba and Muimba-Kankolongo, 2009; Marakoglu and Carman, 2012) indicate that conservation tillage method has a positive influence on crop productivity when combined with early tillage as compared to conventional practice.

On the other hand, conventional tillage includes methods such as ploughing, disking and harrowing that leave most of the crop residues in the soil. It is commonly used in smallholder production (Brouder and Gomez-Macpherson, 2014). This practice results in soil physical degradation, increased erosion, high organic matter decomposition, increased labour, time and energy requirements (Temesgen *et al.*, 2009; Sessiz *et al.*, 2010; Chiputwa *et al.*, 2011; Bisangwa, 2013).

2.2.3 Crop productivity

Productivity is one of the most important indicators of growth within the small-scale agricultural sector. It is also a significant tool that policy-makers use since it improves the living standards of country's households through enhanced livelihoods as well as food security (Maseatile, 2011; Valerio, 2014). Bringing fallow land into cultivation and achieving high productivity on existing farms can aid in sustaining better living standards. Improved productivity has several benefits such as lower food prices, improved country's competitiveness and increased flow of employment opportunities from the agriculture to other sectors of the economy. It can be measured using single input (factor or partial productivity) or multiple inputs (multiple factors or total factor productivity) (Ahmed *et al.*, 2005; Coelli *et al.*, 2005; Valerio, 2014).

Crop productivity is defined differently across agricultural disciplines. The definition has been improved from time to time because of the shortcomings that various researchers identified. The standard definition of crop productivity is output per unit of land cultivated (Coelli *et al.*, 2005; Valerio, 2014). Other authors criticized this definition as it partially measures productivity and it disregards the contribution of different physical, socio-economic and technological inputs used in the production process. For this reason, researchers refined the definition to ensure that it does not give misleading estimations. For example, Reynolds *et al.* (2015) pointed that environmental factors also have an impact on crop productivity. As such, measuring crop productivity should consider these factors. Cassidy *et al.* (2013) alluded that accuracy in measuring productivity can be achieved by defining crop productivity as the number of people fed per hector of land planted.

This study will adopt the economics definition by ((Ahmed *et al.*, 2005; Coelli *et al.*, 2005; Valerio, 2014), who defined crop productivity as the quantity of output produced for a given amount of production input used. It measures the efficiency of input use in the production process.

2.2.4 Food security

Food security is defined as the situation where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to live a healthy and active life (FAO, 2006). The commonly accepted definition comprises the following pillars: availability, access, utilization, and stability. Food availability implies the availability of sufficient quantities of appropriate, necessary types of food from domestic production or imports (Napoli *et al.*, 2011). Food availability assumes that increasing the amount of food available will reduce malnutrition levels.

Food access refers to the ability of households to procure and acquire quality food in a socially acceptable way (Napoli *et al.*, 2011; FAO, 2015b). The availability and accessibility of food are not enough if the food is not safe and nutritious. The third pillar of utilization covers a range of aspects such as safe and nutritious food, clean drinking water, and sanitation for people to live a healthy and active lifestyle. The last pillar of food security, stability, emphasizes that households' or individuals should have access to safe and nutritious food at all times. Households' or individuals should not live in fear of experiencing either transitory or chronic food insecurity (Napoli *et al.*, 2011).

Measuring food security remains complicated and expensive, with data limitation and/or availability making things worse (Hendriks, 2005; Tandon *et al.*, 2017). Hendriks (2005) explains that the multiple dimensions of food security make measurement difficult. Studies use either direct and/or proxy indicators as to measure food security. The direct indicators include the use of households perceptions of food security and food security index (Tandon *et al.*, 2017). However, using the direct indicators makes measuring food security even more complicated due to high cost and measurement errors.

2.3 Linkage between agricultural productivity and food security in developing countries

A large proportion of the population in most developing countries relies directly or indirectly on agriculture for its livelihoods (McGranahan and Beale, 2002; Muyanga and Jayne, 2014). According to the World Bank (2008), at least 3 billion people in developing countries lives in rural areas. An estimated 2.5 billion are in households involved in agriculture, and 1.5 billion are in smallholder households. Many of these households suffer from persisting poverty and food insecurity (World Bank, 2008). Several studies (Simbi, 1998; Pingali, 2002; Muchopa *et al.*, 2004; Baiphethi and Jacobs, 2009; Daniels *et al.*, 2013) agree that agricultural production can be of great importance in improving the livelihoods of rural households. For this reason, increased agricultural productivity has the potential of reducing poverty and food insecurity in the rural households (Verma, 2008; World Bank, 2008; Mozumdar, 2012; Elias *et al.*, 2013).

Growth in agricultural productivity correlates positively with lower food prices, better nutritional intake and increased capital flow from agriculture to different sectors of the economy (World Food Summit, 1996; Timmer, 2002; Mozumdar, 2012). Agricultural growth in developing countries is vital for helping the poor reduce poverty and enhance food security. Furthermore, increased agricultural productivity can also improve the country's economy (Shapouri *et al*., 2009; Schneider and Gugerty, 2011; Fuglie and Rada, 2013). Consequently, the sustained growth in agricultural productivity can contribute to combating hunger, reducing dependence on imported food and increasing overall food security.

Most developing countries, notably those in SSA, are still experiencing slow growth in agricultural productivity (Shapouri *et al.*, 2009; Fuglie and Rada, 2013). The level of poverty and food insecurity in SSA is the same as it was 30 years ago, with about one-third of the population suffering from severe food insecurity and poverty (Sasson, 2012; FAO, 2015a). Ahmed (2015) stresses that agricultural productivity in smallholder farms remains low because most farmers still rely on relatively limited human, animal and mechanical power sources for tillage and planting, which delays timely execution of crop production activities. Hence, attaining improved agricultural productivity remains one of the most significant challenges in most countries.

2.4 Farmers' perception of alternative traction power sources for tillage

The attributes associated with each power source influence the perception of farmers towards alternative power sources (Nwaobiala and Ezeh, 2012). According to Ranjan *et al*. (2014) and Pathak and Rao (2015), the noted advantages of alternative power sources include time-saving, labour saving, simplicity, accessibility, and improvement of work quality. For example, Belal *et al*. (2015) and Umaru *et al.* (2013) discovered that farmers perceive that animal power is more available, affordable, reduce drudgery and time spent on a particular production task.

Akila and Chander (2009) evaluated farmers' attitude towards utilization of animal power in India. The study found that apart from the advantages associated with each alternative traction power source, ownership and dependence on a particular power source also influence farmers' perception of its attributes. The study showed that most farmers who owned or relied highly on animal power had favourable perceptions of its attributes relative to the alternatives. The results of the study conducted by Belal *et al*. (2015) revealed that animal power was perceived to have benefits such as increased area under cultivation and crop productivity compared to tractors. Bisangwa (2013) also found that farmers relate the use of animal power with increases in maize yield.

Comparing farmers using ox and those using tractors, Conroy and Teweldmehidin (2010) found that farmers perceived the use oxen for production to be cost-effective than using a tractor. By contrast, Ghosh (2010) studied the determinants of farm mechanization in modern agriculture in Burdwan districts of West Bengal and found that most farmers used hired tractors for tillage although they owned bullock for animal power. This is because they perceived tractors to be less costly, save labour and time. Instead, they used animal power mainly for transportation and a source of food.

2.5 Availability of tillage power in SSA

Tillage is the dominant user of traction power in crop production, hence its availability is critical. Availability of traction power sources incorporates the ability of farmers to own or easily hire traction power for timely execution of tillage and other activities in crop production. Any factor that decreases the availability of traction power source for tillage threatens farmers' livelihoods by reducing area cultivated, crop productivity and food security level (Bishop-Sambrook *et al.*, 2004; Anerua-Yakubu, 2014).

According to Srivastava (2004), there is a close relationship between the availability of traction power, timely execution of farm operations and productivity. Farmers who own or can easily hire alternative traction power can realize improved crop productivity and food security. Improved crop productivity requires the availability of adequate traction power for tillage and other activities, but this is a challenge in SSA (Abdu-Raheem and Worth, 2011; Houmy, 2013; Baudron *et al*., 2015; Sims and Kienzle, 2015).

Table 2.1 Alternative power used in selected countries

Country/ Region	Human power %	Animal power %	Tractor power %
Sub-Sahara Africa	80	16	4
Botswana	20	40	40
Kenya	84	12	4
Tanzania	80	14	6
Zimbabwe	15	30	55
South Africa	10	20	70
India	18	21	61
China	22	26	52

Source: (COSMEC (1992) cited by Manjengwa, 2011)

Human power: The use of human muscle as a source of power for tillage persists in some Sub-Saharan African countries (Table 2.1) (COSMEC (1992) cited by Manjengwa, 2011). However, several challenges result in the poor availability of labour and weak labour force for tillage and other farming activities. Firstly, HIV/AIDS pandemic depletes the available human power source for tillage. According to Sims (2012), HIV/AIDS has the observable impact on men than women. This incident leaves females with a burden of tillage and other farm activities for agricultural production to take place. This is because, apart from working on the farms, they have various household responsibilities such as childcare, cooking, collecting wood, fetching water and giving birth. These duties reduce the availability of labour and time allocated for tillage during the farming season (Meinzen-Dick et al., 2011; Croppenstedt *et al.*, 2013). Rural-urban migration further exacerbates human power depletion. Rural people continuously migrate to urban areas in search for better job opportunities or education to improve their livelihoods. According to FAO (2011) cited in Sims (2012), 70% of the population will comprise urban people by the year 2050. These statistics show an expected significant decline in human power source for agricultural operations in rural areas. In 2016, about 54% of the global population comprise of urban people.

Animal power: An alternative to human power for tillage is the animal power. Animal power is available for use by smallholder farmers in two ways: the farmer either owns or hires the animals from fellow community members (Umaru *et al*., 2013). Farmers who own a pair of animals have readily available power for farm operations. However, Oladeji (2012) reported that farmers lack knowledge and skills on how to use animals efficiently. Furthermore, diseases, climate change, and limited grazing land because of the high population growth result in a decline in availability of animal power for tillage. These challenges delay timely execution of tillage, regardless of whether the farmer owns or hires. Another critical problem is that animals no longer have the strength to carry out the operation because of very high temperature during the farming season due to climate change (Ellenberg, 2000; Umaru et al., 2013; Lohan *et al*., 2015).

Mechanical power: Like animal power, farmers use the mechanical power source that is available through ownership or hire. Nevertheless, it is challenging and not always economically possible for smallholder farmers to own mechanical power. For this reason, farmers mostly rely on private or government tractor hiring services for tillage. The difficulty with accessing credit or acquiring sufficient capital to become private tractor service providers limit private tractors service supply in rural communities (Ajah, 2014; Takeshima, 2015). Furthermore, government tractor hiring schemes fail because of their poor maintenance and other difficulties causing a decline in the availability and use of tractor by smallholder in Sub-Saharan Africa (Bishop-Sambrook, 2005).

2.6 Transformation of the available traction power sources for tillage in SSA

The history and direction of farm power change influenced various factors such as land and labour availability in an economy, demand for non-agricultural labour and the demand conditions for agricultural products (Pingali, 2007).The transition started from human power through to traction power sources such as animal and mechanical power (Paman *et al*., 2012).

Historically, human power was the primary source of power for tillage (Bishop-Sambrook, 2005; Houmy, 2013). According to Bishop-Sambrook (2005), during the early 1900s, almost all farmers in Sub-Saharan Africa relied solely on human power for tillage. However, with time there was limitations and drudgery concerning the area that can be cultivated. Also, labour cost seemed to be high as the farming intensity increased (Vergnani, 2013). The domestication of animals provided enough traction to undertake crop production was used to overcome human drudgery problem (Pingali, 2007).

The change from human to animal power resulted in the expansion of area cultivated, higher yields, reduced labour requirement, and the development of animal husbandry (Opara, 2004; Houmy, 2013). Likewise, animal power had problems such as diseases and poor veterinary services that made its use expensive (Makki, 2014). Also, the imported equipment was often too heavy for the animals to pull. Moreover, the size of oxen, and the competition between land use for grazing and crop production because of intensification of agriculture further discouraged the use of animal power in sub-Saharan countries (Bishop-Sambrook, 2005). Due to these problems, there was an introduction and adoption of mechanical power.

Use of mechanical power took place after the First World War, which led to a gradual decline in the use of animal power (Manjengwa, 2011). Mechanical power ensured timely tillage and improved overall agricultural productivity (Verma, 2008; Houmy, 2013). Despite the benefits associated with mechanical power, most smallholder farmers retained the use of animal power as compared to commercial farmers who reduced its use. The behaviour of smallholder farmers was because of the lower suitability of tractor power for use in small farming operations (Pingali, 2007; Manjengwa, 2011).

Nevertheless, there has been an increased use of tractors followed by a slow decline across some SSA countries since the year 1945. The provision of most tractors for tillage was through cooperative farms, state farms or tractor hire services (Bishop-Sambrook, 2005). Between 1960s-1970s, some farmers combined the use of animal and mechanical power sources. During this period, the use of animal and mechanical power was high but followed by a decline during the 1980s. According to Anerua-Yakubu (2014), high running costs of tractors and implements, and fuel scarcity are some of the factors that reduced tractors use. Bishop-Sambrook (2005) also indicates that government-designed hiring schemes were unsustainable and therefore, lead to a decline in the use of tractors.

Most smallholder farmers in SSA countries currently rely on human power, mostly from female, elderly people and children, for tillage (Langford, 2015). Despite this dependence on human power, they face a dilemma of labour shortages due to diseases such as HIV/AIDS and rural-urban migration (Bishop-Sambrook, 2005).

2.7 Factors influencing the choice of alternative traction power source for tillage

Most previous studies found that household characteristics significantly influence the use of alternative traction power for tillage (Shapiro, 1990; Chisango, 2010; Chiputwa *et al.*, 2011; Beaman and Dillon, 2012; Mabuza *et al.*, 2013; Ajah, 2014), and these are reviewed below.

Education

Farmers' ability to fully understand and use various agricultural technologies depends highly on their educational level. In studying factors limiting small-scale farmers' access and utilization of tractors for mechanization in Nigeria, Ajah (2014) found that the majority of farmers had only primary education, which constrained the use of tractors and encouraging the use of hand or animal tools. Tractors, as newly developed and improved technologies within the agricultural sector, are relatively knowledge intensive such that farmers with a high level of education are more likely to use them (Maliwichi et al., 2010; Burton, 2014; Kolade and Harpham, 2014). This view implies that there is a positive relationship between farmers' level of education and the use of improved agricultural technologies (Challa, 2014). According to Langyintuo and Mungoma (2008), educated farmers can acquire and process information about available technologies and their benefits. On the other hand, Sanni (2008) studied animal traction among farming communities in Nigeria using binary logistic model and found education level to have an insignificant influence on the use of animal power. This outcome suggests that a farmer can use animal power for tillage whether educated or not.

Training on animal power use

Training is necessary to encourage adoption of various innovations and technologies. Training provides knowledge and exposure to hands-on experience on how to perform and use specific tools, innovations, and equipment in agriculture (Mulanda *et al*., 1999). There is a definite relationship between agricultural training and the use of technologies. For this reason, farmers who receive agricultural training are more likely to use technologies. Natarajan *et al*. (2016) reported that farmers could keep livestock for consumption purpose, yet not take advantage of the additional benefits such as a power source for crop production activities and transportation. They suggested that use of the animal power can only be achieved when farmers receive training in this area. However, Akila and Chander (2012) indicate that the majority of farmers are not interested in getting training on animal utilization and management. Akila and Chander (2012), Oladeji (2012) and Ghosal and Behera (2013) assume that this might be due to the lack of awareness on benefits of using the animal power source for farm operations. Nevertheless, on overall, few farmers who receive training on animal use for tillage use less mechanical power. These studies concur that there is a need for awareness and training on draught animal utilization and management. Makki *et al*. (2016) partly attributed this to the limited availability of experienced staff and precise curricular training content on the usage of animal power.

Household size

Household size partly reflects access to family labour supply for production, which is critical for smallholder production. A household comprises people living in the same dwelling space, share a household head and work together in an agricultural plot other income-generating activity (Beaman and Dillon, 2012). A large household size usually implies readily available labour to perform farm operations (Adikwu, 2014). Larger households comprised of adults may be less interested in hiring tractors for tillage because of available human power (Ajah, 2014), which creates an opportunity for them to reduce inputs cost (Laxmi and Mishra, 2007). On the other hand large households may prefer using less labour intensive technologies for tillage and transfer extra labour to off-farm income generating activities. Chisango (2010) studied agricultural mechanization for sustainable agriculture and food security in Zimbabwe using a production function approach and established a positive relationship between household size and the use of mechanical power for tillage. Shapiro (1990) observed a decline in cultivated area per worker as household size increases. This observation suggests that households would instead use tractors for cultivation and use the saved labour for off-farm activities or leisure. Sanni (2008) also indicates that the use of animal power increases with an increase in the household size.

Farming experience

Farming experience and age of household head are challenging factors to link with adoption or use of agricultural technologies (Burton, 2014; Abrha, 2015). According to Laxmi and

Mishra (2007) and Chiputwa et al. (2011), the number of years of farming experience can positively or negatively influence adoption of new agricultural technologies. Farmers with more years of farming experience can certainly/quickly adopt new technologies since they have accumulated capital, knowledge, and skills that can be used to take advantage of the new technologies. On the other hand, the very same farmers may be reluctant to change techniques they have been using for many years (Laxmi and Mishra, 2007). According to Ajah (2014), farmers with more years of experience use mechanical power for farm operations. More years of experience is usually associated with the availability of capital to invest in the use of mechanization and aware of the benefits associated with using it. Likewise, according to Sanni (2008), older farmers are more likely to adopt the animal power technology since they have greater access to institutional assistance and may be in control of more wealth.

Gender

Gender matter in the use of alternative traction power source for farm operations since it influences access to agricultural resources and inputs. Compared to men, women are less likely to own agricultural resources such as land, livestock, and are less likely to have access to credit, education, extension services and adopt new technologies (Ragasa *et al.,* 2013). Women adopt technologies more slowly than men due to their differences regarding access to inputs and services because of social and cultural norms (Hart and Aliber, 2015; Van Eerdewijk and Danielsen, 2015). Additionally, women usually have low education levels which constrain them from taking advantage of opportunities and innovations in the agricultural sector. Amutha (2012) highlights that although there are various programmes to encourage women's access to productive agricultural resources, different institutional (formal and informal) rules serve as obstacles; for example, women have poor access to land. In cases where they have access to land, its productivity is low. In studying gender issues regarding livestock production in Zimbabwe, Mupawaenda *et al.* (2009) found that stereotypes with regards to cattle ownership of by women worsen things. The belief is that, if women own cattle their productivity will be low. Because of these institutional rules and stereotypes, female-headed households usually use the human power source for tillage. Additionally, it is rare to find women who own and use tractors for farm operations in Sub-Saharan Africa. Women are less mechanized and rely on labour-intensive technologies, or employ workers. Female farmers who own or can afford to and/or hire are more likely to use mechanical or animal power for tillage (Van Eerdewijk and Danielsen, 2015).

Household income and wealth

Household income indicates the economic status of households. It also plays an essential role in guiding decisions in the agricultural production process. Previous studies (Langyintuo and Mungoma, 2008; Mabuza *et al.*, 2013) measured household wealth based on the availability of assets such as televisions, decoders, cell phones, refrigerator, radio, car ownership, materials for the house and source of energy for cooking. Wealthy households can take the risk of investing in agricultural technologies such as tractor since they have the means of bearing the negative impacts that might arise (Awotide *et al.*, 2012; Edirisinghe, 2015; Negeri *et al.*, 2015). According to Chiputwa et al. (2011), wealthy farmers can own or hire mechanical power source for tillage as opposed to the disadvantaged ones. The underprivileged farmers settle for using zero tillage that eventually has a disadvantage of high labour requirement for weeding. Evidence from Mabuza *et al.* (2013), in studying factors influencing the use of alternative land cultivation technologies in Swaziland, also indicate that household wealth and income significantly influences the use of tractor for tillage. As the farm income increases, farmers tend to use hired tractors for tillage and not animal power. Another study by Shapiro (1990) shows that wealthy households cultivate relatively large areas because of better access and affordability of required inputs such as a tractor. They also have the seeds and fertilizer necessary for the production process.

Land characteristics

Land is the most crucial input in crop production. Nevertheless, most smallholder farmers operate on relatively small landholdings. According to Livingstone et al. (2011) and Gollin (2014), the average land size of smallholder farmers' is one to two hectares. The size of landholdings continues to fall due to increasing population growth and demand for communal grazing land. Labour intensive tillage technologies are suitable for relatively these small plots (Challa, 2014). Therefore, farmers with small land holding tend to rely on human power for tillage while those with relatively large land holding use less labour-intensive technologies such as mechanical and animal traction power sources. However, in some cases, smallholder farmers do have access to large landholdings but lack adequate resources to work the land. In cases where the farm size is large, the manual labour is not an appropriate power source for tillage. Therefore farmers usually resort to cultivating gardens only (Van den Berg *et al.*, 2007).

Van der Veen (2005) identifies gardens and field plots as two types of land were agricultural production can take place. The garden plots are relatively small, located close to households, require low inputs and technologies for production activities. On the contrary, field plots are usually large, found far from homes; they need high inputs and technologies (Manual, 2005). According to Ndwandwe and Mudhara (2014), farmers who are tilling gardens find it economically beneficial to use human muscle as a source of power while when it comes to field plots either animal or mechanical power is used depending on availability and ease of access.

Ownership of animal power

Animal power has been used over the years as a source of power to perform agricultural operation such as tillage, planting, weeding, transportation, etc. (Manjengwa, 2011; Umaru et al., 2013). Most of the smallholder farmers cannot afford to use the tractor as owners or through hiring. For this reason, some farmers who own animal power use it as it reduces human drudgery and ensures timely tillage (Sikhwari, 2009; Ahmad and Abubakar, 2010; Amadi et al., 2013; Houssou et al., 2014). The ownership of oxen determines farmers' ability to perform farm operations because if farmers do not have oxen, they would be obliged (i) to rent out their land to other farmers, (ii) hire oxen from fellow members of the community, (iii) hire tractor from government or private service providers (Simalenga et al., 2000; Ahmed, 2014; Okello et al., 2015). According to Dijkman et al. (2000), farmers can either have short term or long term ownership of traction animals. In terms short-term ownership, farmers can buy a pair of oxen for a certain cropping season, once the season ends they then sell them. Ownership of these traction animals reduces farmers' dependence on hiring which in most cases do not allow timely execution activities in crop production. Similarly, Mabuza *et al.* (2013) support this by emphasizing that, farmers who own pair(s) of traction animals find it cheaper to use them for tillage than alternative technologies.

Government traction power programme(s)

Governments of various countries have introduced agricultural programmes and projects with a mandate of achieving rural and agricultural development, more especially the developing countries (World Bank, 2008; DAFF, 2012; DAFF, 2013). However, the programme(s) sometimes face a challenge of providing farmers with equal chances of receiving traction services when needed. According to Ajah (2014), this problem arises because of improper maintenance of government tractors. Also, many tractors are available, but there are only a few implements to be mounted on the tractors. In South Africa, the government introduced public tractor services with a mandate of bringing land that has long been fallow under cultivation through the provision of mechanization services and other inputs (DAFF, 2012; DAFF, 2013; Zwane et al., 2015). Therefore, farmers participating in government tractor programme(s) are more likely to use mechanical power for tillage.

2.8 The effect of tillage traction power availability on crop productivity as well as food security

There is a consensus that smallholder farmers crop productivity and food security are positively correlated (Aliber, 2009; Jacobs and Baiphethi, 2015). This concurrence exists because crop productivity increases the availability of food for household consumption and sale. It also reduces households' dependence on food markets, leading to a reduction in household food consumption expenditure.

The use of alternative traction power sources help farmers cultivate relatively large land and thus generate high income from sale; this consequently translates to improved food security. Hossain (2014) conducted a study to evaluate the impact of project enhancement of agricultural and rural employment, the findings of the study indicate that the availability of alternative traction power sources enhances crop production and productivity due to timeliness and better-quality operations. The productivity increases correlate with increased farm income and consequently household food security. The availability of alternative traction power source also allows for expansion of agricultural production ensuring marketable surplus to generate income. Moreover, it enables household members to engage in non-farm jobs and other income-generating activities (Verma, 2008; Sims, 2012; Houmy, 2013; Hossain, 2014).

According to Obi (2010), the use of mechanical power is one of the critical contributors to the growth of smallholder farmers' income. Farmers using tractors generate more income than farmers using other traction power sources. The high income generated plays an important role in improving the food security status of the farmers' households. However, when farm sizes are small tractor use and ownership is not economically feasible. Yuyan *et al.* (2015) also found a positive association between household food security and mechanical power availability, when studying factors influencing food security in China.

Cunguara and Darnhofer (2011) assessed the impact of improved agricultural technologies on household income in rural Mozambique. These authors used three econometric approaches: doubly robust estimator, sub-classification regression and treatment effect model to ensure robustness. The study found a significant influence of tillage power availability on household income, and consequently, consumption expenditure. However, the effect differs from one quintile of the surveyed households to another. These authors also found that the use of mechanical or animal power is profitable in large cropped areas. Farmers using the two-traction power source on large land size can obtain high household income from production as compared to those who use them on relatively small land. This finding implies that farmers who use mechanical or animal power for tillage in large plots can attain high crop productivity as well as food security.

Nkegbe *et al.* (2017) employed ordered probit model in estimating the determinants of food security in the savannah accelerated development authority zone of Ghana. The study emphasized that households that own or can easily access mechanized farm equipment are more likely to be food secure. On the other hand, farmers who own large livestock that is capable of being used as traction power are less likely to be food secure than those who do not own. The large livestock tends to form part of the household expenditure rather than an income generating mechanism or traction power source to undertake crop production activities.

Bedeke (2012) used a binary logistic model to measure food security and coping strategy in East Hararghe, Ethiopia. The study found that the availability of ox in the household is an essential contributor to food security since it is a critical production factor. In examining the determinants of food security, Abafita and Kim (2013) confirm the importance of the availability of animal power to food security by indicating that it is closely related to production especially in Ethiopia where farmers use it as the primary power source. Beyene and Muche (2010) discovered that timely available animal power ensures that farms perform better and can achieve sustainable food security.

Restrictions regarding access to land and other farming inputs are the primary reason for persisting poverty and food insecurity in rural areas (Moyo, 2008; Abdu-Raheem and Worth, 2011). Abrha (2015) investigated factors affecting the agricultural production of farm households in the regional state of Tigray, Ethiopia, using OLS. The study discovered that households with large landholding are food secure as opposed to those with small landholding. However, there are cases whereby farmers have large landholdings but still obtain low crop productivity. This situation happens in cases where farmers with large landholding rely on human power source in the production process (Adesoji and Farinde, 2006). This makes the availability of traction power sources such as mechanical and animal power important in achieving improved production.

Animal power ownership correlates with crop productivity and, household income generation especially if farmers hire them out. According to studies conducted by (Simalenga and Jongisa, 2000; Conroy and Teweldmehidin, 2010; Rampokanyo, 2012; Umaru *et al.*, 2013; Okello *et al.*, 2015; Karugia, 2017) animal power ownership significantly contributes to crop productivity and food security. Other studies related to factors affecting crop productivity (Xu *et al.*, 2009; Kibaara and Kavoi, 2012; Nazir *et al.*, 2013; Tanaka *et al.*, 2013; Abrha, 2015) indicated that traction power availability significantly contributes to efficiency in crop production.

2.9 Summary

Traction power availability plays a vital role in ensuring timeliness and quality operations in crop production and consequently crop productivity as well as food security. In this chapter some key concepts of the study, namely, traction power source, tillage, crop productivity and food security. This chapter also reviews the theoretical and empirical literature on the factors influencing the choice of traction power for tillage. The reviewed literature shows that farmers' socioeconomic and institutional factors play a significant role in the choice of traction power source they use for tillage. This chapter also reviewed the literature on the effect of traction power availability on crop productivity as well as food security. The reviewed studies showed that traction power availability is essential if improved crop productivity, as well as household food security, is to be achieved. The studies show that in general availability of traction power enhances timeliness and quality operation which is vital in improving crop productivity. The improved crop productivity gives an incentive for market participation for income generation through the sale of surplus produce.

CHAPTER 3. FACTORS INFLUENCING FARMERS' CHOICE OF TRACTION POWER SOURCE FOR TILLAGE IN KWAZULU-NATAL, SOUTH AFRICA

3.1 Abstract

The challenge with traction power availability is amongst factors responsible for poor tillage and late planting among smallholder farmers. Smallholder farmers confront a dilemma of either not planting at all or planting late because traction power is not readily available for tillage. The problem with timely availability of alternative traction power source and other socioeconomic factors influence farmers' choice of traction power used for tillage. An understanding of the basis for farmers' choice is crucial in developing strategies and programmes to address traction power availability problems. This chapter aimed to determine the factors influencing the choice of alternative traction power source for tillage in smallholder farms. Using a sample of 204 households selected from six rural villages in the Okhahlamba Municipality, KwaZulu-Natal, data were analysed using the multinomial logistic regression (MNL). Three categories of traction power used by farmers for tillage include: mechanical power, animal power and a combination of the two-power source. The results from the MNL model reveal that the probability of choosing alternative traction power is influenced by gender, main occupation, income, farming experience, farm size, participation in government tractor programme(s), own animal power and training on the use of animal power. There is a need to consider socio-economic and institutional factors in developing programmes to ensure timely available tillage power source.

Keywords: *Smallholder farmers, choice, traction power source, tillage, Multinomial logistic regression*

3.2 Introduction

The global population in 2016 was 7.4 billion and is expected to reach approximately 9.6 billion in 2050 (Sims, 2012; Mottaleb *et al.*, 2016). As a result, food consumption is expected to continue rising with the increase in population, especially in developing countries. To ensure food security as population increases, growth in productivity of smallholder farmers is required since they dominate production in most areas vulnerable to food insecurity (Tilman *et al.*, 2011; Gerland *et al.*, 2014). This situation is complicated by smallholder farmers' difficulty in accessing agricultural inputs, especially tillage power (Godfray and Garnett, 2014). Generally, smallholder farmers are resource poor and usually face difficulties with investing in physical assets, especially traction power. Consequently, these farmers at times they rely on hiring traction power from either private or government service providers. In many developing countries the private and the public sector have limited capacity of providing traction power to undertake crop production activities due to relatively large demand or poor policy making.

Farmers in South African have been using animal power for many years. Initially, farmers power adopted animal power as an alternative to human power in order to reduce drudgery and improve crop production (Fowler, 1999; Simalenga *et al.*, 2000). According to (Mrema *et al.*, 2008) and Sims (2012), agricultural production in SSA relies, to a large extent, on human power. However, using human power has inherent limitations in terms of energy needs, quality and size of operations. The use of human power may possibly not be suitable for use in South Africa, where there is a high degree of rural-urban migration and high occurrence of diseases such as HIV/AIDS, which result in scarce and weak labour force. FAO (2009) indicated that HIV/AIDS has dual effects on labour availability, i.e., the loss of labour from the infected person and the family members who should care for the infected person. Furthermore, the high degree of rural-urban migration exacerbates the problem of labour availability for agricultural production. According to the Population Reference Bureu (2016) about 65% of the South Africa population lives in urban areas, the older people dominate rural areas who constitute weak labour force. Moreover, Daniels *et al.* (2013) found that there is low level of employment in agriculture in rural areas and there was a decline in the number of people employed in the sector due to rural-urban migration, hence the need to improve the availability and access of alternative traction power sources.

In the United States almost all animal power was replaced by tractors between 1925 and 1940. Between the 1930s and 1940s, the use of mechanical power was introduced in Africa, however, in the SSA countries the use of tractors received serious attention in 1961 (Mrema *et al.*, 2008; Sims, 2012). Government operated tractors and tractor schemes were used to encourage the use of tractor, and some farmers were provided with credit to purchase the machinery (Simalenga *et al.*, 2000; Mrema *et al.*, 2008; Sikhwari, 2009) . The government tractor schemes failed in most African countries because of government incompetence in providing finance for fuel, maintenance and employment of tractor operators. In addition, the fare charged by the government scheme was below the break-even point compared to the private service providers, hence its unsustainability.

Despite the failure of government tractor scheme in SSA, government of South Africa re-introduced the scheme under the Comprehensive Agricultural Support (CASP) to improve the availability of traction power for bringing more land into cultivation. The main challenge is to provide farmers with equal opportunity to use the tractors when needed, since in rain-fed production, farmers need traction power at about the same time (Manjengwa, 2011). For this reason some farmers choose to hire from private service providers, while others opt to use animal power. Manjengwa (2011) and Mabuza *et al.* (2013) noted that some farmers cannot afford to pay for traction power to undertake farm operations. These challenges and the socio-economic characteristics of farmers influence the traction power source farmers use. An understanding of what influences farmers' choice of traction power source can be an important tool for policy makers to develop strategies and programmes for agricultural growth and development. Therefore, this paper aims to determine factors influencing the choice of traction power source for tillage in smallholder farms.

3.3 Research methods

3.3.1 Study area

The data were collected in KwaZulu-Natal (KZN) province, South Africa in Okhahlamba Local Municipality. The municipality is located in the mountainous regions of KwaZulu-Natal in Uthukela District Municipality (Figure 3.1) and covers approximately 3971 km^2. It has a population of approximately 132 068, which is lower than in 2001. The decline is attributed to factors such as migration from the municipality and HIV/AIDS pandemic, which has a negative implication on development. There are two traditional authority areas within the municipality, namely the Amangwane and Amazizi. The study site is marked with a bold rhombus on Figure 3.1.

The Okhahlamba Local Municipality is made up of 397100 hectares, 23% of this is arable (Elleboudt, 2012). Agriculture is one of the most important contributors to the economy of this municipality through production, provision of resources to the processing and manufacturing sector and job creation. This municipality has an advantage in producing maize, soya bean, potatoes, vegetables and livestock (Okhahlamba Local Municipality, 2012).

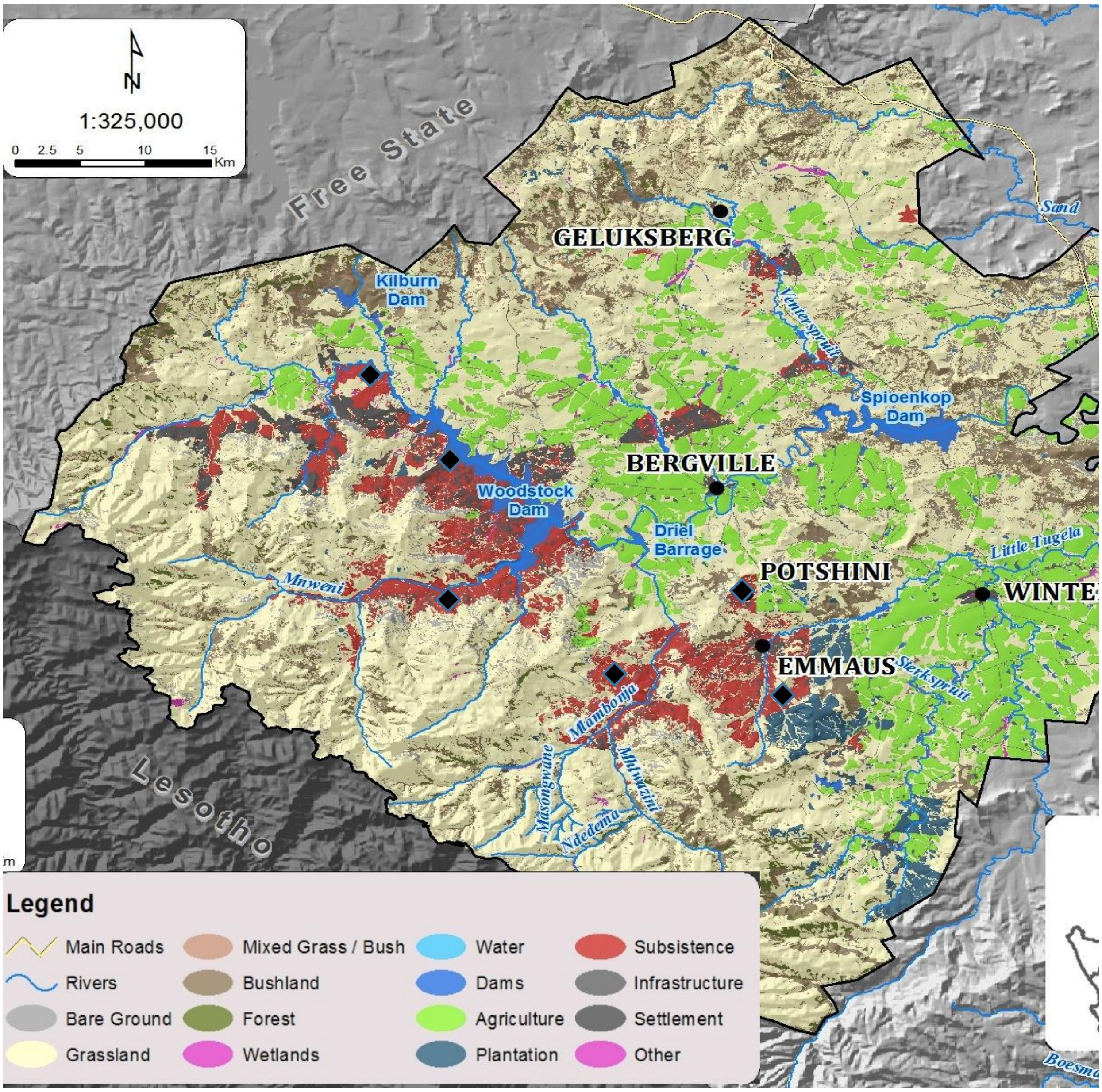

Figure 3.1 Okhahlamba local municipality within KwaZulu-Natal, South Africa. The red colour represents smallholder agricultural production while the green represents commercial.

Source: Elleboudt (2012); courtesy of the institute of natural resources, Pietermaritzburg.

Agricultural production in this district is dual, however, small-holder producers dominates in the municipality (Ndoro *et al.*, 2014). Although smallholder farmers dominate in the municipality, they produce for household consumption, whereas there are numerous opportunities for improving productivity and commercializing. Development is constrained by the fact that smallholder farmers do not have access to adequate inputs such as farm power to prepare their land and produce for home consumption and sale (Okhahlamba Local Municipality, 2012).

3.3.2 Data collection procedure

Eight key informant interviews were conducted in November 2015; the information obtained was used in developing the questionnaire for the household survey. Household surveys were conducted between January and February 2017. The questionnaire was pre-tested in January 2017 and a total of 207 questionnaires were administered. The sample size of 207 selected from 15091 smallholder farmers was determined using the guide specified by Kothari (2004) . The questionnaire captured information about the household demographic, socio-economic and institutional factors. A Multistage probability sampling technique was used to select six rural villages and the survey respondents within the Municipality. A list of villages within the Okahlamba Local Municipality was obtained from the Farmer Support Group (FSG), and six villages were randomly selected. There was no list of farmers for each of the six randomly selected villages, therefore households were randomly selected in the field. The number of farmers interviewed from each village varied because of the differences in the village(s) population size. The interviews were conducted in Zulu by four trained enumerators who are fluent in Zulu and English, the enumerators were supervised daily. The data collected was analysed using Statistical Package for Social Science (SPSS) and Stata 14.0.

3.4 Conceptual framework

Farmers' choice of tillage power source in this paper is modelled based on the perceived satisfaction of the available alternatives. The decision to choose a particular power source is based on the maximization of the underlying satisfaction, and a farmer will choose power source based on the perceived satisfaction. If the perceives satisfaction of choosing a certain tillage power source is higher than other, this traction power will be selected. The decision is made considering the costs and benefits, subject to constraints. Mabuza *et al.* (2013) conceptualised the use of MP (Mechanical Power) as an improved technology because of its ability to ensure timeliness operations and labour saving.

3.5 Econometric estimation –Multinomial logistic model (MNL)

Following Mabuza *et al.* (2013) let a farmer observe three alternative traction power sources for tillage: MP, AP (Animal Power), and MPAP (Mechanical and Animal Power). Given that farmers in the study area have three alternative traction power sources, the MNL model was employed to determine factors influencing the choice of alternative traction power source for tillage. Let P_j denote the probability associated with the choice of tillage traction power with j=1 if the farmer uses MP, j=2 if the farmer uses AP and j=3 if farmer uses MPAP. The MNL model is specified as:

$$P_{ij} \; = \exp(\beta j \; Xi) \Big/ [1 + \sum_{j=1}^{3} (\beta j \; Xi)] \quad \text{for categories j} = 1,2,3 \qquad (3.1)$$

The probability that a farmer will choose the base category is given by

$$P_i \; (j = 1| \; Xi) \; = 1 \Big/ [1 + \sum_{j=1}^{3} (\beta j \; Xi)] \qquad (3.2)$$

The probability that a farmer will choose category 2or 3 can be calculated as

$$P_i \; (\text{j} = \text{m}| \; \text{Xi} \;) = \exp(\beta j \; Xi) \Big/ [1 + \sum_{j=1}^{3} (\beta j \; Xi)] \qquad (3.3)$$

The marginal effects of the individual factors on the probabilities are estimated by differentiating equation (3.1)

$$\frac{\partial P_j}{\partial X_i} = P_j [\beta_j - \sum_{j=1}^{3} P_j \beta_j \;] = P_j \left[\beta_j - \beta\right] \qquad (3.4)$$

The MNL model has less need for restrictive assumptions and the explanatory variables do not have to be multivariate normally distributed. This assumption makes the model relatively easy to estimate and interpret. A major disadvantage with the model is the independence of irrelevant alternatives (IIA). The assumption requires that addition or exclusion of any category does not affect the relative risk associated with the explanatory variables in the remaining categories.

3.6 Description of variables

The explanatory variables which are hypothesised to influence the choice of tillage power source and their expected signs are presented in Table 3.1. These variables were selected based on previous studies (Aybek and Senel, 2009; Kassie *et al.*, 2012b; Kassie *et al.*, 2015; Makki *et al.*, 2017).

Table 3.1 Definition of variables used in MNL model

Variables	Description	Expected sign	
Dependent variable		**AP**	**MPAP**
Choice of tillage power source	j=1 farmer uses mechanical power (MP) j=2 farmer uses animal power (AP) j=3 farmer uses a combination of MP and AP		
Explanatory variables			
Gender	1= if the household head is male, 0= female	+	+
Main occupation	1= if the farmer is employed, 0= otherwise	-	-
Education level	Number of years completed in school	-	+/-
Farming experience	Number of years of farming	+/-	+/-
Household income	Household wealth and income	-	-
Household size	Number of people in the household	+/-	+/-
Plot size	Size of arable land	-	+
Participation in Government Tractor programme(s)	1= if the farmer forms part of government tractor programme(s), 0 otherwise	-	+
Household own animal power (Cattle)	1= if the farmer owns animal power, 0=otherwise	+	+
Training on the use of animal power	1= if the farmer received training on the use of animal power for tillage, 0=otherwise	+	+

Dependent variable(s)

The dependent is the choice of tillage power source. It has three (j=3 categories). j=1 farmer choose MP, j=2 farmer choose AP, j=3 farmer choose a combination of MP and AP.

Explanatory variables

Gender (gender of household head) – it has been argued that women have less access to productive agricultural resources and inputs for the production process (Kassie *et al.*, 2012a). Therefore, it is expected that male farmers are more likely to use MPAP or AP for tillage than females.

Main occupation- the source of employment is associated with the time and effort dedicated to agricultural activities (Kassie *et al.*, 2015). Household heads who are working full time in the farm are more likely to rely on labour-intensive technologies for farming activities. It is expected that full-time farmers will use AP or MPAP relative to MP for tillage.

Education level (Education level of household head) – The level of education may increase the ability of farmers to access and implement improved technologies, and increase the benefits from the new technology compared to the old ones (Kassie *et al.*, 2015). For this reason, it is expected that educated household is more likely to use mechanical power for tillage.

Farming experience - Farming experience can be associated with accumulation of physical and social capital thereby making technology adoption much easier. However, farming experience can also be associated with more risk aversion (Kassie *et al.*, 2015). For this reason, the relationship between farming experience and technology adoption is uncertain. Therefore, farming experience is expected to positively or negatively influence the use of MP for tillage than AP or MPAP.

Household income – Includes income obtained from engaging in farm and non-farm activities. Households with high income can invest in adoption of various agricultural technologies and inputs. Therefore, it is expected that household income will have a positive effect on choosing MP for tillage than AP or MPAP.

Household size - Family size can determine the availability of labour (Kassie *et al.*, 2012a). It is expected that large households are less or more likely to use MP for tillage. This uncertain relationship is due to the idea that as household size increases, the additional labour might be transferred off-farm income generating activities, hence the use of MP. On the contrary, as household size increase, some farmers might see it as a cheaper source of power for farming activities.

Plot size – There is a strong correlation between the plot size and mechanisation use for farm operations (Aybek and Senel, 2009).It is expected that households with relatively small plot size are less likely to use mechanical power for tillage.

Participation in government tractor programme(s) - Government support programmes in developing countries are a common way of developing agricultural production in smallholder farms (Kassie *et al.*, 2012a). When such programmes are properly implemented they can help notice progress in reducing poverty and food insecurity. Government tractor programme provides farmers with tractor services for tillage. It is expected that farmers participating in government tractor programme are less likely to use AP for tillage than the non-participants. On the contrary, farmers participating in government tractor programmes are more likely to use MPAP for tillage.

Animal power ownership – Animal power is best suitable when mechanical power is unavailable or unaffordable and where the use of manual labour is unfeasible or affects farmer's productivity (Makki *et al.*, 2017). It is expected that farmers who own AP are less likely to use mechanical power for tillage.

Training on the use of animal power - Training provides farmers with hands-on experience on how to use various agricultural technologies. It is expected that farmers who received training on the use of animal power are less likely to use MP for tillage.

3.7 Empirical results and discussion

3.7.1 Descriptive statistics

The descriptions of demographic and socioeconomic characteristics from continuous and categorical variables are presented in Tables 3.2 and 3.3. The descriptive statistics for categorical variables are then presented in 3.4, and 3.5. Tables 3.2 and 3.4 shows the result of the ANOVA analysis and the significance across three groups. The significance does not provide information about which groups differ. The detailed pairwise comparison on Table 3.3 provides information on which groups differ significantly. Some of the variables which were found to be insignificant in the ANOVA analysis were found to be significant in the pairwise comparison. The reason for this could be that one of the groups had large variance and others had small variance, then the ANOVA would say there are no differences between the means.

About 54.9%, 23.0%, 22.1% farmers use MP, AP and MPAP for tillage respectively.

Table 3.2 ANOVA descriptive statistics from continuous variables

Variable description	MP (n=112) Mean	AP (n=47) Mean	MPAP (n=45) Mean	ANOVA F-test
Age	49.7 (15.691)	48 (14.286)	49.31 (11.838)	ns
Education level in years	6.83 (4.45)	6.77 (3.708)	6.64 (3.113)	ns
Household size in adults equivalent	4.21 (2.011)	3.79 (1.614)	3.62 (1.628)	ns
Years of farming experience	14.1 (8.213)	14.32 (9.88)	16.84 (9.913)	ns
Household income	6966.54 (6191.950)	4578.57 (6423.365)	6879.8 (9578.981)	ns
Plot size	1.096 (0.821)	1.043 (1.622)	1.789 (1.917)	***

Notes: ***, **, *= statistically significant at 1%, 5%, 10%, respectively. ns = not statistically significant; Standard errors in parenthesis.
Source: Household survey (2016)

The difference in the age of household head was significant between AP and Non-AP, MPAP and Non-MPAP at 10% and 5% respectively. The average age was high for Non-AP, as well as MPAP. It was also found that the Non-AP users had large household size. The MPAP users had significantly large farm sizes and more years of farming experience.

Table 3.3 Pairwise descriptive statistics from continuous variables

Variable description	AP users n=47	Non-AP n=112	Sig.	MPAP users n= 45	Non-MPAP n=112	Sig.
Age	48	49.31	*	49.43	49.04	**
Education level(years)	6.77	6.78	ns	6.64	6.81	**
Household size in adults' equivalent	5.77	6.64	**	5.91	6.58	ns
Years of farming experience	14.32	14.89	ns	16.84	14.16	*
Household income	4578.51	6941.67	**	6879.78	6260.64	ns
Plot size	1.043	1.2946	ns	1.7887	1.0819	***

Notes: ***, **, *= statistically significant at 1%, 5%, 10%, respectively. ns = not statistically significant.
Source: Household survey (2016)

Table 3.4 ANOVA descriptive statistics from categorical variables

Variable description	MP (n=112) Mean	AP (n=47) Mean	MPAP (n=45) Mean	ANOVA F-test
Gender	0.37 (0.484)	0.43 (0.500)	0.53 (0.505)	ns
Main occupation	3.87 (1.858)	2.98 (1.950)	2.78 (2.131)	***
Participation in government tractor programme	0.13 (0.342)	0.04 (0.204)	0.18 (0.387)	ns
Own animal power (Cattle)	0.38 (0.489)	0.47 (0.504)	0.53 (0.505)	ns
Training on the use of animal power	0.01 (0.094)	0.19 (0.398)	0.24 (0.435)	***

Notes: ***, **, * = statistically significant at 1%, 5%, 10%, respectively. ns = not statistically significant; Standard errors in parenthesis.
Source: Household survey (2016)

Table 3.5 shows that the gender of the household head was significantly different between the MPAP and Non-MPAP users at 10%. Participation in government tractor programme(s) was significantly high for Non-AP users. The training and ownership of animal power was significantly high for the farmers using MPAP for tillage.

Table 3.5 Pairwise descriptive statistics from categorical variables

Variable description	Categories	AP users n=47	Non-AP n=112	Sig.	MPAP users n=45	Non-MPAP n=112	Sig.
Gender	1= male	42.6	41.4	ns	53.3	38.4	*
	0= female	57.4	58.6		46.7	61.6	
Main occupation	1=full-time farmer	44.7	30.6	*	53.3	38.4	**
	0=otherwise	55.3	69.4		46.7	61.6	
Participation in government tractor programme	0= no	95.7	85.4	**	82.2	89.3	ns
	1= yes	4.3	14.6		17.8	10.7	
Household own animal power (Cattle)	0= no	53.2	57.3	ns	46.7	59.1	*
	1= yes	46.8	42.7		53.3	40.9	
Training on the use of animal power	0= no	80.9	92.4	**	75.6	93.7	***
	1= yes	19.1	7.6		24.4	6.3	

Notes: ***, **, *= statistically significant at 1%, 5%, 10%, respectively. ns = not statistically significant.
Source: Household survey (2016)

3.7.2 Factors influencing the choice of alternative traction power source for tillage

The results for the estimated MNL on the choice of tillage power are presented in Table 3.6. The results show a statistical significant Wald X^2 ($p<0.01$), suggesting that the explanatory variables included in the estimation explain the variation in the choice of traction power for tillage well. The parameter estimates and marginal effects all have the prior expected signs.

The coefficients of the parameter estimates for the MNL model provide the direction of the effect of the independent variables on the dependant variable only, but do not give information about the actual size of the probabilities. The marginal effects denoted by *dy/dx* in (Table 3.6), which measures the size of change in the dependent variable because of changes in the independent variables and are used for interpretation.

Table 3.6 Determinants of traction power choice-MNL model

Variables	AP vs. MP Coeff.	*dy/dx*	MPAP vs.MP Coeff	*dy/dx*
Constant	9.405 (2.362)		4.836 (2.361)	
Gender	0.265 (0.417)	0.008 (0.064)	0. 757 (0. 447)	0.117* (0.073)
Main occupation	-0.489 (0.296)	-0.036 (0.046)	-1.018 (0. 316)	-0.148*** (0.045)
Education level	-0.013 (0. 053)	-0.002 (0. 0087)	0. 012 (0. 047)	0.002 (0.007)
Farming experience	-0.272 (0. 410)	-0.073 (0. 066)	0. 584 (0. 309)	0.110** (0.048)
Household income	-1.107 (0. 296)	-0.155*** (0. 048)	-0. 731 (0. 275)	-0.071* (0.041)
Household size	-0.331 (0. 524)	-0.021 (0. 083)	-0. 759 (0. 530)	-0.111 (0.080)
Plot size	-0.263 (0. 127)	-0.053** (0. 019)	0. 181 (0. 163)	0.042* (0.024)
Participation in Government Tractor programme(s)	-0.981 (0. 817)	-0.151** (0. 074)	0. 529 (0. 554)	0.142 (0.112)
Household own animal power	1.193 (0. 479)	0.157** (0. 077)	0. 999 (0. 504)	0.108 (0.075)
Training on the use of animal power	3.645 (1.245)	0.285** (0.132)	3.756 (1.191)	0.327** (0.125)
Pseudo R^2	0.2334			
Likelihood test ratio: $Chi^2(20)$	95.288			
Wald $Chi^2(20)$	69.74			
Prob > Chi^2	0.0000			

Notes: Notes: ***, **, *= statistically significant at 1%, 5%, 10%, respectively; the standard errors in parenthesis are robust; MP-mechanical power, AP-animal power, MPAP-combination of animal and mechanical power. MP is the base category.
Source: Household survey (2016)

The estimated coefficient for gender is positively and statistically significant for the likelihood of farmers choosing MPAP, implying that male farmers are more likely to choose MPAP for tillage over MP. The probability of using MPAP relative to MP is 11.7% more for male farmers compared to females. The logical reason for this outcome is that male farmers have better access to productive inputs for production. Moreover, they are usually the first to know about government tractor programmes and can easily get their services for tillage because they have more societal ties. The results are consistent with Van Eerdewijk and Danielsen (2015), who found that male-headed households are more likely to have the advantage of using animal and mechanical power for tillage since they own animals capable of performing the tillage task.

The estimated coefficient for main occupation is negatively associated with the likelihood of farmers choosing MPAP relative to MP for tillage. The marginal effects suggest that probability of using MPAP relative to MP is 14.5% less for those who are not full-time farmers. Individuals who have off-farm employment dedicate less time and effort towards agricultural production activities. For this reason, they usually rely on less labour-intensive technologies such as tractor.

The effect of farming experience is positive and significant for the likelihood choosing MPAP for tillage relative to MP. The marginal effects suggest that the probability of using MPAP relative to MP increases by 11 % for every year increase in the years of farming experience. Farming experience is associated farmers' acquisition of wealth, skills, knowledge and social capital, which enables farmers to switch or combine alternative traction power source to ensure that their timelines of farm operations are not delayed. The results are consistent with Ajah (2014) and Sanni (2008) who argue that farmers with more farming experience have accumulated wealth, knowledge, and skills, which enable them to adopt and use alternative traction power source. Moreover, these farmers have strong social and institutional relationships that enable them to get access to services, information, and inputs.

The estimated slope coefficient on the level of household income is negatively and significantly influences the likelihood of farmers choosing MPAP or AP for tillage relative to MP. The marginal effects suggest that the probability of using AP and MPAP reduces by 15.3 % and 7% respectively for every Rand increase in the level of household income. The level of household income is an indicator of the farmer's ability to purchase or hire inputs for production activities. Furthermore, because of relatively high income, farmers are not afraid of investing in agricultural technologies like tractor since they have they have the means of bearing the negative effects which may arise. The results are consistent with Mabuza *et al.* (2013), who indicated that farmers with relatively high income can afford to invest in tractor or hire from private service providers for tillage.

The estimated coefficient for plot size is negatively associated with the likelihood of farmers choosing AP for tillage relative to MP. The marginal effects suggest that the probability of using AP relative to MP decreases by 5.3% for every additional hectare of the farm size owned by the i^{th} household. The negative influence implies that the use of AP is suitable for use in relatively small farms. Using animals on large farms consume time, and the animals might not have enough strength to till/cultivate for long. There will have to be multiple tillage days before planting can take place. The results concur with Yadav (2003), who found that animal power could only be used to till a maximum of 1.9 ha compared to a tractor that can till a maximum of 20 ha per day. Ghosh (2010) and Challa (2014), also learned that it is disadvantageous or not economically feasible to use the tractor on small farm sizes. Mabuza *et al.* (2013) alluded that use of animal power on a relatively large farm is only possible if the farmer owns a relatively large number of animals and there is sufficient labour to operate them. On the contrary, farm size has a statistically significant positive influence on the likelihood of choosing MPAP relative to MP for tillage

The estimated coefficient for participation in government tractor programme(s) is negatively associated with the likelihood of farmers choosing AP for tillage relative to MP. The marginal effects suggest that the probability of using AP relative to MP is 15.2% less for households that participate in government tractor programs (Table 3.6). Government services about how farmers acquire mechanization for tillage have an influence on their choice of power source. According to Kansanga (2016) and Manta and Aduba (2013), government facilitation on acquiring mechanization services for tillage and other farming activities is important for enhanced agricultural productivity. The challenge is that government tractor programme has only a few tractors and not properly maintained. Moreover, there are only a few private tractors the government can hire under the government farm programs (Diale, 2016).

The estimated coefficient for animal power ownership has a positive and statistically significant effect on the likelihood of farmers choosing AP for tillage relative to MP. The marginal effect suggests that the probability of using AP relative to MP is 15.35% more for farmers owning animal power. A possible explanation is that owning animal power gives farmers an advantage of timely tillage when MP is delayed, or they cannot afford the costs associated with tractor hire. The results are consistent with Mabuza et al. (2013), who mentioned that farmers owning animal power find it cheaper to employ them for tillage.

However, Ahmad and Abubakar (2010), revealed that using animal power is also constrained by the fact that majority of farmers owning animals that can be used for tillage rely on the free range to feed their animals. In most cases, the cattle are not fit to be used when the time for tillage starts, due to drought causing food shortage during the dry season.

The estimated coefficient for training on using animal power is positively associated with the likelihood of farmers choosing MPAP or AP for tillage relative to MP. The marginal effects suggest that the probability of using AP or MPAP relative to MP is 28.7% or 32.6% (respectively) more for farmers who received training on the use of AP. The logical reason for this outcome is that training equips farmers with the skill and the technical know-how. This makes them prefer to take advantage of the relatively cheaper and available traction power for tillage. These results concur with are supported by Sinyolo (2013), who found that agricultural training improves farmers' skills and reduces their reliance on trial and error. Moreover, Natarajan *et al.* (2016) argued that efficient use of animal power is achieved when farmers are provided with thorough knowledge and training.

3.8 Conclusion

The study employed data collected from 204 rural household in Okhahlamba municipality, KwaZulu-Natal South Africa. The study determined factors influencing the choice of tillage power source. Three categories of traction power used by farmers for tillage are mechanical power (MP), animal power (AP) and a combination (MPAP) of the two-power sources. The results from MNL model reveals that the probability to choose alternative traction power is influenced by gender, main occupation, income, farming experience, farm size, participation in government tractor programme(s), own animal power and training on the use of animal power. It is concluded that participation in government tractor programme(s) influences the choice of traction power; farmers that participate in government tractor programmes are more likely to use MP for tillage than other alternatives. In addition, is that household income influences the choice of traction power. It is concluded that farmers with relatively high income are more likely to choose MP for tillage than other alternatives. Ownership of animal power and training on the use of animal power also influence the choice of traction power for tillage. Farmers who received training and/ or own animal power are more likely to use AP or MPAP for tillage. Besides, farmers with relatively large farms are more likely to choose MP or MPAP for tillage. Gender, main occupation and farming experience are also factors that influence the choice of tillage traction power.

The study identifies steps that need to be considered in developing traction power programme(s) to ensure timely execution of crop production activities and consequently crop productivity and food security. Since there are limited tractors from government and private service providers, farmers who own animal power should be encouraged to use them during the farming season. This can make them incur less production and opportunity cost of waiting for tractor services that may be available late. In case were labour availability for operating animal power is a problem, farmers can be encouraged to cooperate and help plough each other's fields. Moreover, farmers must be trained and educated on the use of animal power and the benefits associated with it. This will enable them to take advantage of the cheap and readily available power source. Policy interventions should also enforce gender equity within the rural communities.

CHAPTER 4. THE EFFECT OF TRACTION POWER AVAILABILITY ON MAIZE PRODUCTIVITY OF SMALLHOLDER FARMERS IN KWAZULUNATAL, SOUTH AFRICA

4.1 Abstract

Agricultural productivity has been the centre of attention for the policy makers and the population at large. The contribution of the small-scale agricultural sector to the economy of South Africa has been declining because of low productivity. The productivity has been diminishing/ stagnant due to input availability challenge, with lack of traction power source as the most important. An understanding of the effect of traction power availability on crop productivity can be a starting point of addressing this challenge. This paper evaluated the effect of traction power availability on maize productivity. A total of 204 households were randomly selected from six rural villages in the Okhahlamba Municipality, KwaZulu-Natal. The data collected was analysed using the Cobb-Douglas production function. Three categories of traction power source were identified: MP (mechanical power), AP (animal power), and MPAP (mechanical and animal power). The econometric results indicated that the availability of traction power source for tillage positively affects maize productivity. This implies that to improve maize productivity, timely availability of tillage power source is crucial. The empirical results further indicate that other factors such as marital status, farming experience, household size, the size of cultivated area, type of seeds and soil texture affected maize productivity. Policy interventions should focus on overcoming all the bottlenecks that affect timely availability of tillage power source.

Keywords: *Smallholder farmers, traction power source, tillage, maize productivity*

4.2 Introduction

The majority of the population in most developing countries lives in rural areas and agricultural production accounts for a large portion of their economic activities. These rural people and policy makers are faced with a challenge of limited resource availability to meet the food needs of a growing population. For this reason, agricultural productivity has been the centre of attention for policy makers and the population at large. Agricultural productivity measures the performance and provides a guide to effective and efficient use of the finite resources. Moreover, it has the potential of improving the economies of most developing countries through efficient supplies of raw materials to the agricultural and non-agricultural sectors, job creation, and increasing demand for locally produced products.

A declining contribution of the agricultural sector in South Africa has been recorded due to low productivity, amongst other things. However, the sector continues to be the most important tool for developing the economy with the backward and forward linkage to other economic sectors. The sector is made up of various subsectors, with maize as the most important field crop and a staple food to most of the people, especially, the poor. In Southern African Custom Union (SACU), South Africa is the main maize producer (GSA, 2015). Approximately 2.5 to 2.75 million hectares of maize are planted by commercial farmers annually, while about 350 000 to 500 000 hectares are planted by smallholder farmers annually (Maize Trust, 2014; GSA, 2015). According to Goldblatt (2010) the annual average maize production in SA has remained constant over-time relative to population growth. This is a serious concern since there continues to be growth in the number of people to be fed. Increasing input costs were behind the constant growth in maize production, with traction power as the second most expensive input due to high fuel and maintenance.

A long-standing discussion in the literature is on the role that agricultural traction power plays in agricultural growth and development (Jabbar, 1980; Adolfsson, 1999; Bobobee, 1999; Fowler, 1999; Sims and Kienzle, 2006; Singh *et al.*, 2010; Baudron *et al.*, 2015). The unavailability of traction power can affect crop productivity and food supply. Verma (2008) and Houssou and Chapoto (2015) have indicated that the use of mechanical and/ or animal power led to an increase in area cultivated, high cropping intensity and labour productivity. Furthermore, both animal and mechanical power increases agricultural productivity and profitability through timeliness of operations, better quality of work and efficient inputs use.

Previous studies suggest that the availability of traction power for tillage is one of the most important constraints towards crop productivity. For example, Tanaka *et al.* (2013) assessed yield variation and determined factors causing the variation in Southern-Central Benin. The study showed that the yield was high for farmers using tractors for ploughing than those relying on human power. Hormozi *et al.* (2012) evaluated the impact of mechanisation on technical efficiency. The results showed that there were variations in the efficiency based on the power source used. Farmers who used mechanical power for production obtained higher efficiency than those relying on animal or human power.

Rampokanyo (2012) determined factors causing inefficiencies in smallholder maize production. The study showed that even farmers who own animal power hired tractors during the maize production season since most of their animals were unhealthy. Despite hiring tractors, farmers obtained low productivity due to late tractor services since there were limited service providers. Chisango (2010) examined the performance of a mechanization programme in Bindura district. The study disclosed that the program had a significant impact on participating farmers'. However, overall production and productivity of farmers remained low. The authors suggest that this could be associated with the tractor supply constraint. This paper evaluates the effect of traction power availability on maize productivity.

4.3 Research methods

4.3.1 Study area

The data were collected in KwaZulu-Natal (KZN) province, South Africa in the Okhahlamba local municipality, which covers approximately 3543.63 km^2. The Municipality is in the mountainous regions of KwaZulu-Natal in the Uthukela District Municipality (Figure 3.1). A sample of 207 households was collected in the six villages. The sample was determine using guidelines by Kothari (2004) . The study area was described in detail in Chapter 3.

4.3.2 Data collection procedure

The data collection procedure for this chapter was similar to the one described in Chapter 3, Section 3.3.2.

4.4 Conceptual framework

Crop productivity can be conceptualized using the production function. Production function expresses the relationship between the physical volume of output and a combination of various inputs (Wongnaa, 2013). The production function of each farmer is determined by resource availability. The production function can be either deterministic or stochastic. The production function was used to determine the effect of alternative traction power sources for tillage on crop productivity. The stochastic production function is based on the frequently used Cobb-Douglass production function. The simple two-factor Cobb-Douglass model is given by:

$$Q = AL^{\propto}K^{\beta} \tag{4.1}$$

Where:

Q =output,

A, α and β are constants. The terms α and β are the output elasticities of labour and capital respectively. They measure the response of output to changes in labour and capital used in the production process.

L and K are labour and capital, respectively.

4.5 Econometric estimation – Production Function

When applying the previous relationship to the study, the production function can be specified as:

$$Y_i = f(L_{it},\ K_{it}, X_{it}; A; e_i\ ) \tag{4.2}$$

Where Y_i is the output by the i^th^ farmer, $L_{it} and\ K_{it}$ are labour and capital inputs respectively, X_{it} captures all other inputs farmer use in the production process, The pre-requisite for estimating the Cobb-Douglass production function is that, one must log all the input(s) and output(s) data. Defined in logarithmic form, the production function in equation (4.2) can be expressed as

$$Ln(Y_{it}) = \beta_0 + \beta_1 Ln(L_{it}) +\ \beta_2 Ln(K_{it}) + \ldots \ldots \beta_n Ln(X_{it}) + U_{it} \tag{4.3}$$

Where ln is the natural logarithm, subscripts *i* and *t* represents the i^{th} farmer and t^{th} observation respectively. U_{it} represents the error term.

4.6 Description of variables

The explanatory variables selected for the crop production function regression and their descriptions are presented in Table 4.1.

Table 4.1 Description of variables used in the production function

Variables	Description	Expected sign
Dependent variable		
Y_t	Maize productivity measured in kg/ha	
Explanatory variables		
USEAP	1= if the farmer use AP, 0= otherwise	+/-
USEMPAP	1= if the farmer use MPAP, 0= otherwise	+
Gender	1= if the household head is male, 0= female	+
Marital status	1= if farmer is married, 0= otherwise	+
Farming experience	Number of years of farming	+/-
Household size	Number of people in the household	+/-
Education level	Number of completed years in school	+/-
Cultivated area	Total size of cultivated area (Ha)	+
Seed purchased	Quantity of improved maize seeds varieties used (Kg)	+
Quantity of manure	Quantity of manure applied (Kg)	+/-
Quantity of herbicides	Litres (*l*) of herbicides applied (Ha)	+/-
Own animal power	1= if the farmer own AP, 0= otherwise	+
Training on use of animal power	1= if the farmer received training on the use of animal power for tillage, 0=otherwise	+
Participation in government tractor programme(s)	1= if the farmer participates in government tractor programme(s), 0 otherwise	+
Tillage schedule	1= if farmer tilled on time, 0= farmer tilled Late	+
Extension contact	1= if the farmer receives extension services, 0= otherwise	+
Soil texture	1=if clay-loam, 2=loam, 3=sand	+/-

Dependent variable(s)

Maize productivity measured in kg/ha

Explanatory variables

Gender (gender of household head) - The involvement of both males and females in agricultural productivity is important. However, in most cases there continues to be biases towards access to agricultural production inputs and information by women. For this reason, it is hypothesized that male household heads are expected to obtain high maize productivity than female-headed households (Endale, 2011; Malek & Usami, 2010)

Marital status - Married household head usually have more family responsibilities of providing food and other necessities in the household. For this reason, they are likely to invest most of their time and money in farming to improve productivity. Hence, it is expected that farmers who are married will obtain high maize productivity than those who are unmarried.

Farming experience - Farming experience provides information about capital, knowledge and skills accumulation, which are important in obtaining high crop productivity. It also indicates the strength and time that the household head can allocated to crop production activities. It is expected that farming experience will positively influence maize productivity (Adebiyi & Okunlola, 2013; Shumet, 2011; Anyanwu, 2009 and Abay & Assefa, 2004).(Pietola, 1998; Langyintuo and Mungoma, 2008)

Household size - is a continuous variable measured as the number of people living together in a household. Household size can positively or negatively affect productivity. An increase in household size can improve productivity by through labour availability (Musafiri, 2017). On the other hand, household size can negatively affect productivity through inefficiencies that may arise as more labour is added to the production process (Bayissa, 2011). It is expected that large households are more or less likely to attain high maize productivity.

Education level (Education level of household head) - Education is measured as the number of years of schooling. Educated farmers can acquire, analyze and evaluate information on various agricultural inputs which can potentially contribute to improved productivity. They are also expected to be innovators of new agricultural technology and/or ideas (Uwagboe et al., 2012 (Kibaara and Kavoi, 2012). Hence, a positive relationship is expected between education and maize productivity.

Size of cultivated area - The size of cultivated area is a continuous variable measured in hectares. There is a negative relationship between the size of cultivated area and productivity (Ali and Deininger, 2015; Ladvenicová and Miklovičová, 2015). Applying the theory of increasing returns to scale, cultivating small area is more productive than the large ones. Hence, a negative relationship is expected between size of cultivated area and maize productivity.

Seeds variety - it is a continuous variable expressed as the kg/ha of improved maize seeds variety used in the production process. The effective use in improved seed varieties can contribute significantly to enhanced agricultural productivity and increased farm income (Kugbei, 2011; Maruod *et al.*, 2013). It is expected that farmers using improved seeds varieties obtain high maize productivity than those who rely on seeds stored from the previous cropping season.

Manure and herbicides - The use of manure and herbicides serves as an important input that improves crop production. The variable manure is measure in kg/ha, while herbicides are measure in litres/ ha. Manure improves the fertility of the soil which is important in plant growth and development. A positive association between manure, herbicides and maize productivity is expected (Kibaara and Kavoi, 2012).

Animal power ownership - Animal power ownership is observed as the most important assets in the rural areas. A farmer who owns a pair of animals can achieve timeous and quality tillage, which consequently affect crop productivity (Manjengwa, 2011; Amadi *et al.*, 2013; Umaru *et al.*, 2013). Hence, it is expected that farmers who own animal power obtain high maize productivity.

Training on the use of animal power - Training provides farmers with hands-on experience on how to use various agricultural technologies (Akila and Chander, 2009; Oladeji, 2012; Ghosal and Behera, 2013). It is expected that farmers who received training on the use of animal power are more likely to attain high maize productivity than those who were never trained.

Participation in government tractor programme(s) -. Government tractor programme provides farmers with tractor services for tillage. However, it is seldom possible to provide farmers with timeous tractor service. It is expected that farmers participating in government tractor programme attain high maize productivity than those who do not (Hossain, 2014) .

Tillage schedule - It has been included in the model to show the effect of the time of tillage on maize productivity. Tillage schedule determines whether plating take place late or on-time (Kibaara and Kavoi, 2012). Therefore, it is expected that farmers who till their land in time will obtain high maize productivity than those who till their land late.

Contact with extension officers - Farmers who have contact with extension officers are believed to have exposure to new inputs/ innovations and information that can aid in improving maize productivity. Therefore, a positive relationship is expected between extension contact and maize productivity (Wondimagegn et al., 2011).

Soil texture - The soil texture is an important environmental factor that affects crop productivity since it has effect on seed germination and emergence. It is expected that farmers planting on loam soil will obtain high productivity than those who operates on clay soil (Tueche *et al.*, 2013b).

4.7 Empirical results and discussion

4.7.1 Descriptive statistics

The descriptive statistics for the demographic and socioeconomic characteristics for the continuous variables are presented in Tables 4.2 and 4.3. Tables 4.3 and 4.4 present descriptive statistics from the categorical variables. Tables 4.2 and 4.5 shows the result of the ANOVA analysis and the significance across three groups. The significance does not provide information about which groups differ. The pairwise comparison on Tables 4.3 and 4.5 provides information about which groups differ significantly.

The descriptive statistics presented in table 4.3 indicate the significant difference in maize production between the AP and Non-AP, MPAP and Non-MPAP at 10%. The difference in the age of household head was significant between AP and Non-AP, MPAP and Non-MPAP at 10 and 5 percent respectively. The average age was high for Non-AP, as well as MPAP. It was also found that the Non-AP users have large household size. The MPAP users have significantly large farm sizes and more years of farming experience.

Table 4.2 ANOVA descriptive from continuous variables

Variable description	MP (n=112) Mean	AP (n=47) Mean	MPAP(n=45) Mean	ANOVA F-test
Age	49.7 (15.691)	48 (14.286)	49.31 (11.838)	ns
Education level in years	6.83 (4.45)	6.77 (3.708)	6.64 (3.113)	ns
Household size in adults equivalent	4.21 (2.011)	3.79 (1.614)	3.62 (1.628)	ns
Years of farming experience	14.1 (8.213)	14.32 (9.88)	16.84 (9.913)	ns
Household income	6966.54 (6191.950)	4578.57 (6423.365)	6879.8 (9578.981)	ns
Size of cultivated area	0.926 (0.709)	0.754 (0.980)	1.499 (1.672)	***
Seed variety	14.46 (9.026)	10.81 (6.513)	13.62 (9.941)	*
Quantity of manure	62.77 (67.653)	91.28 (88.879)	134.33 (122.147)	***
Quantity of herbicides	0.95 (3.249)	0.02 (0.148)	2.00 (11.985)	ns

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant; Standard errors in parenthesis.
Source: Household survey (2016)

Table 4.3 Pairwise descriptive statistics from continuous variables

Variable description	Mean AP n=47	Mean Non-AP n=112	Sig.	Mean MP n=45	Mean Non-MPAP n=112	Sig.
Quantity of maize harvested	479.85	661.10	*	795.11	569.60	*
Education level in years	6.77	6.78	ns	6.64	6.81	**
Household size in adults' equivalent	5.77	6.64	**	5.91	6.58	ns
Years of farming experience	14.32	14.89	ns	16.84	14.16	*
Household income	4578.51	6941.67	**	6879.78	6260.64	ns
Size of cultivated area	0.7538	1.0906	*	1.4996	0.8754	***
Seed variety	10.81	14.22	**	13.62	13.38	ns
Quantity of manure	91.28	83.28	ns	134.33	71.19	***
Quantity of herbicides	0.2	1.25	**	2.00	0.67	**

Notes: ***, **,* = statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant.
Source: Household survey (2016)

The Non-AP and MPAP users have the highest cultivated area and used more herbicides for weeding than other farmers. On average, Table 4.3 indicates that the Non-AP users mostly rely on improved maize seeds varieties. It was also found that the amount of manure applied was significantly high for farmers using MPAP for tillage.

Table 4.4 ANOVA descriptive from categorical variables

Variable description	**MP (n=112) Mean**	**AP (n=47) Mean**	**MPAP (n=45) Mean**	**ANOVA F-test**
Gender	0.37 (0.484)	0.43 (0.500)	0.53 (0.505)	ns
Marital status	1.95 (0.919)	1.87 (0.875)	2.09 (0.900)	ns
Own animal power (Cattle)	0.38 (0.489)	0.47 (0.504)	0.53 (0.505)	ns
Training on the use of animal power	0.01 (0.094)	0.19 (0.398)	0.24 (0.435)	***
Participation in government tractor programme	0.13 (0.342)	0.04 (0.204)	0.18 (0.387)	ns
Tillage schedule	0.38 (0486)	0.21 (0.414)	0.44 (0.503)	*
Extension contact	0.21 (0.412)	0.13 (0.337)	0.29 (0.458)	ns
Soil texture	2.24 (0.589)	2.49 (0.621)	2.36 (0.712)	*

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant; Standard errors in parenthesis.
Source: Household survey (2016)

Table 4.5 shows that the training on the use and ownership of animal power was significantly high for the farmers using MPAP for tillage. The gender of the household head was also significantly different between the MPAP and Non-MPAP users at 10%. Table 4.5 also indicates that participation in government tractor programme(s), early tillage and access to extension contact were significantly high for the Non-AP users. The soil texture for most AP users was sandy, while most of the Non-AP was loam soil.

Table 4.5 Pairwise descriptive statistics from categorical variables

Variable description	Categories	AP users n=47	Non-AP n=112	χ^2	MPAP users n=45	Non-MPAP n=112	χ^2
Gender	1= male	42.6	41.4	ns	53.3	38.4	*
	0= female	57.4	58.6		46.7	61.6	
Marital status	1= single	31.9	28.7	ns	20	32.1	ns
	2= married	59.6	56.1		64.4	54.7	
	3= divorced	0	4.5		4.4	3.1	
	4= widowed	6.4	9.6		8.9	8.8	
	5=Cohabiting	2.1	1.3		2.2	1.3	
own animal power (Cattle)	0= no	53.2	57.3	ns	46.7	59.1	*
	1= yes	46.8	42.7		53.3	40.9	
Training on the use of animal power	0= no	80.9	92.4	**	75.6	93.7	***
	1= yes	19.1	7.6		24.4	6.3	
Participation in government tractor programme	0= no	95.7	85.4	*	82.2	89.3	ns
	1= yes	4.3	14.6		17.8	10.7	
Tillage schedule	0= on time	21.3	39.5	**	44.4	32.7	*
	1= tilled late	78.7	60.5		55.6	67.3	
Extension contact	0= no	87.2	76.4	*	71.1	81.1	ns
	1= yes	12.8	23.6		28.9	18.9	
Soil texture	0= Clay loam	6.4	9.6	*	13.3	7.5	ns
	1= Loam	38.3	53.3		37.8	53.3	
	3= Sand	55.3	36.9		48.9	39.0	

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant.
Source: Household survey (2016)

4.7.2 The effect of tillage traction power availability on maize productivity

The estimated coefficients for the Cobb-Douglas production function are presented in Table 4.6. The results suggest that about 48.65% of the total variability in maize productivity is explained by the explanatory variables considered in the model. The percentage of the variation is acceptable since the data under consideration is cross-sectional. The F-statistic is highly significant at $p<0.01$, suggesting that the mode is well specified. Regression tests were conducted to test for econometrics problems in the data such as multicollinearity and heteroscedasticity. The VIF of 1.66 indicates no evidence of multicollinearity (Appendix C). The data is normally distributed and robust standard errors were used to deal with possible heteroscedasticity.

The traction power source was included in the model as a categorical independent variable with three choices: MP, AP, and MPAP. The MP was used as a base category since it was the most commonly used power source for tillage. The results of the analysis indicate that factors such as alternative traction power source (AP, MPAP) used for tillage, marital status, farming experience, household size, the size of cultivated area, type of seeds and soil texture significantly affected maize productivity.

Table 4.6 Effect of traction power availability on maize productivity

Variables	**Estimated coefficient**	**Standard error (robust)**
Constant	3.465***	0.614
USEAP	0.389***	0.217
USEMPAP	0.355***	0.213
Gender	0.186	0.123
Marital status	-0.468**	0.167
Farming experience	0.687***	0.185
Farming experience2	-0.0006*	0.0003
Household size	-0.535***	0.173
Education level	-0.003	0.016
Cultivated area	0.289***	0.045
Seed purchased	0.594***	0.0964
Quantity of manure	0.0003	0.0008
Quantity of herbicides	0.010	0.010
Own animal power	0.222	0.136
Training on use of animal power	-0.152	0.183
Participation in Fetsa-Tlala	0.260	0.304
Tillage schedule	0.219*	0.130
Extension contact	0.326	0.362
Soil texture	0.502**	0.228
F (22,178)	11.99***	
R^2	0.4865	
n	204	

Notes: Notes: ***, **,* = statistically significant at 1%, 5%, 10%.
Source: Household survey (2016)

The availability of AP for tillage had a positive and statistically significant effect on maize productivity, similarly availability of MPAP had a positive and significant effect. This implies a relatively elastic response of maize productivity to changes in the tillage power source.

Maize productivity is higher by 38.9% for farmers using AP for tillage than those using other power sources. The results are consistent with Conroy and Teweldmehidin (2010) who found that those who use animal power for tillage performs better in terms on physical productivity than farmers who rely on tractors. Guthiga *et al.* (2007) concur that the use of animal power increases crop productivity. However, they suggest that aspects such as affordability, availability of relevant implements, knowledge and skills should be considered as they are likely to impede the full potential of animal power in increasing productivity.

Similarly, maize productivity is higher by 35.5% for farmers using MPAP than those who use alternative power sources. The results are consistent with Rampokanyo (2012) who found that farmers who relied on a combination of animal and mechanical power were more productive than others. On the contrary, Kibaara and Kavoi (2012) and Tanaka *et al.* (2013) found that maize productivity was high for farmers using a mechanical power for tillage These authors argue that using tractor allows timely tillage, planting and weeding. However, they conclude that the technical efficiency due to the use of tractors for tillage is only achieved when tractors are made available to farmers.

A surprise result, however, is the statistically significant and negative association between marital status and crop productivity. Suggesting that married household head obtains low (46.8%) maize productivity compared to the unmarried. The negative association may be attributed to the inefficiency that occurs as family labour increases, since married household heads are more likely to have large households than their counterparts. Moreover, they are more likely to dedicate most of their time to off-farm activities in order to diversify household's means on deriving livelihoods.

The results suggest a statistically significant and positive effect of farming experience on maize productivity. Maize productivity increases by 68.7% for every additional year in farming experience. However, when the farming experience is squared a negative effect on maize productivity is observed. This shows that maize productivity increases with an increase in farming experience up to a point where an increase in farming experience results in a decline in productivity. The results are consistent with Mohammad and Showkat (2014) who found a positive relationship between farming experience and technical efficiency. However, the relationship became once the farming experience was squared. The negative association between maize productivity and farming experience squared can be attributed to the fact that farmers with relatively high experience are more likely to be old. These old farmers may be less educated and unwilling to adopt improved inputs and hence expected to attain less productivity.

The estimated model shows that household size had a statistically significant and negative effect on maize productivity. A percentage increase in household size causes maize productivity to decrease by 53.5%. A logical explanation for this outcome is that, as household size increases, members might choose employment in the non-farm sector thereby causing a decline in labour availability to undertake crop production activities that can cause a slow growth or fall in productivity. Alternatively, the negative association between household size and maize productivity can be explained based on the theory of diminishing marginal returns. As more labour becomes available due to an increase in household size, a point will be reached whereby addition of labour is less efficient, hence a decline in productivity.

The size of cultivated area has a statistically significant and positive effect on maize productivity. Farmers tilling relatively large farms realize better maize productivity compared to farmers who are cultivating relatively small farms. This is evidenced by a positive relationship between cultivated area and crop productivity; a percentage increase in the size of cultivated area is associated with 28.9% increase in maize productivity. The results are consistent Obasi (2007), the author found a direct/ positive relationship between the farm size used for production and crop productivity. Karugia (2017) supports the results of the study; this author emphasizes that an increase in the size of cultivated land area usually result in a switch from human to mechanical power, and this increases crop productivity. Ahmed *et al.* (2005) also support the findings by indicating that an increase in area cultivated improves sorghum productivity by enabling farmers to achieve economies of scale.

Most smallholder farmers still rely on maize seeds stored from the previous cropping season, although this differs with household characteristics. The reliance on stored seed deteriorates crop productivity compared to using improved seed varieties each season. The results in Table 4.6 show that the use of improved seed had a statistically significant and positive effect on maize productivity. Farmers using improved seeds varieties obtain more (59.4%) maize productivity than those who rely on seeds stored from the previous cropping season. The results are consistent with Hormozi *et al.* (2012), the authors revealed that improved/ high yielding cultivars had a strong and positive effect on productivity compared to the low yielding cultivars. Kugbei (2011) also confirmed that improved seed varieties help farmers attain high crop productivity.

Tillage schedule has a positive and statistically significant effect on crop productivity. Maize productivity is high by 21.9% for farmers who till/cultivate their land earlier than farmers who tills late. Soil texture has a positive and significant effect on maize productivity. Famers operating on loam soil obtain high 50.2% maize productivity than those who operates on clay soil. These results are consistent with Tueche *et al.* (2013a), these authors found a positive and significant correlation between clay content and tomato yields, while other soil textures showed a negative relationship.

4.8 Conclusion

This chapter evaluated the effect of traction power availability on crop productivity by estimating the Cobb-Douglass production function. The results show that traction power availability for tillage positively affect maize productivity, this is indicated by the positive relationship of USEAP and USEMPAP with productivity. It can be concluded that farmers using AP or MPAP obtain relatively high maize productivity than farmers using other power sources. Another variable affecting maize productivity is tillage schedule. It can be concluded that farmers who till their land in time are more productive than those who till late. The use of improved seeds varieties affects maize productivity. It can be concluded that farmers using improved seeds varieties are more productive than those relying on stored seeds from the previous cropping season. Gender of the household head affects maize productivity. It can be concluded that male farmers are more productive than female ones. Farming experience, marital status, size of cultivated area and soil texture also affect maize productivity. Input policy needs to be geared towards ensuring availability of inputs at relatively lower cost, especially improved seed varieties. Policy interventions should also pay attention to overcoming all the bottlenecks directly or indirectly constraining the availability of traction power for tillage. The intervention should also ensure that farmers till their land timely. Interventions should also pay attention to policy that would remove gender biases and discrimination in rural communities.

CHAPTER 5. THE EFFECT OF TILLAGE TRACTION POWER AVAILABILITY ON FOOD SECURITY IN SMALLHOLDER FARMERS' HOUSEHOLDS, KWAZULU-NATAL, SOUTH AFRICA

5.1 Abstract

Agricultural input availability remains an impediment to poverty reduction and achievement of food security in Sub-Saharan African countries. Timely availability of traction power is important in crop production, yet its availability is limited among smallholder farmers due to capital constraints, location bias of government traction power programmes and relatively small landholdings. This paper aimed to evaluate the effect of traction power availability on household food security. A Multistage probability sampling was used to select six villages from Okhahlamba Local Municipality, whereby 204 households were surveyed. The study identified three main categories of tillage power that smallholder farmers use, i.e., tractor, animal power, and a combination of the two sources. The multinomial regression results identified household characteristics significantly influencing the choice of traction power source for tillage. The empirical results from the multinomial endogenous treatment effect model show that traction power availability affects food security. Using animal power and a combination of mechanical and animal power showed a positive effect on household food security. The results suggest that the policies and programmes affecting traction power availability directly or indirectly through ownership, hire or government services should be improved as they affect food security. Also, there is need to enforce gender equity strategies in rural areas to ensure equal access to inputs and participation in government programmes.

Keywords *smallholder farmers', traction power source, tillage, food security, multinomial endogenous treatment effect model.*

5.2 Introduction

The notion of food insecurity has been given emphasis in the past 40 years and it is a serious obstacle towards sustainable development (Jacobs, 2009). Progress is being made in the fight against this developmental challenge, however, there continues to be a large proportion of the world population who lack food needed to have a healthy and active life. The global estimates by FAO (2015b) between 2014 and 2016 shows that approximately 795 billion people experience food insecurity. Food security exists "when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs"(World Food Summit, 1996). In 1970 the global emphasis of food security was on self-sufficiency, whereby the main goal was that countries should produce enough food and reduce reliance on the international markets. However, self-sufficiency was difficult for some of the continents, especially Asia and Africa (Jacobs, 2009).

Seventeen years after democracy South Africa is still characterised by skewed income distribution leading to poverty and food insecurity in the rural and peri-urban areas. Although South Africa is regarded as an upper-middle income country (Van der Berg, 2011), its economic inequality resulted in an increase in the number of persons living under the food poverty line of (R441) per month from 11 to 13.8 million between 2011 and 2015 (StatsSA, 2017). FAO (2015b) and du Toit (2011) emphasise that SA is food secure at the national level. However, that does not translate to food security at household level. According to FAO (2016), although there is national food security, households continue to experience food insecurity because their determinants differ.

Majority of the people vulnerable to or experiencing food insecurity are rural dwellers who derive most of their livelihoods from agricultural production (World Bank, 2008; Muyanga and Jayne, 2014; FAO, 2016). For this reason, several researchers and institutions believe that agricultural production and development is an appropriate tool to fight food insecurity, especially in African countries. Shapouri *et al.* (2009) and Schneider and Gugerty (2011) mentioned that agricultural production increases food availability, reduce food prices, creates employment, increase farm wages and consequently reduces food insecurity. However, it has been noted that productivity within this sector continues to be low due to various causes, hence the low contribution towards ensuring household food security.

Agricultural input availability is one of the constraints in realizing the full potential of agriculture on reducing food insecurity. Traction power for tillage is one of the most important input and yet is seldom readily available for smallholder farmers. As a result, timeliness and quality operations are not achieved, hence low productivity and food insecurity. Several studies beyond the barriers of SA shows that traction power availability has an important contribution to food security (Beyene and Muche, 2010; Cunguara and Darnhofer, 2011; Bedeke, 2012; Abafita and Kim, 2013; Yuyan *et al.*, 2015; Nkegbe *et al.*, 2017). For example Cunguara and Darnhofer (2011), Nkegbe *et al.* (2017) and Yuyan *et al.*

(2015) found that mechanical power positively affects household food security. While Beyene and Muche (2010), Bedeke (2012) and Abafita and Kim (2013) found a positive effect of animal power on food security. Therefore, it is vital to evaluate the effect of input availability on food security in the SA context to ensure that agriculture is effectively addressing the food insecurity. The paper aims to evaluate the effect of availability of tillage traction power on food security.

5.3 Research methods

5.3.1 Study area

The data was collected in KwaZulu-Natal (KZN) province, South Africa in the Okhahlamba local municipality, which covers approximately 3543.63 km^2. The Municipality is located in the mountainous regions of KwaZulu-Natal in the Uthukela District Municipality (Figure 3.1). A sample of 207 households was collected in the six villages. The sample was determine using guidelines by Kothari (2004). The study area was described in detail in Chapter 3.

5.3.2 Data collection procedure

The data collection procedure for this chapter was similar to the one described in Chapter 3, Section 3.3.2.

5.4 Conceptual framework

Farmers endogenously self-select themselves into using alternative traction power sources for tillage (Teklewold *et al.*, 2013). Observable and unobservable factors influence the decision to use a particular power source. Excluding the unobservable variables in regression analysis result in selection bias (Heckman *et al.*, 2000; Joo and LaLonde, 2014). The error term captures the unobservable factors, thereby correlating with the consumption expenditure (outcome variable) and traction power source used (treatment variable) resulting in inconsistent and biased parameter estimates. The inclusion of all relevant variables in the model controls for selection bias from observable factors. However, it is hard to control the selection bias from unobservable factors since they are difficult to capture (Heckman and Vytlacil, 2001; Heckman and Vytlacil, 2005). The unobservable factors include farmers' drive to succeed, motivation, skills, managerial ability, etc. Exclusion of these unobservable factors results in biased estimates because of omitting relevant variables. For this reason, the multinomial endogenous treatment effect model is employed to ensure consistent and unbiased estimates.

The estimation procedure is divided into two stages. The first stage involves estimation of the MNL model to evaluate factors influencing the choice of alternative traction power source for tillage. The second stage involves estimation of the multinomial endogenous treatment effect model to evaluate the effect of traction power availability on household consumption expenditure, a proxy of food security.

5.5 Econometric estimation –Multinomial endogenous treatment effect model

The first stage of the multinomial endogenous treatment effect model is presented in Chapter three, Section 3.7.2. The second stage evaluates the effect of the chosen alternative power sources on consumption expenditure. As indicated in Table 3.1, the use of mechanical power is the base category, denoted by j=1 and (j = 2, 3) are the two alternative categories (AP and MPAP). Following Manda *et al.* (2016) the multinomial endogenous treatment equation is given as:

$$E\ (yi|di, Xi, li) = \sum_{j-1}^{j} {}^{\gamma}jdij + \sum_{j-1}^{j} \lambda jlij \qquad (5.1)$$

In equation (5.1), y_i is the consumption expenditure for household i, X_i represents the independent variables with parameter vectors β. Parameters γ_j measures the effect of traction power availability on household consumption expenditure. E $(y_i|d_i,X_i,l_i)$ is a function of the latent variable; as a result consumption expenditure is affected by the unobserved factors that also affect farmers selection into the treatment.

Using multinomial endogenous treatment effect model requires an instrumental variable(s) that will cause variation in the treatment variable but does not correlate with the outcome variable. In this case, a village is a variable that correlates with the traction power source used but does not correlate with unobserved characteristics that affect consumption expenditure. The study hypothesizes that proximity to the Department of Agriculture (DoA) offices would influence farmers' decision on the traction power source to use for tillage, but does not necessarily influence household consumption expenditure. Farmers located close to the department offices are more likely to have access to information on government traction power programmes.

5.6 Description of variables

Table 5.1 presents the description of variables used in the multinomial endogenous treatment effect model and their expected signs.

Table 5.1 Description of variables used in multinomial endogenous treatment effect model

Variables	Description	Expected signs
Dependent variable		
Consumption expenditure	Total household consumption expenditure per adult equivalent measured in Rand(s)	
Explanatory variables		
USEAP	1= if the farmer use AP, 0= otherwise	+
USEMPAP	1= if the farmer use MPAP, 0= otherwise	+
Age	Age of household head	+/-
Gender	1= if the household head is male, 0= female	+
Main occupation	1= if the farmer is employed, 0= otherwise	+
Education level	Number of completed years in school	+
Farming experience	Number of years of farming	+
Household income	Household wealth and income	+
Household size	Number of people in the household	+
Plot size	Size of arable land used	+
Participation in government farm programs	1= if the farmer participates in government tractor programme, 0 otherwise	+
Household own animal power	1= if the farmer owns AP, 0= otherwise	+
Training on the use of animal power	1= if the farmer received training on the use of animal power for tillage, 0=otherwise	+/-

Dependent variable(s)

The dependent variable is consumption expenditure measured as a continuous variable. The food from own production for the year 2015 was converted to their market value using 2010 average prices and included in the consumption expenditure. The consumption expenditure indicator is one of the most economical ways of determining the households' ability to meet food security needs (Hendriks, 2005). This is attributed to the strong relationship between the household's food purchasing power and food security. Jacobs (2009) explains the relationship by indicating that, any changes in the level of household income modify the quality and quantity of food purchased and consumed, holding other factors constant.

Explanatory variables

Gender – In the rural settings, the household head are assumed to be the primary decision maker. In most cases men are the ones who have access and full control of resources in the household than men (Mignouna *et al.*, 2012; Sekhampu, 2012). Therefore, it is hypothesized that male-headed households will have high consumption expenditure compared to female-headed.

Main occupation – The family with household head who is fully employed in the farm is more likely to have less consumption expenditure probably because a share of their food consumed comes from their farms (Mignouna *et al.*, 2012; Sekhampu, 2012).

Farming experience –Farmers with more farming experience are most likely to be risk averse and engage in diversified production. For this reason, they usually produce sufficient for household and sale to generate additional income for other household expenditure (Mignouna *et al.*, 2012). A positive relationship is expected between farming experience and household consumption expenditure.

Household income – Total household income has a positive correlation with consumption expenditure. The level of household income determines the quality and quantity of food purchased and produces (Mignouna *et al.*, 2012; Sekhampu, 2012). It is expected that households with relatively high income are more likely to have high household consumption expenditure.

Household size – It is included in the model to consider the effect of the composition of household towards consumption expenditure. A large household size is more likely to be associated with high consumption expenditure (Mignouna *et al.*, 2012; Sekhampu, 2012). Therefore, it is expected that household size will have a positive relationship with consumption expenditure.

The size of land holding – The plot size used for production is likely to affect consumption expenditure. Large plot size is more likely to be associated with high consumption expenditure particularly when there is efficiency in land and other production inputs (Mignouna *et al.*, 2012). It is expected that households with relatively large farm size are more likely to have high consumption expenditure

Participation in government tractor programme(s) -it is expected that farmers participating in government tractor programme are more likely to have high consumption expenditure.

Animal power ownership - It serves as an indication of social and economic status. Apart from being used as traction power, households can slaughter cattle and sell during food shortages. Moreover, they can hire out to other farmers as power source for crop production activities to generate income (Chaminuka *et al.*, 2014). As such animal power ownership has a positive effect on household consumption expenditure. It is expected that households owning animal power are more likely to have high consumption expenditure than their counterparts.

Training on the use of animal power –Training enables farmers to take advantage of the new technologies, thereby improving productivity (Sinyolo *et al.*, 2014). It is expected that farmers who received training on the use of animal power are more likely to have low household consumption expenditure.

5.7 Empirical results and discussion

5.7.1 Descriptive statistics

The descriptive statistics for the demographic and socioeconomic variables from continuous and categorical variables are presented in Tables 3.2 and 3.3. Table 3.3 and 3.4 presents the descriptive statistics for categorical variables. Table 3.2 shows the result of the ANOVA analysis and the significance across three groups. The significance does not provide information about which groups differ. The pairwise comparison on Table 3.3 provides information to find out which groups differ.

The average consumption expenditure was statistically significant between AP and Non-AP users (Table 5.3). The Non-AP users had the highest consumption expenditure than farmers using other power sources. The age of household head affects input access, labour productivity, and adoption of agricultural innovations, which are important in improving crop productivity as well as food security. The difference in the age of household head was significant between AP and Non-AP, MPAP and Non-MPAP at 10 and 5 percent respectively. The average age was high for Non-AP, as well as MPAP. It was also found that the Non-AP users had large household size. Large household size implies the availability of labour for undertaking farm operations or to engage in non-farm activities for income generation. The

MPAP users had significantly large farm sizes and more years of farming experience (Table 5.3).

Table 5.2 ANOVA descriptive statistics from continuous variables

Variable description	MP (n=112) Mean	AP (n=47) Mean	MPAP(n=45) Mean	ANOVA F-test
Consumption expenditure	1285.77 (507.590)	972.21 (351.168)	1146.62 (448.41)	***
Age	49.7 (15.691)	48 (14.286)	49.31 (11.838)	ns
Education level in years	6.83 (4.45)	6.77 (3.708)	6.64 (3.113)	ns
Household size in adults equivalent	4.21 (2.011)	3.79 (1.614)	3.62 (1.628)	ns
Years of farming experience	14.1 (8.213)	14.32 (9.88)	16.84 (9.913)	ns
Household income	6966.54 (6191.950)	4578.57 (6423.365)	6879.8 (9578.981)	ns
Plot size	1.096 (0.821)	1.043 (1.622)	1.789 (1.917)	***

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant; Standard errors in parenthesis.
Source: Household survey (2016)

Table 5.3 Pairwise descriptive statistics from continuous variables

Variable description	AP users n=47	Non-AP n=112	Sig.	MPAP users n=45	Non-MPAP n=112	Sig.
Consumption expenditure	972.21	1245.89	**	1147.69	1193.08	ns
Age	48	49.31	*	49.43	49.04	**
Household size in adults equivalent	5.77	6.64	**	5.91	6.58	ns
Years of farming experience	14.32	14.89	ns	16.84	14.16	*
Household income	4578.51	6941.67	**	6879.78	6260.64	ns
Plot size	1.043	1.2946	ns	1.7887	1.0819	***

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant.
Source: Household survey (2016)

Table 5.5 shows that the gender of the household head was significantly different between the MPAP and Non-MPAP users at 10%. Participation in government tractor programme(s) was significantly high for Non-AP users. The training and ownership of animal power was significantly high for the farmers using MPAP for tillage.

Table 5.4 ANOVA descriptive statistics from categorical variables

Variable description	MP (n=112) Mean	AP (n=47) Mean	MPAP (n=45) Mean	ANOVA F-test
Gender	0.37 (0.484)	0.43 (0.500)	0.53 (0.505)	ns
Participation in government tractor programme	0.13 (0.342)	0.04 (0.204)	0.18 (0.387)	ns
Own animal power (Cattle)	0.38 (0.489)	0.47 (0.504)	0.53 (0.505)	ns
Training on the use of animal power	0.01 (0.094)	0.19 (0.398)	0.24 (0.435)	***

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant; Standard errors in parenthesis.
Source: Household survey (2016)

Table 5.5 Pairwise descriptive statistics from categorical variables

Variable description	Categories	AP users n=47	Non-APn=112	Sig.	MPAP users n=45	Non-MPAP n=112	Sig.
Gender	1= male	42.6	41.4	ns	53.3	38.4	*
	0= female	57.4	58.6		46.7	61.6	
Participation in government tractor programme	0= no	95.7	85.4	*	82.2	89.3	ns
	1= yes	4.3	14.6		17.8	10.7	
Own animal power (Cattle)	0= no	53.2	57.3	ns	46.7	59.1	*
	1= yes	46.8	42.7		53.3	40.9	
Training on the use of animal power	0= no	80.9	92.4	**	75.6	93.7	***
	1= yes	19.1	7.6		24.4	6.3	

Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; ns = not statistically significant.
Source: Household survey (2016)

5.7.2 Factors influencing the choice of alternative traction power source for tillage

The results of the treatment model for the effect of alternative traction power source on food security are presented in Table 5.6. The two columns present the estimated coefficients and significance levels of the t-values for the effect of using AP on consumption expenditure, while the last two columns are for MPAP. The coefficient Chi^2-rho for both AP and MPAP is positive and statistically significant ($p < 0.01$). This demonstrates the existence of positive selection bias. This coefficient indicates that the unobservable factors that increase the likelihood of farmers choosing MPAP or AP for tillage are associated with higher consumption expenditure. The coefficient proves that if OLS was used to determine the effect, biased and inconsistent estimate (Appendix D&E) were going to be reported.

Table 5.6 shows that estimated coefficient for the availability of animal power (USEAP) has positive and significant effect on consumption expenditure per adult equivalent. These results suggest that the availability of AP increases consumption expenditure by R486.73 per month for those who rely on animal power for tillage. The results are consistent with Pietola (1998) and van der Veen and Gebrehiwot (2011). These studies found that animal power availability controls how and when farmers undertake tillage and other crop production activities, which in most cases is timely. This makes them incur relatively low production costs and they are left with more money in their pockets for household expenditure and invest in the next farming season. Moreover, farmers hire out animal power for cash; the revenue generated was almost equal to the household monthly income. Other food security benefits from availability of animal power include access to meat and milk for household consumption or sale. In analysing the contribution of cattle to livelihoods Chaminuka *et al.* (2014) showed that apart from using cattle as power source, households in Mhinga also got milk and slaughtered cattle for own consumption as well as sale.

Similarly, Table 5.6 shows that estimated coefficient for the availability of a combination of mechanical and animal power (USEMPAP) has positive and significant effect consumption expenditure per adult equivalent. These results suggest that the availability of MPAP increases consumption expenditure per adult equivalent by R578.59 for farmers who rely on both mechanical and animal power for tillage. The outcome was expected because using MPAP allows farmers to cultivate relatively large farms (garden and field plots). Moreover, farmers combining the use of AP and MP do not have to wait for either of the two power sources but use whichever is available. As a result, this reduces the risk of delayed tillage and planting, therefore likely to increase output. Also, they are likely to harvest enough and store; this makes them have food security for several months. The results are consistent with Cunguara and Darnhofer (2011).

Table 5.6 Effect of tillage traction power availability on food security

Variables	Consumption expenditure (AP users)		Consumption expenditure (MPAP users)	
	Estimated coefficients	**Standard error**	**Estimated coefficients**	**Standard error**
Constant	439.717***	99.943	410.729***	95.109
USEAP	487.868***	82.228	-	-
USEMPAP	-	-	578.309***	100.472
Gender	-47.008	41.743	-29.167	44.735
Main occupation	30.675**	11.459	26.009**	12.716
Farming experience (In)	4.847	3.352	7.157**	3.641
Household income (In)	0.011**	0.004	0.014**	0.005
Household size (In)	42.073**	19.952	38.805**	20.059
Farm Size (In)	100.751***	21.986	99.485***	24.104
Participation in government farm programs	36.370	82.210	43.069	70.619
Own animal power	5.917	47.839	-14.735	50.428
Training on the use of animal power	-50.069	71.038	-31.921	85.763
athrho	-1.273***	0.221	-1.302***	0.205
lnsigma	6.114***	0.094	6.131***	0.106
rho	-0.855	0.059	-0.862	0.053
sigma	451.959	42.906	459.964	48.661
lambda	-386.289	57.158	-396.610	63.613
Chi^2 rho	33.05***		40.31***	

Notes: Notes: ***, **,*= statistically significant at 1%, 5%, 10%, respectively; the standard errors in parenthesis are robust; MP-mechanical power, AP-animal power, MPAP-combination of animal and mechanical power. MP is the base category.
Source: Household survey (2016)

Other factors which affected consumption expenditure were main occupation, income, household size and farm size. The estimated coefficients of these variables are similar for AP and MPAP although they differ according to the strength of effect on consumption expenditure. As expected, household income has a statistically significant positive effect on household consumption expenditure per adult equivalent. Households with relatively high income are more likely to have high consumption expenditure compared to those with relatively low income. Moreover, the main occupation of the household head has a positive and significant effect on consumption expenditure. The level of household size per adult equivalent also has a positive and significant effect on consumption expenditure. These results are consistent with the literature (e.g., Beyene and Muche, 2010; Cunguara and Darnhofer, 2011; Bedeke, 2012; Abafita and Kim, 2013).

5.8 Conclusion

The study evaluated the effect of traction power availability on consumption expenditure as a proxy for food security among 204 randomly selected households in Okhahlamba municipality. The results show that traction power availability has a significant effect on household food security. This confirms the importance of traction power availability in reducing household food insecurity. The use of MPAP or AP affects household consumption expenditure positively. Main occupation, household income, household size and farm size are some of the factors affecting household consumption expenditure. These findings suggest that there should be interventions to address any problem that directly or indirectly affects traction power availability in smallholder farms. The interventions should be focused on ensuring timely availability of traction power to undertake crop production activities as it affects household food security.

CHAPTER 6. CONCLUSION AND POLICY RECOMMENDATION

6.1 Re-capping the purpose of the study

Agricultural production remains the major sector in the fight against the developmental challenges of poverty and food insecurity in most of the SSA countries including South Africa. However, low productivity hinders the full potential of this sector in significantly addressing the developmental challenges. The productivity of this sector can be improved by increasing the availability and use of improved inputs. Traction power source remains one of the less available inputs in smallholder farmers’ crop production activities because of constraints such as lack of capital, location bias of government, small land holding and gender equity matters. Limited and non-timely availability of traction power source constrains timelines and quality of crop production activities, especially tillage. Overcoming these constraints requires an understanding of factors influencing the choice of traction power source for tillage.

Following transition in the farm power source to undertake crop production activities, smallholder farmers have alternative traction power source they can use for tillage. These traction power sources offer different benefits, which determine farmers' choice of a more beneficial traction power and consequently, the impact on crop productivity as well as food security. Considering the importance of traction power availability in improving crop productivity as well as food security there is a need to determine farmer's choice and the effect on crop productivity as well as food security.

This study addressed the knowledge gaps and drew relevant policy implication to improve the availability of traction power source for tillage and crop productivity as well as food security. The study pursued the following objectives: (i) determine the factors influencing the choice of traction power for tillage; (ii) evaluate the effect of traction power availability on crop productivity, and (iii) evaluate the effect of traction power availability on food security.

Various conceptual and empirical models were used to address the objectives. The multinomial logistic model was used to determine factors influencing the choice of alternative traction power source for tillage. Cobb-Douglas production function was used to evaluate the effect the availability of alternative traction power source on crop productivity. The multinomial treatment effect model was employed to evaluate the effect of traction power availability on consumption expenditure, as a proxy of food security.

6.2 Conclusion

Based on the empirical findings, the significance of ownership of animal power implies that the ownership of alterative traction power source is important in decision making. Furthermore, farm size was found to play a significant role in the choice of traction power source. Farmers owning cattle have a high probability of choosing a combination of mechanical and animal power. The decision farmers make also depends on their farm size.

The study revealed that farmers who received training on the use of animal power have a high probability of using AP or MPAP for tillage. The results suggest that training on the use of animal power gives farmers an incentive to use it as a source of power for tillage. Households had a high probability of choosing MPAP for tillage, possibly because they have access to improved inputs, training, and information on government programmes. Furthermore, households with relatively high income had a high probability of choosing MP for tillage. The positive influence of income in choosing MP implies the affordability of farmers to purchase a tractor or acquire service from private tractor owners.

The empirical results established that the availability of traction power source affects maize productivity as well as food security. The use of AP had a positive effect on maize productivity as well as food security. Similarly, the use of MPAP had a positive effect on maize productivity as well as food security. This suggests that traction power availability and training on the use of AP can play a crucial role in improving maize productivity as well as household food security.

6.3 Policy Recommendations

Based on the findings of this study it is recommended that:

- There is a need to improve policies that directly or indirectly affect the availability of traction power by the public or private service providers. For example, land tenure security should be addressed, farmers cannot commercialize without title deeds, which can serve as collateral for credit to purchase more land that will give some farmers an incentive to invest in purchases of traction power to improve productivity as well as food security. Also, there is a need to improve rural road infrastructure to reduce the selection bias of government tractor programmes. There is a need to design a mechanism for management and regular maintenance of government tractors so that they are functional by the time they are needed to provide traction services in smallholder farms. What can also be done to supplement the limited traction services from government is to encourage group ownership because in this way it becomes easier to get capital for investing in the purchase of traction power.

- There is a need to train smallholder farmers on the use of animal power so they can be able to take advantage of the readily available traction power source.
- The study showed that farmers operate on relatively small farmland, making it expensive to use tractors. For this reason, there is a need to consider the introduction of tillage power that is suitable for the land sizes that smallholder farmers operate.
- The study showed that male farmers are able to use a combination of the available traction power source more than females. Therefore, there is a need to enforce gender equity policies in rural areas to ensure equal access to inputs and participation in government programmes.

6.4 Limitations of the study and suggestion for future research

Several limitations were experienced in pursuit of this thesis. Firstly, the choice of traction power source and the effects of its availability on maize productivity as well as food security were analysed using cross-sectional data. The results from cross-sectional data have limitations in providing a robust picture of the effect of traction power availability on maize productivity as well as food security. It is, therefore, recommended that panel-data be used to evaluate the effect of traction power availability on maize productivity as well as food security. The main advantage of using panel-data is that there is less risk of obtaining biased estimates since it captures the complexity of human behaviour better than cross-sectional data (Hsiao, 2007).

Secondly, the effect of traction power availability has been examined on maize only. It is recommended that future research evaluating the effect of traction power availability on other crops be done to get a clear picture of how traction power availability affects crop production.

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APPENDICES

Appendix A: Questionnaire

University of KwaZulu-Natal

Discipline of Agricultural economics

The information to be captured in this questionnaire is strictly confidential and will be used for research purposes by staff and students at the University of KwaZulu-Natal working on a project **"An evaluation of traction power source availability for tillage and its effect on smallholder farmers' livelihoods"**. There is no wrong or right answer to these questions. You are free to be part or not part of this survey and you can withdraw from the survey anytime you feel like doing so. However, your cooperation is appreciated.

Would you like to participate in this survey? 1 = Yes 2 = No

Signature of respondent…………………………………………….

Name of interviewer………………………………………………………………………..   Name of village…………………………………………….………………………….   Date………………………………………………………………………………………..   Respondent is household head (yes/no)……………………………………………………

1. **Household demographics**

1.1. What is the total number of your household members? Please complete the table below (record household head details in the first row)

Name	Position in the household	Age	Gender	Education level	Main occupation	Availability at the farm (days per week)
	Head					

Key

Household position	*Gender*	*Main occupation*	

1=Spouse 2=Daughter 3=Son 4=Other specify…….	1=Male 0=Femal e	1= Full-time farmer 2= Regular salaried job 3=Temporary job 4=Unemployed (engaged in agriculture) 5= Unemployed	6=Self employed 7=Student 8=Retired 9=Other specify……..

1.2.How long has the household head been engaged in farming?......................

2. Household expenditure patterns

2.1.Please indicate the food items your household bought, the frequency and cost incurred for buying the food items in the last 30 days? *Refer to table below*

List of food items consumed by household	Quantity bought e.g. kg	Frequency bought per month	Price per unit	Total amount
a) Mealie meal				
b) Rice				
c) Flour				
d) Vegetables				
e) Sugar				
f) Salt and spices				
g) Eggs				
h) Samp				
i) Oil				
j) Margarine				
k) Fish				
l) Beans				
m) Beef Meat				
n) Chicken meat				
o) Sheep meat				
p) Goat meat				
q) Tea/coffee				
r) Soft drinks				
s) Other, specify………				

2.2.Please indicate the non-food items your household mainly spent money on, how much was spent and the frequency in the past 12 months? *Refer to table below*

Expenditure item(s)	Amount paid (e.g. monthly)	Frequency (e.g. Monthly)	Total (e.g. monthly)
a) Medical care			
b) Transport			
c) Personal items (e.g, clothes, shoes, etc.)			
d) Education (e.g., school expenses)			

e) Entertainment (e.g, liquor, tobacco, etc.)			
f) Home (e.g., furniture, maintenance, etc.)			
g) Toiletries			
h) Service bills (e.g, electricity, water, telephone, etc.)			
i) Other, specify…………………………			

2.3.For each of the following questions, consider what has happened in the past 30 days. Please answer whether this happened, 0= never, rarely (once or twice) =1, sometimes (3-10 times) =2, often (more than 10 times)=3 in the past 30 days?

Question	**Response option**			
	0= never	**Rarely (once or twice) =1**	**Sometimes (3-10 times) =2**	**Often (More than 10 times) = 3**
(a) Were you worried that your family would run out of food?	☐ 0	☐ 1	☐ 2	☐ 3
(b) Did you and your family members eat types of food that you did not like because of lack of resources?	☐ 0	☐ 1	☐ 2	☐ 3
(c) Did you or a member of your family eat less varied food each day because you did not have enough food or resources to buy food?	☐ 0	☐ 1	☐ 2	☐ 3
(d) Did you or your family member eat the food that you would not want to eat because you did not have food or resources to buy food?	☐ 0	☐ 1	☐ 2	☐ 3
(e) Did you or your family eat less food that you would have wanted because of lack of enough food?	☐ 0	☐ 1	☐ 2	☐ 3
(f) Did you or a member of your family eat a lesser number of meals because you lack enough food?	☐ 0	☐ 1	☐ 2	☐ 3
(g) Was there a time you family did not have food because you lack the resources to buy food?	☐ 0	☐ 1	☐ 2	☐ 3
(h) Did it happen that you or a member of the family went to sleep without eating because there was no food?	☐ 0	☐ 1	☐ 2	☐ 3
(i) Did it happen that you or a member of your family went the whole day without eating because	☐ 0	☐ 1	☐ 2	☐ 3

there was no enough food?				

2.4. In the past 12 months, how long did you consume food from own production? *Refer to table below*

Food from own consumption	Duration	
	0-6 months	7-12 months
a) Maize		
b) Potatoes		
c) Beans		

3. Source of household income

3.1. What were the sources of income in the past 12 months? Indicate the amount, and frequency received? *Refer to table below*

Source of household income		**Amount received (R) (e.g. monthly)**	**Frequency (e.g. monthly)**	**Total received (e.g. monthly)**
a) Agricultural activities				
b) Welfare grants	Old person's grant			
	Child support grant			
	Foster child			
	Disability			
	Care dependency			
c) Remittance				
d) Permanent employment				
e) Temporary employment				
f) Other, specify………				

3.2. In the past 12 months, how much income was received from different agricultural enterprises? *Refer to table below*

	Enterprise	Amount received (R) (monthly)	Frequency (in 12 months)	Total amount received (in 12 months)
a) Crop production	Maize			
	Potatoes			
	Beans			
	Spinach			
b) Livestock production	Cattle			
	Goats			
	Sheep			

	Pig			
	Chickens			

4. **Household assets**

4.1.Do you own any of the following assets? *Refer to table below*

a) Block tile house		g) Wheel-barrow		m) TV	
b) Block, zinc house		h) Tractor		n) Car	
c) Round, thatch house		i) Plough		o) Motorcycle	
d) Round pole and mud or shack house		j) Radio		p) Bicycle	
e) Spades		k) Cell phone		q) Other, specify…..	
f) Hoes		l) Telephone			

4.2.Which of the following animals do you own? *Refer to table below*

Animal type		**Number currently owned**	**Money spent on feeds, vet services in the past 12 months**	**Number sold in the past 12 months**	**Price per unit**	**Number slaughtered in the past 12 months**
a) Cattle	Oxen					
	Cows					
	Bulls					
	Calves					
b) Small stock	Sheep					
	Goat					
	Pig					
	Chickens					
c) Donkeys						
d) Horses						
e) Other, specify.......						

4.3.In the past 12 months, did you hire out traction power? Yes=1/No=0

4.4.If yes, which out traction power source did you hire out? (Tractor=1/ Animal power=0)

4.5.How much income did you generate from hiring out each source? *Refer to table below*

Type of power	Income (*per hire)*	Frequency *(in a month)*	Total income received
a) Tractor			
b) Animal			

5. **Land**

5.1.Does your household own arable land? Yes=1/No=0

5.2.If yes,

5.2.1. What is the total area of land your household operates?	a) Field plot	(ha)
	b) Garden	(ha)
5.2.2. How much land was cultivated in the past 12 months?	a) Field plot	(ha)
	b) Garden	(ha)
5.2.3. How far is the field plot from your household?		km

6. **Crop production**

If you grow crops on field plot only answer 6.1
If you grow crops in the garden only answer 6.2
If you grow crops on field plot and garden answer both 6.1 and 6.2

6.1.Please indicate the crops you grow on field plot, the area planted, output produced in the past 12 months (complete below)

Crop name	**Area planted (ha)**	**Quantity harvested (e.g., kg)**	**Quantity sold (e.g., kg)**	**Price per unit sold**

Key

Crops	
1. Maize	6. Spinach
2. Potatoes	7. Cabbage

3. Beans	8. Carrots
4. Butternut	9. Beetroot
5. Tomatoes	10. Other, specify……..

6.2.Please indicate the crops you are growing the garden, the area planted, the output produced in the past 12 months (complete below)

Crop name	**Area planted (ha)**	**Quantity harvested (e.g., kg)**	**Quantity sold (e.g., kg)**	**Price per unit sold**

Key

Crops	
1. Maize	6. Spinach
2. Potatoes	7. Cabbage
3. Beans	8. Carrots
4. Butternut	9. Beetroot
5. Tomatoes	10. Other, specify……..

6.3.Please indicate which of the following inputs were used for crop production on either garden or field plot? Refer to the table below

Type of land	**Input used (ha)**	**Quantity purchased (e.g., kg)**	**Cost (ha)**
Field plot			
a) Seeds			
b) Fertilizer			
c) Manure			
d) Herbicides			

e) Pesticides			
f) Tractor			
g) Oxen			
Garden			
a) Seeds			
b) Fertilizer			
c) Manure			
d) Herbicides			
e) Pesticides			
f) Tractor			
g) Oxen			

7. **Tillage**

7.1.Do you till your land soon after harvesting? (Never=0 Sometimes=1 Always=2)

7.2.If never to 6.2, state the reason (s)……………………………………………..
…………………………………………………………………………………………

8. **Tillage and power source**

8.1.Which traction power source do you use for tillage? *Refer to table below*

Type of power source	Tick	
	Field plot	Garden
a) Tractor power		
b) Animal power		
c) Both animal and tractor power		
d) Other, specify……………….		

If you are using both animal and tractor power for tillage answer questions 8.2 to 8.13

If you are using only tractor power for tillage, answer 8.2 to 8.6

8.2.If a tractor is used for ploughing:
8.2.1. Which tractor did you use?

a) Four wheeled tractor		b) Power tiller	

8.2.2.Did you hire (Yes=1/No=0) or Borrow (Yes=1/No=0)

8.3.If tractor is hired/borrowed, where do you hire/borrow it from? *Refer to table below*

Tractor service	**Tick**
Hire	
a) Government services	

b) Private service provider	
c) Fellow farmers	
Borrow	
a) Private service provider	
b) Fellow farmers	

8.4. Did you receive training on ploughing with a tractor? (Yes=1/No=0)

8.5. If using own, government or private tractor services, what are the challenges faced? *Rank the challenges on a scale of 1-5, with 5= the most important challenge and 1= the least important challenge.*

Challenges	Tractor service provider	
	Government	Private
a) Not always available		
b) Not Always on time		
c) High tractor fees		
d) Household financial problems which delay access tractor service		
e) Work is not well done		

8.6. Do the challenges mentioned in 8.5 make you fail to plant crops? *Refer to table below*

a) Not at all		b) Somewhat		c) Absolutely	

If you are using only animal power for tillage, answer 8.7 to 8.13

8.7. Do you use your own animals for tillage? (Yes=1/ No=0)

8.8. If no, do you hire or borrow? Please indicate the cost. *Refer to table below*

Animal power service	Cost per ha
a) Hire	
b) Borrow	

8.9. Did you receive training on how to use animal power for tillage? (Yes=1/ No=0)

8.10. In the past 12 months, how many hectors did you plough using animal power?........................

8.11. How often did you plough in the past 12 months?

a) Once		b) Twice		c) More than twice	

8.12. How many animals did you use for ploughing?....................

8.13. Did you face any shortages of animals for power source during the last cropping season? (Yes=1/ No=0)

8.13.1. If yes, did you solve the problem? Yes=1/No=0.

8.13.2. If yes, how did you solve the problem?

a) Hiring tractor power		b) Hiring animal power	
c) Cooperating with others		d) Using hand tools	
e) Other, Specify………………			

9. Traction power availability

9.1.What do you do when you cannot afford power source for tillage? *Refer to table below*

a) Plant crops without tilling the land		b) Do not plant at all	

9.2.Are you able to till your entire land with the hired power source? *Refer to table below.*

Type of traction power source	Government	Private service provider
a) Tractor power	(Yes=1/ No=0)	(Yes=1/No=0)
b) Animal power	(Yes=1/ No=0)	(Yes=1/No=0)

9.2.1.If no, how much land are you able to till? *Refer to table below*

Type of power	Government	Private service provider
a) Tractor power	(ha)	(ha)
b) Animal power	(ha)	(ha)

9.3.Are you always able to till the land in the time required? (Never=0 Sometimes=1 Always=2)

9.3.1.If never to 9.3, what delays tillage schedule? *Refer to table below*

a) Limited traction power services available		b) No money to pay for traction service	

*9.3.2.*What do you do when you realize you are late for tillage because of delayed power service? *Refer to table below*

a) Plant crops, although it is late		b) Do not plant crops for that season	

9.3.3.If you plant crops, although it is late does this have an effect on crop output? (Never=0 Sometimes=1 Always=2)

9.3.4.What effect does late planting have on crop output? *Refer to table below*

a) Low crop output		b) High crop output	

10. Traction power source and crop output

10.1. What soil type do you plough on in your field plot or garden? *Refer to table below*

Soil type	Field plot	Garden
Soil texture		
a) Clay		
b) Loam		
c) Sand		
Soil colour		
a) Dark or black		
b) Red		
c) Grey		

10.2. In your observation, does the traction power source used for ploughing have an effect on output? (Never=0 Sometimes=1 Always=2)

10.3. If always/ sometimes, which traction power source leads to more crop output on different soil types? *Refer to table below*

Soil type	Field plot		Garden	
Soil texture				
	Tractor power	Animal power	Tractor power	Animal power
a) Clay				
b) Loam				
c) Sand				
Soil colour				
a) Dark or black				
b) Red				
c) Grey				

11. Please rate the extent to which you agree with the following statements pertaining to your perception on the attributes of tractor and animal power. Tick appropriate box

11.1. Evaluation of farmer perception on the attributes of tractor power,

Attribute	Perception on tractor power			
	0=Strongly agree	1=Agree	2=Disagree	3=Strongly disagree
Do you agree that tractor power:				
a) Increases crop yield				
b) Cost effective				
c) Labour saving				
d) Time-saving				
e) Simple to use				
f) Easily accessible				
g) High daily output				

11.2. Evaluation of farmer perception on the attributes of animal power

Attribute	Perception on tractor power			
	0=Strongly	1=Agree	2=Disagree	3=Strongly

	agree			disagree
Do you agree that animal power:				
a) Increases crop yield				
b) Cost effective				
c) Labour saving				
d) Time-saving				
e) Simple to use				
f) Easily accessible				
g) High daily output				

Thank you/Siyabonga/ Re a leboga

Appendix B: Key informant guide

1. Does the use of different types of traction power source depend on:
    - Age of household head
    - Gender
    - Education level
    - Other
2. Do farmers grow crops in:
    - gardens only
    - only in field plots
    - on both gardens and field plots
3. Do farmers in the village till land before planting?
    - Do they consider tilling on both field plots and gardens?
    - Which power source is commonly used (tractor/animal power?
    - Do most of the farmers own or hire government or private traction power source?
4. In which season does ploughing take place? Assess the ease of accessing the traction power source (tractor/animal) during the ploughing season.
5. What are the notable positive experiences farmers have with using (tractor/animals)
    - Own traction power source
    - Government power source
    - Private traction power source.

6. What notable disappointment do farmers have with using (tractor/animals).

- Own traction power source
- Government power source
- Private traction power source.

7. What soil colors and textures are found in the area?
    - Do the different soils influence the type of traction power source farmers choose to use for tillage?
8. Are there any differences in crop productivity and food security amongst households in the village based on use of traction power?

Appendix C: VIF

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. vif
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Variable	VIF	1/VIF
infarmingexp	2.87	0.348481
farmingexp2	2.59	0.385797
partfetsatla	2.44	0.410390
inextncont~2	2.43	0.412359
inuseap	1.78	0.562017
inciltvtda~a	1.77	0.564992
quantmanure	1.48	0.676311
ownap	1.46	0.685083
inhhsize	1.44	0.694897
inusempap	1.37	0.729868
quantherbici	1.37	0.731814
trainusean~p	1.37	0.732000
intillontime	1.32	0.757974
inmaritals~s	1.32	0.759568
insoiltex	1.28	0.781220
inquantseeds	1.24	0.809154
gender	1.16	0.864872
educationl~1	1.16	0.865025
Mean VIF	1.66	

Appendix D: OLS results for AP

Linear regression			
	Number of obs	=	204
	F(11, 192)	=	10.03
	Prob > F	=	0.0000
	R-squared	=	0.4311
	Root MSE	=	371.07

consexpnditure	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
use_ap	-145.7892	55.72529	-2.62	0.010	-255.7016	-35.87683
age	-1.072214	2.141469	-0.50	0.617	-5.29604	3.151613
gender	-73.73922	48.14391	-1.53	0.127	-168.6981	21.21965
mainccupation	30.35654	13.27663	2.29	0.023	4.169756	56.54333
farmingexp	5.221976	4.135723	1.26	0.208	-2.935309	13.37926
hincome	.0140788	.0055838	2.52	0.013	.0030654	.0250922
hhsize	50.39935	20.36508	2.47	0.014	10.23135	90.56736
ttlndsze	102.1184	25.22271	4.05	0.000	52.36926	151.8676
partfetsatla	-4.839474	78.32	-0.06	0.951	-159.3176	149.6386
ownap	-18.49677	56.69612	-0.33	0.745	-130.324	93.33045
trainuseanimal	-48.32255	82.9555	-0.58	0.561	-211.9437	115.2986
_cons	591.6549	142.4001	4.15	0.000	310.7855	872.5242

Appendix E: OLS results for MPAP

Linear regression			
	Number of obs	=	204
	F(11, 192)	=	8.20
	Prob > F	=	0.0000
	R-squared	=	0.4189
	Root MSE	=	375.03

consexpnditure	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
use_mpap	-65.26199	55.47806	-1.18	0.241	-174.6867	44.16275
age	-.932154	2.185341	-0.43	0.670	-5.242513	3.378205
gender	-67.47986	48.12906	-1.40	0.163	-162.4095	27.44973
mainccupation	29.98546	13.64692	2.20	0.029	3.068325	56.90259
farmingexp	5.312844	4.244989	1.25	0.212	-3.059957	13.68564
hincome	.0152086	.005676	2.68	0.008	.0040134	.0264039
hhsize	51.96731	20.35608	2.55	0.011	11.81704	92.11758
ttlndsze	110.593	25.78959	4.29	0.000	59.7257	161.4603
partfetsatla	32.50786	72.53053	0.45	0.655	-110.5511	175.5668
ownap	-25.71529	58.3659	-0.44	0.660	-140.836	89.40541
trainuseanimal	-65.9731	87.64754	-0.75	0.453	-238.8488	106.9026
_cons	535.486	138.8859	3.86	0.000	261.548	809.424

Appendix F: Ethical Clearance