ASSESSEMENT OF THE FACTORS INFLUENCING IMPROVED POTATO VARIETAL CHOICE AND CHANGE IN SOUTH WESTERN HIGHLAND AGROECOLOGICAL ZONE OF UGANDA

BY

SSEBBANJA HOSSAM DIRISA

BSC. MAKERERE UNIVERSITY

REG NO. : 2014/HD02/565U

A THESIS SUBMITTED TO THE DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS OF MAKERERE UNIVERSITY

MARCH, 2022

DECLARATION

I do hereby declare that except for the references cited, which have been duly acknowledged, this thesis titled "***Assessment of the factors that Influence Improved Potato Varietal choice in the South Western Highland Agroecological Zone of Uganda***" is the product of my own research work in pursuit of Masters of Science in Agricultural Economics in the Department of Agribusiness and Natural Resource Economics, Makerere University. I also declare that this thesis has not been presented either in whole or in part for the award of another degree in this University or elsewhere.

Signature ..... Date ....16/03/2022....
Ssebbanja Hossam Dirisa (Student)

This thesis has been submitted for examination with approval as supervisors.

Signature..... Date...16/03/2022....
Dr Ilukor John
(First Supervisor)

Signature..... Date...16/03/2022....
Dr Gracious M Diiro
(Second Supervisor)

DEDICATION

I dedicate this work to my dear children Ameerah Alzik Bukirwa Hossam, Arham Hossam Ddumba, Nairah Fatumah N. Hossam and Naim Attah Nyanzi Usama, my dear parents the late Hajj Dirisa Ddumba, and Mrs. Yudaya Male, my Aunt Hajjat Fatumah Nakatudde and my sister Namukwaya Shamirah

ACKNOWLEGDEMENT

In the name of God the most gracious, the most merciful, I do thank Him for the gift of life, courage and strength throughout my entire life more so during the time of course works, data collection, analysis and writing of this thesis. I would like to convey my sincere gratitude to my academic supervisors Dr Ilukor John and Dr Diiro M Gracious for the guidance throughout the entire process of research work. I really appreciate the time and effort put in to shape my work from proposal writing to thesis. I also appreciate the professional guidance and connections my two supervisors have referred me to during the entire process. I'm also greatly indebted to Dr Alex Barekye, the director of Research Kachwekano Zonal Agricultural Research and Development Institute (KAZARDI-NARO), for offering me academic guidance, encouragement and financial research support.

I am also greatly indebted to Wilbert Vundru of the World Bank (Uganda) and Andrew Mupere of Uganda Bureau of statistics for the guidance and training offered to me while designing my questionnaire using the survey solutions-CAPI software. Also its worth to thank my team of enumerators; Inocent Uzatunga, Anitah Tusiimire, Macline Kyomugisha and Mateka Benon for the commitment and courtesy while collecting data. At the same time I convey my sincere thanks to a number of fellow students who have greatly helped me to make this work a success, these include: Namwanje Diana, Nassolo Sarah, Robert Asimwe, Ariong M Richard, Aminah Subira Mubuka, Stanslus Okurut, Okello Daniel and Opolot Deogracious.

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ABSTRACT

This study sought to assess the factors influencing improved potato varietal choice in south western highland agro-ecological zone of Uganda.The study examined the drivers of potato varietal choice and varietal change using data collected from 147 households randomly selected from South Western Highlands of Uganda, a leading potato producing region. The study identified most cultivated or preferred potato varieties by farmers, determined varietal attributes that influence farmer's choice of Potato varieties and factors influencing farmers decisions to change varieties planted from season to season.

Results reveal that the two majorly grown potato varieties are Kinigi (46%) and Rwangume (32%). However potatato farmers are changing from old improved varieties to old improved varieties rather than to the newly improved ones. Varietal change is driven by seed system factors mainly distance to the seed source.

CHAPTER ONE
INTRODUCTION

The chapter provides a detailed background to the study, the problem statement, objectives, hypotheses and significance of the study.

1.1 Background

Potato *(Solanum tuberosum)* is the world's top non-grain crop (Walker *et al.*, 2014; Tolno *et al.*, 2016). Global production over the past two decades has increased from 275 to 375 million tons with the developing countries share of 52% surpassing that of the developed world (FAO, 2008). Potato industry generates employment in the farm economy hence serving as a source of cash income for low income farm households through access to higher value markets along the potato value chain (Kirub *et al.*, 2013). In East Africa, potato is a staple food for many rural and urban families and there is a growing trade in potatoes to supply the fast growing cities and towns with cheap staple food, as well as satisfying the demand of the growing fast food industry (Kaguongo *et al.*, 2008).

In Uganda, the consumption continues to increase at the rate of 3-6% as a result of increasing population, urbanization, and economic growth (Witte, 2013). Uganda's population increased from 24 millions in 2002 to 35 millions in 2014 representing an annual growth of 3.0% hence projected to be 54 millions by 2030 (UBOS, 2019). The Uganda urban population increased from one million persons to three million from 1980 to 2002 and; to 6.4 million in 2014 which is expected to triple by 2025 (Mukwaya *et al.*, 2010). The largest Ugandan urban population is concentrated in the central region with 25 per cent of its people residing in urban centers in 2002. Kampala City, showed characteristics of primacy, with 41 percent of the total urban

population in the countryout of 77 per cent that was found in the 20 biggest urban centers in the country (Mukwaya *et al.*, 2010).

As a result of population increase and urbanization, demand for potatoes and its products are experiencing a boom, with ever big quantities being processed for the convenience of food and snack industries. Potato's importance as subsistence crop continues to expand, hence a very good opportunity for potato farmers in Uganda to earn higher incomes and for fighting poverty (Mbowa & Mwesigye, 2016). In Uganda, potatoes have traditionally been grown in the highland areas, which include Kabale and Kisoro districts of the south western and Kapchorwa district on the slopes of Mt. Elgon in the Eastern. According to Kaguongo *et al.* (2008), Kabale district alone produces 60% of the potatoes consumed in Uganda. However recently, other districts like Mbarara, Bushenyi, Kasese, Kabarole, Isingiro, Lyantonde, Mubende, Kibale, Nebbi, Zombo, Mbale and Sironko have joined potato production mainly because of the market opportunities (Mukhwana *et al.*, 2005).

In 2009, the total production of potato was 154,435 tons from a total of 32,759 hectares of land, of which 87.6% tons from 79.7% hectares was produced from the South Western part of the country (UBOS, 2010). Thus this indicates an average production rate of 5.2 tons of potato per hectare from the Western part of Uganda. The production of potato in Uganda from 2008 to 2011 increased from 154,000 to 180,000tons (UBOS, 2012). The increase in potato production has been driven by area expansion. However Gildemacher, *et al.*, (2009), reports that further potato production increase through area increase will become increasingly difficult. Thus the most feasible manner in which the growing demand of potato could be satisfied is through increased productivity, however potato productivity is still low in relation to

the acreage (Figure 1). According to FAOSTAT, there was a gradual increase in the potato acreage in Uganda since 2008 to 2015 by 1.2%, however productivity reduced from 1.5t/ha to 1.1t/ha (Figure 1).

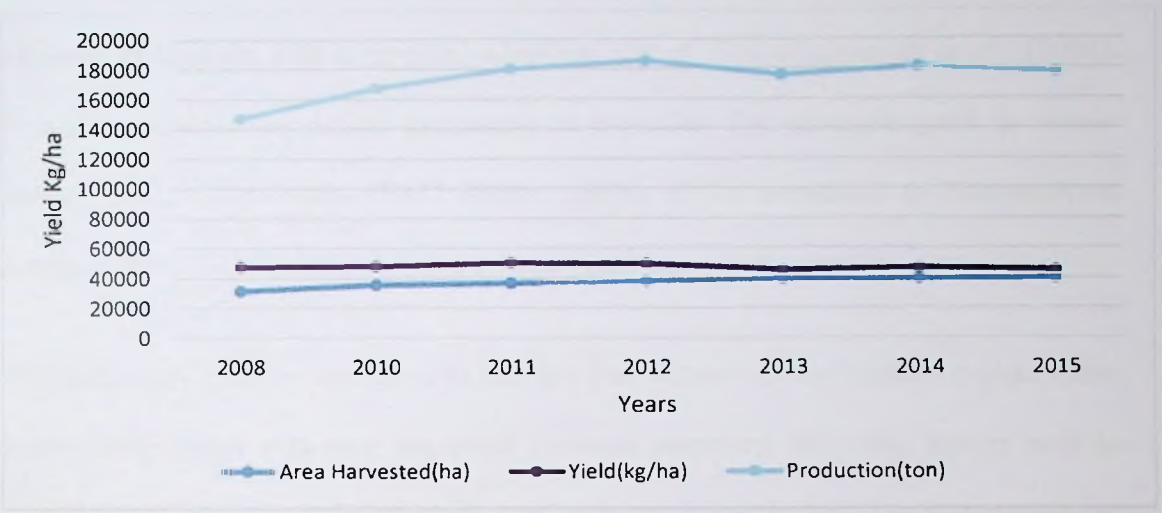

Figure 1:Potato Production Statistics in Uganda (Source: FAOSTAT)

The main factor that could have led to decline in potatao productivity in Uganda especially in SWHAEZ is increased incidence of pest and diseases mainly driven by climate change (Ilukor *et al.*, 2014; Stäubli *et al.*, 2008). The major potato diseases that have greatly affected potato production in Ugand are late blight (*Phytophthora infestans)* and bacterial wilt (*Pseudomonas solanacearum*) while the major pests are cutworms (*Agrotis* spp.), aphids (*Myzus persicae* (Sulzer)), and potato tuber moth (*Phthorimaea operculell*) (Sikhu & Kroschel, 2016). Late blight alone is estimated to be causing up to 70% yield loss resulting to over 129 million Dollar loss in Uganda's revenue annually (2BLADE, 2016). Moreover, the late blight pathogen in Western Uganda became resistant to fungicide (Mulema *et al.*, 2004). Fortunately, there are new varieties that have been released or developed with the resistance to potato

diseases and pest. They include Victoria, Nakpot 1, Nakpot 2, Nakpot 3, Nakpot 4, Nakpot 5, Kachpot 1, Kachpot 2 and Rutuku (Table 1).

1.2 Problem statement

Several diseases resistant, early maturing and high yielding potato varieties have been released in Uganda with a reported adoption rate of 77% (Kaguongo *et al.*, (2008). However, productivity is not increasing as expected. For example yield in farmer fields stands at 13tones/ha (FAO 2008a; UBOS, 2010), compared to 22tones/ha at research stations (NARO, 2017) implying a yield gap of 11tonnes/ha.

This yield gap could be attributed to the fact that farmers are not able to replace older improved varieties with new improved varieties assuming that other factors such as measurement error are held constant. Past research suggests that if new materials are not replacing the old ones, returns to genetic improvement stagnate (Brennan & Byerlee, 1991). Simply put, the permanency of first- generation improved varieties in farmers' fields will lead to declining productivity because of the disease and pest pressures thus necessitating new release of varieties in crop improvement.

However, most of the studies measuring the effectiveness of crop improvement research in Sub-saharan Africa have focused more on assessing the level of adoption of improved cultivars and their impacts than choice and varietal change. Yet, the level of adoption tells only one part of the story of crop improvements (Walker *et al.*, 2014).

Thus the contribution of this study to literature of performamnce of crop germplasm improvement programs is in (1) Characterizing potato farmers basing on varietal choice and the extent varietal change (2) determining varietal attributes that drive

farmers to chose one potato variety over another, and (3) determining varietal attributes that drive potato varietal change in the South Western Highlands of Uganda.

1.3 Objective of the study

The general objective was to assess drivers of improved potato varieties choice and varietal change in South Western Highlands of Uganda. The specific objectives were: To characterize potato farmers in the South Western Highlands of Uganda based on varietal choice and varietal change

1. To identify popular potato varieties in the South Western High lands of Uganda
2. To determine the driving factors of improved potato varietal choice in the South Western Highlands of Uganda
3. To determine the driving factors of improved potato varietal change in the South Western Highlands of Uganda

1.4 Hypotheses of the study

1. Social economic attributes like, age, education level influence potato farmers' choice of varieties
2. Recently released potato varieties are more popular than old released varieties
3. Varietal attributes such as, resistance to bacterial wilt, early maturity and market availability, influence potato farmers' choice of potato varieties
4. Varietal attributes drive potato farmers' decision to change potato varieties

1.5 Significance of the study

A number of potato varieties have been generated and are being grown by the farmers in the South Western Highland Agroecological zone of Uganda according to NARO, however the drivers of the varietal choice and change by farmers had not clearly been established and documented. Henceforth this study sought to establish the factors that drive improved potato varietal choice and varietal change in the South Western Highland Agroecological Zone. This helped to identify the varieties to be popularized in the zone. Thus directing the breeding program to be followed by the breeders. Here the attributes that are identified as drivers of varietal choice and varietal change can be incorporated in the varieties that are to be bred in the future crop improvement programs. Hence forth one important variety could be generated combining all the identified attributes (socio-economic, agronomic/crop attributes and institutional)

1.6 Scope of the study

This study basically focused on the South Western Highland Agro ecological Zone (SWHAEZ) of Uganda and specifically covered the districts of Kabale and Kisoro. Major emphasis was put on the varieties which were grown in the farmer fields at the time (2015B/2016A). We focused on households which earn their living from potato growing direcly. From the districts the stated sub counties with the highest potato growing household were purposively selected as well as the villages. Only households which had potato gardens at the time were interviewed.

CHAPTER TWO
LITERATURE REVIEW

This chapter provides a detailed insight into the potato research in Uganda, determinants of improved crop varietal choice, determinants of crop variety change and the challenges of crop varietal choice and change analysis.

2.1. Potato Research in Uganda

Improved potato varieties are varieties that have been developed or cleaned up from diseases by Potato International Center (CIP) and National Research stations since 1970 (Kaguongo *et al.*, 2008). These varieties are considered to be superior in qualities such as yields, resistance to diseases, dormancy period, maturity period and taste as compared to existing or local varieties In Uganda, potato was introduced by colonial administrators before mid 1900s, it rapidly spread in the highland areas as a garden crop, but was practically wiped out by late blight in 1946 (Low, 1997; Adipala *et al.*, 2005).

A Potato Improvement Program for Uganda whose objective was the development of potato varieties with multi-gene resistance to late blight (horizontal resistance) was initiated in 1968 by Makerere University College and the Ministry of Agriculture with support from Rockefeller Foundation (Low, 1997). By 1974, four varieties were released in Kabale and Kisoro (Goossens, 2002), these varieties are; Rutuku (CIP 720097), Malirahinda, Makerere and Rosita. Due to civil wars from 1979 to 1986 the program was interrupted affecting potato production in the country, however farmeres continued growing these varieties and because of the diseases pressure productivity was lowered.In 1989, National Agricultural research Organization (NARO), in collaboration with International Potato Center (CIP) and Regional Potato and

Sweetpotato Improvement Program for Eastern and Central Africa (PRAPACE) rembarked on a potato improvement program again (Adipala *et al.*, 2005) and have released twenty two improved potato varieties (Table.1) in Uganda. The recently (2003-2016) released varieties exhibit; a high level tolerance to bacterial wilt, moderate/early maturity, a hard skin texture, high palatability and high yield (18-30t/h) (Kaguongo *et al.*, 2008; Mbowa & Mwesigye, 2016).

Table 1: List of Potato Varieties Released by NARO and CIP Since 1972 to 2016

Variety Name	*Year of Release*	*Early Maturity*	*Resistance to bacterial wilt*	*Thickness of the Tuber skin*	*Taste*	*Yield*
NAROPOT 4 (Rwangume)	2016	Medium Maturity	Tolerant	Hard	Very Palatable	19t/h
NAROPOT 3	2016	Medium Maturity	Tolerant	Hard	Very Palatable	21t/h
NAROPOT 2	2016	Medium Maturity	Susceptible	Hard	Very Palatable	24t/h
NAROPOT 1	2016	Medium Maturity	Tolerant	Hard	Very Palatable	29t/h
Kachpot 2	2006	Early Maturity	Tolerant	Very hard	Very Palatable	16t/h
Kachpot 1	2006	Late Maturity	Susceptible	Very hard	Very Palatable	18t/h
Nakpot 5	2003	Late Maturity	Tolerant	Hard	Very Palatable	30t/h
Nakpot 4	2003	Medium Maturity	Tolerant	Very hard	Palatable	20t/h
Nakpot 3	1999	Late Maturity	Tolerant	Hard	Palatable	20t/h
Nakpot 2	1999	Early Maturity	Tolerant	Very hard	Palatable	20t/h
Nakpot 1	1999	Early maturity	Tolerant	Hard	Palatable	20t/h
Kinigi	1994	Medium Maturity	Susceptible	Hard	Very Palatable	25t/h
Victoria (CIP 381381.2)	1991	Early Maturity	Susceptible	Soft	Palatable	18t/h
Kabale (CIP 374080.5)	1991	Early Maturity	Tolerant	Hard	Palatable	25-30t/h
Kisoro (CIP 381379.9)	1991	Late maturity	Tolerant	Soft	Palatable	18t/h
Cruza (CIP 720108)	1989	Late Maturity	Susceptible	Soft	Palatable	28t/h
Sangema	1989	Early maturity	Tolerant	Hard	Very palatable	15t/h
Kenya Baraka	1977	Early Maturity	Tolerant	Hard	Palatable	18t/h
Rosita	1974	Early Maturity	Tolerant	Hard	Palatable	16t/h
Makerere	1974	Early Maturity	Tolerant	Hard	Palatable	20t/h
Rutuku (Mexican 7209970)	1972	Late Maturity	Very Susceptible	Very hard	Very Palatable	28t/h
Malirahinda	1972	Early Maturity	Tolerant	Hard	Palatable	20t/h

Source: Kachwekano ZARDI, NARO (2017); (Kaguongo *et al.*, 2008)

2.2. Determinants of improved crop varieties choice

Varietal choice is a farmers decision to select or choose scarce resources to plant or produce; or not to plant or produce and particularly the variety. The first issue in choice analysis is to consider whether the choice is in discrete state with binary variables (a farmer either choses or not) or whether the choice is a continuous measure (Doss, 2006). Muthoni *et al.* (2013) reported that diseases resistance, in addition to other good traits may increases the chances of a cultivar choice by the farmers as this may reduce production costs. Kaguongo *et al.*, (2008), in their study on adoption of improved potato varieties found out that various end uses of potatoes require specific tuber characteristics and cultivar, thus the attributes considered in ranking a potato cultivar by farmers are; high yield potential, late blight resistance, taste, maturity period, market demand, bacterial wilt resistance, tuber size and drought resistance in the order.

Lee and Eastwood (2003), conducted a study on consumer technology adoption and reported that there is a significant relationship between proximity and choice. They also reported that an improved methodology of estimating the effects of accessibility increases choice of a particular technology. Kasirye (2009), in his review of the National Agricultural Advisory services (NAADS) progress under Worlbank, reported that a key determinant of sustained choice and retention is the profitability of agricultural enterprises. The changing prices for agricultural products are shown to be a major factor in agricultural technology retention or change, and as reported by Kijima (2011), initially attracted by higher product prices, farmers can abandon the technologies if the expected benefits are lower than the prevailing costs among other factors. According to Oster *et al.*, (2010), peer effects can lead to economies of scale

by lowering transportation costs, helping individuals gain knowledge of the benefits of the technology from their friends hence leading to uptake, however it can also lead to increased competition and land prices, which can spur change.

A number of variables could be hypothesized to influence the probability of farmers' choice of improved crop varieties out of which some are found to be significantly influencing choice, retention or change in the study area. In this regard according to Musa *et al.* (2009), household size, marital status, educational level of household head and participation in promotional activities were found to be significant and positively affecting the choice of improved maize varieties in the Kano and Katsina states of Nigeria.

Choice of improved agricultural technologies according to, Olarinde & Fatunibi (2017) has been associated with: higher earnings and lower poverty, improved nutritional status, lower staple food prices, and increased employment opportunities as well as earnings for landless labourers. At the global level, according to Kasirye (2009), the choice of improved agricultural technology is now considered critical to the attainment of the Millennium Development Goal one(1) of reducing extreme poverty and hunger. Although substantial public resources have been devoted to the development and provision of modern crop varieties in Sub-Saharan Africa (SSA) in the past 30 years, overall retention rates for improved technologies have lagged behind other regions (Janvry *et al.*, 2008).

Chandio & Yuansheng, (2018), in their study on adoption of improved rice reported that the factors that are observed to influence the probability of crop choice/uptake are; education, farm size, seed access, extension service, yield potential and

consumers' acceptability of rice varieties. Technology specific variables for example yield potential and acceptability are significant for explaining choice behavior(Olarinde & Fatunibi, 2017), implying that it is important to take farmers' preferences to varietal characteristics into consideration in the design of a research and development program. Given the significant role played by extension and access related variables (Himire *et al.*, 2015), increased emphasis on information dissemination, extension demonstration, and farmers' participatory research and training programs to popularize new rice varieties and enhance their uptake rate are required (Wake *et al.*, 2019).

2.3 Determinants of crop varieties change

Farmers' variety selection and retention criteria are diverse reflecting their multiple needs (Kolech, *et al.* 2017), for example in addition to yield, early maturity and lateblight resistance; Ethiopian farmers highly value traits such as food value, long term storability, suitability for sequential harvesting and resistance to abiotic stresses such as drought, wind and heavy rains among others as factors for retention of potato varieties. In this regard interventions to develop new crop varieties should not focus solely on the often assumed desirable traits such as early maturity but should also pay attention to the consumption and market attributes.

Zawedde *et al.* (2014), reported that non yield production characteristics such as taste, price and ease of cooking are significant factors in farmers' assessments of the value of a new variety in relation to indegenous sweetpotatoes. This implies that future efforts aimed at varietal improvement should pay attention to market and food quality attributes to increase technology uptake. Othieno *et al.* (2011), also reported that future research and development efforts should recognize farmers' multi-strategy

needs and thus the demand for different varietal traits which are likely always to be required in more than one improved variety in order to facilitate change to improved varieties.

While the largest number of farmers consider yield stability, including tolerance to native biotic and abiotic stresses; (Forexample; diseases, drought, poorsoils, weedy field) as critical (Zawedde *et al.*, 2014), good taste remains a key attribute for varietal change or replacement to be effective. In line with biotic and abiotic factors, Zivamonoyo & Mukarati,(2009), also indicate that in most cases the new varieties or cultivars's non adaptability to the local environment lead to higher levels of performance diminish over time, leading to native variety retention and in the end hindering change to new varieties. Piecemeal harvesting capability is also considered a key factor by a substantial number of the farmers (Zawedde *et al.*, 2014), however most of the new varieties are not considered to have good piecemeal harvesting characteristics.

Production costs, market volatility and uncertainity greatly affect variety change, this was the case with maize farmers in Mexico under the North American Free Trade Agreement (NAFTA) reforms (Sanchez *et al.*, 2018). The importance of government support during the production process and market prices may play an important role in mitigating risk perception as reported by (Sanchez et al., 2018), this would also be a valid strategy in increasing the rate of technologies change from old to new improved crop varieties.

Agricultural development strategies should address the various categories of farmers and locations to successfully and efficiently promote change to new technological

innovation and additionally, extension efforts should be strengthened to increase the flow of information to farmers (Zivamonoyo & Mukarati, 2009). Young farmers with low numbers of family members and high numbers of generations, who are also dedicated to agriculture (Sanchez et al., 2018), with sufficient information about innovation and are willing to take risks (Nyamai, 2010), are more likely to take up improved seeds. Milkias & Abdulah, (2018), observed that farm size, household income, access to credit, contact with extension agents as well as participation in training and field day positively and significantly influenced variety change as for the case of maize in Toke Kutaye district of Ethiopia.

Education level, farming experience, market information, farm machinery ownership and extension contact significantly and positively influence the uptake of improved rice varieties (Chandio & Yuansheng, 2018). Also the price of existing crop variety, level of education of farmers, the size of the farms, government policies and incentives and credit availability (Sanchez *et al.*, 2018; Milkias & Abdulah, 2018), were observed to positively influence varietal change.

The farmer and farm characteristics that significantly influence varietal change decisions include the status of being male-headed, total farm size and number of visits by extension agent (Sanchez *et al.*, 20180; Olarinde & Fatunibi, 2017), hence households with educated male heads are more likely to change to improved varieties. Affordability of improved maize seed varieties also positively interact with the change to improved maize seed varieties (Olarinde & Fatunibi, 2017) and this also suggests that efforts should be made to reduce the cost of purchasing the technology or alternatively, assist farmers in accessing credit for purchase. Bearing the problem in distribution system for the modern inputs (improved seed and fertilizer) in mind, it

becomes necessary to increase effort aimed at ensuring an efficient extension delivery system (Saka & Lawal, 2009). This would provide for accelerated distribution and consequently uptake of the high potential improved varieties (Wake et al., 2019).

Membership to farmer groups and experience with improved maize varieties positively influence the likelihood of farmers' choice of improved maize seeds (Nyamai, 2010). Creating access to training and information gives awareness to farmers on the yield advantages of improved varieties and enhance the technical capacity of farmers on the agronomic practices. The technical capacity and perception of the farmers as being model farmer and social capital of individual households like availability of friends, relatives and neighbors who cultivate improved varieties encourages variety change on the farm characteristics front (Wake *et al.*, 2019).

2.4 Challenges of Varietal Choice and Change analysis

To be able to do varietal choice and change analysis, varieties should be uniquely identified (Poets *et al.,* 2020), and the most common methods for varietal identification are farmer elicitation and use of phenotypic attributes by showing visual aid photos because they are affordable. Farmer elicitation works if the cultivated seeds are purchased from a formal seed system that truthfully label purchased seed attributes and the container still exist or if farmer have better access to the extension (Ilukor *et al.*, 2019). However, given the well-documented weaknesses in extension and seed systems as well as the reliance on informal methods of seed acquisition, farmers may misidentify or not be able to correctly identify the varieties they plant (Ilukor *et al.*, 2019).

Where as the use of morphological descriptors, based on data from plant breeders about expected phenotypic characteristics of individual varieties to aid farmer reporting has been proposed as a promising method for uniquely distinguishing varieties (Poets *et al.*, 2020), the feasibility and the accuracy of this approach has shortcomings. Morphological characteristics are often multi-genic and are not available at all growth stages and as reported by (Meridia K *et al.*,2015), morphological attributes are not stable and may reflect an adaptation to environmental conditions.

The questionable challenges with estimating the adoption of improved varieties using farmer based self reports, point to a wider use of DNA finger printing likely to become the gold standard of variety identification (Kosmowski et al., 2016). The variety naming systems that emerge in the absence of formal seed systems and that exhibit variation across time and space is another complicating mediating factor in obtaining reliable information from survey respondents (Ilukor *et al.*, 2019). Consequently, adoption estimates may be incorrect, estimated impacts could be questionable, and policy implications could be misleading (Ilukor *et al.*, 2019).

The alternative to subjective, self-reported data from farmers, is to collect samples of plant material for example leaf tissue from standing plant, grains produced at harvest, or seeds used in planting from specific plots which are then subjected to Deoxyribonucleic acid (DNA) fingerprinting (Meridia K *et al.*, 2015). DNA fingerprinting techniques rely on molecular markers that are not only unaffected by the factors that may affect morphological descriptors but that are also present throughout plant genomes (Kosmowski et al., 2016). Genome-wide markers, such as single nucleotide polymorphisms (SNP), can be used to identify the field sample

varieties based on the genetic distance estimates between the sample and the universe of possible varieties represented in a reference library.

There are several interesting findings revealed by DNA fingerprinting of the farmer samples and library accessions (Meridia K *et al.*, 2015), that have implications on the breeding program, the seed system, and for impact assessment (Gourlay *et al.*, 2017). However getting high quality DNA for genotyping is a challenge, especially when samples are collected from farmers' fields, hundreds of miles from extraction laboratories (Poets *et al.*, 2020)

The potential for scaling up DNA fingerprinting as part of household surveys will depend on several factors including; logistics of collecting, tracking, storing and transporting the samples from farmers' fields to a labaratory facility (Meridia K *et al.*, 2015). The cost of DNA fingerprinting which includes; establishing the reference library, DNA extraction and genotyping service should also be put in consideration in a bid to achieve the use of the gold standard DNA fingerprinting method (Ilukor *et al.*, 2019). The challenges in distinguishing varieties properly are likely to increase as seed systems and breeding technologies evolve and the introduction of closely related but distinct varieties onto the market becomes more common hence justifying the use of DNA finger printing (Poets *et al.*, 2020).

CHAPTER THREE
METHODOLOGY

3.1 Study area

The study was conducted in two main potato producing districts in Uganda namely; Kabale and Kisoro. The two districts are in the South Western Highland Agro-ecological Zone (SWHAEZ), of Uganda. Kabale and Kisoro are grouped together because they are majorly made up of highlands with low temperatures ranging from $26^0\,C$ to $28^0 C$. In terms of potato production, Kisoro district is the leading producer with a total of 138,000 metric tons from 3000 hectares followed by Kabale 61,000 metric tons from 9,000 hectares, Kanungu with 860Mt from 523ha (UBOS, 2010a). Thus, for this study, the districts of Kabale and Kisoro were selected because they have the same agro ecological conditions and higher production levels.

3.2 Sampling and Sample Size

The sampling units of this study were a household and and a plot, and at each household one potato plot was selected. Data for this study was collected from the two districts of Kabale and Kisoro using a combination of purposive and random sampling technique. To obtain a sample of respondents for this study, the two districts of Kabale and Kisoro were selected purposively because they are the leading potato producing districts. To control for variations in Agro-ecological zones, Kabale and Kisoro were purposively selected as study districts. In each of the district, two subcounties were purposively selected based on volumes of potatoes produced and number of farmers producing potatoes (UBOS, (2010a); Mbowa & Mwesigye, 2016). In each sub county 5 villages were randomly selected and a list of all households growing potatoes was generated. A random sample of 10 households was selected

from each village making a total of 200 households. The fieldwork was conducted in the second season of 2016.

3.3. Data Collection and Processing

Cross sectional data was collected using questionnaires administered to sampled households in the study districts. Data was collected using survey solutions supported computer assisted personal interview (CAPI). The survey tool had four key modules namely: (1) socio-economics (age, sex, education, household size, gender, and experience); (2) farm characteristics (distance to the seed source, access to credit, access to agricultural information, membership in a farmer group, ownership of farm assets, access to extension); (3) Potato varieties planted in 2016 and varieties cultivated in 2015; (4) potato varietal attributes (Resistance to bacterial wilt, Dry matter content, Tuber skin texture-hard/soft, early maturity, marketability, taste tuber size and number of tubers per plant). This data was collected at household and plot level. A plot is defined as a contiguous piece of land within a parcel on which a specific crop or a crop mixture is grown. During my study the average size of a plot grown with potato was half an acre. At the time of the interview the plot grown with potato was considered. There are farmers who had more than one plot but with the same potato variety; for the purpose of this study all (same potato variety plots) were lumped up in one and the acreage estimated. This was standardized to a hectare at data analysis. It is not a common practice for farmers to plant multiple varieties. However there are few farmers who plant two varieties. In my survey only twelve (12) farmers had grown more than one variety on a plot; henceforth these were not included in data analysis. For yield, a yield track record was left with the farmer at the time of data collection, this was collected at harvest time.

3.4 Crop varietal choice and change analytical methods

Doss (2006), notes that choosing how to model a choice will depend on the type of technology, the local context and the research question being examined. The farmer will choose a technology if the expected profit function achieved from choosing it is greater than the expected function of choosing another (FAO, 2015). Hence farm households choose an improved agricultural technology when expected utility from that technology is higher than their traditional practices or varieties (Jaleta *et al.*, 2013; Lee & Eastwood, 2003).Technology choice is considered to be a discrete or binary.

Decisions to chose a variety in households will primarily be made by the household head. This justifies disaggregation of the data based on gender of household heads so as to tease out the factors that affect household variety choice in the two households and hence forth determine if differences do exist among these households. A regression approach can be adopted to examine the impact of individual/household characteristics on variety choice or change . Assuming that the residual is uncorrelated with the regressors and normally distributed, ordinary least squares (OLS) can be used to estimate parameters of interest. If the dependent variable is binary in nature (taking on values of 1 if individual chose a potato variety and zero otherwise), probability models are the most appropriate (Greene, 2012), thus a linear probability model (LPM) would be adopted. The coefficient in LPM would be interpreted as the effect of X on Y (partial effect) holding other factors constant. However, continually increasing the values of X would drive Y (probability) above 1 or below 0. A plot of estimated residuals against the fitted shows that the values of the residuals decrease with an increase in fitted Y, highlighting a serious problem of

heteroskedasticity of the error terms. While the estimated coefficients remain unbiased, the standard errors and hence the t-statistic are affected therefore affecting inference from the results.

To solve these problems, LPM and OLS method of estimation are abandoned and an option for a response model is taken. The maximum likelihood method of parameter estimation is used. We can choose between a logistic or normal distribution for F hence a logit model or probit model respectively. Since the choice decision is inherently multivariate, attempting univariate modeling may exclude useful information contained in interdependent and simultaneous adoption decisions. However, a multivariate probit model technique (Dawa, 2015) simultaneously models the set of explanatory variables on each of the different varieties (practices) while allowing for potential correlation between unobserved disturbances, as well as relationships between adoption of different varieties. We could thus use Multivariate probit model (FAO, 2015; Dawa, 2015), a technique applied to multiple observations. For the case potato varieties (improved),multivariate probit model treats choice of different varieties as independent from each other except for modeling their underlying errors as jointly normally distributed.

Another model that could fit the analysis of varietal choice is multinomial logit. The model permits the analysis of decisions across more than two categories of the dependent variable (Ayuya, *et al.*, 2012). The MNL model is also simple to compute compared to its counterpart the multinomial probit (Ayuya *et al.*, 2012). In order for the parameter estimates for the MNL model to be unbiased and consistent, the independence of irrelevant alternatives (IIA) is assumed to hold. The IIA assumption requires that probability of choosing one improved variety by a potato farmer is

3.5 Analytical framework

Statistical descriptives were used to analyze the different potato varieties grown by farmers in the South Western Highland Agro ecological zone. To determine the drivers of farmer choice of potato varieties in the South Western Highland Agro Ecological zone of Uganda, a multinomial probit (MNP) model was estimated. The model was preferred because it permits the analysis of decisions across more than two categories in the dependent variable. In addition, since the probability of choosing one potato variety is not independent of choosing another variety, the independence of irrelevant alternatives (IIA) cannot hold. The estimation of the multinomial logit model would lead to biased and inconsistent estimates. Multinomial probit model which is a natural alternative model that relaxes the independence restrictions built into the multinomial logit (MNL) model is estimated (Greene, 2012). The estimated model for drivers of farmer choice of potato varieties is represented by the following regression equation (Theoretical model)

$$Y_{ph} = \alpha_{ph} + \beta A_{ph} + \gamma F_{ph} + \partial M_{ph} + \rho D_{ph} + \varepsilon_{ph} ------(1)$$

where p and h denote plot and household, respectively; $\boldsymbol{Y}$ represents one of the three outcomes, namely, (1) a farmer planted or chose the variety Kinigi, (2) a farmer planted or chose the variety Rwangume, and (3) a farmer planted or chose the other varieties other than Kinigi and Rwangume; and $\boldsymbol{A}$ is a vector of varietal attributes which include early maturity, high yields, resistance to bacterial wilt, marketability, Tuber skin texture (hard /thick/roughs Vs soft/ smooth) and dry matter content. $\boldsymbol{F}$: a vector of farm-level and institutional variables including distance to access to extension services, access to credit, seed source, and distance to seed source; $\boldsymbol{M}$: a vector of household attributes, inclusive of age, gender, education, marital status, and

experience of farmer in potato production as well as type of dwelling. ***D***: a vector of district level fixed effects; and α and ε are constant and error terms, respectively.

The dependent variable is a categorical variable taking on three outcomes representing three alternative varieties for a farmer to choose either one, two or all but planted in different plots, $Y \in \{1, 2, 3\}$

$$Y_{ph} = \begin{cases} 1\ is\ farmer\ choice\ to\ plant\ variety\ denoted\ 1 \\ 2\ is\ farmer\ choice\ to\ plant\ variety\ denoted\ 2 \\ 3\ is\ farmer\ choice\ to\ plant\ variety\ denoted\ 3 \end{cases}$$

The empirical model is:

$$\begin{aligned} Y_{ph} = \alpha_{ph} + \beta E_{ph} + \beta H_{ph} + \beta R_{ph} + \beta M_{ph} + \beta Tst_{ph} + \beta FT_{ph} + \gamma Ext_{ph} \\ + \gamma Cred_{ph} + \gamma SS_{ph} + \gamma DSS_{ph} + \partial Age_{ph} + \partial Gen_{ph} + \partial Edu_{ph} \\ + \partial Mar_{ph} + \partial HT_{ph} + \partial Exp_{ph} - - - 2 \end{aligned}$$

Where the variables are as in Table 2;

Table 2: Variables Used in the Empirical Model

Variable Symbol	Variable Name/ Desription
E	Early Maturity
H	High yielding
R	Resistant to Bacterial wilt
Tst	Tuber Skin Texture (Hard/Rough vs soft /smooth)
FT	Food taste/nature (Marsyh vs crispy/chips)
M	Marketability
Ext	Access to extension information
Cred	Access to credit by the farmer
SS	Seed source
DSS	Distance to the seed source
Age	Household head Age
Gen	Gender of the household head
Edu	House hold head Education level
Mar	Marital status of the household head
Exp	Duration for which farmer has grown a variety
HT	Household house type

To determine the drivers of farmers' potato varieties change/retention in the South Western Highland Agro Ecological zone of Uganda, a probit model was estimated. The probit model constrains the estimated probabilities to be between 0 and 1, and relaxes the constraint that the effect of the independent variable is constant across all predicted variables (Nagler, 1994). For empirical analysis, focusing on varietal change or retention factors a linear expression is assumed as also suggested by (Frank Elly, 2014).

The dependent variable is change of potato variety grown between season 2015B and 2016A (Y_c). Y_c is binary, hence a probit model was estimated as follows:

$$Y_c = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k + \mu - - - (3)$$

Where Y_c is the binary outcome, c is the indicator function, returning 1 if a household changed varieties grown and 0 otherwise.Then the empirical model model estimated is as follows:

$$Y_c = \beta_0 + \beta_1 E + \beta_1 H + \beta_1 R + \beta_1 M + \beta_2 Ext + \beta_2 Cred + \beta_2 SS + \beta_2 DSS + \beta_3 Age + \beta_3 Gen + \beta_3 Edu + \beta_3 Mar + \beta_3 Exp \text{ ---(4)}$$

Variables are as defined in Table.2

Table 3: Summary Statistics of Variables for Assessing Varietal Choice and Change

Variable	Description	P/M
Kinigi Variety	Is equal to one (1) if a farmer planted Kinigi, and zero (0) Otherwise	68
Rwangume	Is equal to one if a farmer planted Rwangume and zero (0) Otherwise	48
Other[1]	Is equal to one if a farmer planted other[1] variety , and zero (0) otherwise	31
Variety change	Is equal to one (1) if a farmer changed variety, and zero (0) otherwise	85
Access to credit	Is equal to one (1) if a farmer accessed credit and zero (0) otherwise	86
Access to extension	Is equal to one (1) if a farmer received extension info and zero (0) otherwise	77
House hold head is married	Is equal to one (1) if the couple at the household is married and zero (0) otherwise	134
House head sex	Is equal to one (1) if the household head is a male, and zero (0) otherwise	131
Educational level of household head	Is equal to one (1) if the household head acquired Primary level & above, and zero (0) if he/she acquired no formal education	76
House hold house type	Is equal to one (1) and tempory if the house is made up of mud and wattle ; zero (0)& permanent if the house is made up of bricks and cement	36
Seed source	Is equal to one (1) if the farmer used accredited sources like NARO, UNSPPA & NAADS and zero (0) from own farm harvest	88
Land tenancy type	Is equal to one (1) when one used Own land and zero (0) otherwise (rent)	121
Soil type	Is equal to one (1) if the farmers' plot had Loam soil type and zero (0) otherwise (sandy clay loam)	98
Tuber skin texture	Is equal to one (1) if the skin texture is rough/ hard/thick and zero (0) otherwise	88
Cooked food nature	Is equal to one (1) if the cooked food is firm &chips crispy and zero otherwise (mealy floury)	59
Household size	Number of people living in the household	5.1
Householdheadage	Average age of the household head (years)	43
Seed source Dist.	Distance to the seed source (Km)	3.9
Experience	Duration for which the farmer has grown/ known a variety (years)	9.6
Resistance to bacterial wilt	Is equal to one if the variety is reported to be resistant to bacterial wilt, and zero (0) otherwise.	13
Maturity period of the variety	Is equal to one if the variety is reported to be Early maturing and zero (0) otherwise	27
Varietal Market	Is equal to one (1) if the variety is reported to be marketable and zero(0)	93

Other[1]:Victoria, Nakpot 5, Kachpot 1, Rutuku, Cruza, Mbumbamagara, Rwashaki,Kimuri

3.5.1 Measurement of variables and hypothesized relationships

The decision to take up and maintain a particular potato variety is a dependent variable. The explanatory variables that are believed to affect the choice and varietal retention/change of improved potato varieties in the SWHAEZ are divided into: Farmer/social characteristics (age, education level, household size, gender and experience), Institutional/market related factors (Distance to the seed source, access to credit, access to agricultural information and belonging to a farmer group). These represent both continuous and categorical variables; where a continuous variable takes on any numerical value while categorical takes a numerical value of one or zero also termed as binary or dummy variable (Table.3)

Access to credit takes 1 if one received credit and 0 if one did not. Access to credit is considered to be a major determinant factor in in choice, change or retention because credit can be used to access a number of inputs including improved clean seed. Access to information is expected to positively influence the choice of improved potato varieties. Information concerning improved or modern technologies facilitate the choice and hence retention of improved varieties.

Marital status takes 1 if one is married and 0 if one is not. Marital status is expected to positively influence the choice of improved varieties. Married individuals have an obligation to provide for their families so any economic activity which brings money to family is taken up especially for smallholder farmers in rural areas. Seed source and distance is expected to positively affect the choice and uptake of improved potato varieties, as it directly affects availability of the improved clean seed. Market availability is expected to positively affect the choice of a given technology. The general perception is that the shorter the distance from the household to the nearest market in addition to good access/ feeder roads, the higher the probability of up take of the technology.

Household size is expected to positively affect the choice of improved technology, as the household size increases the need for income and food increases at the same time family labour is readily available to work in the fields. As reported by Abebe *et al.* (2013) household size has a positive impact on choice of technology which could relate to improved varieties being higher yielding hence larger family size (with more dependents) might view improved varieties as a better option for home consumption. They also argue that a large family size means large labour force which could positively affect adoption decision.

Farmer education level is measured as 1 if one attended above primary school and 0 if a farmer acquired some primary education or no formal education at all. The importance of education and experience in enhancing human capital through acquisition and learning of skills has been well documented. More educated farmers are typically assumed to better process information and search for appropriate technologies (Abebe *et al.*, 2013). Household head age; it may be that older farmers are more risk-averse and less likely to be flexible than younger farmers and thus have a less likelihood of getting involved in taking up new improved potato varieties. It could also be that older people have more experience and are in a better position to assess characteristics of new technology than younger farmers, and hence a higher probability of adopting the new technology (Deressa, 2015).

Tuber skin texture and cooked food nature are potato attributes. A hard skin texture is expected to positively affect the choice of improved potato varieties. Cooked food nature is a dummy variable for firm salad crisps, chips,firm food and mealy flour type, henceforth the firm type is expected to positively affect the choice while mealy flour is negative. Pests and diseases resistance is another crop attribute which is expected to positively affect the choice of an improved crop technology.The relationship between the predictor variables that drive improved potato varietal choice and change in the SWHAEZ was determined (Table.9). The

results helped to predict the variables that were used in the multinomial Probit model for objective three and probit model for objective four.

DIAGONOSTIC TESTS

Fallacy dichotomy is considered to be material in which an urguement is poorly prepared with incorrect conclusion being prepared (Brisson *et al.*, 2018). In this case fallacy dichotomy is considered at a level of 12 farmers who had planted more than one varieties at the time of data collection. The farmers there in referred to were excluded at analysis level.

Multicollianirity represents a high degree of linear intercorrelation between explanatory variables in multiple regression model and leads to incorrect results of regression analyses. Diagonistict tools of multicolliniarity include the variance of inflation (VIF) mainly. Tha variance (σ_h^2) of the regression coeeficients constituting the final regression model are proportional to the $VIF\ \frac{1}{1-R_h^2}$. Hence an increase in R_h^2 (strong multicolliniarity increases variance σ_h^2. Tha larger variance produces unreliable probability values and confidence intervals of regression coeeficients. Multicollianirity is present when the VIF is higher that 5-10. Excluding multicollinear explanatory variables leads to statistically stable multiple regression models.

Multicollinearity distorts the results obtained from multiple linear regression analysis (Kim, 2019). The inflation of the variances of the regression coefficients due to multicollinearity makes the coefficients statistically insignificant and widens their confidence intervals. Multicollinearity is determined to be present if the variance inflation factor and condition number are more than 5 to 10 and 10 to 30, respectively. However, they cannot detect which explanatory variables are multicollinear. To identify the variables with multicollinearity, the variance decomposition proportion is used. If the variance decomposition proportions of more than 0.8 to 0.9 correspond to the condition indices of more than 10 to 30, the

explanatory variables, which are associated with the variance decomposition proportions corresponding to common condition indices, are multicollinear. In conclusion, the diagnosis of multicollinearity and exclusion of multicollinear explanatory variables enable the formulation of a reliable multiple linear regression model.

CHAPTER FOUR
RESULTS

In this chapter, results are presented following the objectives of the study alignment. Thus the results presented include; characterization of potato farmers in the South western Highland Agro-ecological Zone of Uganda based on variety change; Multinomial probit model results for drivers of improved potato varietal choice and change in the SWHAEZ are also presented in this section.

4.1. Local and Improved Potato Varieties grown by Farmers in the SWHAEZ of Uganda

Table 4. presents the incidence of local and improved potato varieties grown in season two of 2015 (2015B) and season one in 2016 (2016A) where A and B denote first and second rain season respectively within the same calendar year. The results reveal that the most grown varieties are Kinigi and Rwangume in both 2016A and 2015B. However, the growing of Kinigi and Rwangume declined in 2016A as farmers chose other varieties.

Growing of Rwashaki increased by 12% and that of Victoria by 2%. In addition, other varieties that were not initially grown in 2015B emerged although their levels were generally low. The new varieties, Kinigi and Rwangume grown in season 2015B reduced from 50.3 to 45.6 percent and 34.2 to 31.6 percent in season 2016A respectively.There was an increment in the growing of Victoria and Rutuku which are new varieties by 2 percent and 0.7 percent respectively. However local varieties that were hitherto not grown in season 2015B were grown in season 2016A, these are Mbumbamagara, Rwashaki and Kimuri at 0.67 percent, 1.2 percent and 1.34 percent respectively.

However the newly released varieties including; NAROPOT 4, NAROPOT 3, NAROPOT 2 and NAROPOT 1 are conspicuously missing in the list of others. Only the old released

varieties including; Victoria, Nakpot 5, Kachpot 1 and Cruza make it to the list of others the rest being local varieties.

Table 4: Levels of Local & Improved Potato Varieties grown in Seasons 2015B And 2016A in the South Western Highland Agroecological Zone (SWHAEZ) of Uganda

Variety Name	Variety Level (2015B) (%)	Variety Level (2016A) (%)	Level of Change (%)
Kinigi	50.30	45.6	-4.70
Rwangume	34.20	31.6	-2.70
Other	15.50	22.8	7.30
Total	100.00	100.0	

4.2 Characterisation of potato farmers basing on extent of varietal change

Table 5. presents the social and economic charatcteristics of farmers that change varieties from season to season. Potato farmers are categorized into two: those farmers who retained the potato variety grown in 2015B (Retainers) and the category of those who changed the variety in 2016A (Changrers). Households in the study sample were comparable in most socio-economic attributes except household size, household house type and education levels attained by the household heads. Average household size was six and five among retainers and changers respectively and significant at 5% level . The proportion of temporary household dwellers who retained the variety was 33 % compared to 19% of those who changed and significant at 5% level. The proportion of household heads with primary education level and above who retained the variety was 59 % compared to 47 % of those who changed and significant at 5% level

Table 5: Characteristics of the sampled households Based on Variety Change Extent

	Variety Retainers (66%)	Variety Changers (34%)	
Variables	Mean/Proportion	Mean/Proportion	Difference
Credit Access	0.53	0.60	0.07
Access to extension services	0.51	0.52	0.01
Being Married	0.92	0.89	-0.03
Education level House hold head	0.59	0.47	-0.12*
Household house type	0.33	0.19	-0.14*
Land tenancy type	0.86	0.79	-0.07
House hold size	6.33	5.03	-1.30*
Household head age	43.90	42.40	-1.50
Seed Source Distance	3.20	4.20	1.00
Early Maturity	0.14	0.19	0.05
Resistance to bacterial wilt	0.08	0.10	0.02
Tuber skin texture	0.48	0.67	0.19

The study also examined the extent to which varieties are retained Figure.2, shows varietal change between the second season of 2015 (left Panel) and the first season of 2016 (right panel) as reported by the Potato farmers. The results reveal that in 2016A, 66% of the farmers cultivated the varieties they grew in 2015B while 34% changed or did not retain the variety they planted the previous season (Figure 2). Farmers who reported a change from Kinigi in season 2015B grew Rwangume, Victoria, Nakpot 5, Kachpot 1 in 2016A in descending order. Farmers who reported a change from Rwangume grew Kinigi, Victoria, Kachpot 1 and Cruza. While farmers who reported a change from Nakpot 5 grew Kinigi in 2016A , the Vicoria variety changers grew Kinigi and Rwangume.

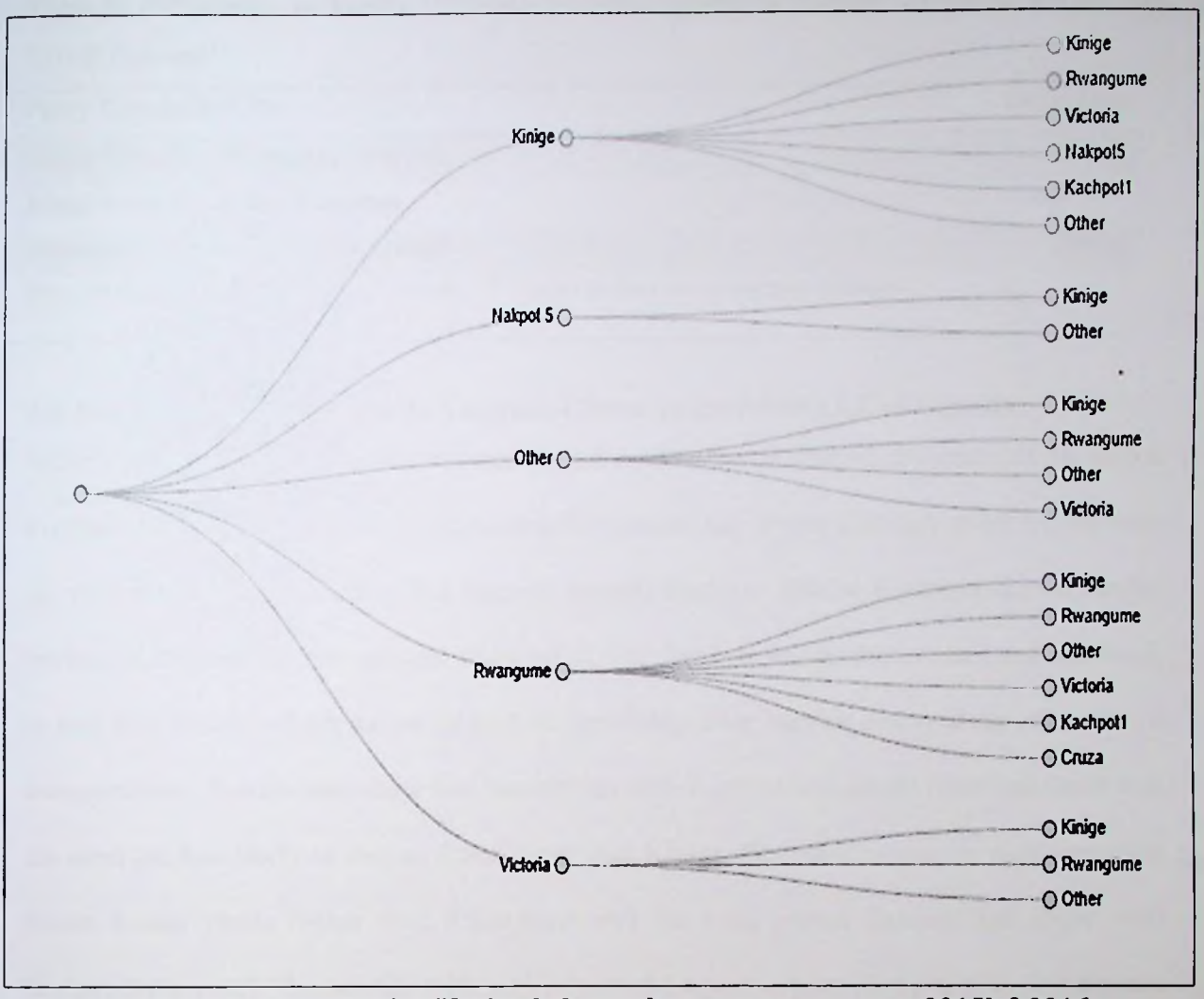

Figure 2: Dendograms showing Varietal change between two seasons:2015b&2016a

The results showed that the yield for the two most grown varieties (Kinigi and Rwangume which were released in 1994 and 2016 respectively) on average were 10 tones/ha and 8 tones/ha respectively while the mean of other varieties was 4 tones/ha. Results from the t test of unequal variances shown in Table 6, reveal the presence of statistical significant evidence that the yield of two main adopted varieties is significantly different from other varieties but no significant difference exists to suggest that the yield difference between the yield or performance of the two varieties in farmer field.

Table 6: Difference in Yields of Potato Varieties grown in Farmer Fields in 2015A and 2016B Seasons

Purity Threshold: 95%	Difference
Kinigi Variety - Rwangume Variety	810
Kinigi Variety - Other Varieties	2471***
Rwangume Variety- Other Varieties	1661*

Here, the P vcalues are ; * p<0.05, ** p<0.01, * based on the t test of unequal variances**

4.3. Drivers of Improved Potato Varieties Choice in the SWHAEZ of Uganda

Table 7 presents results of a multinomial probit model, the likelihood chisquare of 36 with a P-value of 0.0001(p> 0.0001), indicates that this model fits better than any other model with no predictor. The results show that farmers are less likely to choose Rwangume over Kinigi because Rwangume is less resistant to bacterial wilt, has low dry matter content and has weak or soft skin texture which has an impact on storability after harvest and peeling off while in transportation. Results also show that households with married household head and those that are aged are less likely to choose Rwangume over Kinigi, this coud be due to yield variation where Kinigi yields higher than Rwangume and the long period farmers had spent with Kinigi (experience). Households with high household size are more likely to pick Rwangume over Kinigi. With regards to other varieties, results reveal that households with large household size are more likely to plant other varieties other than Kinigi by 24 percentage points, while households' permanent dwellings, better loamy soils, and those who get high yields are less likely to plant other varieties over Kinigi as shown in Table 6.

On the varietal attributes front, results reveal that low resistance to bacterial wilt reduce Rwangume variety choice by 44 percentage points compared Kinigi. Skin texture (smooth tuber skin texture) reduce Rwangume variety choice by 13 percentage points compared to Kinigi. Dry matter content reduce Rwangume variety choice by 32 percentage points. On the socioeconomic front results reveal that marital status (being a married household head)

reduce Rwangume variety choice by 62 percentage points. Also being a male headed household reduce Rwangume variety choice by 43 percentage points. On the same front household head age reduce Rwangume variety choice by 23 percentage points. As household size increases, they tend to choose Rwangume over Kinigi by 2 percentage points.

Table 7: Determinants of Farmer choice of Potato Varieties in the South Western Highland Agroecological Zone (SWHAEZ) of Uganda

Variables	Marginal effects (Kinigi choice)	Marginal effects (Rwangume)	Marginal effects (Other choice)
Gender	0.522*(0.25)	-0.426**(0.23)	-0.095(0.23)
Household size	-0.034*(0.01)	0.021** (0.016)	0.024*(0.016)
Resistance to bacterial wilt	0.336**(0.135)	-0.438** (0.127)	0.075 (0.111)
Early maturing	-0.057(0.099)	0.109 (0.070)	-0.039 (0.089)
Market availability	-0.021(0.081)	-0.057(0.075)	0.085 (0.073)
Seed source distance	-0.009*(0.004)	-0.000 (0.003)	0.005 (0.003)
Credit Access	0.053(00076)	0.080 (0.063)	-0.096 (0.064)
Access to extension	0.253(0.075)	0.020 (0.066)	-0.071 (0.068)
Marital status dummy	0.670***(0.143)	-0.619**(0.113)	0.039 (0.119)
Education level of household head	0.015(0.074)	-0.009 (0.067)	0.016 (0.063)
Household house type	0.172*(0.090)	-0.082 (0.079)	-0.114* (0.083)
Household head age	0.038**(0.020)	-0.023* (0.016)	-0.018 (0.019)
Household head age^2	0.000(0.000)	0.0001* (0.000)	0.000 (0.000)
Experience	0.005(0.006)	0.001 (0.004)	-0.006 (0.004)
Soil type	0.134**(0.076)	-0.031 (0.064)	-0.112* (0.064)
Seed Source	0.002(0.013)	0.112 (0.072)	-0.012 (0.072)
Plot yields	0.002*(0.001)	-0.001 (0.000)	0.000* (0.000)
Tuber skin texture	0.122(0.075)	-0.134* (0.058)	-0.003 (0.065)
Dry matter content	0.245***(0.652)	-0.325* (0.056)	0.094 (0.057)
Kisoro			
Constant			
N			147
Wald Chi^2 (36)			126.65
Prob > chi^2			0.000

Other: Victoria, Nakpot 5, Kachpot 1, Rutuku, Cruza, Mbumbamagara, Rwashaki, and Kimuri

4.4 Drivers of farmers to change potato varieties in the SWHAEZ of Uganda

The results of the estimated model are presented in Table 8. The results suggest that distance to the seed source reduces the likelihood of farmer changing the variety by 1.4 percentage

points. This implies that as the distance from the seed source increases, farmers tend to keep the same variety by recycling the previous season's seed hence retaining the same variety for a time. In addition, farmers who have cultivated the same variety for the long time are also less likely to change potato varieties by 1.2 percentage points. Being married, age and Potato tuber skin texture increases the likelihood of changing potato variety planted by 46, 3.7 and 18.2 percentage points respectively.

Table 8: Driver of Farmer decision to Change Potato Varieties planted in SWHAEZ

Model	***Probit with district level fixed effects***	
Variables	***Probit Coefficients***	***Marginal effects***
Gender	0.820(0.63)	0.248(0.18)
Household size	0.080 (1.28)	0.025 (1.30)
Plot yield differences	0.005 (0.24)	0.002 (0.24)
Resistance to Bacterial Wilt	0.263 (0.58)	0.081 (0.59)
Early maturity	0.107 (0.36)	0.033 (0.36)
Marketability of the variety	0.083 (0.31)	0.025 (0.31)
Distance to seed source	-0.046* (-2.21)	-0.014* (-2.28)
Access to credit	-0.011 (-0.04)	-0.003 (-0.04)
Access to extension	0.260 (1.07)	0.080 (1.07)
Married household heads	0.504* (2.17)	0.456* (2.25)
Education level of Household head	0.160 (0.67)	0.049 (0.68)
Household house type	0.437 (1.37)	0.134 (1.40)
Household headage	0.125* (2.39)	0.037* (2.46)
House hold headage^2	-0.001* (-2.16)	-0.000* (-2.21)
Variety Experince	-0.039* (-2.39)	-0.012* (-2.47)
Soil type	0.400 (1.55)	0.123 (-1.58)
Seed Source	0.082 (0.30)	0.025 (0.30)
Tuber skin texture	0.594* (2.40)	0.182* (-0.25)
Dry matter content	-0.003 (-0.01)	-0.000 (-0.01)
Kisoro	-0.004 (-0.02)	-0.324 (-0.86)
Constant	-4.891*** (-3.86)	-0.001 (-0.02)
N		147
Wald chi^2(16)		42.46
Prob > chi^2		0.0015
Pseudo R^2		0.2028

t statistics in parentheses and the P values are ; * p<0.05, ** p<0.01, *** p<0.001

CHAPTER FIVE

5.0 Results discusion

The results reveal that the two main grown potato varieties in South Western Uganda are Kinigi (46%) and Rwangume (32%) (Table 4). However these results clearly contradict findings by Kaguongo *et al.*, (2008), who found that Victoria variety was the most highly adopted variety in South Western Uganda followed by Mbumbamagara and Cruza variety with percentages of 44,19 and 17 respectively. The contradiction could be due to high susceptibility of Victoria to late blight compared to other newer varieties. However, this could be good because continuous turnover of crop varieties is critical to climate change adaptation and reduction in yield loss arising from diseases and pest (Atlin *et al.* 2017; Smale *et al.* 2008; Macholdt & Honermeier 2016). Atlin *et al.* (2017) argue that the objective of breeding and seed systems serving smallholder farmers should be to ensure that they use varieties developed in the last 10 years. However, in the case of potato varieties in Uganda, farmers are still using varieties like Kinigi that were released over 10 to 40 years ago, yet we have over six varieties released in last 10 years.

According to Kaguongo *et al.*(2008), Victoria had the highest level grown, probably due to it's wide adaptability (low and high altitude) followed by Rwangume and Kinigi. However the current status show a big decline in the levels of Victoria with a sharp increase in the levels of Rwangume and Kinigi (Fig.4). This means that Rwangume and Kinigi show the highest adoption levels but Victoria has the highest level of turnover, this is probably because of its high susceptibility to late blight, low yields and white flesh which is less liked compared to the brown.

The main potato varietal attribute that drives varietal change is the thickness (hardness) of the potato tuber skin texture. This could be attributed to the fact that thick potato tuber skin

prevents pathogen invasion and fluid loss thus providing a tuber with a natural defense mechanism against pathogens invasion (Niederwieser 2014; Barel & Ginzberg 2008). The hard tuber skin textures ensures also that the potato tuber is kept for quite a longer time without going bad and it also ensures that the skin does not peel off during transportation.

The seed system based attributes that drive varietal change are the distance to the seed source and years of a farmer cultivating the variety (experience). The results suggest that reducing the distance to seed market or source would increase growing of new varieties and varietal change. This is supported by earlier findings (Shiferaw *et al.*, 2014; Doss 2014; Matuschke & Qaim 2009 and Witcombe *et al.*, 1999) who found out that the shorter the distance to seed source or input market increase growing (uptake) of new improved seed thus reducing longevity of farmers growing one variety.

The Socio-economic attributes that were found to influence varietal change are marital status and age of the household head. Age is usually considered as proxy for experience and being knowledgeable of agricultural technologies thus increasing the likelihood of adopting or changing to new variety (Matuschke & Qaim, 2009). Marital status reflects economic status stability (Hoffman, 1977), and married farmers are known to adopt improved technologies (change to new varieties) because they have financial ability to afford them.

Results from the analysis of varietal choice reveal that the potato varietal attributes that influence choice of varieties over other varieties are yield, resistance to bacterial wilt, tuber dry matter content and thickness/hardness of the tuber skin. Kinigi is cultivated over other varieties like Victoria, Cruza, Mbumbamagara and Rutuku because it performs better. The results support earlier findings (Heisey *et al.*, 1987; Kaguongo *et al.*, 2008 and Witcombe *et al.*, 2000) that have shown that farmer choice of varieties is influenced by yield gains.

However, the farmers' choice between Kinigi and Rwangume is not influenced by yield. Indeed, the results (Table 5) from t test of unequal variances reveal that there is no statistical significant difference in yield of Kinigi and Rwangume but a significant difference in yields exists between these two varieties and other varieties like Victoria, Cruza, Mbumbamagara and Rutuku.

One of the key factors that drives farmers' choice of Kinigi over Rwangume is resistance to bacterial wilt. Bacterial wilt is an endemic and catastrophic potato disease in Uganda with no easy chemical solution once it strikes (Kaguongo *et al.*, 2008). Based on the results, it seems that Kinigi is resistant or tolerant to bacterial wilt more than Rwangume yet in Table 1 Rwangume is tolerant to bacterial wilt while Kinigi is susceptible. Our consultation with potato breeders at Kachwekano research station revealed that Rwangume (NAROPOT 4) is a CIP breeding line 396034.103, which escaped into the system between 1999 and 2002 alongside the NAKPOT (1-5) varieties. All these varieties were tested during the stated period 1999-2002. The NAKPOT lines passed and were released. However, Rwangume was not released due to its high susceptibility to bacterial wilt and viruses. However, farmers found it nice and decided to retain it. The CIP breeding line 396034.103 was cleaned, revaluated and released as NAROPOT 4 in 2016. However, the planting material in farmer fields at the study time (2016) was the one that escaped during the period of 1999- 2002. This confirms susceptibility to bacterial wilt reported by the farmers due to low variability as a result of too much recycling of the same planting material for a period of approximately 17 years.

Kinigi is also preferred over Rwangume because it's considered to have a high dry matter content and hard tuber skin textures than Rwangume. As stated earlier, hard potato tuber skin prevent pathogen invasion and fluid loss thus providing a tuber with a natural defense

mechanism against pathogens invasion (Niederwieser, 2014; Barel & Ginzberg, 2008). Moreover, the thick potato tuber skin enables the potato tuber to be kept for a longer time without going bad and reduces likelihood of the skin peel off during transportation. The high dry matter content on the other hand is linked to high net returns because 100 tubers of variety with high dry matter content will weigh more than the 100 tubers of the variety with low dry matter content (Norell *et al.,* 2016). These attributes make Kinigi more marketable and desirable variety compared to other varieties.

The Social economic factors that influence choice of potato varieties are marital status and age of the household head. As stated earlier marital status is reflection of household economic status while age is a proxy of experience or knowledge. Both these factors are found to influence change to new improved productive agricultural technologies (Matuschke & Qaim, 2009). In this case Kinigi variety is considered to be a better new improved productive technology compared to Rwangume.

With regard to other varieties, Kinigi was chosen by households with low household size, permanent dwellings and better soils. These factors are reflection of poverty status and household living conditions. Large families tend to be poor (Lanjouw & Ravallion, 2018; White & Masset, 2003) while dwelling or housing quality is considered better measure of poverty (Fiadzo *et al.,* 2014; Hood 2005). Barrett & Bevis (2015) argue for the existence of self-enforcing link between poverty or economic status to poor soil quality. Different empirical studies have shown that household living standard or economic status has a significant positive impact on adoption of better technologies. Since Kinigi variety, is highly adopted and yield difference are higher than other varieties, we assert that households with better economic status are more likely to choose better yielding varieties than poorer households.

CHAPTER SIX

6.0 Conclusion

This study sought to assess the factors influencing improved potato varietal choice and change in south western highland agro-ecological zone of Uganda. Specifically the study set out ; (1) To characterize potato farmers in the South Western Highlands of Uganda based on varietal choice and varietal change, (2)To identify popular potato varieties in the South Western High lands of Uganda, (3)To determine the driving factors of improved potato varietal choice in the South Western Highlands of Uganda and (4)To determine the driving factors of improved potato varietal change in the South Western Highlands of Uganda. Results reveal that two majorly grown potato varieties are Kinigi (46%) and Rwangume (32%. However potatato farmers are changing from old improved varieties to old improved varieties rather than to the newly improved ones.

On the Social economic front, varietal choice was influenced by;marital status, age of the household head and household size. Being married household head reduce Rwangume variety choice over Kinigi. Being aged reduces Rwangume variety choice while a big (high) household size increases Rwangume variety choice over Kinigi. Low household size and permanent dwellings were found to positively affect choice of high yielding improved varieties. On the varietal attribute front choice was influenced by thickness of the potato tuber skin, resistance to bacterial wilt, tuber dry matter content. Kinigi is preferred over Rwangume because it's considered to have high dry matter content and thick tuber skin texture than Rwangume. Another key factor that drives farmers' choice of Kinigi over Rwangume is resistance to bacterial wilt. Based on the above we conclude that varietal attributes do influence varietal choice.

Varietal change is mainly driven by distance to the seed source, experience, marital status and age of the household head. Farmers tend to recycle the same improved old potato variety as the distance to the seed source increases. On the same front farmers who have cultivated an old variety for a long time are less likely to take up a new variety.Being married and advanced age of household head increases the likelihood of changing to a new improved potato variety. Potato tuberskin texture is the only varietal attribute that was observed to increase the likelihood of changing the potato variety. Hence forth we conclude that varietal change is based on seed system factors.

6.2 Recommendations

From the conclusions above, new improved varieties are not replacing older improved varieties. This is due to seed system factors, mainly the distance to the seed source henceforth participatory/ community based seed multiplication should be promoted. The extension linkages should also be strengthened to ensure that improved varieties reach out to the farmers.

Breeders should also incorporate thick skin texture and high dry matter content along side the main attributes of early maturity, bacterial wilt resistance and high yield in the breeding program.

APPENDIX

Table 9: Correlations of the variables that were used in the Multinomial Probit and Probit models

	RWD	Kinigi	Other[1]	House size	Wilt Resistant	Early maturity	Seed source	Marital state	House type	House age	House age^2	Saved seed	Tuber texture	Cooked food
RWD	1.000													
Kinigi	-0.021	1.000												
other1	0.049	-0.489**	1.000											
House size	0.274**	0.018	0.007	1.000										
Wilt Resistant	0.086	0.186	-0.005	-0.019	1.000									
Early maturity	0.239**	-0.1	-0.042	0.050	0.041	1.000								
Seed source	-0.183	-0.134	0.090	-0.101	-0.078	-0.062	1.000							
Marital state	0.141	0.107	0.036	0.103	-0.0234	0.063	0.020	1.000						
House type	0.039	0.249	-0.146	0.129	-0.020	0.033	-0.028	0.051	1.000					
Hh head age	-0.099	0.038	-0.067	-0.032	0.073	0.141	0.102	-0.258	0.246**	1.000				
Hh headage^2	-0.116	0.008	-0.052	-0.106	0.069	0.149	0.095	-0.25	0.234**	0.988**	1.000			
Saved seed	-0.019	-0.055	-0.037	0.087	0.027	-0.088	0.363	0.047	-0.030**	0.068	0.042	1.000		
Tuber texture	0.054	0.217	-0.010	0.07	-0.022	0.065	0.044	-0.026	0.258**	0.008	-0.018	-01142	1.000	
Cooked food	-0.109	0.305***	0.104	0.050	-0.013	-0.022	-0.052	0.055	0.059	0.013	0.008	0.039	0.108	1.000

*RWD Rwangume Dummy

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