EFFECT OF FARM INPUTS AND SMALLHOLDER FARMER CHARACTERISTICS ON IRISH POTATO (*SOLANUM TUBEROSUM L.)* PRODUCTION TECHNICAL EFFICIENCY IN MOLO SUB COUNTY, NAKURU COUNTY, KENYA

PAULINE NYOKABI KAMAU

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CHUKA UNIVERSITY

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DECLARATION AND RECOMMENDATIONS

Declaration

This thesis is my original work and has not been presented for an award of Diploma or conferment of degree in any other Institution.

Signature__________________ Date 12/09/19

Kamau Pauline Nyokabi
NM24/38572/18

Recommendations

This thesis has been examined, passed and submitted with our approval as University supervisors.

Signature__________________ Date 12/09/19

Dr. Geoffrey K. Gathungu, Ph.D
Department of Plant Science
Chuka University

Signature__________________ Date 12/09/19

Dr. Rael Mwirigi, Ph.D
Department of Business Administration
Chuka University

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DEDICATION

I dedicate this thesis to my lovely parents George Kamau and Elizabeth Wanjiru, my sister Joyce Waithira and my brother Kennedy Kung'u.

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ABSTRACT

In Kenya, irish potato is the second most consumed food crop after maize. The sub-sector contributes significantly to the country's food security and generates income and employment to many smallholder farmers. Irish potato farming is an important enterprise for smallholder farmers in Molo Sub County. Despite its significance, smallholder irish potato farmers' production is constrained by low farm inputs technical efficiency. The national actual production of irish potato is far much below the potential production level. For maximum and sustainable irish potato production to be attained efficient use of the available farm inputs in necessary. Therefore, this study focused on assessing the effect of farm inputs and smallholder farmer's characteristics on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya. Cross-sectional data on the 2018/2019 production season was collected using multistage sampling technique from a sample of 360 irish potato farmers. Respondents in the study area were sampled using purposive and random sampling methods. The study employed a questionnaire to collect the relevant data. Descriptive statistics were used to describe the socio-demographic and institutional attributes of the smallholder irish potato farmers. Effect of farm inputs was modelled under the Cobb-Douglas function form under stochastic frontier analysis approach. The model parameters estimated using the maximum likelihood method indicated that land allocated to irish potato production (0.262), seeds (0.629), fertilizer (-0.299) and fungicide (0.131) were significant inputs in irish potato production at 5% level of significance. The level of irish potato production technical efficiency amongst the smallholder farmers was varied. The relative deviation of irish potato production from the maximum possible production level due to technical inefficiency was determined by the discrepancy ratio which was estimated to be 94%. The respondents' estimated mean technical efficiency was 71%, which implies there is an opportunity of increasing irish potato production by 29% through efficient use of the available farm inputs. Education, gender, access to extension services and farmer group significantly affected the smallholder irish potato production technical efficiency. The negative coefficients on the education, gender, access to extension and farmer group variables indicated that an increase in any one of them while holding the other factors constant would result in a significant increase in the level of technical efficiency. Therefore, smallholder irish potato farmers were producing below their optimum production level with the available farm inputs. This study encourages smallholder irish potato farmers to increase use of the land, seed and fungicide to boost production. Soil testing is also encouraged to ensure that the fertiliser used replenishes the soil nutrients for irish potato production. In order to boost irish potato production, farmers are motivated to increase their literacy levels, form or join existing groups. Access to extension services can also be urged to improve irish potato production levels.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADC	Agricultural Development Corporation
CIP	International Potato Centre
DAP	Diammonium Phosphate
FAO	Food Agricultural Organization
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
KALRO	Kenya Agricultural and Livestock Research Organization.
NPCK	National Potato Council of Kenya
SACCO	Savings and Credit cooperative
SD	Standard Deviation
SE	Standard Error
SPSS	Statistical Package for Social Sciences
USAID	United States Agency for International Development

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Globally irish potato (*Solanum Tuberosum L.)* stands as the fourth largest food crop produced following wheat, rice and maize production (Alam, Kobayasi, Matsumura, Ishida, Mohamed & Faridulla, 2012). It is the most significant root and tuber crop, grown in more than 125 countries and consumed daily by more than a billion people (Lutaladio, Ortiz, Haverkort & Caldiz, 2009). The largest irish potato producers in the world are China, India and Russia (De Haan & Rodriguez, 2016). Globally, irish potato production has gradually risen from 267 million tonnes in 1990 to 373.83 million tonnes in 2016 (Torero, 2018) and it is expected to rise to more than 400 million tonnes by 2020 (Scott, Rosegrant & Ringler, 2000). From the years 1981-2015, the total area under the irish potato crop in Asia had increased by 300% and in Africa, it had increased by 237% making valuable contributions towards food security and livelihoods of smallholder farmers (Lutaladio *et al*., 2009; De Haan & Rodriguez, 2016; Food and Agriculture Organisation [FAO], 2017).

Globally, the average irish potato yield 18.9 tonnes per hectare. Africa has an average yield of 14.2 tonnes per hectare. In Africa, the gap in irish potato yield is high in comparison with other continents such as Asia which has 18.3 tonnes per hectare, Europe which has 21.1 tonnes per hectare and America that has 25.9 tonnes per hectare (De Haan & Rodriguez, 2016). The international irish potato cropping systems range from smallholder, non-mechanized family farming for home consumption to large-scale mechanized production for income generation. However, smallholder irish potato farming system is predominant (De Haan & Rodriguez, 2016). Generally, irish potato crop has two cropping seasons that coincide with the rainy seasons.

In Europe and United States there is rising demand for processed irish potatoes (flakes, chips and crisps) from convenience, snack and fast food stores. This trend is mainly attributed to the increasing urban residents, growing incomes, change in diets and lifestyles that has left many people with less time for cooking irish potatoes (De Haan & Rodriguez, 2016). Other than consuming Irish potato as a vegetable, it has a variety of other uses such source of starch, animal feed, seed tubers (Lutaladio *et al*., 2009). Production of irish potato is constrained by a number of challenges such as shortage of quality seeds, traditional production systems, poor technology transfer, pests and diseases, cash constraints, inadequate access to extension services and low yields (Gebru , Mohammed, Dechassa & Belew, 2017; Karanja, Belew & Makokha, 2014).

In Kenya, irish potato happens to be second after maize as the highest consumed staple crop with an average of 2-3 million tonnes of irish potato valued at Ksh.40-50 billion being produced annually against an annual average of 40 million bags of maize worth Ksh. 120 billion (Ministry of Agriculture, Livestock and Fisheries[MOALF], 2016). Most irish potato farms are located in the highland areas of central, eastern and rift valley parts of Kenya (Kaguongo, Makokha, Barker, Nganga & Guenthner, 2013). Irish potato producing areas include Meru, Embu, Nyeri, Kiambu, Nyandarua, Kirinyaga, Laikipia, Bomet, Narok, Nakuru, Keiyo, Marakwet, Taita Taveta (International Potato Centre [CIP], 2008). Molo Sub County in Nakuru County is the second largest irish potato growing area after Nyandarua (Muthoni, Shimelis & Melis, 2013).

The agricultural sector in Kenya is characterised by large scale and smallholder farmers. Smallholder farmers mainly practise potato production in Kenya, on land size below 5 acres (Omiti, Otieno, Nyanamba, McCullough, 2009).Smallholder irish potato farmers mainly produce potato as a food and a cash crop making it an important source of rural income and food. In Kenya, irish potato is mainly grown during the short and long rains season. Smallholder farmers intercrop irish potato with maize and beans while some rotate it with barley, wheat or maize (D'Alessandro, Caballero, Lichte & Simpkin, 2015). Therefore, the sub-sector performs a significant function in attainment of food security in Kenya (Dube, Ozkan, Ayele, Idahe & Aliye 2018). It also generates income and employment to over 800,000 farmers growing irish potato and 2.5 million employees in other sub-sectors such as processors, transporters, exporters, vendors and market agents (FAO, 2013). In Kenya, smallholder irish potato farmers encounter problems such as unavailability of good quality seeds, inadequate funds, unavailability of fertilizer in time, diseases, inadequate labour and small land sizes (Karanja *et al*., 2014).

Kenya is a food deficit country with households exposed to food and nutrition insecurity (Laibuni, Nyangena & Laichena, 2018). The changing climatic conditions being experienced are worsening this situation. The high rate of population growth in the country necessitates matching the population increase with increase in food production. Kenya's Vision 2030 strategy identifies the agricultural sector to be among the priority sectors for attaining food security and economic growth. Hence, institutions have made more efforts towards developing modern agricultural technologies to boost agricultural production (Jote, Feleke, Tufa, Manyong & Lemma, 2018). To attain food self-sufficiency and equitable distribution of nutrients to all Kenyan citizens, the government has developed the food security pillar under the 'Big Four Agenda'. Under the food security pillar, government has set up strategic interventions on expanding food production, which includes promoting irish potato production. The government has identified irish potato as one of the indigenous foods that can contribute towards diversification of the staple food and boost total volume of food production in the country (Laibuni *et al*., 2018).

In agricultural production, where inputs are used to produce a single output, technical efficiency is realized when a specified set of inputs is used to produce maximum output or a particular level of output is obtained from the least set of inputs given the best production technology available. Regardless of how productive a technology may be, maximum production can simply be achieved when the technology is efficiently used (Aminu, Ayinde & Ibrahim, 2015).At the farm level, farmers' best use of the limited resources can increase agricultural production (Hossain, Hassan & Naher, 2008; Khan, 2015). Farrell (1957) pointed out that efficiency in a firm is made up of technical and allocative efficiency. Technical efficiency refers to a firm's capability to maximize output from a particular set of inputs while allocative efficiency is the firm's capability to exploit the inputs optimally, taking into account their respective prices and production technology available. Economic efficiency is determined collectively by the two elements. Factors such as education, age, labour, farm location, farm type, intensity of inputs, policy, infrastructure, credit and extension services affect technical efficiency. These factors can be broadly categorized as farm specific characteristics, demographic, socio-economic, environmental and non-physical aspects (Chepkowny, 2014).

Farmers can improve agricultural production by considering several alternatives such as implementation of modern technology, intensification and better utilisation of the available inputs. Accessibility of modern agricultural technology stems from research and development efforts while intensified use of inputs rests on farmers socio-demographic and institutional factors. Nkegbe (2018) pointed out that, farmers' access to credit, information and managerial capability influences their capability to generate maximum output from a specified set of inputs Inefficient farm management practices lead to difficulties in boosting agricultural yield because its affects the use of inputs effectively (Ayedun & Adeniyi, 2019).

Irish potato demand in Kenya has risen over the years especially among urban consumers (Ministry of Agriculture [MoA], 2007). However, Kenya's average irish potato national production is estimated to be about 10 tonnes per hectare contrary to a national potential production of 40 tonnes per hectare (Kaguongo *et al*., 2013). Africa's potential in irish potato production is estimated to be 20 tonnes per hectare while in North America the potential yield is estimated to be 40 tonnes per hectare (Vaughan, 2017). The area under irish potato production in Kenya has been gradually expanding (109,614 hectares in 2007 to 192,341 hectares in 2017) but the annual output has been fluctuating downwards from an average of 2,192,280 tonnes in the year 2007 to about 1,519,870 tonnes in the year 2017 (FAOSTAT, 2017). According to Horticulture Crops Directorate (2016), Nakuru County, the second largest producer of irish potato in Kenya experienced a reduction in yield per unit hectare from 12.86 tonnes per hectare to 12.76 tonnes per hectare. Muthoni and Nyamongo, (2009) suggested that decline in irish potato yields is attributed to poor farming practices, and low use of farm inputs. However, there is a knowledge gap on the effect of farm inputs on irish potato production and the factors that influence irish potato production technical efficiency in Nakuru County.

Chepkowny (2014) used a Translog functional form to analyse irish potato technical efficiency while Nyagaka, Obare and Nguyo (2009) studied technical efficiency of irish potato production by employing the two-step approach in Nyandarua. However, this approach has been criticised for its inconsistent assumptions regarding the factors that have an effect on technical efficiency. This two-step approach tends to underestimate the effect of the factors on technical efficiency levels (Johnson & Kuosmanen, 2015; Wang & Shmidt, 2002). The solution to this statistical bias problem is a one-step approach. It involves a model that is correctly specified by considering the relationship between the exogenous variables and technical efficiency in estimating the input parameters and technical efficiency levels. Battese and Coelli (1995) suggested simultaneous estimation of the input coefficients and technical efficiency as an explicit function of specific factors using of one-step approach. Therefore, this study sought to adopt one-step approach.

1.2 Statement of the Problem

Irish potato farming is a valuable enterprise for smallholder farmers in Molo Sub County. This is because it contributes positively towards the country's and county's food security and income levels. The irish potato sub-sector is a crucial segment of the agricultural sector owing to the increased food demand triggered by the rising population in the urban centres. The Kenyan government together with other stakeholders have been investing in potato development programmes by focusing on seed variety improvements, multiplications and distribution systems to optimize irish potato production. Improving of irish potato production is not only attainable through application of modern technology alone since production is determined by a set of inputs used. Smallholder irish potato farmers production is constrained by low technical efficiency in resources utilization. Therefore, there is need to consider how efficient use of the inputs affect irish potato production. Farmers' technical efficiency level is influenced by the socio-demographic and institutional factors. These factors influence how farmers allocate and manage the available inputs efficiently. Against this background, this study sought to analyse the effect of farm inputs on smallholder irish potato farmers production and determine the effect of socio-demographic characteristics and institutional factors on irish production technical efficiency.

1.3 Objectives of the Study

1.3.1 Broad Objective

The broad objective of this study was:
To assess the effect of farm inputs and smallholder farmer characteristics on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.

1.3.2 Specific Objectives

The specific objectives included;

i. To analyse the effect of farm inputs on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.
ii. To determine the effect of smallholder farmer socio-demographic characteristics and institutional factors on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.
iii. To determine the effect of smallholder farmer institutional factors on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.

1.4 Hypotheses

The study tested the following null hypotheses;

H_{01}: There is no statistical significant effect of farm inputs on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.

H_{02}: There is no statistical significant effect of smallholder farmer socio-demographic characteristics and institutional factors on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.

H_{03}: There is no statistical significant effect of smallholder farmer institutional factors on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya.

1.5 Significance of the Study

This study provides better understanding to smallholder farmers on the use of farm inputs to boost irish potato production and contribute towards efficient allocation of farm inputs. It also provides insights on the factors that influence technical efficiency of the smallholder irish potato farmers. Agricultural policy makers can use information from this study to help develop appropriate policies and programs in irish potato sub-sector at county and national government levels related to boosting irish potato production. The study results may also contribute towards developing policies that would help in the realization of the Kenya’s Vison 2030 objectives under the economic pillar through optimising irish potato production. When potato production is maximized, the food security pillar under the Big Four Agenda can also be actualized. This investigation is also of benefit to both academicians and researchers as it sheds more information on the socio-demographic and institutional factors that contribute towards irish potato production technical efficiency. Past studies on irish potato production technical efficiency in the country, adopted the two-step approach which has been criticised for underestimation of the technical efficiency levels and parameter estimates but this study adopts one-step estimation approach to deal with the statistical biasness.

1.6 Scope of the Study

The study concentrated on five farm inputs: land, seeds, labor, fertilizer and fungicide used in irish potato production in Molo Sub County of Nakuru County. The socio-demographic variables that were considered included education, gender, household size and farming experience. Institutional factors including access to extension services farmer group and credit were considered for this study. Molo Sub County was selected since it is a major irish potato producing area (Food and Agricultural Organization [FAO] 2013). The study was conducted from late April to end of June 2019 concerning the 2018 /2019 planting season.

1.7 Limitations of the Study

This study was limited to the smallholder farmers’ ability to recall information regarding the last planting season. Some of the respondents were uncooperative and reluctant to provide any information. This was resolved by looking for other respondents willing to participate in the study survey and assuring them that the information gathered from them was purely meant for academic purposes.

1.8 Assumptions of the Study

The following assumptions provided a foundation for this study:

i. The existing state of irish potato technology did not change for smallholder potato farmers in Molo Sub County, Nakuru County, Kenya.

ii. Relevant socio-demographic, institutional and potato production factors were taken into account.

1.9 Definition of Terms

Allocative Efficiency: Occurs when a given level of inputs are used in proportions which minimize cost of production given input prices.

Economic Efficiency: Is a situation where a farmer generates a specified amount of production at the least cost with the existing state of technology.

Efficiency: Refers to the probability of farmers generating maximum amount of output from a particular group of inputs.

Irish Potato Production: Refers to the quantity of irish potato produced in terms of kilograms.

Production Frontier: Refers to the highest quantity of yield achieved from a particular input set with the available technology.

Smallholder Farmer: Is an irish potato farmer who operates on an area of land less than five hectares of land either owned or leased.

Technical Efficiency: Occurs when the largest possible level of output is obtained from a given group of inputs.

Technical Inefficiency: Occurs when there is loss of output because of not attaining the highest quantity of output achievable from a particular input set with the available technology.

Production Function: Denotes a technical and mathematical relationship amongst output and inputs in production.

Farm Input: Are resources used in agricultural production such as land, labour, seeds, fertilizer and fungicide

Socio-demographic Factors: Refers to characteristics of a population in terms of age, gender and education and household size.

Institutional Factors: Are known as human devised restrictions that form human interactions such as extension services, farmer group and financial institutions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Irish Potato Production in Kenya

Irish potato stands out as the fourth largest consumed staple crop in the world (Carputo, Aversano & Fruscuante, 2005). The European settlers introduced irish potato farming in 19^{th} century primarily in the Rift Valley. After World War II, irish potato production expanded to Elburgon, Meru, Kiambu, Murang'a and Nyeri districts (Crissman, 1989). In Kenya, irish potato seconds maize as smallholder farmers in the highland areas traditionally grow this important food crop. In high altitude areas, farmers can grow the crop three times in a year thus having high production per unit area and time. The crop has high starch and energy levels in addition to nutrients such as vitamins, proteins, calories, potassium and fibre. Carputo *et al*. (2005) classified irish potato to be a non-fattening nourishing and healthy food. In addition to being significant in human diets, irish potato can also be utilised to make animal feed and as a basic material in starch and alcohol manufacturing. The sub-sector performs a key function in national food availability and providing employment to many people. According to the National Potato Council of Kenya (2017) pointed out that the top three irish potato producing counties include: Nyandarua (29.8%), Nakuru (18.9%) and Elgeyo Marakwet (16.2%).

However, there are productivity concerns because of the decline in the annual production estimates since the growing population and middle class spend a lot of their money on buying chips triggering the rise in demand for irish potatoes. According to Vaughan (2017) Kenya's average irish potato national yield is estimated to be about 10 tonnes per hectare contrary to Africa's potential of 20 tonnes per hectare and a yield of 40 tonnes per hectare for developed regions like North America. In Kenya, irish potato average yield is fluctuating downwards and from the years 2012-2017, the average yields are declining as depicted in Table 1.

Table 1. Irish Potato production trends in Kenya from 2007-2017.

Year	Irish Potato production in tonnes	Area in ha	Yield in tonnes/ha
2007	2192280	109614	20.0
2008	2900000	135000	21.5
2009	2299086	120246	19.1
2010	2725936	121542	22.4
2011	2365263	123390	19.2
2012	2915067	143325	20.3
2013	2192885	152007	14.4
2014	1626027	115604	14.1
2015	1963495	133532	14.7
2016	1335883	145967	9.2
2017	1519870	192341	7.9

Source: FAOSTAT (2017)

Among the challenges facing irish potato production are low soil fertility, shortage of quality seeds, attacks by pests and diseases, poor agronomic practices and inefficient use of farm inputs (Wang'ombe &Van Dijk, 2013). Government and other non-government organisations such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), United States Agency for International Development (USAID), International Potato Council (CIP) and National Potato Council of Kenya (NPCK) have focused much of their efforts in developing various irish potato seeds. These include Ambition, Challenger, Derby, El Mundo, Evora, Faluka, Jelly, Lady Amarilla, Laura, Markies, Musica, Sagitta, Saviola, Royal, Panamera, Rodeo, Sifra, Voyager, UNICA, Konjo, Carolus, Zafira, Milva, Connect, Sarpo Mira, Mayan Gold and Shangi. Shangi is the most popular among the farmers with a market share of about 70% (NPCK, 2017).

Initiatives have been undertaken by various stakeholders to boost irish potato production by introducing new technologies such as aeroponics and hydroponics where mini tubers are grown in a greenhouse and later multiplied in field reducing the time of producing first generation from seven to ten years to three years (NPCK, 2017). Agricultural Development Corporation began producing irish seed potatoes through the hydroponics system to raise its productivity. The corporation has a laboratory established in Molo, Nakuru County to multiply disease free plants sourced from Kenya Agricultural and Livestock Research Organization (KALRO), Tigoni and CIP. The concerned stakeholder have geared themselves towards irish potato production technologies focused on developing commercial irish potato varieties, certified seeds correct seed size and good agricultural practices.

However, unless farmers combine efficient use of the available resources with introduction of new technology, increase in production is not a guarantee. Technically efficient production is needed for people to have sufficient access to food and poverty alleviation in a country. Technical inefficiency takes away the benefits obtained from both existing resources and from improved inputs. Hence, generating the highest possible yield from a specified level of inputs with the existing level of technology requires improving the existing level of technical efficiency in production (Asfaw, Geta & Mitiku, 2019).

2.2 Technical Efficiency of Production

Farrell (1957) divided efficiency into technical and allocative efficiency. A firm's capability to produce the highest quantity of output from a specified level of inputs is known as technical efficiency. Technical efficiency is expressed as a ratio of observed output to its frontier output (Tiruneh, Chindi & Woldegiorgis, 2017). Allocative efficiency refers to the capability of a firm to exploit inputs in optimum proportions, taking into account their respective prices and available technology (Nchare, 2007). The two elements combined indicate the degree of economic efficiency. An efficient farm is one that can generate a specified amount of goods by use of minimum combination of inputs with the available a state of technology,

Existence of technical efficiency in production results from efficient exploitation of limited resources (Farrell, 1957). Technical efficiency is crucial for improving and sustaining agricultural production. Efficient resource use by farmers is essential in developing economies where most of them have limited access to resources. Farmers are technically efficient if they produce as much as possible with the inputs, they have actually employed (Lovell, 1993). The degree of technical efficiency can be modelled using two main approaches: stochastic frontier analysis (parametric) and Data envelopment analysis [DEA] (non-parametric). Data envelopment approach is a non-parametric mathematical programming method for frontier approximation (Charnes, Cooper, Rhodes, 1978). The method consists of a linear envelopment frontier over the data points in a manner that all the observed points lie on or below the production frontier. The line segments joining the observed efficient production units forms a convex envelope curve. This approach does not require a functional form of the production frontier and the error term assumption is not made (Charnes *et al*., 1978). This approach lacks a statistical technique for testing hypothesis and does not consider measurement of errors and random effects to be important. The approach assumes that all the deviations from the frontier are caused by the farm's inefficiency. DEA is very susceptible to outliers and extremist values (Coelli, Rao, Christopher, Donnell & Battese, 2005).

The second approach is parametric approach, which involves applying econometric concept in the approximation of a production function with a functional form that is already established (Aigner, Lovell & Schmidt, 1977; Meeusen &Van den Broeck, 1977). The stochastic frontier method is common as it takes into account random shocks and measurement of errors caused by weather conditions, strikes and luck in agricultural production (Alam *et al*., 2012). Therefore, it incorporates random shocks and measurement errors separately. The stochastic frontier approach is ideal for the evaluation of efficiency in agriculture for the reason that inherent stochasticity is included. The production function functional form should be specified in advance in stochastic frontier approach. The common functional forms used are Cobb-Douglas and Translog production functions (Coelli *et al*., 2005). Cobb-Douglas production function is commonly and extensively adopted since it represents the technological relationship between various inputs used and output produced as pointed out by Gemeyida, Haji and Tegegne (2019), Abubakar and Sule (2019), Ayedun and Adeniyi (2019) and Bajracharya and Sapkota (2017).

2.2.1 Irish Potato Production Technical Efficiency

This section exhibits a review of a few studies on technical efficiency. Early researchers such as Aigner *et al*. (1977), Meeusen and Van den Broeck (1977) employed the stochastic approach in the analysis of technical efficiency. Shahriar, Hasan and Kamruzzaman (2013) conducted a study on 60 potato producers' in Bangladesh. The stochastic frontier approach was used to find a mean technical efficiency of 86% implying that there was a 14% chance of improving the farmers' efficiency level with present level of technology through better reallocation of resources. Alam *et al*. (2012) to examine potato production technical efficiency of 76 farmers adopted the same approach. The maximum likelihood estimation outcomes suggested that the overall mean technical efficiency level was 81.2%.The findings indicated a likelihood of improving potato generation by 19% through better utilization of the available resources given the current state of technology.

Shavgulidze *et al*. (2017) employed a stochastic frontier approach to evaluate potato production technical efficiency in mountainous Kazbegi district of Georgia. The production frontier parameters were estimated by applying the maximum likelihood method. The approximated mean technical efficiency level in potato production was 81% in the study area. These results demonstrated a possibility of increasing potato production through better utilization of the available inputs and better management practices. In a study by Tiruneh *et al*. (2017) technical efficiency was analysed by employing the stochastic frontier and Translog functional form in a one-step approach. The maximum likelihood parameter estimates for the model indicated that rain-fed and irrigated potato farmers in the study area were not technically efficient. Rain-fed and irrigated potato farmers mean technical efficiency was 81% and 68% respectively.

To assess potato production technical efficiency of 147 smallholder farmers in Dinsho District of Bale Zone of Ethiopia Dube *et al*. (2018) used a Cobb-Douglas functional form under the stochastic frontier approach. The model results suggested that smallholder wheat farmers' mean technical efficiency level was 89%. The result demonstrated that wheat producers have a chance (11%) to boost wheat production with the available amount of inputs and existing technologies accessible to the smallholder wheat producers. The above literature points out that stochastic frontier analysis is commonly preferred as evidenced from its adoption in analysing irish potato production technical efficiency. Therefore, SFA was suitable for estimating technical efficiency in this study since the approach had not been adopted in the study area.

2.3 Farm Inputs and Irish Potato Production

Agricultural resources are significant determinants of yields of any type of agricultural production. Farm inputs consist of but are not limited to seed, fungicide, manure, fertilizer, labor and machinery. Irish potato production is influenced by availability of clean seeds, diseases and labor (Lamin, Fatty & Sambou, 2013; Muthoni *et al*., 2013). Seeds are a crucial element in agricultural production while fertilizers incorporate the necessary soil nutrients at various stages of production. Fungicides are also a necessary farm input, as crops are susceptible to pests and diseases that can lead to huge losses for smallholder farmers. Fluctuations in inputs, technical inefficiency and random shocks lead to the variations (Alam *et al*., 2012). Thus, a deterministic model assuming that output level fluctuations are due to inefficiency is not adequate. A stochastic frontier model captures output fluctuations because of technical inefficiency and random shocks and decomposes them. This approach can be used to model the input – output relationship in irish potato production to find out whether the cause of variations in production (Coelli *et al*., 2005).

2.4 Smallholder Farmers' Socio-demographic Characteristics and Irish Potato Production Technical Efficiency

Socio-demographics refer to the population characteristics such as farming experience, gender, education level, marital status and race that determine the population's behaviour. Specific farmer characteristics affects their agricultural production (Cooker, Ibrahim & Ibbeziako, 2018) by influencing how they exploit the farm inputs. Therefore, socio-demographic characteristics of farmers influences their production technical efficiency (Von Braun & Mirzabaev, 2015). Understanding the socio-demographic features of smallholder farmers is significant in providing a basis to policy makers for formulating strategies that focus on enhancing irish potato production (Taiy, Onyango, Nkurumwa & Ngetich, 2017). Mere knowledge on whether the farmers are technically efficient or not is not beneficial unless the causes of inefficiency are known (Dessale, 2019). Furthermore, Mwaniki (2006), Abdul-kareem and Sahinli (2018) emphasized that improving of agricultural production capacity amongst farmers' needs sufficient information about their socio-demographic characteristics. Thus, to improve irish potato production adequate information on farmers' socio-demographic characteristics affecting their capacity to generate the highest level of output for a particular group of inputs is crucial.

2.5 Smallholder Farmers' Institutional Factors and Irish Potato Production Technical Efficiency

Several studies have indicated that institutional factors tend to influence technical efficiency of agricultural production (Rahut & Scharf, 2012; Piya & Lall, 2013). Institutions are known as human devised restrictions that form human interactions (North, 1990) such as extension services, farmer group and financial institutions. Institutions forbid, allow or require a particular type of action aimed at decreasing transaction costs, boosting information flows, defining and implementing property rights. Institutions are categorised into formal (governed by formal written rules) and informal institutions guided by unwritten informal codes of conduct.

In agricultural sector, institutions such as extension services, farmers group and financial institutions contribute significantly to decreasing transaction costs along all stages of the agricultural chain. According to Gebremichael (2016) and Premarathne (2011) total agricultural production not only relies on the economic factors such as labour, capital, land and water but also on institutional factors. Therefore, analysing the effect of institutional factors on irish potato production is necessary to boost irish potato yields as it shows which institutions support farmer to be technically efficient.

2.6 Effect of Farm Inputs on Crop Production Technical Efficiency

2.6.1. Land and Crop Production Technical Efficiency

Land is an important farm input in crop production. Land size is directly correlated to production (Taiy *et al*., 2017). Thus, farmers with large land sizes are expected to experience increased production. In the analysis of sorghum production technical efficiency of smallholder farmers in Konso district, Southern Ethiopia Gemeyida *et al*. (2019) found that land is a significant farm input in raising the amount of sorghum produced in the study area. In contrast, Barasa, Odwori, Barasa and Ochieng (2019) examined technical efficiencies of smallholder irish potato farmers in Trans Nzoia County. The maximum likelihood estimates of the stochastic frontier indicated that the land was not a significant factor of production in irish potato farming.

A study by Dube *et al*. (2018) analyzed technical efficiency of potato generation by smallholder farmers in Dinsho District of Bale Zone of Ethiopia. The Cobb-Douglas production results indicated that the land under potato was positive and significantly determined irish potato production. Similarly, Tolno, Kobayashi, Ichizen, Esham and Balde (2016) surveyed the determinants of the potato production by smallholder farmers in Guinea. The model outcomes demonstrated that land under potato significantly affected the potato yield. Taiy *et al*. (2017) examined the faming system of smallholder farmers in Nakuru County by describing the farm size under potato crop. Majority of the irish potato farmers were reported to have farms ranging from 0.1 to 0.5 hectares. In another study Muthoni *et al*. (2013) analysed potato production in Nakuru County and reported that the average farm size under potatoes for Molo and Elburgon to be 1.13 hectares and 0.89 hectares respectively. From the studies reviewed, land is key factor in crop production but the effect of land under irish potato production in Nakuru County remains unclear.

2.6.2 Seed and Crop Production Technical Efficiency

Planting more seed increases the crops population and therefore raises production. Ayedun and Adeniyi (2019) examined efficiency of 408 rice peasant farmers in North Central zone of Nigeria focusing on Benue and Nasarawa States. From the Cobb-Douglas frontier model, results demonstrate that the amount of rice seed planted positively and significantly affected rice production. Similarly, Barasa *et al*. (2019) found that the amount of seed positively and significantly affected irish potato production of farmers in Trans Nzoia County. A study by Wollie (2018) sought to investigate on barley production technical efficiency of 123 smallholder farmers in Meket region, Amhara national regional state, Ethiopia. The study results implied that barley seed had a negative effect on barley production.

Asfwa *et al*. (2019) established wheat production economic efficiency of smallholder farmers in Abuna Gindeberet district, Oromia National Regional State, Ethiopia. They found out that wheat seed to be significant in wheat production. In Baglung district of Nepal, Bajracharya and Sapkota (2017) examined the productivity of potato and found that potato seed quantity to affect potato production. Taiy *et al*. (2017) did an analysis on the farming experiences of the smallholder farmers in Nakuru County.

The researchers reported on access to potato seed based on the source and availability of seed to the producers. Majority of the farmers were found to obtain seed from open-air markets. From the above literature reviews, seed input is seen as a significant farm input in crop production but there exists a knowledge gap on the effect of potato seed on irish potato production in Nakuru County.

2.6.3 Labour and Crop Production Technical Efficiency

Crop production is a labor-intensive activity and thus its significance cannot be ignored. A study was carried out by Ayedun and Adeniyi (2019) on rice production efficiency of farmers in North Central zone of Nigeria focusing on Benue and Nasarawa States. From the Cobb-Douglas frontier model results, there is a positive and a significant relationship between rice production and the amount of hired labor. Gemeyida *et al*. (2019) assessed technical efficiency of 124 sorghum smallholder farmers in Konso district, Southern Ethiopia. From the estimated stochastic production frontier model, labour was observed to be an important factor in increasing the level of sorghum output in the study area.

Abubakar and Sule (2019) assessed technical efficiency of 120 maize farmers in Rijau local government area of Niger state. The Cobb-Douglas results suggested that labour increase improves maize production in the study area. A study by Dube *et al*. (2018) on technical efficiency of potato production by smallholder farmers in Dinsho District of Bale Zone of Ethiopia revealed that labor in man-days was positive and significant in irish potato production. The above studies signify the importance of labor in crop production but there is a knowledge gap on the effect of labor on irish potato production in Molo Sub County.

2.6.4 Fertilizer and Crop Production Technical Efficiency

Fertilizer plays a key role in replenishing used up soil nutrients. Irish potato producing areas especially in the highlands have low soil fertility (Muthoni and Nyamongo, 2009). Abubakar and Sule (2019) did an analysis of technical efficiency of maize production in Rijau local government area of Niger state. The Cobb-Douglass results implied that fertilizer is a significant farm input in maize farming. A consistent observation was made by Gemeyida *et al*. (2019) who investigated smallholder farmers’ sorghum production technical efficiency in Konso district, Southern Ethiopia .From the estimated stochastic production frontier model Urea and DAP chemical fertilizers were observed to be important factors in increasing the level of sorghum production.

Maganga (2012) in his study of irish potato technical efficiency in Dedza district, found that fertilizer was significant in irish potato production based on the results obtained from the Translog stochastic production frontier model. In another study, Tolno *et al*. (2016) assessed the determinants of potato production by smallholder farmers in Guinea. The results of the Cobb Douglas production function showed that fertilizer positively influenced the potato production in the study area. The above studies reported that fertilizer positively affected various crop outputs but the effect of fertilizer on irish potato production in Molo Sub County is not known.

2.6.5 Fungicide and Crop Production Technical Efficiency

Crop diseases are a major contributor to crop low yields and thus the need for fungicides. A survey on technical efficiency of maize production in Rijau local government area of Niger state done by Abubakar and Sule (2019). The Cobb-Douglas results suggested that agro-chemicals were significant in maize production. However, Barasa *et al*. (2019) in determining technical efficiency of 384 smallholder irish potato farmers in Trans Nzoia County found that fungicides were not significant in increasing irish potato production in the study area.

Gela *et al*. (2019) analyzed the production efficiency of smallholder sesame farmers in Ethiopia. From the stochastic frontier model, the coefficient of fungicide variable was positive and significant in sesame production. Therefore, it increased sesame output. Shavgulidze, Bedoshvili and Aubacher (2017) utilized the stochastic frontier to investigate technical efficiency of irish potato production in mountainous Kazbegi District, Georgia. The analysis results found fungicides to be significant in influencing potato production. Muthoni *et al*. (2013) analysed farmer practices and constraints in potato production in three major districts Bomet, Molo and Meru. The study revealed that over 75% of the farmers cited diseases as the main potato production constraint. However, the authors did not show the effect of fungicide on irish potato production in Molo Nakuru County.

2.7 Effect of Socio-demographic Factors on Crop Production Technical Efficiency

2.7.1 Education and Crop Production Technical Efficiency

A study on 385 small-scale sesame farmers' technical, allocative and economic efficiencies in West Gondar zone, Ethiopia was conducted by Gela, Haji, Katema and Abate (2019).The Cobb-Douglass stochastic frontier results indicate that education level of the sesame producers positively and significantly influences technical efficiency. Asfaw *et al*. (2019) did a study on smallholder wheat farmers' economic efficiency in Abuna Gindeberet district, Western Ethiopia. The study sought to approximate the degree of technical, allocative and economic efficiencies amongst the smallholder wheat producers and to identify the factors influencing their efficiency levels. Stochastic production frontier approach and a two-limit Tobit model were applied in the analysis of data and the model results implied that education positively and significantly affects technical efficiency.

In another investigation, carried out by Dube *et al*. (2018) on potato production technical efficiency of 147 smallholder farmers in Dinsho district in Ethiopia. The approximated stochastic frontier production model jointly with the inefficiency model demonstrated that education substantially affects the farmers' efficiency levels in the study area. Using a stochastic frontier model Jote *et al*. (2018) showed that education level of the farmers is an important socio-demographic determinant of sweet potato production technical efficiency in Southern region of Ethiopia. Tiruneh *et al*. (2017) studied the technical efficiency determinants of potato production in Welmera district, Oromia, Ethiopia. A Translog functional form was utilized to analyse the factors that influence potato production technical efficiency using a one-step approach. Education level of the family head positively and significantly influenced potato farmers' technical efficiency. Taiy *et al*. (2017) analysed the education level of smallholder irish potato farmers in Nakuru County. The study results revealed that majority of the farmers have low education level (primary and secondary education).Nevertheless; the authors did not show whether education affects their technical efficiency. The studies above extensively covered the effect of education on crop production technical efficiency in Ethiopia. However, in Nakuru County there is still a knowledge gap on the effect of education on crop production technical efficiency.

2.7.2 Gender and Crop Production Technical Efficiency

Gender does affect agricultural production as it is concerned with access and control of the production factors (Taiy *et al*., 2017). Danquah, Twumasi and Asiamah (2019) reported that gender of the household head was not fundamentally critical in maize production technical efficiency in the study area. They sought to examine the effect of land fragmentation on technical efficiency of 461 maize growers from the transitional zone of Ghana. The investigation utilized the stochastic production frontier model. Similarly, Botiabane, Zhou, Oluwatayo, Oyedokum and Oyelana (2017) analysed the effect of socio-economic factors on technical efficiency of smallholder sorghum farmers in South Africa. Using the Cobb-Douglas production functional form under the stochastic frontier approach, the authors found that gender was positive but did not significantly influence technical efficiency.

Abera (2019) did an investigation on teff production technical efficiency amongst 246 smallholder farmers in Debra Libanos district, Oromia National Regional State, Ethiopia. Parametric stochastic production frontier model was utilized to appraise level of technical efficiency in teff production while the two-limit Tobit regression model was utilized to gauge the variables influencing technical efficiency. The two-limit Tobit model results demonstrated that was gender of the family unit head positively and significantly influenced technical efficiency. Itam, Ajah, Ofem and Abam (2015) applied the stochastic production frontier in analysing technical efficiency of smallholder cassava growers in Cross River state. They found that gender was negative and significantly affected cassava production technical efficiency. Susan (2011) argued that female-controlled households are more technically efficient than male-controlled household in their farm activities.

Taiy *et al*. (2017) conducted a study to determine the socio-economic characteristics of smallholder irish potato producers in Nakuru County. The results reflected that most of the farmers were male. The authors failed to establish the effect of gender on irish potato production. The reviewed literature suggests that gender can affect technical efficiency or not. However, information on the effect of the gender on irish potato production technical efficiency in Nakuru County is not clear.

2.7.3 Household Size and Crop Production Technical Efficiency

A study by Ayedun and Adeniyi (2019) analysed rice production efficiency by peasant farmers in North Central zone of Nigeria using Benue and Nasarawa States as case studies. A stochastic production frontier approach was applied to assess the sources of technical inefficiencies. Among the variables considered to affect technical inefficiency included family size. The study outcomes suggested that family size negatively affected technical efficiency. Gemeyida *et al*. (2019) examined factors that affect efficient use of farm inputs by 124 smallholder sorghum growers in Konso district, Southern Ethiopia. Technical efficiency levels at individual farm capacities were assessed by applying the stochastic frontier production function approach and the approximated model demonstrated that family size significantly affects the level of technical efficiency.

Likewise, Dube *et al*. (2018) analysed the technical efficiency of 147 smallholder potato farmers in Dinsho District of Bale Zone of Ethiopia. The inefficiency parameters showed that family size significantly determined the efficiency level of farmers in potato production in the study area. According to Nwachukwu and Onyenweaku (2007) household size reduces the magnitude of resources allocation to farming activities, as they observed that households with relatively fewer active members fully exploit the available resources and hence being more efficient. Mulinga (2017) analysed the socio-economic factors affecting technical efficiency of smallholder maize farmers in Rwanda. Maximum likelihood method was used to estimate technical inefficiency effects of socioeconomic factors. The study concluded that the family size had no significant impact on farmers' inefficiency. Gichimu, Macharia, Mwangi (2015) did a study on the factors affecting efficiency of passion fruit producers in the Kenya highlands. The production frontier results found household size does not affect the level of technical efficiency. Based on the above studies household size cannot be assumed to affect technical efficiency of the smallholder irish potato farmers. Therefore, this study sought to build knowledge on its effect on irish potato technical efficiency in Molo Sub County.

2.7.4 Farming experience and Crop Production Technical Efficiency

Tukura and Ashindo (2019) performed a study on the determinants of technical efficiency of sesame production in Kurmi local government area of Tarabe state, Nigeria. The results of the stochastic frontier indicated that farming experience is negative in the inefficiency model and significantly affects technical efficiency. Mwalupaso, Wang, Rahman, Alavo and Tian (2019) carried out a study on technical efficiency of maize production in Zambia. To estimate the effect of farming experience on maize farmers' technical efficiency, a Cobb-Douglass production function was adopted. The results indicated that farming experience variable is significantly and positively associated with technical efficiency. Gichimu *et al*. (2015) conducted a study on factors that affect passion fruit production technical efficiency in Kenyan highlands. The study esults established surprisingly that farming experience in passion fruit farming reduces farmers' level of technical efficiency. Chepkwony (2014) also did find that Irish potato farmers experience has a significantly negative influence on technical efficiency made a similar finding.

Abubakar and Sule (2019) investigated technical efficiency of 120 maize farmers in Rijau local government area of Niger state, Nigeria using a stochastic frontier approach. The study determined the technical efficiency of the maize farmers and the factors that influence it by applying the Cobb-Douglas functional form of the stochastic frontier model. The results revealed that farming experience did not significantly affect technical efficiency of the maize producers. In light of the above studies, judgement on the effect of farming experience on irish potato production technical efficiency cannot be conclusively made. Thus, the study sought to find out the effect of farming experience on irish potato production technical efficiency.

2.8 Effect of Institutional Factors on Crop Production Technical Efficiency

2.8.1 Access to Extension Services and Crop Production Technical Efficiency

Gemeyida *et al*. (2019) estimated the technical efficiency and identified sources of technical inefficiency in sorghum production by 124 smallholder farmers in Konso district, southern Ethiopia. The Cobb-Douglas functional form was specified to estimate the stochastic production frontier and estimate the determinants of technical efficiency. The model results found that farmers who accessed extension services were technically efficient. Asfaw *et al*. (2019) aimed to identify the factor affecting efficiency of smallholder wheat farmers in Abuna Gindeberet district, western Ethiopia. The two-limit Tobit model result showed that technical efficiency was positively and significantly affected by access to extension services. Another study by Dube *et al.* (2018) analyzed the technical efficiency of potato production by smallholder farmers in Dinsho District of Bale Zone of Ethiopia. Cobb-Douglas stochastic frontier approach was used to estimate the technical efficiency levels in potato production. The estimated stochastic production frontier model together with the inefficiency parameters showed extension services significantly determined efficiency levels of farmers in potato production.

Ullah, Khan and Zheng (2017) employed Translog stochastic production frontier model to examine the technical efficiency and its determinants of peach farmers in Khyber Pakhtunkhwa province of Pakistan. The results suggested that access to extension services has a positive influence on technical efficiency. In another survey, Ntabakirabose (2017) carried out an investigation on the factors influencing maize productivity and efficiency in Rwanda. The researcher used a Tobit model to identify factors affecting efficiency level and access to extension services was found to be statistically significant. Ho, Yanagida and Illukpitiya (2014) examined the effect of extension services on technical efficiency of smallholder coffee farming in the Krong Ana Watershed, Vietnam. The authors deduced that access to agricultural extension service affected technical efficiency positively in coffee production. Similarly, Ahmed, Suleiman and Aminu (2013) reported that technical efficiency of farmers is positively associated with their access to extension services. Ogeto, Mshenga, Cheruiyot and Onyari (2012) analysed farmers' institutional characteristics and their influence on participation in sorghum production in Nakuru County. Data was analysed using double hurdle model and access to extension was found to significantly influence sorghum production. The above studies showed that access to extension services influences technical efficiency of crop production. Nevertheless, the effect of access to extension services on crop production technical efficiency is not clear in Nakuru County.

2.8.2 Farmer Group and Crop Production Technical Efficiency

Farmer group or association is an organizations owned and controlled by the members with the aim of rendering services for mutual benefit of all its members. Farmer group enhance accessibility to credit, extension services, marketing of produce and farm inputs for smallholder farmers. Through farmer group, members are expected to enhance adoption of modern agricultural technologies, which is anticipated to increase agricultural production (Ahmed & Anang, 2019).

Farmer associations are crucial institutions for empowering and alleviating poverty amongst farmers and the rural poor (Otego *et al*., 2012). Individual smallholder are vulnerable when operate on their own. Collective action is important in agricultural production as it contributes towards reduction of transaction costs and strengthens farmers' production power (Kherallah & Kirsten, 2001). Furthermore, farmer groups' benefit members when they are adequately resourced. The benefits such as access to services and input delivery contribute towards improving farms' performance and profitability. Nevertheless, farmer groups' may digress from their core mandate while free-riding behavior of some members may also reduce the groups' effectiveness. Furthermore, increased politicization of farmers has the tendency to reduce effectiveness of these groups due to political influences and favoritism (Ahmed & Anang, 2019).

In a study to examine and compare the technical efficiency of shallot production in different seasons Astuti, Daryanto, Syaukat and Daryanto (2019) employed the stochastic frontier analysis. The study found out that membership to farmers group was positive and significantly affected the level of technical inefficiency. This meant that farmers who were members of farmers group had a lower level of technical efficiency. This could be because farmers who members of a farmer group spend more time planning and requesting input assistance from the government or the private sector, seeking information about higher prices, and has variety of market access than increasing knowledge in the field of agronomy. Hence, farmer groups' transfer of knowledge and technology from was not focused on cultivation commodity of shallot. Gela *et al*. (2019) analyzed technical allocative and economic efficiencies of small- scale farmers in west Gondor zone, Ethiopia. The Cobb-Douglas stochastic frontier result showed that association membership variable positively and significantly affected production efficiency of sesame producers. This was because farmers who were a member of an association will have a chance to obtain current information and an opportunity to receive credit for purchase of farm inputs that makes a producer to be more technically efficient in sesame production.

An analysis was done by Mbarga, Sotamenou, Tabe-Ojong and Molua (2018) employing the two-staged DEA technique to evaluate the technical efficiency of maize farmers in the Lekie division of the Centre region of Cameroon and the determinants of technical efficiency. The results showed that participating in a farmer group significantly increase technical efficiency. Similarly, Ma, Renwick, Yuan and Ratna (2018) similarly pointed out that technical efficiency for farmers who were members of a cooperative was higher relative to those who were non-members of cooperatives. Ogeto *et al*. (2012) analysed institutional factors in sorghum production in Nakuru County. The double hurdle model results imply that access to group membership significantly influences sorghum production. From the above empirical studies access to extension services influences technical efficiency in the production of various crops. However, the effect of farmer group on technical efficiency in the context of smallholder irish potato farmers remains unclear in Molo Sub County.

2.8.3 Access to Credit and Crop Production Technical Efficiency

Credit availability improves farmers' liquidity situation thereby improving access to new technology, and inputs in particular, for increased technical efficiency. Abate, Dessie and Mekie (2019) analysed technical efficiency of smallholder farmers in red pepper production in North Gondar zone Amhara regional state, Ethiopia. The estimated stochastic frontier production model together with the inefficiency parameters shows that credit access was statistically and significantly affects the level of technical efficiency of red pepper farmers in the study area. Dessale (2019) conducted a study on identifying the level of technical efficiency of smallholder wheat producers of Jamma district, Ethiopia and its determinants. The estimated stochastic production frontier model together with the inefficiency parameters showed that credit had a negative effect on technical inefficiency. Therefore, that credit availability leads to more technical efficiency.

Similarly, Ullah *et al*. (2017) pointed out that credit access has positive influence on technical efficiency. Credit availability enables farmers to buy inputs on time that they could not buy from their own resources. Credit accessibility facilitates overcoming liquidity constraints, which may affect smallholders' ability to apply inputs and implement farm management decisions on time (Gebremichael, 2016). Ho *et al*. (2014) examined the factors affecting technical efficiency of smallholder coffee farming in the Krong Ana Watershed, Vietnam. The authors deduced that the access to financial credit influences technical efficiency in coffee production. Taiy *et al*. (2017) conducted a study to determine the socio-demographic characteristics of smallholder farmers in Nakuru County. The researchers elicited information on gender, age, education, farming systems, household income and household practices but failed examine the institutional factors of the smallholder irish potato farmers. The above studies point out the significance of access to credit on technical efficiency in various crops. However, there is a knowledge gap on the effect on smallholder irish potato farmers technical efficiency in Nakuru.

2.9 Theoretical Framework

2.9.1 Production Theory

This section provides a review of the production theory on which this study is anchored. Wicksteed (1894) was the initial economist to put together the relationship between production and inputs. However, Humphrey (1997) suggested that Johann von Thunen was the first to formulate the connection between inputs and production 1840's. Smallholder farmers problems include establishing what to produce, how much to produce and how to produce. A farmer needs to make decisions about the optimal inputs combination and mix for obtaining the final output. A production function shows the highest production coming from a particular set of inputs. Therefore, a production function formalizes the relationship between inputs and outputs. The relation between inputs and output can be expressed as:

$$Q = f(X_i) \quad \text{......i}$$

where, Q = output and X_i= various inputs. The Cobb-Douglas production function refers to a given level of technology such that if the levels of technology changes, the production function also changes. Thus, combinations of various inputs and output can be modelled using the Cobb-Douglas production function as follows:

$$Q = AL^{\beta}K^{\alpha} \text{……………..…………………………………ii}$$

where,

Q = Quantity of output produced

L= Labour input

K= Capital input

A =Total factor productivity

α = Output elasticity of capital

β= Output elasticity of labour.

The sum of α and β indicates the nature of returns to scale whether constant returns to scale (α+ β=1), decreasing returns to scale (0 ≤ α+ β ≤1) or increasing returns to scale ((α+ β>1) (Doll & Orazem, 1984).

Production systems are associated with technical efficiency and allocative efficiency as pointed out by Libenstein, Blair and Hodgson (1988), Farrell (1957) and Lovell, (1993). Production technical efficiency in a farm occurs when the maximum quantity of output is obtained from a given set of inputs. A farm is termed to be efficient when with a given technology; it can produce a given amount of output using minimum combination of inputs. Thus, farms operating along the production frontier are termed to be technically efficient while for those operating below the production frontier are said to be technically inefficient since they are producing less. The production function helps towards formulating a function that relates the irish potato production to the farm inputs used to produce it. Therefore, for this study the production function allowed irish production (Q) to be expressed as a function of the farm inputs such as land, seed, labour, fertilizer and fungicide. Hence, the production function of smallholder irish potato farmers in the study area was expressed as:

$$Q = f(X_1, X_2 , X_3, X_4, X_5) \text{…………………………………………………iii}$$

where, Q =Irish potato production, X_1 =land variable, X_2 =seed variable, X_3=labour variable, X_4 =fertilizer variable and X_5= fungicide variable. As more inputs are used, output is expected to increase up to a particular point whereby more inputs will have negative effects on production due to overutilization. Therefore knowing the maximum levels of farm inputs to use is important.

2.9.2 Efficiency Theory

Farrel (1957) pointed out that the success of an enterprise is measured by producing maximum output from a given set of inputs. This is known as technical efficiency. The manner in which farm resources are handled affects realization of maximum production. The same amount of farm inputs can be used to produce more output or the inputs can be reduced to generate the same amount of output with the available level of technology. A particular farmer's level of technical efficiency can be determined by comparing the observed output with the ideal or potential production (Greene, 2003). Efficient use of inputs among the smallholder irish potato farmers' is expected to be affected by their socio-demographic traits and institutional factors. These factors affect the farmer's ability to manage and exploit resources efficiently. This relationship can be expressed as:

$$TE = f(W_1, W_2, W_3, W_4, R_5, R_6, R_7) \qquad \text{iv}$$

where, TE= Irish potato production technical efficiency, W_1= education variable, W_2= gender variable , W_3=household size variable , W_4=farming experience variable, R_5= extension service variable, R_6= farmer group variable and R_7= credit variable.

2.10 Conceptual Framework

The production process involves a transformation of inputs into outputs. Inputs alongside outputs can be different from one type of production to another. In potato production, inputs comprise of land, quantity of fertilizer, quantity of potato seed, labour and fungicide to produce output. Transformation of inputs into output efficiently is not only dependent on the inputs alone but also on how the farmer manages and exploits the farm inputs. Irish potato production technical efficiency in particular in the study area are likely to be affected by different farm inputs, farmer socio-demographic characteristics and institutional factors (Figure 1). Past studies, for instance, Gemeyida *et al*. (2019), Abate *et al*. (2019) and Gela *et al*. (2018) showed that socio-demographic and institutional factors influence technical efficiency of production. These factors directly or indirectly affect the quality of farm management by the farm operator. Therefore, they are believed to bring about technical efficiency variation among smallholder irish potato farmers. Some external factors such as government policies also affect irish potato production technical efficiency. The irish potato subsector is governed by relevant clauses anchored in the Crop Production and Livestock Act [CAP.321] (Ministry of Agriculture, Livestock and Fisheries [MOALF], 2016).

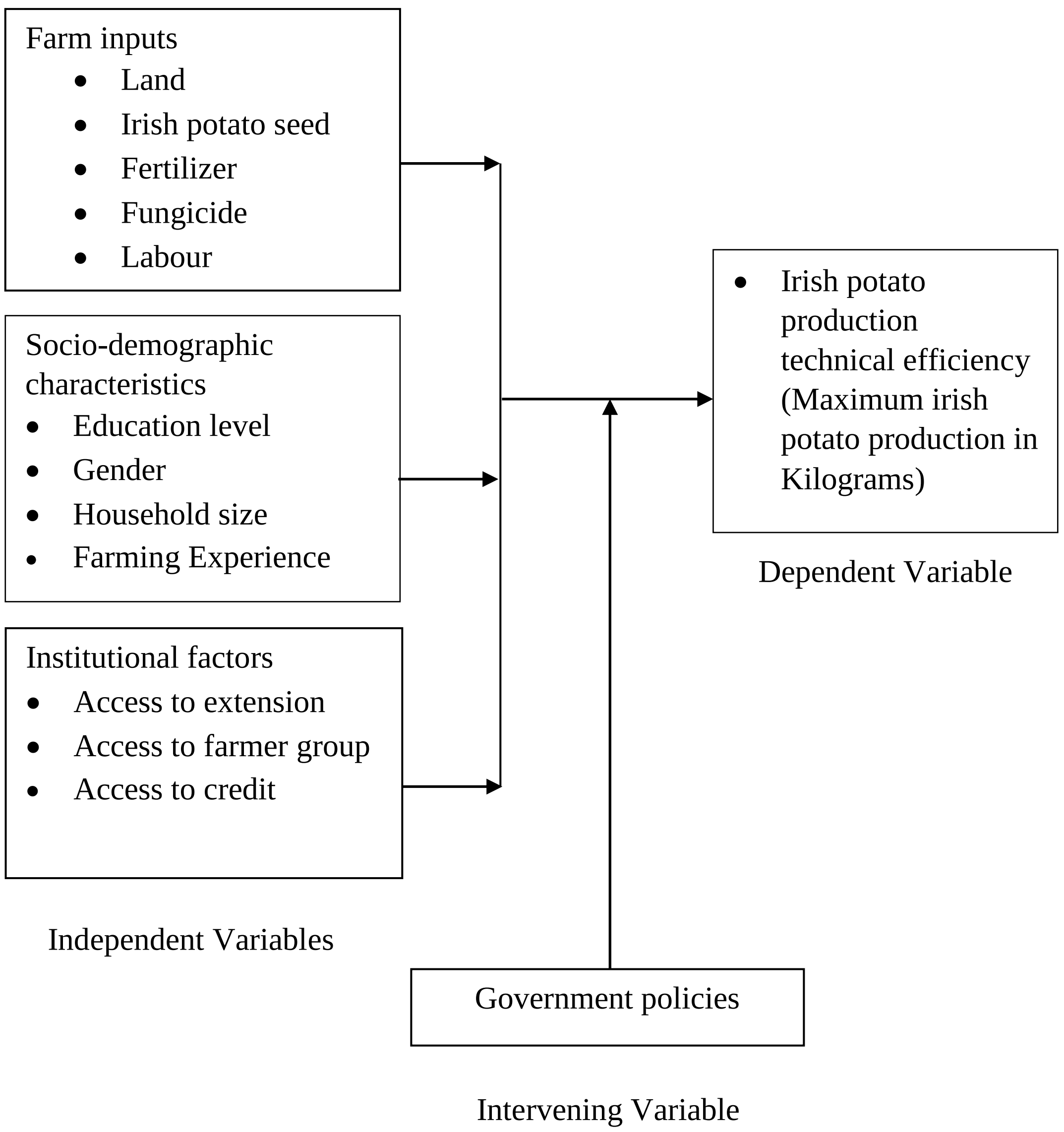

Figure 1: Conceptual Framework

CHAPTER THREE

METHODOLOGY

3.1 The Study Area

The study was conducted from April to June 2019 in Molo Sub County in Nakuru County located in the Rift Valley (Figure 2). Molo Sub County is one of the six Sub Counties in Nakuru County. The Sub County has a total area of 478.79 Km^2 and a population of 140,584(County Government of Nakuru, 2017). It is located along the Mau forest running on the Mau escarpment. Administratively, the Sub County has four wards: Mariashoni, Elburgon, Turi and Molo.

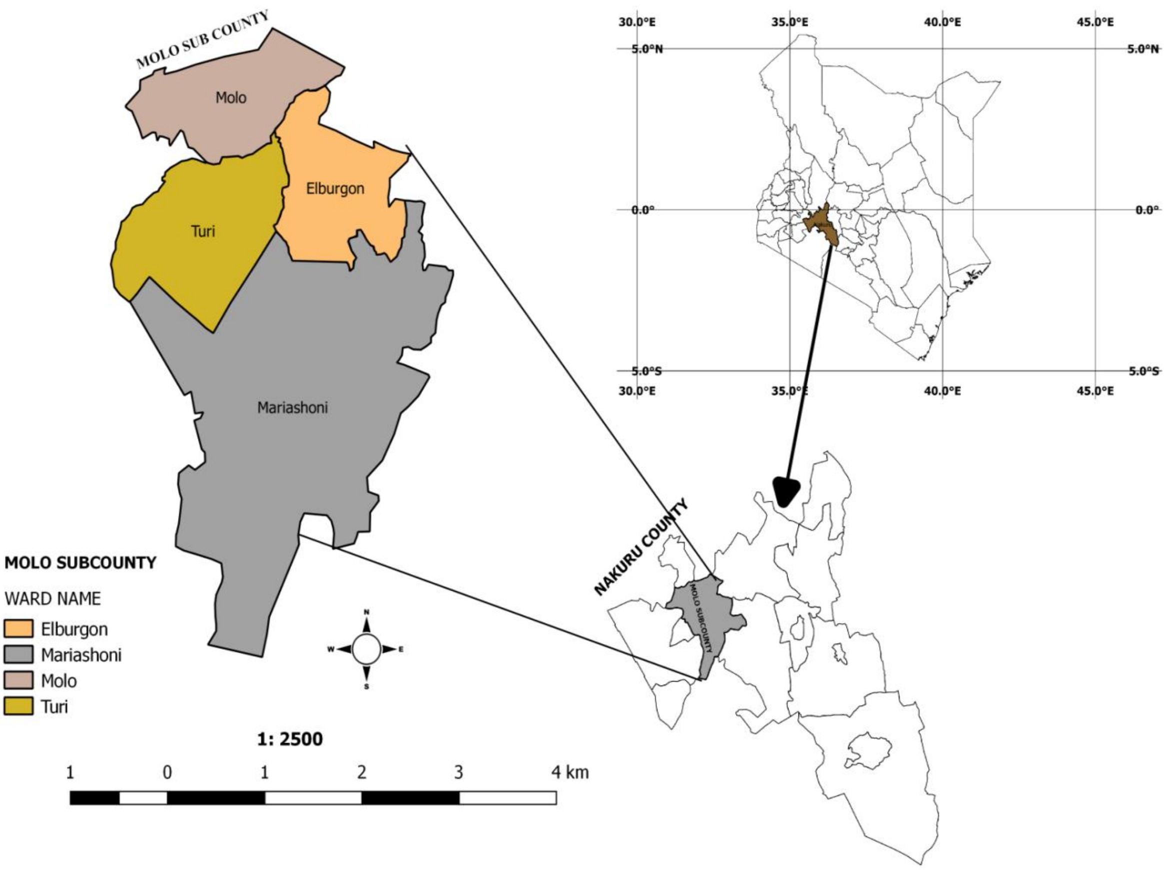

Figure 2: Molo Sub County Map (Kiptoo, Itumbi, Ngari and Kingori, 2017)

Most of its inhabitants migrated from Central and Nyanza regions due to its soil fertility and vast vegetation. Molo Sub County is situated at 0.25° South latitude, 35.73° East longitude and 2534 meters above sea level, with 27,896 inhabitants. Molo is ranked the second largest irish potato producer in Kenya with fertile lands. It hosts the irish potato seed multiplication project aimed at enhancing availability of certified seed for better yields. The areas climate is categorized as warm and temperate with the average temperatures at 14.1°C and an average rainfall of 1131 millimetres. The average farm size for food crops is less than an acre per household due to over subdivision of land into small parcels of land confirming most farmers in the study area to be smallholder farmers (NCIDP, 2013). Generally, the main economic activities in this area include crop farming, dairy and sheep rearing. The main crops are maize, pyrethrum, irish potato and barley (Jaetzold, Schmidt, Hornetz & Shisanya, 2006).

3.2 Research Design

The study adopted descriptive research design to provide a snapshot of smallholder irish potato farmers in Molo Sub County. The research design allowed for a description of the socio-demographic and institutional factors that characterize smallholder irish potato farmers at a given point in time (Levin, 2006). The advantage of cross-sectional research data is that researchers are able to compare many different variables at the same time or at a specific point in time. Thus, description of the smallholder irish potato farmers and their activities provided preliminary data for making inferences about possible relationships (Hall, 2011).

3.3 Target Population

Smallholder farmers cultivate on land that is less than two hectares of land (Salami, Kamara & Brixiova, 2010). This study concentrated on smallholder irish potato farmers located in Molo Sub County. The Annual Development Plan for the County Government of Nakuru (2017) approximates smallholder irish potato farmers in Molo, Turi, Mariashoni and Elburgon wards to be 6,450.

3.4 Sample Size and Sampling Procedure

The study sample size of smallholder irish potato farmers was computed as in Yamane (1967):

$n = \frac{N}{1+N(e)^2} = \frac{6450}{1+6450(0.05)^2}$ = 377 smallholder irish potato farmers…………………....v where,

n= desired sample size

N=population size

e = sampling error.

The study assumed 95% confidence (5% sampling error) to obtain a sample size of 377 smallholder irish potato farmers in the Molo Sub County. The study obtained the sample size for each ward proportionate to the population size of each ward. A multi-stage sampling technique was adopted in selecting farmers to be part of the sample. During the 1st stage, four wards in Molo Sub County were purposively selected and from each ward sub-locations were randomly selected. In the 2nd stage, villages from the selected sub-locations were identified randomly. Lastly, a list of smallholder irish potato farmers from the selected villages was generated with the support of the local administrative leaders and the ministry of agriculture extension officers to aid in the random selection of the farmers to be interviewed.

3.5 Pre-Test

Pre-testing of the survey questionnaire was carried out in Timau, Meru County from 15-19th of April 2019 targeting smallholder irish potato farmers in the region. The area has an altitude of 2300 meters above sea level making it a suitable for irish potato farming. During the pilot study, content validity and reliability analysis were performed to check whether the questionnaire contains all the relevant data.

3.5.1 Validity

Validity refers to how well the collected data covers the actual area of investigation (Taherdoost, 2016). Validity of the data collection instrument means that the questionnaire includes all essential elements while undesirable elements are eliminated. Content validity refers the extent to which an instrument reflects the content of the universe to which the instrument will be generalized (Taherdoost, 2016). The study used the judgemental approach of content validity involving conducting an exhaustive literature review to identify relevant items to be included in the questionnaire. The academic supervisors and experts in the field of irish potato production such as the ministry of agriculture extension officers validated the questionnaire used for this study.

3.5.2 Reliability

Reliability is the degree to which measurement of an occurrence gives stable and consistent outcomes. Reliability deals with repeatability (Taherdoost, 2016). Testing for reliability shows whether there is consistency across the questionnaire. A questionnaire is said to have high internal consistency reliability if repeat measurement made by it under constant conditions will give the same result. Reliability analysis was performed using the Cronbach Alpha and the Cronbach Alpha coefficient was $\alpha = 0.82$ (Table 2). Therefore, the items in the questionnaire proved to be worthy to be retained. George and Mallery (2003) provided the following rules of thumb: $\alpha > 0.9$ - excellent, $\alpha > 0.8$ - good, $\alpha > 0.7$- acceptable, $\alpha = 0.6$ - questionable, $\alpha = 0.5$ =poor, and $\alpha < 0.5$ = unacceptable.

Table 2. Results of the reliability analysis using the Cronbach Alpha

Variable	Value
Average interim covariance	1.25
Number of items in the scale	12
Scale reliability coefficient	0.82

3.6 Data Collection

The data collection tool was a survey questionnaire (Appendix 1) organized into the following main parts covering; farm inputs used in the last planting season, socio-demographic characteristics of the smallholder irish potato farmer, the institutional factors and the amount of irish potato produced. The interviewer obtained verbal responses used to fill the questionnaire accordingly.

3.7 Data Analysis

After data collection, coding was done followed by data analysis. To present and summarise information obtained from the interviewed smallholder irish potato farmers descriptive statistics for instance percentages, frequencies, means and standard deviations were used Econometric analysis was also performed on the data collected from the sampled farm households. It involved testing hypothesis to establish the appropriate production functional form that adequately represents the data using the generalized likelihood ratio test. The model parameters were estimated through the maximum likelihood method.

3.7.1 Econometric Model Specification

Economic relationships founded on optimization behaviour involve defining efficient frontier of maximum production attainment. Traditional econometric models assume that all economic agents are effective in attaining maximum production. However, Battese and Coelli (1995) asserted that the stochastic frontier is more relevant than traditional production function models in agriculture since production is affected by exogenous variables and random shocks. Factors that are beyond the farmers control such as; pest, diseases, weather conditions and a one-sided factor account for inefficiency in agricultural production (Boundeth, Nanseki & Takeushi, 2012). The specification of stochastic frontier model permits for the non-negative random factor in the error term to develop a function of technical inefficiency or the proportion of real or anticipated highest output level given a specific inputs and the existing technology (Boundeth *et al.*, 2012).

Battese and Coelli (1995) analysed technical efficiency and its determinants using a two-step approach. Their approach involved a first step of specifying and approximating the stochastic frontier model with the assumption that the inefficiency effects are identically distributed. In the second step, a regression model for the inefficiency model is then specified. However, this negates the earlier assumption of identically distributed inefficiency effects in the stochastic frontier leading to statistical biasness (Wang & Schmidt, 2002). Consequently, Belotti, Daidone, Ilardi and Atella (2012) proposed a one-step approach that allows for simultaneous approximation of both the stochastic and inefficiency model parameters through the maximum likelihood method. The one-step approach has the advantage of simultaneous approximation of the stochastic production function and determination of the factors influence technical efficiency (Danquah *et al*., 2019). Before conducting the analysis, it was appropriate to know the production function form that adequately represents the data.

3.7.2 Diagnostic Test

The likelihood ratio tests were performed to test the stochastic frontier model assumptions. Testing of hypothesis related to the model parameters was carried out through the generalized likelihood ratio statistic. The hypotheses tested were used to identify the correct production functional form for the study data set, to check for the presence of technical inefficiency and for variables that explain the variation in technical efficiency.

3.7.2.1 Justification of the Stochastic Functional Form

For this study, both Translog that is flexible and the Cobb-Douglas production function that is less flexible were considered. Among the possible algebraic forms, the common functional production forms include transcendental logarithmic (Translog) and Cobb-Douglas production functions. The Cobb- Douglas production function has some benefits over other functional forms since it allows for comparison of adequate fit and computational practicability. It is preferred where there are more than two independent variables and judicious with respect to degrees of freedom (Khai & Yabe, 2011). Its coefficients represent the elasticity of production hence making it easy to determine elasticity of the inputs (land, labour, fertilizer, fungicide and irish potato seeds. However, Cobb-Douglas functional form enforces strong assumptions on the nature of the farm technology making it restrictive.

The Translog functional form can also fit the data adequately if the cross product effects of the independent variables have an important role to play in the maximum likelihood estimation of the model parameters. This functional form is flexible in estimation and it can allow interaction among the factors of production (Sherestha, 1992 cited in Mohammad (1999). Although, Translog functional form suffers from the problem of multicollinearity (Shumet, 2011). For the selection of the correct functional form, a test was done on the null hypothesis by calculating the likelihood ratio (LR) as shown in equation 4 as suggested by Greene (2003). The test statistic is calculated as:

$$LR = -2\{ Ln[L(H_0) - L(H_1)]\} \ldots\ldots \text{vi}$$

where,

LR= likelihood ratio

$L(H_0)$ = log likelihood value of the Cobb-Douglas functional form

$L(H_1)$ = log likelihood value of the Translog functional form

Ln = natural logarithm.

The critical chi square value of the test is contained in Koode and Palm (1986) since the likelihood ratio statistic has a mixed chi-square distribution. To verify technical inefficiency existence among the smallholder irish potato farmers a null hypothesis specifying that technical inefficiency effects are absent from the model was suggested. This meant that irish potato farmers in the study area were technically efficient and there was no room for improving output. The null hypothesis fails to be accepted when the log likelihood value is found to be greater than critical chi-square value otherwise it is accepted.

The discrepancy ratio (γ) was also be used to determine the presence inefficiency by indicating by how much the socio-demographic and institutional factors of the individual farmers cause the variation in output levels. To ascertain that the variables explain the difference in efficiency the log-likelihood value of the function under stochastic frontier approach (a model without explanatory variables:H_0) and the full stochastic frontier model (a model with explanatory variables that are expected to determine inefficiency:H_1) were calculated. If the calculated likelihood ratio value is greater than the critical value, then the null hypothesis fails to be accepted.

3.7.3 Estimation of the Empirical Model

The stochastic frontier model parameters were estimated using STATA version 14 under one-step approach. The stochastic frontier approximation involved estimating the farm input parameters and identifying the factors that affect technical efficiency simultaneously using the maximum likelihood estimation method.

3.7.3.1 Effect of Farm Inputs on Irish Potato Production

A Cobb-Douglas functional form of a stochastic frontier model was adopted to test the first hypothesis that there is no statistical significant relationship between farm inputs on the irish potato production. The model was proposed by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977). It is usually appropriate for fitting agricultural production data because of its mathematical properties, computational ease and straightforward interpretation (Heady & Dillon, 1969).The stochastic frontier approach was applied because it has the ability to determine the effect of the farm inputs on output and at the same distinguish technical inefficiency from statistical noise. Irish potato production is likely to be influenced by random shocks such as harsh weather conditions, diseases, pest infestation, drought and measurement errors may be high and farmers technical efficiency level. Consequentially, a model that explains the effect of the inputs, statistical noise and the causes of inefficiency is more suitable. Thus, the stochastic frontier approach was suitable for this study. A basic stochastic frontier can be presented as:

$$Y_i = f(X_i, \beta) + \varepsilon_i \qquad \text{i =1, 2…, 377 farmer} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{vii}$$

where,

Y_i= Irish potato output for the 377 farmer in Kgs

X_i= $\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix}$ = the vector of farm inputs used in irish potato production

β_i= $\begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix}$ is a vector of farm inputs coefficients to be estimated

$f(x, \beta)$ = is a suitable Cobb - Douglas production function

ε_i= error term made of two separate components v_i and u_i

where,

$$\varepsilon_i = v_i - u_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{viii}$$

Component v_i contains the production variations because of random factors outside the control of the producer for example weather, natural disasters and measurement errors. The model assumes that each is independently and identically distributed N (0,δ_u^2). The u_i component represents technical inefficiency of the 377 farmers and takes only positive values ($u_i \geq 0$). Each u_i is distributed independently as a skewed normal distribution with zero mean and variance (δ_u^2). A farmer's production is said to be technical efficient if u_i =1 and technical inefficiency exists if, $u_i > 0$ irrespective of the value taken by u_i. Technical inefficiency in production (output deviation from the frontier because of socio-demographic and institutional factors) represented by the non-negative random variable u_i can be expressed as:

$$u_i = Z_i\beta_i \text{……………………………………………………………..ix}$$

where, $Z_i = \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \\ Z_5 \\ Z_6 \\ Z_7 \end{bmatrix}$ = vector of farmers' socioeconomic and institutional factors, $\delta_i = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \end{bmatrix}$ = vector of coefficients to be estimated. Using a linear representation, the stochastic frontier can be presented as:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + v_i - u_i \text{……...…………………x}$$

where, Y = natural logarithm of irish potato is the production

X_1=natural logarithm of land size

X_2=natural logarithm of seed quantity

X_3= natural logarithm of fertilizer quantity

X_4= natural logarithm of labor quantity

X_5= natural logarithm of fungicide quantity

β_0=constant

β_i= regression coefficient of the ith variables

v_i= variations due to random factors beyond the control of the farmer

u_i= technical inefficiency model

Technical efficiency of the 377 farmers may be expressed as a ratio between the observed irish potato production to the potential or frontier irish potato production, given the available technology. Hence, technical efficiency level can be expressed as:

$$TE = \frac{Y_i}{Y^*} = \frac{\exp(\beta X_i + V_i - U_i)}{\exp(\beta X_i + V_i)} = \exp(-U_i) \text{ ....xi}$$

where, Y_i=observed irish potato production level , Y^*= predicted irish potato production level. Technical efficiency takes a value ranging from zero to one indicating the level of technical efficiency for a farmer (Battese & Coelli, 1995). A value of one denotes that a farmer is completely technically efficient.

3.7.3.2 Effect of Smallholder Farmers' Socio-demographic characteristics and Institutional Factors on Technical Efficiency in Irish Potato Production

The farm inputs coefficients were simultaneously estimated with those of the socio-demographic and institutional factors. The technical inefficiency model was expressed as a function of socio-demographic and institutional variables as specified below:

$$u_i = \delta_0 + \delta_1 W_1 + \delta_2 W_2 + \delta_3 W_3 + \delta_4 W_4 + \delta_5 R_1 + \delta_6 R_2 + \delta_7 R_3 + e_i \text{............xii}$$

where, W_1= education variable

W_2=gender variable

W_3= household size variable

W_4= farming experience variable

R_1=access to extension service variable

R_2=access to farmer group variable

R_3= access to credit variable

δ_0= Intercept term

δ_1= Education regression coefficient

δ_2 = Gender regression coefficient

δ_3 = Household size regression coefficient

δ_4 = farming experience regression coefficient

δ_5 = access to extension service regression coefficient

δ_6= access to farmer group regression coefficient

δ_7= access to credit

u_i= inefficiency model.

e_i= error term

The stochastic frontier model proposed by Coelli and Battese (1995) is decomposed into a production function, random error term and factors affecting the technical inefficiency. The hypothesized variables of the production and technical inefficiency function are provided in Table 3.

Table 3. Description of the variables and their Expected Signs

Variable	Variable description	Measurement	Expected sign
Potato Output	Dependent Variable	Kilograms	
Independent Variables Inputs			
Land	Land allocated to potato farming	Hectare	+
Seed	Potato seed used	Kilograms	+
Fertilizer	Chemical fertilizer used	Kilograms	+
Labour	Labour used	Man days	+
Fungicide	Amount of fungicide applied	Litres	+
Socio-demographic Factors			
Education level	Education level	Years	+
Gender	Male or Female	Dummy (1= Male, 0= otherwise)	+/-
Household size	Person per household	Persons	+
Farming experience	Irish potato farming experience	Years	+
Institutional Factors			
Access to Extension services	Extension service	Dummy (1= Yes, 0= otherwise)	+
Access to farmer group	Farmer group	Dummy (1= Yes, 0= otherwise)	+
Access to credit	Credit	Dummy (1= Yes, 0= otherwise)	+

The rationale for inclusion of the particular factors was based on previous agricultural production literature. The model coefficients were expected to have either a positive or a negative sign, which signifies the effect of the variable on the dependent variable. A positive sign implies that the explanatory variable has an increasing effect on the explained variable.

3.8 Ethical Considerations

This study maintained high levels of integrity to ensure privacy and confidentiality of respondent's information. A research introductory letter (Appendix 2) informing respondents on the nature of this study and its objectives were availed by the researcher. The study ensured there was anonymity and confidentiality of respondents' responses for those who willingly participated in the study. The study complied with the Chuka University institutional ethical requirements (Appendix 3). A research permit was also obtained from National Commission for Science, Technology and Innovation (Appendix 4) with regard to collecting data and information related to this study.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Response Rate

This section shows the number of questionnaires that were filled and returned by the respondent. The results are as presented in Table 4.

Table 4. Response Rate of the Respondents

Ward	Population	Sample size	Achieved sample	Percentage
Elburgon	645	37	37	8.34
Mariashoni	2252	132	120	27.06
Molo	1319	77	77	17.36
Turi	2234	131	126	28.41
Total	6450	377	360	81.17

The information provided in Table 4 indicates that 81.17% (360) of the respondent filled and returned the questionnaires. This is an acceptable response rate and was achieved through the drop and pick method.

4.2 Land Management, Land Tenure System and Farm Size

Information on land management and land tenure system by the sampled smallholder irish potato farmers are as presented in Table 5.

Table 5. Land Management of the Sampled Irish Potato Farmers

Manager of the land	Frequency	Percentage
Household head	234	65.00
Spouse	47	13.06
Jointly (Household head and spouse)	65	18.06
Another male	8	2.22
Another female	6	1.67
Total	360	100
Land Tenure System	Frequency	Percentage
Land with title deed	174	48.33
Land without title deed	81	22.50
Communally owned	24	6.67
Rented in	69	19.17
Rented out	12	3.33
Total	360	100

The information presented in Table 5 shows that more than half (65%) of the heads of household sampled manage their farms. About 18.06% of the respondents jointly (household head and spouse) managed the land while management of land by another male was 2.22% and by another woman was 1.67%. Ayedun and Adeniyi (2019) reported consistent findings that household heads are the ones that mainly manage their land. The finding indicates the household heads mainly make farm management decisions in the study area. Therefore, he or she is the main decision maker of the household.

The results on land ownership system shows that about 48.33% of the respondents own land that has tittle deeds while 22.50% own land that does not have title deeds. Land owned communally was about 6.67% of the sampled farmers. This observation is most likely due to national government's increased effort to promote land ownership through issuance of tittle deeds in the study area. Land is a scarce resource hence not everyone in the study area owned a piece of land as 19.17% of the sampled households rented land for agricultural production and 3.33% of the sampled households rented out land. This finding is consistent with the study result of Taiy *et al*. (2017) who reported that most of the smallholder irish potato farmers in Nakuru County had tittle deeds. Land ownership system is an important consideration in agricultural production as it determines the kind of developments a farmer adopts on his or her land. Famers are willing to start long term and permanent undertakings on pieces of land that they own. The total farm size helps a farmer to decide on the kind of farming system to carry out and determines the level of production that will be obtained. Results on the total farm size of the respondents are as presented in Table 6.

Table 6. Average Farm Size of the Sampled Irish Potato Farmers

Variable	Mean	SD	Min	Max
Total farm size	2.297	1.427	0.25	6

According to the results, the average farm size is about 2 hectares with some of the smallholder farmers having 0.25 hectares as the minimum farm size and 6 hectares as the maximum farm size. These results are consistent with the findings of Muthoni *et al*. (2013) that potato farmers' average farm size is around 2 hectares. This confirms that irish potato farming is carried out by smallholder farmers in the study area.

4.3 Irish Potato Seed Use

This study sought to establish the kind of irish potato seed used by the farmers in the study area. The results on irish potato use and source are as provided in Table 7.

Table 7. Irish Potato Seed Type

Type of Irish Potato Seed	Frequency	Percentage
Certified	58	16.11
Uncertified	254	70.56
Both	48	13.33
Total	360	100
Source of Irish Potato Seed	Frequency	Percentage
Own farm	200	55.56
Other farmers	79	21.94
Government institutions	21	5.83
Irish potato seed companies	60	16.67
Total	360	100

The results indicates that more than half (70.56%) of the surveyed irish potato farmers in the study area use uncertified irish potato seed while 16.11 % use the certified seed in the production of irish potatoes. About 13.33% of the interviewed farmers use both certified and uncertified irish potato in the last planting season. Muthoni *et al*. (2013) reported that majority of the irish potato farmers use uncertified irish potato seeds. This implies that there is inadequate supply of certified irish potato seed forcing most of the farmers to use uncertified irish potato seeds. Another possible explanation for using uncertified irish potato seeds may be because the certified irish potato seed are expensive in comparison to the uncertified seeds thus most farmers resorted to using the uncertified seeds that are easily accessible

The survey results suggest that slightly more than half (55.56%) of the respondents obtain irish potato seed from their own farms. Thus, they use some of the irish potato harvested from previous seasons as seed for more irish potato production. Only, 21.94%, 5.83% and 16.67% respectively of the sampled farmers acquire their seed input from other farmers, government institutions and irish potato companies respectively. The government institutions for example KALRO and Agricultural Development Corporation (ADC) in Molo are key seed multipliers in the region. Taiy *et al*. (2017) similarly observed that potato farmers sourced their potato seeds from various places such as open-air market, other farmers, research centres and their own seed. Nyamwamu, Ombati and Mwangi (2014) reported consistent results indicating that the farmers obtained potato seed from their own farms, other farmers', farmer group, agricultural training centres and research institutions. The study result implies that most of the farmers do not obtain potato seed from recommended sources and this finding can be explained by poor seed supply and distribution system.

4.4 Fungicide Use

This study sought to establish the frequency at which farmers use fungicide in irish potato production in the study area. Table 8 presents results on the use of fungicide by the sampled smallholder irish potato farmers.

Table 8. Fungicide use by smallholder Irish Potato Farmers

Application rate	Frequency	Percentage
Always	132	36.67
Once in a while	228	63.33
Total	360	100

The study results show that all the smallholder irish potato farmers did apply fungicide in the last planting season. More than half (63.33%) of the respondents applied fungicide occasionally whereas about 36.67% always used fungicide in irish potato production. The results show that the frequency of fungicide use was low amongst the farmers. In contrast, Muthoni *et al*. (2013) observed that in Molo about 30% of the farmers did not use fungicides at all. This may be because fertilizer is expensive and the subsidized fertilizer is not easily accessible to the farmers.

4.5 Descriptive Statistics of Farm Inputs and Irish Potato Production.

Descriptive results on the five farm inputs namely land, seeds, fertilizer, fungicide and labour used in the analysis of irish potato production technical efficiency are as at presented in Table 9.

Table 9: Farm Inputs and Irish Potato Production

Variable	N	Mean	SD	Min	Max
Land (Ha)	360	2.229	1.403	0.25	6
Seed (Kgs)	360	912.036	84.514	50	4800
Fertilizer(Kgs)	360	0.938	0.024	0	1
Fungicide(Litres)	360	1.340	1.129	0.08	6.4
Labor(Man-days)	360	7.344	1.129	4	22
Irish potato production(Kgs)	360	2699.389	200.443	20	9000

The information presented in Table 9 depicts that the sampled irish potato farmers' allocated an average of 2 hectares to irish potato production. The mean land size under irish potato confirms that smallholder farmers carry out irish potato farming. The average amount of seed used is about 912 Kgs. The average amount of fertilizer applied in the production of irish potato is 0.938 Kgs during the last planting season with a standard deviation of 0.024 Kgs ranging from 0 to 1 Kg. All the sampled respondents were found to apply chemical fertilizer on their irish potato. On average, the sampled farmers applied 1.34 Litres of fungicide. The surveyed households employed an average of 7 man-days of labor in irish potato production. Labor comprised of both hired and family labor mainly used in farm operations such as ploughing, planting, weeding, and fungicide application. The average yield was 2,699.389 Kgs with 20 Kgs as the minimum yield and 9,000 Kgs as the maximum yield. Smallholder irish potato farmers mainly produced potatoes twice per annum since they depend on the rains (long and short rains). The results indicate that there is variability in irish potato production amongst the farmers.

4.6 Socio-demographic Characteristics of Respondents

The average statistics of the socio-demographic characteristics of the surveyed smallholder irish potato farmers in Molo Sub County are as provided in Table 10.

Table 10. Sampled Irish Potato Farmers' Socio-demographic Characteristics

Variable	N	Mean	SD	Min	Max
Age	360	38.461	5.180	19	77
Education	360	10.813	2.328	2	16
Household size	360	5.611	1.794	1	16
Farming experience	360	4.431	1.218	1	10

The results imply that the mean age of smallholder irish potato farmer was 39 years ranging from 19 to 77 years with a standard deviation of 5.180 years in the study area. This finding is in line with Osinowo and Tolorunju (2019) and Abubakar and Sule (2019) who reported that those involved in agricultural production were in their prime stage of life (below 50 years of age).This infers that most of the respondents were in their productive stage of life. Age has a significant role in the provision of labor for performing farm operations. The mean education level attained by the sampled farmers was 10 years of formal schooling ranging from 2 to 16 years. The study results are consistent with the outcomes of Danquah *et al*. (2019) who found that farmers with secondary school education recorded the highest percentage of education level (28.6%) in comparison with the other levels of education. This implied that they were literate but they had attained secondary school level of education. The average education level suggests that the respondents had low level of education. Education determines stock of farmers' human capital and was expected to influence technical efficiency positively. Consequentially, the greater the stock of human capital, the better a farmer's ability to organize and manage the factors of production for maximum efficiency. A farmer's level of education can influence his/her ability to adopt agricultural innovations and decide on various farm management issues. It boosts management of resources, acceptance of modern agricultural technology and by extension, increases production. This makes education to be an instrumental element in agricultural production.

The survey results indicate that the mean number of people living in a particular household size was about 6 persons per household. Danqua *et al.* (2019) reported consistent results with majority (55.3%) of the farmers had households containing an average of 6 persons. The findings coincide with Abubakur and Sule (2019) who reported that most of the sampled households in maize production had around 6 individuals. The members living in a household are a major source of family labour for the farm activities. Thus, a farmer's household size may influence agricultural production level through its supply of labour. The study expressed the smallholder farmers' potato farming experience in terms of years with the overall mean being around 4 years of experience with a minimum of 1 year and a maximum of 10 years. Similarly, Kebede *et al.* (2017) stated that the sampled irish potato farmers in Ethiopia had a mean farming experience of about 4 years in irish potato production. In contrast, Gebru *et al*. (2017) reported that the irish potato farmers mean farming experience of 20 years indicating that the farmers had a rich experience in irish potato farming. This study results implies that the farmers were moderately experienced in irish potato farming. Experienced farmers tend to make good farming decisions involving use of the farm inputs such as fertilizer rate, seed rate, seed spacing and efficient use of inputs in the farm. The more experience a farmer has the more likely production is to increase. Experienced farmers know how to manage farm inputs better minimizing production losses. The gender representation of the respondents was as presented in Table 11.

Table 11. Gender of Respondents in the Study Area

Gender	Frequency	Percentage
Male	204	56.67
Female	156	43.33
Total	360	100

The results show that male irish smallholder potato farmers were 56.67% of the respondents. The result is consistent with Abubakar and Sule (2019) who reported that maize production in Niger is male dominated. Similarly, Danquah *et al*. (2019) found that most of the surveyed farmers in the study area were males. Tukura and Ashindo (2019) also reported that the male sesame farmers were more than women were in Nigeria. This shows that males are actively involved in agricultural production than females. This study finding reflects that gender inequality existed in irish potato production in the study area. Probably, the men had more access to resources used in agricultural production than their female counterparts did. This may be because in an African setting women do not own land and have to stay at home to look after the children. The gender of a farmer is significant in agricultural production especially where family labour is the main source of labour. Male farmers give more labour input than female farmers do. Given the same amount of time to complete a farm activity, female farmers are more likely to take more time than men do or they would probably take more man-days than men do (Doss, 2018). Thus, male farmers play a crucial part in the provision of labour input and reduce the cost of hiring labour.

4.7 Institutional Factors

4.7.1 Access to Extension Services

This section displays information on the accessibility of extension services by the respondents in the study area as presented in Table 12.

Table 12. Access to Extension Services by the Sampled Smallholder Irish Potato Farmers

Access to Extension Services	Frequency	Percentage
Yes	256	71.11
No	104	28.89
Total	360	100
Source	Frequency	Percentage
Researchers	24	9.37
Farmer to farmer	32	12.50
Seed companies	28	10.93
County government	122	47.66
NGO's	26	10.16
Online groups	24	9.38
Total	256	100
No of Extension Contact	Frequency	Percentage
1-3	161	63
4-6	82	32
7-10	13	5
Total	256	100
Mean	1.07	
Minimum visits	1	
Maximum visits	10	

Access to extension services increases diffusion and adoption of innovation among farmers leading to increase in production, income and living standards of the farming households. The study results revealed that majority (71.11%) of the sampled irish potato farmers had access to extension services. Only 28.89% of the respondents did not access extension services in the study area. These findings contrast Nyagaka *et al.* (2009) who reported that majority of the irish potato farmers in had no access to extension services but are in line with Kebede *et al*. (2017) who reported that most of the respondents (111 out of 192) had access to extension services. Similarly, Ogeto *et al*. (2012) concluded that majority (58%) of the sorghum farmers in Nakuru County accessed agricultural extension services. This finding may be attributed to efforts made by government institutions and non-government institutions on dissemination of irish potato production technologies and innovation.

The study results indicate that 47.66% of the respondents accessed extension services from the county government extension officers while 10.93% of them accessed extension services from the irish potato seed companies. Researchers (9.37%), farmer-to-farmer (12.50%), non-government institutions (10.16%) and online groups (9.38%) were also some of the providers of extension services to the farmers. Evans (2014) observed similar results that farmers obtain extension services from government extension officers, non-government organisations, private and input companies. Majority (63%) of the farmers got around 1-4 visits from the extension officers, 32% of the respondents got around 5-8 visits while 5% got around 9-12 visits. Obare, Nyagaka, Nguyo and Mwakubo (2010) reported consistent results that the average number of times extension agents visited the smallholder irish potato farmers was 1.09. These results indicate that most of the irish potato farmers had low contact with the extension officers.

4.7.2. Access to Farmer Group

Farmers' association or group provides a platform for accessing information associated with marketing and availability of new technology. Table 13 shows findings on accessibility to farmer group in the study area.

Table 13. Access to Farmer Group by Smallholder Irish Potato Farmers

Access to Farmer Group	Frequency	Percentage
Yes	100	27.78
No	260	72.22
Total	360	100
Type of group	**Frequency**	**Percentage**
Chama	54	54
SAACO	10	10
Farmers' cooperative	22	22
Producer and marketing group	6	6
Youth group	8	8
Total	100	100
Group Function	**Frequency**	**Percentage**
Produce marketing	14	14
Input access	11	11
Savings and credit	50	50
Farmers training	10	10
Transport services	11	11
Sharing inputs	4	4
Total	100	100

The results of this study shows that out of the irish potato farmers sampled only 27.78% of them belonged to a farmer's group or association .Majority (72.22%) of the sampled smallholder irish potato farmers were not members of any farmer's group in the study area. Mwaura (2014) made a consistent observation that membership to farmer groups in Uganda is low. This is an indication of low farmer group membership. This may be because the farmers perceived benefits to be gained are lower than not joining. The decision to join a farmer group is contingent on the expected utility to be gained from being a member of a group. Hence, farmers are likely to join when the benefits of joining the group are perceived to be higher than not joining. Thus, there is need to mobilize the non-members to join a group so that they can enjoy some of the group benefits.

The study results on the various types of farmer groups that the respondents have access to revealed that slightly more than a half (54%) the sampled household heads were members of a '*Chama*', 10% of them were SACCO members, while 22% of them belonged to farmers' cooperatives . The rest, 6% and 8% of the respondents had access to a producer and marketing group and a youth group respectively. Similarly, Msuta and Ukarassa (2015) reported that the smallholder farmers in Kasulu district belonged to various types of farmer groups. This may be explained by the various benefits they get from them. A farmer group or association allows farmers to derive benefits from collective action. Service providers can also take advantage of these associations to linkup with farmers in the area to provide services such as loans, monitoring of agronomic practices and inputs to ensure improved efficiency in production (Muthoni *et al*., 2013).

The results on the group functions depict that half (50%) of the respondents consider savings and credit to be the core function of their group. Therefore, saving and obtaining credit is the most important function for them. About 14% of the sampled households consider produce marketing to be a significant function of their group, 11% confirmed that input access is the main function of their group. Only 10%, 11% and 4% of the sampled households consider farmers training, transport services and sharing inputs to be significant functions respectively. Kimaiyo, Joseph, Okia, Kegode, Kiptot, Isubikalu, Ssebetuka, Chemangei, Kabwe and Masikat (2017) also identified that farmer groups undertake similar activities and lending and borrowing is the most common group activity. The study results imply that the smallholder irish potato farmers are mainly challenged by financial constraints.

4.7.3 Access to Credit

Access to credit by farmers is essential for realizing full agricultural production potential. Table 14 shows results on the access to credit by the sampled respondents.

Table 14. Access to Credit by Smallholder Irish Potato Farmers

Response	Frequency	Percentage
Yes	65	18.06
No	295	81.94
Total	360	100
Reason	Frequency	Percentage
No need	11	3.73
Not aware of credit availability	55	18.64
Lack of enough collateral	111	37.63
High interest on credit	97	32.88
Long credit application procedures	21	7.12
Source	Frequency	Percentage
Commercial bank	5	7.69
Microfinance institution	11	16.92
SACCO	8	12.31
Farmers group	16	24.62
Informal sources	12	18.46
Mobile applications	13	20.00
Total	65	100
Purpose	Frequency	Percentage
Purchasing farm inputs	52	80.00
Paying school fees	6	9.23
Expanding business	5	7.69
Others	2	3.08
Total	65	100

From the information provided in Table 14, majority (81.94%) of the respondents did not have access to credit that could significantly contribute to their irish potato farming activities while only 18.06% accessed credit. The survey results are in line with Ogeto *et al*. (2012) who found that majority (80.7%) of the sorghum farmers in Nakuru County had no access to credit. Chenaa, Maria and Teno (2018) made similar revelations that majority of the smallholder farmers in their study did not have access to credit. In contrast, Kebede *et al.* (2017) established that 62% of the irish potato farmers accessed credit in their study. The study results imply that most of the farmers had low access to credit. Credit accessibility may reduce constraints experienced during production as credit facilitates timely acquisition of farm inputs. However, since credit access was poor farmer's ability to acquire the much-needed agricultural inputs on time was affected hence expected to reduce their level of production technical efficiency.

The survey results on reasons why most of the respondents did not access credit indicates that inadequate collateral to secure loan facilities was the main (38.01%) cause among the smallholder irish potato farmers in the study area . About 32.88% and 18.64% of the respondents gave high interest on credit and not being aware of where to obtain credit as reasons for not accessing credit respectively. The other reasons were long credit application procedures (7.12%) and 3.73% of them responded that they had no need for obtaining credit. These outcomes contrast Asante-Addo, Mockshell, Siddig and Zeller (2016) who found that the major reason why farmers did not access credit is that they had no guarantor. The study finding suggests that some of the farmers do not have a security for examples title deeds to the parcel of land they own. Therefore, they lacked security for acquiring credit.

The study result on the various sources of credit shows that 80% of the respondents obtained credit to purchase farm inputs, 9.23% of the respondents obtained credit to pay school fees, 7.69% of them took credit to expand their business and 3.08% of them took credit for other purpose such as buying of assets and consumption. This is in line with Awotide, Alene and Manyong (2015) who reported that majority (69.97%) of the cassava farmers accessed a loan buying inputs. These finding imply that most smallholder farmers access credit for agricultural purposes.

The study results further point out that 20% of the sampled household obtained credit from mobile applications, 24.62% of them accessed credit through farmer groups, 7.69% of the respondents obtained credit from commercial banks and 18.46% of the sampled farmers got credit from informal sources. About 16.92% and 12.31% of the sampled irish potato farmers obtained credit from microfinance and SACCO's respectively. These results are in agreement with Isaga (2018) who reported that smallholder farmers finance their activities from credit obtained from farmer association. The study results imply that farmer groups are a major source of credit to smallholder farmers.

4.8 Econometric Results

The study used STATA version 14 to obtain maximum likelihood estimates through the one-step procedure. The parameters of the stochastic frontier and the inefficiency model were estimated simultaneously.

4.8.1 Diagnostic Test Results

Identification of a suitable functional form between Cobb-Douglas and Translog production function was determined through a hypothesis test founded on the generalized likelihood ratio (LR) test. In order to choose between the two alternative functional forms that could represent the data gathered, the null hypothesis (H_0) was that not all the interaction and square terms are equal to zero while the alternative hypothesis (H_1) was that the coefficients are equal to zero. The likelihood ratio statistic was calculated as stated below;

$LR = -2\{\log[\text{Likelihood}(H_0)] - \log[Likelihood(H_1)]\}$= -2{-384.478-(-95.7040)} =577.47……………………………………….……………………………………..xiv

The critical chi square value $[\chi^2_{(5\%,\ 7)]}$ is equal to 13.401 (from Kodde and Palm, 1986), with approximately χ^2_7 distribution with 7 being equal to the number of coefficients assumed to be zero in the null hypothesis. The critical value was lower that computed likelihood ratio value hence, the null hypothesis fails to be accepted. This implies that the Cobb-Douglas production function adequately represented the surveyed smallholder irish potato farmers who were not fully technically efficient.

After establishing the appropriate production function, the next test involved determining the presence of technical inefficiency. The null hypothesis was that the smallholder irish potato farmers were efficient with no room for improving efficiency ($H_0 = \gamma = 0$). The alternative hypothesis was that there was inefficiency among the smallholder irish potato farmers in the study area ($H_{01} = \gamma > 0$).The gamma parameter, $\gamma = \partial u^2/(\partial u^2 + \partial v^2)$ lies between zero and one. If gamma equals to zero, the difference between observed farmer production and the predicted maximum production is due to statistical noise only. However, if the value is close to one then inefficiency significantly affects the production system (Anh, Bokelmann, Nga, & Minh, 2019). In this study, the null hypothesis was rejected since the gamma value for this study was greater than zero (0.944>0). Therefore, technical inefficiency in irish potato farming in the study area existed.

The variance ratio (γ) was estimated to be 0.944 implying that about 94.4% of the differences between observed production and the predicted (frontier) production levels are because of technical inefficiency. Hence, the variation in the observed output from the predicted output can be explained by socio-demographic and institutional factors of smallholder irish potato farmers. Therefore, there is room for improving irish potato output by identifying the institutional and socio-demographic factors causing the variation amongst the farmers. To establish whether the explanatory variables can explain the variation in technical efficiency amongst the smallholder irish potato farmers, a null hypothesis ($H_0: \delta_1 = \delta_2 ... = \delta_7 = 0$) was tested. The likelihood ratio statistic was computed by considering the log likelihood value of the stochastic function without explanatory variables hypothesized to cause inefficiency and the log likelihood value of the full frontier model with explanatory variables that are hypothesized to cause inefficiency. For the sampled households, the calculated value of the $LR = 2(-384.478 - 409.511) = 50.07$ which is higher than the critical value of 13.40 at 7 degrees of freedom. This implies that the null hypothesis that the explanatory variables are simultaneously equal to zero fails to be accepted at 5% level of significance. Therefore, the institutional and socio-demographic variables simultaneously account for the differences in technical efficiency between the sampled farmers in the study area.

The frontier sigma squared ($\partial u^2 + \partial v^2$) value was calculated to be 0.150 and gamma (γ) was 0.949. The calculated values were significantly different from zero, indicating appropriateness of the composite error term assumptions (Astuti *et al*., 2019; Kifle, Moti & Belaineh 2017). Danquah *et al*. (2019) found consistent results on the sigma squared and gamma values while studying the effect of land fragmentation on maize farmer's technical efficiency. Kavoi, Najjuma and Mbeche (2016) also pointed out that Cobb-Douglas functional form is suitable for multiple input modelling and handles multicollinearity and correlation supporting the its appropriateness over Translog functional form.

4.8.2 Effect of Farm Inputs on Irish Potato Production

This study used a Cobb-Douglas stochastic frontier containing five farm inputs. Table 15 presents results of the maximum likelihood estimates of the farm inputs coefficients.

Table 15. Stochastic Frontier Model Parameter Estimates

Variable	Coefficient	SE	Z	P-value	95% Confidence interval	
Constant	2.387	0.265	9.00	0.000	1.867	2.907
Logland	0.262**	0.091	2.87	0.004	0.083	0.441
Logseed	0.629**	0.096	6.55	0.000	0.440	0.817
Loglabor	0.089	0.006	1.52	0.129	-0.026	0.205
Logfertilizer	-0.299**	0.066	-4.50	0.000	-.430	-0.167
Logfungicide	0.131**	0.037	3.52	0.000	0.058	0.203
Log likelihood	-17.957					
Total observations	360					
Prob> chi2	0.000					

*** Represents level of significance at 5%.*

The information in Table 15 indicates that out of the five inputs considered namely; land, seed, fertilizer and fungicide had a significant effect on irish potato production at 5% level of significance (p-value= 0.004<0.05,p-value =0.000<0.05, p-value =0.000<0.05 and p-value =0.000<0.5 for land ,seed, fertilizer and fungicide respectively). The coefficients of the land, seed and fungicide variables were positive except for fertilizer variable. Land was measured in terms of size of land under irish potato. A unit increase in the land size allocated to irish potato farming increases production by a factor of 0.262. This implies that irish potato production would probably increase if the farmers would increase the land sizes under irish potato crop. Danquah *et al*. (2019) had consistent results to the significance and positive effect of land on maize production.

Irish potato seeds were a necessary input for irish potato production. The seed variable has a positive coefficient at 0.629. This implies that an increase in the quantity of potato seed used will increased irish production by a factor of 0.629. Asfaw *et al*. (2019) reported consistent findings that seed is a significant factor in wheat production. Use of more seeds increases the crop population hence increasing production. Thus, a farmer who applies more quality seeds receives higher yields. In this study, fertilizer had a negative effect on irish potato production in the study area. The study results are not in line with Abubakar and Sule (2019) who observed that fertilizer had a significant and a positive effect on maize output. Therefore, for a unit increase in fertilizer amount increases the maize production. This may be because the fertilizer used by the farmers was not compatible with the soil conditions for irish potato production. For a unit increase in fertilizer irish potato production reduced by a factor of 0.299 in this study. This was contrary to the expectation that it would increase irish potato output. The smallholder irish potato farmers might not be applying the recommended fertilizer (DAP) amounts leading to inadequate soil nutrients replenishment. Smallholder farmers also continuously grow crops on the same parcel of land without having a fallow period (Kaguongo, Gildemacher, Demo, Wagoire, Kinyae, Andrade, Forbes, Fugilie, & Thiele, 2008).The farmers could also be applying fertilizer (DAP) without considering the soil requirements of their farms hence reducing their production. Smallholder farmers should consider testing their soil before application of fertilizer in order to determine the soil needs of their farms to boost production.

In addition, the result revealed that for a unit increase in fungicide application the level of irish potato output increases by a factor 0.131. This result coincides with the finding of Chepkowny (2014) that fungicide is a significant input in irish potato production. The sampled smallholder irish potato farmers applied fungicides to deal with early and late blight. The result implies that increasing fungicide use improves irish potato production. Therefore, fungicide increase leads to an increase in irish potato production. However, labor had an insignificant effect on irish potato production. The stochastic production frontier can be expressed as:

$$Y = 2.387 + 0.262X_1 + 0.629X_2 - 0.299X_3 + 0.131X_5 + V_i - U_i \text{ ....xv}$$

where, Y = natural logarithm of irish potato is the production

X_1=natural logarithm of land size

X_2=natural logarithm of seed quantity

X_3= natural logarithm of fertilizer quantity

X_5= natural logarithm of fungicide quantity

V_i= variations due to random factors beyond the control of the farmer

U_i= technical inefficiency model

2.387 is the expected value of irish potato production when farm inputs (land, seed, fertilizer and fungicide) value is zero.

An advantage of the Cobb-Douglas functional form is the straightforward interpretation of its parametric coefficients as partial elasticity of output with respect to the farm input used (Gemeyida *et al*., 2019). This feature allows assessment of the possible effects of changes in the quantities of inputs on output. The coefficients of the input variables in the production function are interpreted as elasticity of production and are as presented in Table 16.

Table 16. Elasticity of Inputs Used in Irish Potato Production

Variable inputs	Elasticity of production
Land	0.262
Seed	0.629
Fungicide	0.131

As the farmer increased land under potato production, amount of seed and fungicide by a unit, production was expected to increase by a factor 0.262, 0.629 and 0.131 respectively. The results depict that amount of irish potato seed has the highest level of responsiveness to irish production, followed by land and then fungicide. The individual elasticities furthermore imply that irish potato farmers do not allocate their resources optimally. However, they have an opportunity to increase their production with better allocation of the significant farm inputs. The distribution of individual farm specific technical efficiency levels for the sampled irish potato farmers is shown in Table 17.

Table 17: Distribution of Technical Efficiency Scores of the Sampled Respondents

Efficiency range levels	Frequency	Percentage (%)
0.21-0.30	5	1
0.31-0.40	6	2
0.41-0.50	47	13
0.51-0.60	35	10
0.61-0.70	87	24
0.71-0.80	52	14
0.81-0.90	80	22
0.91-1.00	48	14
Total observation	360	100
Mean Technical efficiency	70.7%	
Minimum Technical efficiency	0.21	
Maximum Technical efficiency	0.96	

The sampled farmers have different levels of technical efficiency ranging from 0.21 to 0.96. About 1% of the sampled farmers have a technical efficiency level of between 0.21-0.30, 2% of the respondents operate between 0.31-0.40 technical efficiency level, 13% are at a technical efficiency level of between 0.41-0.50 and 10% are operating between 0.51-0.60 technical efficiency level. Majority of the respondents (24%) range between 0.61-0.70 technical efficiency level, 14% have technical efficiency level of between 0.71-0.80, 22% of them have technical efficiency level of between 0.81-0.90 while 14% of the respondents operate between 0.91-1.00 technical efficiency level. The findings are in tandem with Dube *et al*. (2018) who reported that the technical efficiency level was varied among the sampled farmers in Ethiopia but most of them attained a technical efficiency level that was higher than the mean technical efficiency level. These findings indicate presence of variation in irish potato production amongst the smallholder farmers. Despite the variation in efficiency levels, most of the surveyed households achieved an efficiency level greater than the mean technical efficiency level. This denotes that in the long term it might be necessary to introduce a new technology in addition to increasing the current efficiency levels of the farmers to increase potato output level in the study area. Given the functional form used, the average technical efficiency level of irish potato farmers in Molo Sub County was 71% varying from 21% to 96%. This implies that on average, smallholder irish potato farmers can raise their current production level by 29% without raising existing levels of farm inputs. On the other hand, farmers on average can reduce the farm inputs by 29% to get the current production levels if they exploit the farm inputs efficiently.

4.8.3 Effect of Socio-demographic and Institutional Factors on Smallholder Irish Potato Production Technical Efficiency

The study results showing the effect of socio-demographic and institutional factors on irish potato production technical efficiency are as presented in Table 18.

Table 18: Maximum Likelihood Estimates of the Inefficiency Model

Variable	Coefficient	SE	Z	P-value	95% Confidence interval	
Constant	0.633	0.016	3.87	0.000	0.313	0.953
Education	-0.061**	0.001	-4.08	0.000	-0.090	-0.317
Gender	-0.262**	0.001	2.24	0.025	0.033	0.491
Family size	0.022	0.002	1.47	0.141	-0.007	0.520
Farming experience	0.100	0.002	0.62	0.532	-0.021	0.041
Extension services	-0.078**	0.009	0.82	0.041	-0.109	0.266
Farmer group	-0.217**	0.010	-2.07	0.038	-0.421	-0.012
Credit	-0.074	0.010	-0.75	0.454	-0.267	0.119

***represents level of significance at 5%,*
A positive sign (+) signifies increase in the variable causes a decrease in technical efficiency, while negative sign (-) means increase in the variable causes an increase in technical efficiency.

The study hypothesized that factors categorized into socio-demographic and institution would affect irish potato production technical efficiency in the study area. Four of the variables were dummy variables while the remaining three variables were continuous variables. Identifying the sources of irish potato production technical efficiency aids in developing interventions and policies that can increase current level of irish potato production. A negative sign on the parameter coefficient implies that as the independent variable increases, there is an increase in technical efficiency levels as technical inefficiency level is reduced. A positive sign on the parameter coefficient implies that an increase in the independent variable will reduce technical efficiency as technical inefficiency increases. Hence, any negative coefficient increased or improved the farms' technical efficiency level and vice versa. Education, gender, access to extension services and farmer groups were significant at 5% level of significance (p-value= 0.000 <0.05, p-value= 0.025<0.05, p-value= 0.041<0.05 and p-value= 0.038<0.05 for education, gender, access to extension services and credit respectively). The inefficiency model can be expressed as a function of the significant exploratory variables (education, gender, access to extensions services and farmer group) as shown below:

$$U_i = 0.633 - 0.0161W_1 - 0.262W_2 - 0.078R_1 - 0.217R_2 + e_i \text{.....................xvi}$$

where, W_1= Education variable

W_2=Gender variable

R_1=extension service variable

R_2=Farmer group variable

U_i= Technical inefficiency

e_i= error term

0.633= constant

Education variable is negative and this indicates that education had a positive effect on technical efficiency. The findings are in line with Dessale (2019) who observed that education positively affected technical efficiency. Hence, the less educated wheat farmers were not technically efficient in comparison to those who were more educated. Osinowo and Tolorunju (2019) established that the coefficient for education was negative implying that the more educated poultry egg farmers were more technically efficient than their counterparts were. Thus, highly poultry educated farmers are more likely to maximize poultry production from a given set of inputs. In another study by Abubakar and Sule (2019) educated maize farmers were more technically efficient. Therefore, more educated maize farmers were expected to increase maize production. Similarly, Geta *et al*. (2019) found that education level of the maize producers had a positive effect on technical efficiency. Educated maize farmers understand the effect of agricultural technologies with ease and have a greater tendency to adopt improved farm inputs. Probably, as the number of years of schooling for the respondent increase, technical efficiency of irish potato production is expected to increase. Education enhances farmers' managerial and technical skills. It increases farmers' ability to use existing modern agricultural technology and attain higher efficiency levels in their farms. Thus, farmers who are more educated perceive, interpret and respond to new information and adopt modern agricultural technologies such as fertilizer, seeds and fungicides more easily.

The gender variable was negative indicating that male farmers were more technical efficient than their female counterparts. Asfaw *et al*. (2019) reported consistent results that male farmers were more technical efficient than their female counter parts. In contrast, Mwalupaso *et al*. (2019), Dessale (2019) and Ateka, Onono and Etyang (2018) found that the coefficient for gender variable was insignificant implying that technical efficiency of female farmers was not statistically different from technical efficiency of male farmers. However, Oluwatayo and Adedeji (2019) observed that female producers were more technical efficient than male producers. Therefore, male irish potato farmers were technically efficient than female irish potato farmers in this study. This may be because of men easily access resources than females do. Male farmers also provide more labour input than female farmers do because they have more physical strength. Thus, male farmers play a crucial part in the provision of labour in irish potato farming. The study results on the household size and farming experience variable indicate that they are insignificant in determining irish potato production technical efficiency.

Smallholder irish potato farmers' access to extension services was considered in determining the institutional factors that affect technical efficiency. The study results from the inefficiency model indicated that extension services had a positive effect on irish potato production technical efficiency. This study finding is in line with Tukura and Ahindo (2019) who observed that extension services positively and significantly affected technical efficiency of sesame farmers. Therefore, access to extension access increased technical efficiency of sesame farmers. This indicates that smallholder irish potato farmers who access extension services are technically efficient. Therefore, accessibility to extension services increases irish potato production through increasing technical efficiency. The extension agents convey information about recommended practices using demonstrations and practical approaches that enhance adoption of improved technologies and management practices by irish potato farmers. Accessibility to extension services also enables farmers to consult with the agents about the challenges they experience in irish potato production hence improving on their input use and managerial skills.

From the results access to farmer group positively affected smallholder irish potato farmers technical efficiency. Membership to a farmer's group increases irish potato production technical efficiency by a factor of 0.217. This is in line with Gela *et al*. (2019) who reported that group membership has a positive and a significant effect on sesame production technical efficiency. The authors explained that farmers who are members of an association are able to obtain current information and access to credit for purchasing inputs making them to be more technically efficient in sesame production. Similarly, Tukura and Ashindo (2019) established that group membership positively and significantly affected technical efficiency implying that being a member of a group increases technical efficiency. Therefore, irish potato farmers in a farmer group are more technically efficient than those not in a farmer group. Irish potato farmers belonging to a farmer association have an institution through which they can access information and farm inputs more easily. Through the group, they also share information about farming technologies and practices with other farmers. This then improves their production because of better farm input exploitation. Credit accessibility can reduce farmers' cash constraints enabling them to be technically efficient through timely purchase of inputs. Nevertheless, from the findings access to credit did not significantly influence technical efficiency of smallholder irish potato farmers in the study area.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Findings

The purpose of this study was to investigate the effect of farm inputs and smallholder farmer characteristics on irish potato production technical efficiency in Molo Sub County, Nakuru County, Kenya. The study applied descriptive research design to obtain data cross-sectional data. Descriptive research design was used since it aided in obtaining a description of the farm inputs, socio-demographic and institutional factors of the smallholder irish potato farmers. The study targeted to obtain data from a sample of 377 smallholder irish potato farmers identified through multistage sampling technique. To gather data in the study area a questionnaire was used. A Cobb-Douglas production function under the stochastic frontier approach was used to analyse data through one-step approach.

The first objective of study sought to establish the effect of the farm inputs on irish potato production in Molo Sub County. Five farm inputs (land, seed, fertilizer, labour and fungicide) were considered in the stochastic frontier model. The frontier model results implies that land under irish potato farming (p-value=0.004<0.05), seed (p-value=0.000<0.05), fertilizer (p-value=0.000<0.05) and fungicide (value =0.000<0.5) are significant farm inputs in irish potato production. The results further imply that a unit increase in the land size under irish potato farming increased irish potato production by a factor 0.262. For a unit increase in irish potato seed, irish production increases by a factor of 0.629. However, the study results indicate that a unit increase in fertilizer reduces irish potato production by a factor of 0.299. This was contrary to the expectation that it would increase irish potato output. The study found that increasing fungicide use improved irish potato production among the smallholder farmers. A unit increase in fungicide application increases the level of irish potato output by a factor 0.131.

The study also sought to determine the effect of socio-demographic and institutional factors on irish potato production technical efficiency in Molo Sub County. The estimated stochastic production frontier containing the inefficiency model shows that education (p-value = 0.000 <0.05) and gender (p-value= 0.000 <0.025) significantly influenced technical efficiency at 5% level of significance. Education coefficient is negative and this indicated that more educated irish potato farmers are technical efficient. The gender variable was also negative indicating that male irish potato farmers were more technical efficient than their female counterparts. Results on the household size and farming experience variable indicated that they are insignificant in determining irish potato production technical efficiency. Smallholder irish potato farmers' access to extension services was also considered. The study results from the inefficiency model indicated that extension services had a positive effect on irish potato production technical efficiency. Therefore, smallholder irish potato farmers who accessed extension services were technically efficient in irish potato production. From the results, access to farmer group positively affected smallholder irish potato farmers technical efficiency. Access to a farmer group increased irish potato production technical efficiency by a factor of 0.217. Therefore, smallholder irish potato farmers with access to farmer group are more technically efficient than those who had no access.

5.2 Conclusions

Based on the study findings the following conclusions were drawn:

i. Irish potato production can be raised through increased use of land allocated to irish potato farming.
ii. Irish potato production can be improved through increasing used use of irish potato seed and fungicide.
iii. In this study, fertilizer had a negative effect on irish potato production in the study area. This was because the fertilizer used by the farmers was not compatible with the soil conditions for irish potato production.
iv. Farmers with high levels of education, increased irish potato production technical efficiency. Therefore, farmers with high literacy levels are more likely to increase irish potato production.
v. Male irish potato farmers significantly increased technical efficiency in irish potato production. Therefore, male irish potato farmers are more likely to increase irish potato production than their female counterparts.
vi. Institutions such as farmer groups and extension services increased irish potato production.

5.3 Recommendations

Based on the conclusions made by this study the following recommendations were made:

i. The smallholder irish potato farmers are encouraged use of more of the farm inputs (land, seeds and fungicide) to boost irish potato production.

ii. In order for smallholder irish potato farmers to increase potato production, there is need to test soil to determine the appropriate fertilizer to be used for higher irish potato production.

iii. Irish potato farmers are encouraged to increase their literacy level through attaining high levels of formal education since smallholder irish potato farmers with high levels of education increased potato production technical efficiency,

iv. In order to boost production, irish potato farmers are encouraged to form or join existing groups in order to enhance production and benefit from other important matters involved potato production.

v. Accessibility to extension services by irish potato farmers is critical in improving potato production.

vi. The policy makers at county and national government levels to develop policies to boost use of irish potato seeds, fungicide and land.

5.4 Suggestion for Further Research

The study suggests that future studies to:

i. Establish the effect of farm inputs and smallholder farmer characteristics on sweet potato production technical efficiency in Kenya.

ii. Determine effect of technology in enhancing irish potato production amongst smallholder farmers.

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APPENDICES

Appendix 1: Introductory Letter

Dear Sir/Madam,

I am Pauline Nyokabi Kamau, a student pursuing a Master of Science in Agribusiness Management in Chuka University. I am carrying out an academic research on "**Effect of Smallholder Farmers' Technical Efficiency on Irish Potato Production in Molo Sub County, Nakuru County, Kenya**''. The aim of this research is to fulfil partially the academic requirements for the award of the degree of Agribusiness Management in Chuka University. I kindly request that you answer the following questions as honestly as possible. I shall treat all the responses with the highest degree of confidentiality and the information will be used to meet the objectives of this study. Thank you for participating in the research.

Yours faithfully,

Pauline Kamau.

Appendix 2: Survey Questionnaire

Ward: ……… Village: ……........Date of interview: …………Serial No:…………

Part 1: Smallholder Irish Potato Farmers' Socio-Demographic Information

1. Sex of the respondent: 1= Male [ ] 0 = Female [ ]
2. Sex of the household head (HHH) : 1= Male [ ] 0 = Female [ ]
3. Indicate age in years of HHH..
4. Indicate the number of years in formal education of HHH.............................
5. Indicate the number of people living in the household……………….……...
6. For how long have you been growing irish potatoes?..............................(**In years)**

   If not the HHH, how long as the HHH been growing Potatoes?.............(**In years)**

Part 2: Inputs Used in Irish Potato Production

Land

7. How many parcels of land do you owe and practice production on?

	7.1	**7.2**	**7.3**	**7.4**	**7.5**	**7.6**
Plot Number	Size	Who manages the plot **(See Code Below)**	Land Tenure **(See Code Below)**	Description of plot **(See Code Below)**	Do you grow irish potato on this plot **1=Yes 0=No**	If yes proportion of land under irish in last season in %
Plot 1						
Plot 2						
Plot 3						
Plot 4						

Who manages the plot: 1= HH head, 2= Spouse, 3= Joint (HH head & spouse), 4= Other male, 5= Other female, 6= Others, please specify [______]

Tenure system: 1= Owned with title, 2= Owned without title, 3= Communal/public, 4= Rented in, 5= Rented out

Plot description: 1= Homestead, 2= Cash crop, 3= Food crop, 4= Fodder crop, 5= Grazing land, 6=Others, please specify [______]

Irish Potato Seed

8. How much irish potato seed did you use in the last season?..........bags of …...……Kgs
9. Provide the following information:

	9.1	9.2	9.3
Irish Potato seed category	Do you Use **1=Yes 0=No**	Source of the Seed **Code A**	Price per Kg of Seeds
Certified			
Uncertified			
Both			

Code A: 1= Own farm production 2= other farmers [ ] 3= Government institutions/centres [ ] 4 = Irish Potato seed companies, 5=others…. Please specify

Fertilizer

10. Tick the type of fertilizer and how often you used it for irish potato crop production

	10.1	10.2	10.3	10.4	10.5
Fertilizer Type	Do you Use **1=Yes 0=No**	Kg utilized last Season	Planting	Top Dressing	Price per Kg
Organic					
Chemical					
Both					

Fungicide

11. How often do you use chemicals to protect your irish potato crop?

    1= Always [ ]

    2= Once in a while [ ]

    3= Never [ ]

12. How many kilograms of fungicide did you use on irish potato in the last cropping season?............Kgs
13. Price of fungicide?.........Ksh Per ………..(ML, Kg)

Labour

14. How many man-days were spent in the following activities during the last season of irish potato production?

	14.1	14.2
Activity	**Labour type**	
	Family	Hired
Ploughing		
Planting		
Weeding		
Fungicide application		

15. If hired price of one-man day………………Ksh,

Part 3 (Potato Farmers Group)

16. Did you belong to a farmer group or organization in your community during the last 12 months? [______] (1=Yes, 0=No).

If Yes fill the table below. IF No skip to question 5.2

	16.1	**16.2**	**16.3**	**16.4**
Type of Group/Organization *(See the Type of Group codes below)*	What is the most important function of the group or organization? *(See the function codes below)*	Is there a Membership fee? *1=Yes 0=No*	If yes in 5.1.3 How much in Ksh.	Role in the Group *(See the Role codes below*

***Codes**:*

Type of Group: 1=Women Group/ Chama, 2=SACCO/Credit Group, 3=Farmer Cooperative, 4=Input Supply Group, 5=Producer and Marketing Group, 6= Youth Group, 7=Others, please specify [_________]

Function:1=Produce marketing, 2=Input access, 3=Savings and credit, 4=Farmer trainings, 5=Transport services, 6= Share Inputs (Labor, Capital), 7=Other, please specify [__] multiple

Role: 1= Administrative, 2= Ordinally Member, 3= Other, please specify [___]

Access to Extension Services

17. Did you receive extension services in the last 12 months [____] (*1=Yes, 0=No*).

If Yes, fill the table below: If *No* skip to question 7.2

`	**17.1.**	**17.2**	**17.3**	**17.4**	**17.5**
Source of extension services *(use the extension source code)*	What kind of information did you receive from this source (*use the codes below)*	Did you receive this information at the appropriate time? *(1= Yes ,0=No)*	Did you apply this information? *(1= Yes, 0=No)*	What were the terms of provision of the extension services (*use the codes below)*	How many times did the extension service provider pay you a visit or provide extension on the last planting season

Extension Source: 1= Researchers, 2=Farmer to farmer, 3=Media (Magazine, TV/radio, 4=Out grower (seed companies), 5=County Government,6 =NGO, =Development Organization, 7=Online Groups (Facebook, WhatsApp), 8=Religious Group (Churches, church committee), 9=Others (specify)

Kind of information: 1=Pests and diseases, 2=Markets & prices, 3=Government initiatives/ projects, 4= Good agricultural practices, 5= Post-harvest 6= Other, please specify [__________] inputs

Terms of provision of the extension services: 1=Free, 2= Paid, 3=Others, please specify [_______]

Access to credit

18. Did you acquire loan during the last 12 months [____] (1=Yes, 0=No).

19. If No in 6.1 Why NO [____] *use the codes below*

Codes 1=No need, 2=Not aware of the availability of credit, 3=Lack of enough collateral to secure a facility, 4=High interests for the credit 5=Long credit application procedures. 6=. Other, please specify

20.1	20.2	20.3
Loan type *(use codes below)*	The main purpose for which the credit was acquired *(use codes below)*	Amount Received

Codes:

Loan type: 1=Formal bank, 2=Micro finance institution, 3=SACCO, 4=Community group, 5= Informal Sources (e.g. Neighbour / Family), 6=Mobile money, 7=Others, please specify [_]

Loan purpose: 1=Farm inputs, 2=School fees, 3=Food, 4=Land, 5=Livestock, 6= Expand business, 7=Farm implements/equipment 8= Other, please specify [___]

Part 4: Irish Potato Yield

21. How many bags of irish potato did you harvest in the last season?..........bags of …...……Kgs

Thank you for taking the time to respond to the questions and contributing to the study.

Appendix 3: Chuka University Letter of Ethics

CHUKA UNIVERSITY

Knowledge is Wealth *(Sapientia divitia est)* Akili ni Mali

CHUKA UNIVERSITY INSTITUTIONAL ETHICS REVIEW COMMITTEE

Telephones: 020-2310512/18
Direct Line: 0772894438
Email: info@chuka.ac.ke,
P. O. Box 109-60400, Chuka
Website: www.chuka.ac.ke

REF: CUIERC/ NACOSTI/018

8TH JULY 2019

TO: PAULINE NYOKABI KAMAU

Dear Sir/madam

RE: EFFECT OF SMALLHOLDER FARMERS' TECHNICAL EFFICIENCY ON IRISH POTATO PRODUCTION IN MOLO SUB-COUNTY, NAKURU COUNTY, KENYA

This is to inform you that ***Chuka University IERC*** has reviewed and approved your above research proposal. Your application approval number is ***NACOSTI/NBC/AC-0812***. The approval period is ***1st April, 2019 – 31st March, 2020.***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Chuka University IERC***.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Chuka University IERC*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Chuka University IERC*** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***Chuka University IERC***.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely

PROF. ADIEL MAGANA
CHAIRMAN CHUKA UNIVERSITY IERC

Chuka University is ISO 9001:2015 Certified...

Inspiring Environmental Sustainability for Better Life

Appendix 4

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Date of Issue: **16/August/2019**

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This is to Certify that Miss.. Pauline Kamau of Chuka University, has been licensed to conduct research in Nakuru on the topic: EFFECT OF SMALLHOLDER FARMERS' TECHNICAL EFFICIENCY ON IRISH POTATO PRODUCTION IN MOLO SUB COUNTY, NAKURU COUNTY, KENYA for the period ending : 16/August/2020.

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