PREFERENCES FOR AND EXPOSURE TO CLIMATE RESILIENT POTATO VARIETIES: CASE OF SMALLHOLDER FARMERS INMERU COUNTY, KENYA.

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Master of Science Degree in Agricultural and Applied Economics

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Recommendation

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DEDICATION

I dedicate this work to my parents Mr. Moses Kimathi and Mrs. Rosalind Kageni who have invested their time and resources in support of my academic pursuit; my brother Victor Mwenda and my daughter Ailey Tiana Nosizwe for being great source of motivation.

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ABSTRACT

Production of Potato (*Solanum tuberosum. L*) has been declining over the years in Sub-Saharan Africa (SSA) due to climate change and variability. This has resulted to low food supply and low income among smallholder farmers exacerbating levels of food and nutrition insecurity and poverty. Climate Resilient Potato Varieties (CRPVs) are said to have the potential to address this problem by increasing the resilience of farmers to climate variability. However, previous studies show that uptake of these varieties is still significantly low. This study sought to contribute to enhanced farmers' resilience to climate variability through increased adoption of CRPVs. Multistage sampling technique was used to sample 384 farmers from Meru County. Focus group discussions and structured questionnaires through household survey were used to collect primary data. Chi-square was used to compare adaptation practices across different agro-ecological zones. Average Treatment Effect framework was used to determine true population adoption rates and factors affecting exposure to and adoption of CRPVs. To estimate preferences and willingness to pay for CRPV attributes, a discrete choice experiment was conducted and Mixed logit model was used for analysis. SAS, SPSS and STATA softwares were used for designing choice cards, data processing and data analysis respectively. Results revealed that the main adaptation practices among potato farmers in Meru County were irrigation, intercropping, crop rotation, soil conservation, use of organic fertilizers and use of CRPVs. Farmers from Abogeta West and Abothuguchi West were more adapted to climate variability than farmers from Kiirua/Naari and Kibirichia wards. Results further revealed that the main factors influencing exposure to CRPVs positively were education, training and access to credit. Access to information, access to quality seeds, training, group membership and variations in agro-ecological zones were the main factors affecting adoption. The actual population CRPVs adoption rate was 6.3% whereas the potential adoption rate was 30.7% revealing an adoption gap of 24.4% due to partial exposure. Resistant to pests and diseases was the most preferred trait indicated by the high value of willingness to pay. To improve adoption rates for CRPVs, more effort should put in exposing farmers to CRPVs. Finally, breeding programs should also focus in developing potato varieties that are highly resistant to pests and diseases, are high yielding, have low water requirements and short maturation period of less than three months as they are preferred most by farmers for adaptability to climate variability.

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LIST OF ABBREVIATIONS AND ACRONYMS

AERC	African Economic Research Consortium
ATE	Average Treatment Effects
CCAFS	Climate Change, Agriculture and Food Security
CGIAR	Consultative Group for International Agricultural Research
CIP	International Potato Center
CRPVs	Climate Resilient Potato Varieties
CSA	Climate Smart Agriculture
DCE	Discrete Choice Experiment
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agricultural Organization of United Nations
FGD	Focus Group Discussion
GOK	Government of Kenya
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KALRO	Kenya Agricultural and Livestock Research Organization
NCCRS	National Climate Change Response Strategy
SCARA	Strengthening Capacities for Agricultural technology, Research and Adoption
SDGs	Sustainable Development Goals
SPSS	Statistical Packages for Social Sciences
SSA	Sub Saharan Africa
STATA	Statistics and Data
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Potato (*Solanum tuberosum. L*) is an important food crop in Kenya. It doubles up as a major source of income and a staple food. Despite being a key crop, farm produce is usually below the potential level at 8-15T/Ha against a potential production of 40-50T/Ha (CIP, 2019; Kyamanywa *et al.,* 2011; Ogeto *et al.,* 2019). This low productivity can be attributed to increased cases of pests and diseases such as bacterial wilt and late blight, lack of quality seeds and poor extension services; with climate variability being the major constraint to production due to increased temperatures caused by global warming, which increase emergence of pests, and heat stress on plants (Patrick *et al.,* 2020). Heat stress leads to drying of seed materials and also causes potato plants to produce small, poor quality tubers that fetch very low prices (Chakraborty & Newton, 2011). Heavy rains also increase the incidence of bacterial wilt and late blight hence resulting into reduced yields. Floods cause seeds to rot when planted and make land preparation and planting difficult. To counter some of these effects, farmers either abandon that variety or increase input use in terms of chemicals sprayed, which are quite costly for the smallholder farmer (Sinelle, 2018).

Potato production is highly susceptible to variations in rainfall. To yield an approximate of 20T/Ha in one farming season, a minimum of 575mm of rainfall is required. During the 2016-2017 drought in Kenya, a tremendous reduction in potato yields of 56% was reported due to reduced rainfall which reduced from seasonal mean 737mm to 126mm (International Potato Center, 2017). Furthermore, predictions show that due to global warming, equatorial East Africa is likely to further experience 5-20% increased rainfall during the short rain season and 5-10% decreased rainfall during the long rain season by 2050 (Dai, 2011).This is bound to greatly reduce potato production if climate resilient varieties are not developed, disseminated and adopted by potato farmers.

To address these climate-related risks, numerous efforts and resources have been invested into developing and disseminating improved crop varieties that are adapted to climate variability in Sub-Saharan Africa (SSA) (Atlin *et al.,* 2017). In Kenya, International Potato Center(CIP) has been working with farmers from Meru County to increase their resilience to climate variability using Climate resilient potato varieties. These varieties are characterized by early maturity properties, resistance to pest and diseases, heat and drought resistance and

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high yields. Some of the released climate resilient potato varieties in Kenya include; *Lenana, Wanjiku, Chulu, Nyota*and *Unica*. Improvement of Potato varieties can be a pathway to climate variability resilience, increased production and food security in Kenya (Kyamanywa *et al.*, 2011; Paker *et al.*, 2019).

Previous studies show that farmers have adopted different strategies to adapt to climate variability. According to Senyolo *et al.* (2018) some of the climate smart technologies available in Sub Saharan Africa (SSA) include conservation agriculture, harvesting of rainwater and seed varieties that have high tolerance to drought and possess properties of early maturity. However, conservation agriculture and rainwater harvesting are normally associated with high initial investment costs, need of additional labor and intensified management hence making it difficult for smallholder farmers to adopt them.

On the other hand, seed varieties adapted to climate variability in terms of maturation period and resistance to pests and diseases are said to be less costly when accompanied by appropriate agronomic practices, less management intensive and hence have a better chance for adoption by farmers (Senyolo *et al.*, 2018). This makes it convenient for smallholder farmers to use the climate resilient variety technology. According to Fadina and Barjolle, (2018), farmers prefer improved crop variety as the mainstream strategy to cope with climate variability. However, a study by Sinelle (2018), shows that few varieties in the market are actually adapted to climate variability. Available varieties only allow certain ability to cope with surplus rainfall or drought but do not meet other criteria such as high yields or resistant to pests and diseases, traits that are mostly sought for by farmers. The available varieties commonly used in Meru County are shown in appendix iv.

Despite various efforts by the government of Kenya to promote breeding programs for improved potato varieties through public and private institutions such as Kenya Agricultural and Livestock Research Organization (KALRO) and International Potato Center (CIP), there is limited coordination between formal research institutions and farmers. This has resulted into sidelining farmers' preferences especially smallholder farmers leading to lower adoption rates (Sánchez *et al.*, 2017). A study by Kaguongo *et al.* (2008) shows that adoption of improved potato varieties is still low among Kenyan potato farmers from Meru county as compared to farmers from Uganda noting a difference of 24.8% in adoption rates. Therefore, considering farmer preferences and priorities in the breeding process could increase adoption

of improved varieties since it may yield optimal combination of varietal attributes (Sibiya *et al.*, 2013).

Smallholder farming is critical for the economic development of Kenya (IFAD,2008). It is mainly concentrated in the central and Rift valley, and Mount Kenya region. Meru County, which is located in the Mt. Kenya region, is among the leading potato producing counties in the country. Potato is grown for both commercial and household consumption purposes and takes up 3.3% of the county's total agricultural land. However, smallholder farmers are believed to be the most hit by the negative events of climate variability and are assumed to have inadequate knowledge and resources regarding response mechanism (IPCC, 2014). Instead of adopting adaptation strategies, most smallholder farmers respond by abandoning the varieties or reducing their investments in farming which further results into low crop production, threatening food security in the country. More so, breeding programs for improved crop varieties tend to concentrate on large scale producers hence limited in terms of meeting the needs of smallholder farmers.

1.2 Statement of the Problem

The change in climatic conditions leads to a decline in agricultural productivity hence low income and low food supply. This in turn results into food and nutrition insecurity, exacerbating the levels of poverty. As one of the coping strategies, use of climate resilient crop varieties has the potential to form part of the solution to this problem. In Meru County, climate resilient potatoes have been introduced to increase the resilience of farmers against the adverse effects of climate variability. However, the uptake of these varieties still remains low despite the numerous associated benefits of use such as early maturity, resistance to pests and diseases and high yields. A difference of 24.8% in adoption rates between potato farmers in Meru and those in Uganda is noted by Kaguongo *et al.* (2008). This low uptake could be attributed to failure in considering farmers' preferences before the varieties are developed and disseminated. More so, most of the previous technology adoption studies fail to control for exposure of farmers to these varieties, leading to biased and inconsistent estimation of adoption rates. Therefore, this study aimed at adding to the thin literature of uptake of climate resilient varieties by controlling for exposure and documenting the most preferred climate resilient potato varieties based on their attributes.

1.3 General Objective

To contribute to enhanced farmers' resilience to climate variability through increased use of climate resilient potato varieties among smallholder farmers in Meru County, Kenya.

1.3.1 Specific Objectives

i. To compare adaptation practices against climate variability among smallholder potato farmers in Meru County.

ii. To estimate the population adoption rates of climate resilient potato varieties and their determinants among smallholder farmers in Meru County.

iii. To evaluate farmers' preferences and willingness to pay for the various attributes of climate resilient potato varieties in Meru County.

1.3.2 Research Questions

i. What adaptation strategies against climate variability are currently being practiced by smallholder farmers in Meru County?

ii. What are the population adoption rates of climate resilient potato varieties and their determinants among smallholder farmers in Meru County?

iii. Which attributes of potato varieties are most preferred for adaptation to climate variability and smallholder farmers in Meru County are willing to pay for?

1.4 Justification of the Study

There is a 95% chance of global warming exceeding 2^0C by end of the century (Raftery *et al.*, 2017). More so, global productivity of crops is projected to decline by 5-10% per degree of global warming (Challinor *et al.*, 2014). This necessitates development and dissemination of new crop varieties that have higher yields and have an ability to withstand heat and are drought resistance. However, to achieve this, Cramer (2018) recommends that systems for accelerated delivery of climate resilient varieties need to be massively upgraded so as to embrace the full procedure from trait discovery to varietal deployment and seed system development. One of the identified gaps and needs for improved climate smart breeding include knowledge in terms of better understanding of the future trait preferences of different food system actors (Balié *et al.*, 2019). Thus, this study attempts to address this gap by evaluating farmers' preferences for various attributes of climate resilient potato varieties.

This study is also in line with the agricultural recommendations of the Integrated County Plan of Meru (2018-2022) and hence will contribute to achievement of the agricultural goals of the plan. One of the goals aligned to this study is to package and disseminate appropriate agricultural technologies to farmers to address food security and income generation (Republic of Kenya, 2013). This goal is further aligned to SDG 2 of zero hunger.

Furthermore, the results of this study will contribute to the achievement of the Agricultural Sector Transformation and Growth Strategy (2019-2029) which is geared towards sustainable agricultural transformation and food security in Kenya; with an economy that is resilient to the effects of climate change and variability, global fluctuations in staple food prices and effects of emerging pests and diseases (Republic of Kenya, 2019).

1.5 Scope and Limitation of the Study

This study was carried out in Meru County among smallholder potato farmers who are practicing farm production. Climate-related factors, socio-economic and institutional factors were sought to establish how improved varieties are being used to increase farmers' resilience to climate variability.

The study was delimited to analysis of households at farm level. The reference period of this study was between October 2018 and October 2019. Furthermore, this study acknowledged that the nature of decisions on uptake of farm technology is dynamic. However, due to data limitations, analysis was purely static and hence did not look at the dynamics of adoption decisions.

1.6 Operational Definition of Terms

Climate Change: long-term change (more than 1 year) in the average weather conditions for example increased temperatures and rainfall. According to (Ziervogel, *et al.,* 2006)

Climate Variability: Short term fluctuations of weather events that occur from year to year.

Adaptation to Climate variability: process where strategies to reduce the impact of consequences of climate variability are developed, enhanced and implemented (UNDP, 2004).

Climate Smart/ Adaptation Practice: this is an agricultural activity that increases productivity of crops in a sustainable way and ensures food security (FAO, 2010). In this study, the adaptation practices are crop rotation, intercropping, crop

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diversification, irrigation, minimum tillage, soil cover and climate resilient potato varieties use.

Improved/Climate Resilient Potato Varieties: these are adapted varieties developed by research organizations that have unique traits such as high yields, early maturation, disease resistance, drought and heat tolerance. They include; *Unica, Wanjiku, Lenana, Chulu* and *Nyota.*

Smallholder farmer: A farmer who is in possession of 5 acres or less under potato farming in Meru County.

Up takers/ Adopters: Farmers who planted at least one climate resilient potato variety within the reference period (October 2018 to October 2019).

Exposure: to be aware of the existence of at least one climate resilient potato variety.

CHAPTER TWO
LITERATURE REVIEW

2.1 Climate Variability

Climate variability refers to the short term fluctuations of weather events that occur from year to year. It is characterized by seasonal changes in precipitation and temperatures of varying severity and duration. Over the past years, hunger and malnutrition incidences have increased significantly and the available food does not match the growing population in Kenya. The arid and semi-arid areas are the most affected with food insecurity (Atsiaya *et al.,* 2019). Increasing temperatures and frequent droughts have deteriorated the state of smallholder farmers who depend on rain-fed agriculture in these areas. Droughts have led to severe food insecurity and malnutrition in various parts of the world (FAO, 2011). Climate variability has brought about unpredictability in rainfall patterns, increased incidences of pest and diseases in both plants and animals reducing agricultural productivity and production (Patrick *et al.,* 2020; Wekesa *et al.,* 2018). More so, the rural poor are the most vulnerable to these adverse impacts of the climate variability in Kenya (Kogo *et al.,* 2020). This calls for adaptation strategies to cope with these challenges.

2.2 Adaptation Practices against Climate Variability

Adaptation refers the process where strategies to reduce the impact of consequences of climate variability are developed, enhanced and implemented (UNDP, 2004). It could also be defined as those adjustments made in the social, ecological or economic systems in response to expected or actual climatic variability and its impact. It includes a collection of activities that are needed to adjust development, manage risks, which include economic, socio-cultural and environmental to reduce vulnerability of economies, populations and ecosystems to the impacts of climate change and variability.

Adaptation is aimed at moderating the adverse impacts of climatic variability through the reduction of vulnerability using a varied range of intervention. It is necessary and a must, given that the IPCC fourth assessment report gives a confirmation that even if all measures to reduce the greenhouse gases emissions are put in place, the world will still continue to experience the effects of climate change and variability for the next several decades because the amount of greenhouse gases already emitted to the atmosphere are too high. Some impacts of climate change and variability like droughts are unavoidable hence; adaptation remains a principle way to cope with such (IPCC, 2014).

To counteract the effect of climate variability, numerous actors in agricultural sector are promoting farming practices and technologies called climate smart agriculture (CSA) among other coping strategies. These practices and technologies include crop rotation, agro-forestry, intercropping, maintenance of soil cover, minimum tillage, residue retention, conservation of water, improved livestock management, climate resilient crop varieties and animal breeding to adapt to future hostile conditions. Compared to convention methods of production in agriculture, CSA has been documented to register stable and higher yields and thus stable income from farming leading to high resilience in some regions (Wekesa *et al.,* 2018). Various communities use these practices as strategies to cope and adapt to climate change and variability. According to FANRPAN (2013), CSA can be described as farming that increases productivity, resilience and income sustainably.

2.3 Development and uptake of Climate Resilient Potato Varieties in Kenya

Potato production in Kenya is highly threatened by climate variability. Reduced precipitation due to prolonged drought has resulted into reduced yields in the previous cropping seasons. Further, increased temperatures due to global warming has led to emergence of new pests and diseases, heat stress on plants and increased cases of late blight and bacterial wilt. During the 2016-2017 drought in Kenya, a tremendous reduction in potato yields of 56% was reported due to reduced rainfall (International Potato Center, 2017).

Previous studies show that, potato production levels can double up without expanding the area under production by developing, disseminating and adoption of climate resilient varieties (Paker *et al.,* 2019). This has prompted research organization such as KALRO and CIP into developing potato varieties that are climate smart in the last 15 years. These varieties are usually characterized by heat tolerance, resistance to drought and resistant to pests and diseases, for instance *Unica* which was released in 2005. In 2016 and 2017, 5 climate resilient potato varieties were released by CIP in Kenya which have the properties of tolerance to water stress and increased resistance to late blight and bacterial wilt (International Potato Center, 2017). The varieties include *Unica, Wanjiku, Lenana, Chulu* and *Nyota* as shown in Table 2.1. Other common potato varieties in Meru County are shown in Appendix iv.

Table 2.1: Climate Resilient Potato Varieties with their Characteristics

Climate Adaptability Characteristics/ CRPVs	Unica	Nyota	Lenana	Chulu
Maturation Period	3 months	3-4 months	3-4 months	3-4 months
Yield	>40T/Ha	>40T/Ha	>40T/Ha	>40T/Ha
Resistant/Tolerance to Pests and Diseases	Slightly resistance to late blight, highly resistant to Potato Virus X(PVX), and Potato Leaf Roll Virus(PLRV)	Tolerant to late blight	Tolerant to PLRV, late blight and PVX	Tolerant to late blight and PVX
Agro-ecological zones to be grown	Lowlands and highlands tropics (1400-3500m above sea level)	Highlands tropics(1500-3500m above sea level)	Highlands tropics(1500-3500m above sea level)	Highlands tropics(1500-3500m above sea level)

Source: NPCK Catalogue (2019)

However, adoption of these climate resilient potato varieties is said to be low in Kenya despite the associated benefits. A study by Kaguongo *et al.* (2008) shows that adoptions rates for improved potato varieties in Uganda are higher than those of Kenya by 24.8%, a difference that is quite significant. According to Bandiera and Rasul (2006), uptake of agricultural technologies is usually poorly understood by farmers hence resulting to slow adoption. Awareness of climate resilient potato varieties is said to be one of the most constraining factor to the uptake. This therefore, necessitates control for exposure when estimating the adoption rates. Furthermore, to improve adoption rates of smallholder potato farmers, their preferences in developing improved potato varieties should be given a priority.

2.4 Determinants of Uptake of Climate Resilient Potato Varieties

Vast literature exists on the determinants of agricultural technology uptake. The decision of a farmer to adopt or not is based on the characteristics of that technology among other factors

such as socio-economic and institutional factors (Lavison, 2013). The socio-economic factors that potentially influence uptake of climate resilient potato varieties include age, education level, farming experience, household size, land ownership, distance to the markets and gender of the household head. On the other hand, the institutional factors include access to credit facilities, access to quality seeds, access to information, government policies, membership in a farmers' organization or group and access to extension services.

The characteristics of a given technology is a crucial factor influencing the decision of a farmer on whether to adopt or not. Mignouna *et al.* (2011) on a study on Imazapyr-Resistant Maize uptake argued that if farmers perceive a technology to address their needs and preferences in its characteristics, then they will consider it as a beneficial investment and adopt. Thus, the attributes of improved potato varieties such as resistant to pests and diseases, early maturation period, heat stress tolerant and farmers' perception of those attributes form crucial a pre-condition for adoption.

A farmer's human capital is usually assumed to have significant influence on the decision of uptake of a new technology. Keelan *et al.* (2014) and Mignouna *et al.* (2011) attempted to measure human capital through level of education, size of household, age, experience of the farmer and gender. A study by Simtowe *et al.*(2012) on Awareness and adoption of improved pigeon pea varieties in Kenya shows that age had a significant negative influence on adoption. This could be because it is assumed that the older a farmer gets the more averse towards risk one becomes. The attitude of an individual has towards risk affects the willingness to accept and pay for a specific technology (Ayuya *et al.*, 2012). However, in studies that use age as a proxy for experience in farming, the relationship between age and adoption is usually positive. This is because the more experienced a farmer is, the higher the likelihood of adoption (Fadina & Barjolle, 2018).

Availability of finances and capital is also a key determinant of technology uptake. As financial services continue to expand in Africa, the knowledge of smallholder farmer's financial aspects remains inadequate (Both, 2015). The financial constraints on the demand side include: land issues and lack of collateral, bank rules and regulations (Sugden,2015). Collier and Dercon (2014), found out that correcting market imperfection for instance agricultural infrastructure, timely response, access to markets and access to land, which can be used as collateral for loans by smallholder farmers can be a way forward to overcoming

financial constraints that limit smallholder farmers from investing in coping strategies such as improved potato varieties. Agbozo and Yeboah (2012), argued that market imperfections usually result in misallocation of capital, declined agricultural productivity and poverty traps. These poverty traps tend to have a negative effect when it comes to investing in coping strategies such as improved varieties because smallholder farmers are rendered resource-poor.

Kassam and Friedrich (2009), found out that lack of knowledge that is evidence-based and inadequate experience inhibit smallholder farmers from investing in coping strategies. Appropriate knowledge of adaptation and coping strategies remain extremely low in many countries in Africa. There is still a very low uptake of the concept of climate smart agriculture. Mpangwa (2011) states that many agricultural institutions in Africa have a very low capacity in this area. Some studies associate knowledge with education level whereby, more educated farmers are viewed to easily acquire knowledge on adoption of climate resilient technologies such as improved varieties (Ochieng *et al.,* 2012).However higher education levels could also lead to alternative sources of livelihoods that are off-farm reducing the rate of farm level technology adoption (Wekesa*et al.,* 2018).

Household size is usually used as a proxy for availability of labor. According to Mignouna *et al.* (2011), the larger the household, the lower the labor constraints associated with introduction of a new technology. However, Wabwile *et al.* (2016), found a negative relationship between the use of improved variety and household size which could be explained by the fact that smallholder farmers have small parcels of land on average. This study also found out that yield has a significant influence on the farmer's ability to use improved variety. Access to credit is a motivation for farmers to go for new innovations. This is due to the ability to participate in the market for instance input purchase and labor payment. Unfavorable land tenure system may also inhibit investment in CSA Milder *et al.* (2011) and poor governance structure.

Issue of gender in uptake of farm technologies is usually subject to debate especially on roles played by men and women in adoption decision (Mwangi and Kariuki, 2015). Effect of gender on decisions to adopt or not is usually said to be specific to a location and guided by culture (Gbetibouo, 2009). A study on Morris and Doss (1999) on impact of gender on technology adoption found out that there is no significant association between gender and likelihood of adoption of improved maize in Ghana. The argument was, decisions on

adoption do not depend on gender but rather on accessibility of resources such land, credit and labor by the decision maker. However, other studies like Obisesan (2014) found a significant positive relationship between gender and adoption of improved cassava in Nigeria. This is because usually the household head is the key decision maker. Men are said to have greater accessibility to resources whereas women are constrained by social and cultural barriers (Gbegeh & Akubuilo, 2012).

2.5 Research Gaps

Most studies on adoption of agricultural technologies and climate variability adaptation strategies determine adoption rates without controlling for exposure (Fadina & Barjolle, 2018;Kaguongo *et al.*, 2008;Wabwile *et al.*, 2016; Wekesa, 2017). Observed sample adoption rates are not usually the unbiased and consistent estimates of population adoption rates even if the sample used was randomly selected. They suffer from both selection and non-exposure biases. Despite climate resilient varieties being disseminated, a significant fraction of the farmers is not yet exposed to these varieties. Literature shows that exposure of farmers to a certain technology is a necessary condition for its adoption.

Previous studies that have attempted to control for exposure using the classical models such as the simple probit and tobit have had problems in interpreting the coefficients under partial exposure scenario. More so, the classical models cannot identify full population adoption rates estimates. Instead, they only identify adoption rates for the exposed sub populations which does not give consistent estimates (Diagne & Demont, 2007). This study aimed at filling this research gap by controlling for exposure in attempt to correct for non-exposure and selection biases using the Average Treatment Effect model.

Muthoni *et al.*(2017), recommends that climate resilient potato varieties with early maturity characteristics and resistance to drought, heat, pest and diseases should be invested in even more intensively to facilitate climate change resilience of smallholder farmers. However, there is need to consider what a farmer really prefers in terms of the attributes of these varieties so as to promote uptake. Balié *et al.* (2019) identified a gap in knowledge in terms of better understanding of the future trait preferences of different food system actors for climate smart breeding. This study aimed filling this research gap by determining the potato farmers' preferences and their willingness to pay for the preferred varietal traits.

2.6 Theoretical and Conceptual Framework

2.6.1 Theoretical Framework

This study was guided by the theory of Random Utility Maximization. The study assumed that farmers are rational decision makers and therefore would use the Random Utility Maximization Theory to model their decisions. This theory states that a rational decision maker will always make a decision with the objective of maximizing the utility derived. According to (Cascetta, 2009), it is almost impossible to certainly predict the alternative that a farmer will select because utility is random. However, the probability that a farmer will select alternative j given choice set I^i can be expressed as shown below in equation (1). A farmer will adopt climate resilient potato varieties if and only if its perceived utility is greater than that of other available alternatives (Mc Fadden, 1978). Therefore:

$$Pi(j/I) = P(Uji > Uki;\ \forall k \neq j, k \in I) \quad (1)$$

Where: j- alternative of improved potato varieties

k- other adaptation practice alternatives

i- Individual farmer/ decision maker

U_j^i- Perceived utility derived by individual i from selecting the climate resilient variety alternative

U_k^i- Utility derived from other adaptation practice alternatives

We assumed that the perceived utility U_j^i can be decomposed into two terms as follows: -

$$Uji = Sji + eji \quad (2)$$

Where: S_j^i- deterministic term

e_j^i- Random error term

Thus the probability a farmer chooses alternative j over other alternatives was: -

$$Pi(j/I) = P(Uji > Uki;\ \forall k \neq j, k \in I) = P(Sji + eji \geq Ski + eki,\ \forall k \neq j, k \in I) \quad (3)$$

Rearranging: -

$$Pi(j) = P(eki - eji \geq Sji - Ski, \forall k \neq j, k \in I) \quad (4)$$

Equation (4) shows that the probability that a climate resilient potato variety is chosen depends on joint distribution of the differences between the error terms.

2.6.2 Conceptual Framework

Figure 2.1 shows the conceptual framework of the study. This framework shows the linkage between exposure and uptake of climate resilient potato varieties; and livelihood effects on smallholder potato farmers. Exposure and uptake is influenced by various factors such as climate change related shocks, potato attributes, socio-economic and institutional factors. The socio-economic factors include age of the farmers, gender, education level, household size, land tenure, land size, distance to input and output markets and distance to nearest agricultural office. The institutional factors include credit access, extension services, social networks, access to quality seeds and access to information. The climate variability related shocks include shocks in terms of temperature, rainfall, frost, pests and diseases. The potato attributes include resistance to pests and diseases, water requirements, yield, maturation period and input price. The decision to get exposed and eventually adopt the climate resilient varieties will result into better livelihood in terms of increased farmers' resilience to climate variability.

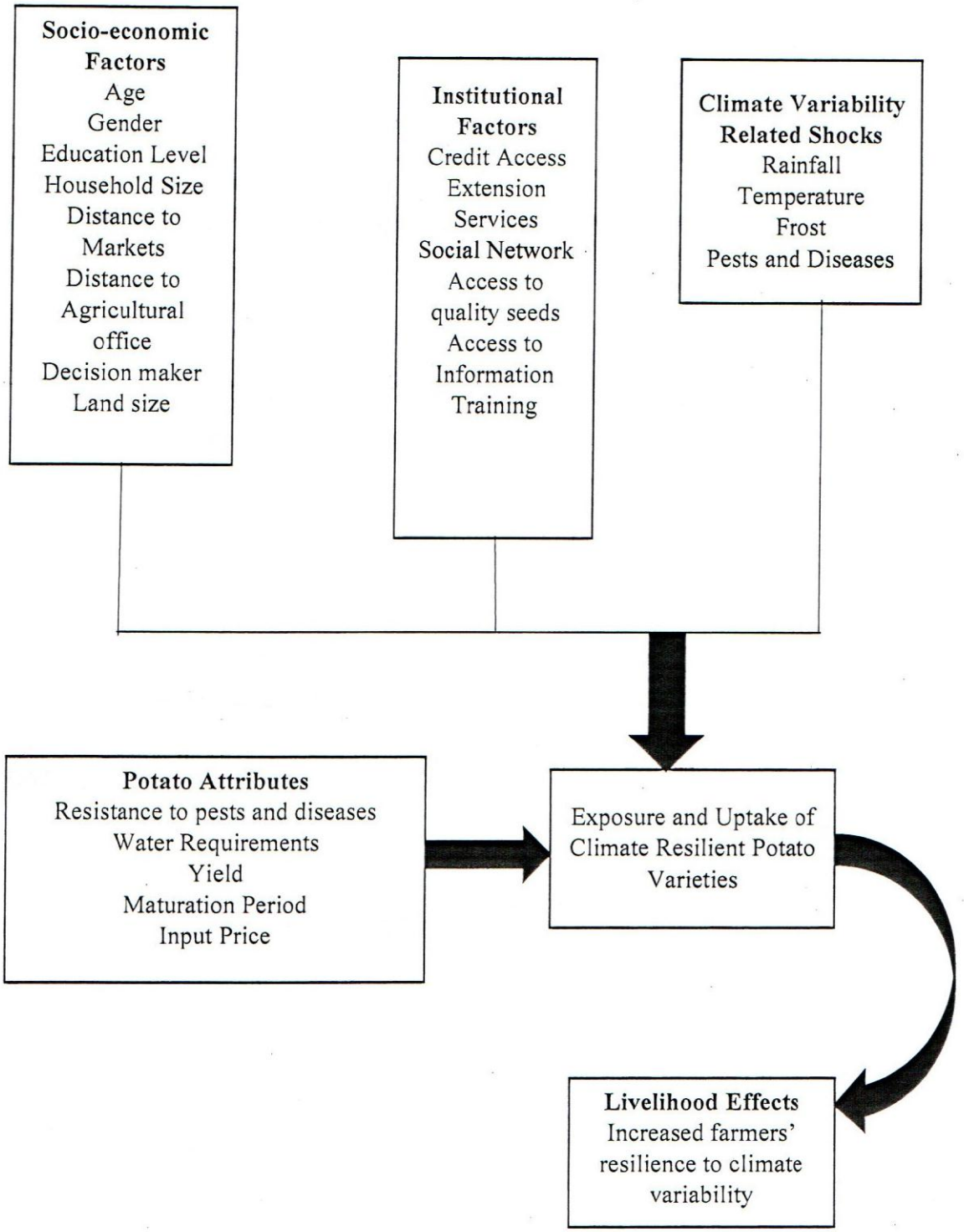


Figure 2.1: Conceptual Framework

CHAPTER THREE
METHODOLOGY

3.1 Study Area

The study was carried out in Meru County, Kenya. Meru county is an agricultural county whereby 23% of its overall land is under food crop including potato. It is located on the eastern side of Mt. Kenya. According to Republic of Kenya (2013), Meru County occupies an overall land area of 693,620 hectares (Ha). It has an altitude that lies between 2230-2900m above the sea level. The estimated area under potato production is 17,534Ha with production being 196,434T (CIP,2019). The county lies between longitudes 38° East and 37° West and also along the equator at latitudes 0°6' North and 0°1' South. It is made up of 45 Wards and 9 Sub- Counties, namely; Tigania West, Tigania East, Igembe Central, Igembe North, Igembe South, Imenti North, Imenti South, Central Imenti and Buuri (Republic of Kenya, 2013).

Meru County is characterized by four main agro ecological zones; the upper highlands where potatoes are mainly grown, the lower highlands, the upper midlands and the lower midlands. The upper highlands have an average precipitation of 700mm to 1000mm per year and average temperatures ranging from 14.90^{0}C- 10.50^{0}C. The altitude levels ranges from 2230-2900mm above sea level. The lower midlands have an average rainfall of 580-1600mm and 24.0^{0}C-20.90^{0}C temperatures. The altitudes range from 750-1300m above sea level (Jaetzold *et al.,* 2007). This zone falls in arid and semi-arid areas. The map of the study area is shown in figure 3.1.

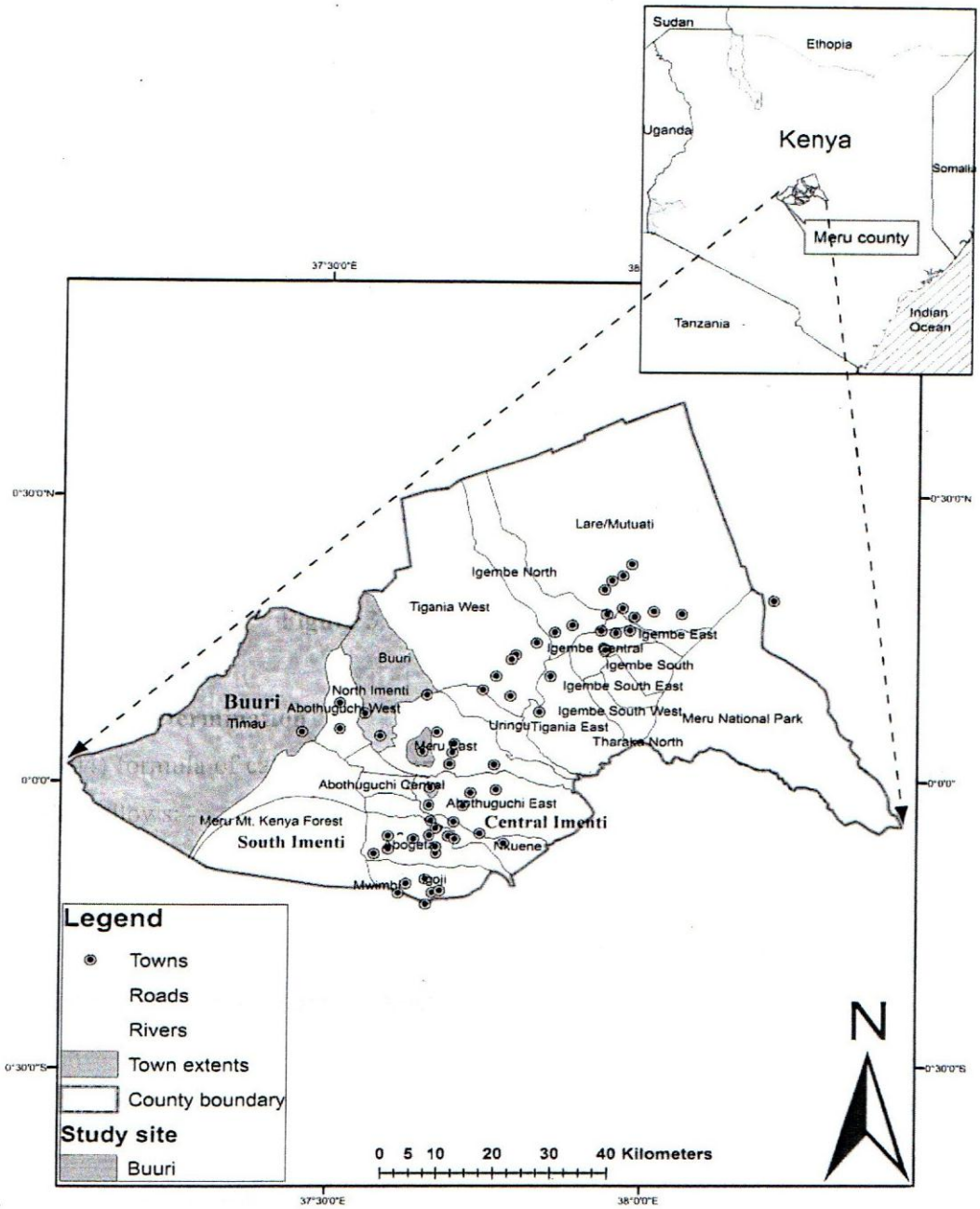


Figure 3.1: Map of Meru County

3.2 Sample Size Determination

Kothari (2004) formula of calculating sample size was employed since the population size is unknown, as follows: -

- $$n = \frac{pqz^2}{E^2} = \frac{0.5*0.5*1.96^2}{0.05^2} = 384 \quad (5)$$

Where, n= size of sample

p= share of population of interest ($p = 0.5$)

q= weighting variable ($q = 1 - p = 0.5$)

z= confidence level ($\alpha = 0.05$)

E= acceptable error ($E = 5\%$)

Usually, in statistics p is assumed to be 0.5 to yield a sample size that is said statistically sufficient especially when the size of the population is unknown. An acceptable error of 5% was used since according to Kothari (2004) a researcher can use an error of less than 10%. This facilitated approximation of 384 respondents who formed the sample size.

3.3 Sampling Technique

Small-scale potato farmers from Meru County made up the population of this study. The sample was selected using multistage sampling technique. In the first stage, Meru County was selected purposively because it is among the highest potato producing counties in Kenya. In the second stage, three out of the nine sub-counties were selected based on potato production and climatic conditions. Imenti South, Imenti Central and Buuri Sub-counties were purposively selected to represent various climatic conditions in the study area. Buuri sub-county lies in the lower midlands which experiences harsher climatic conditions as compared to Imenti South and Imenti Central which lie in the upper highlands agro-ecological zone of Meru County (MoALF, 2016).In the third stage, four wards were randomly selected from the three sub-counties and finally, in the fourth stage, a random sample of 384 farmers was selected from the wards using simple random sampling technique. Table 3.1 shows the distribution of the sample size in the county.

Table 3.1: Sample Size Distribution

Wards	Population	Percentage	Sample Size Proportion
Abothuguchi West	35,901	30.51%	117
Abogeta West	30,338	25.78%	99
Kiirua/Naari	27,031	22.97%	88
Kibirichia	24,409	20.74%	80
Total	**117,679**	**100%**	**384**

Source: (Ngugi *et al.*, 2013)

3.4 Data and Data Collection

Focus Group Discussion (FGD) and Structured Questionnaires were used to collect primary data by conducting household survey in November, 2019. Cross-section survey design was the research design of this study. Questionnaires were administered by trained enumerators whereas the FGD was coordinated by a skilled moderator to determine the potato variety attributes that facilitated designing of choice cards for the choice experiment. The data collected was cleaned and processed using SPSS, SAS and STATA statistical softwares. SPSS was used for data entry; SAS was used for designing choice cards in the choice experiment whereas STATA was used to data analysis. The choice cards and the questionnaires were pretested for validity and corrections were addressed prior to the main field interviews.

3.5 Analytical Framework

Objective 1: To compare adaptation practices against climate variability among smallholder Potato farmers in Meru County

Statistical analysis was carried out to analyze this objective. Descriptive statistics such as mean, frequencies and standard deviations of various qualitative and quantitative variables were obtained. Chi-square inferential statistic was used for comparison of adaptation practices between potato farmers from different geographical locations in the county.

Objective 2: To estimate the population adoption rates of climate resilient potato varieties and their determinants among smallholder farmers in Meru County.

Recent literature on uptake of agricultural technologies has acknowledged that awareness is a necessary condition for uptake, (Diagne & Demont, 2007; Simtowe *et al.,* 2016) hence shifting from the use of classical models such as logit and probit. This is because, classical models are associated with inconsistent results due to non-exposure and selection biases. Non-exposure bias results from the fact that farmers who are not exposed to the new technology will not adopt it even if they had the capacity to had they been exposed (Simtowe *et al.,* 2011). Hence leading to underestimation of true population adoption rates. Exposure is usually non-random and may also suffer from selection bias.

Therefore, this objective was analyzed using the Average Treatment Effect (ATE) Framework so as to control for both non-exposure and selection biases leading to estimation

of true population adoption rates and determinants of uptake as recommended by (Diagne & Demont, 2007) and modified by (Muthini, 2018; Simtowe *et al.*, 2016).

The treatment variable was exposure or awareness to at least one climate resilient potato variety. The 'treated' were those exposed whereas the unaware were the 'untreated'. According to Wooldridge (2002), the ATE parameter is a measure of the population mean potential adoption outcome. The difference between the population mean potential adoption outcome and observed adoption outcome is the non-exposure bias which is basically the adoption gap (Diagne & Demont, 2007).

The treatment effect estimation is usually grounded on a counterfactual outcome framework. Following Rosenbaum and Rubin (1983), let Y_1= Potential adoption outcome of a farmer when exposed to climate resilient potato varieties and Y_0= Potential adoption outcome when not exposed. Since exposure is a necessary condition for uptake, Y_0=0 thus; -

$$E(Y_1 - Y_0) = E(Y_1) = ATE \tag{6}$$

That is the adoption impact of farmer *i.*

Since Y_1 is only observed for the exposed population, $E(Y_1)$ underestimates the true population impact of adoption. Thus;

Let w=1 denote exposure and w=0 otherwise. The impact of exposed sub-population (ATE1) can be derived as a conditional expected value which applies also for the non-exposed sub-population (Assuming *et al.*, 2011).

$$\begin{aligned} ATE1 &= E(Y_1 / w = 1) \\ ATE0 &= E(Y_1 / w = 0) \end{aligned} \tag{7}$$

The two equations in 7 show consistent estimates of the average impact of adoption on the two sub-populations. If $\pi(w = 1)$ is the probability of exposure, then the expected adoption impact on total population ATE can be obtained by taking the difference of the two equations in (7) to get;-

$$ATE = E(Y_1) = \pi(w = 1) * ATE\,1 + 1 - \pi(w = 1) * ATE\,0 \tag{8}$$

$$ATE0 = \frac{ATE - \pi(w=1) * ATE1}{\pi(w=0)} \tag{9}$$

From here, we can obtain the non-exposure bias (NEB) which is also a measure of the adoption gap, and the population selection bias (PSB):

$$NEB = \pi(w=1) * ATE1 - ATE \quad (10)$$

$$PSB = ATE1 - ATE \quad (11)$$

Adoption can be obtained as an observed outcome Y:

$$Y = wY_1 + (1-w)Y_0 = wY_1 \quad (12)$$

Identification of ATE is based on the assumption of conditional independence which states that status of treatment is independent of potential outcomes conditioned on an observed set of covariates (x). The ATE adoption model can be estimated using two models according to Diagne and Demont (2007): pure parametric approach and the two stage approach. This study used the parametric regression-based method where covariates were interacted with treatment variables to account for any heterogeneous impact. Parametric approach was used because parametric tests are said to have a higher statistical power than non-parametric tests. The pure parametric method was also used because there is no much difference between the pure and semi-parametric method (Dibba *et al.*, 2012). The equation that identifies ATE (x) was given as:

$$ATE(x) = E(Y_1 / x) = E(Y / x, w=1) \quad (13)$$

A parametric model for the conditional expectation was then specified as:

$$E(Y / x, w=1) = g(x, \beta) \quad (14)$$

Where g was a parametric probabilistic model since Y was a binary variable, of covariates x and unknown parameter vector β, which was estimated using maximum likelihood estimation procedures using observations (Y_i, x_i) from the exposed sub-population only. After estimating $\hat{\beta}$, predicted values of $g(x_i, \hat{\beta})$ were computed for all the observations in the sample, both exposed and non-exposed sub-populations (Simtowe *et al.*, 2016). Therefore, the estimated average treatment effects were given by:

$$\hat{ATE} = \frac{1}{n}\sum_{i=1}^{n} g(x_i, \hat{\beta}) \quad (15)$$

$$\hat{ATE}_1 = \frac{1}{n_e}\sum_{i=1}^{n} w_i g(x_i, \hat{\beta}) \quad (16)$$

$$\hat{ATE}_O = \frac{1}{n-n_e}\sum_{i=1}^{n} (1-w_1) g(x_i, \hat{\beta}) \quad (17)$$

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$$\hat{JEA} = \frac{1}{n}\sum_{i=1}^{n} Y_i \qquad (18)$$

The effects of determinants of uptake was estimated as measures of marginal effects of the vector of covariates x at a given point $\bar{x}$:

$$\frac{\partial E(Y_i / \bar{x})}{\partial x_m} = \frac{\partial g(\bar{x}, \hat{\beta})}{\partial x_m} \quad \text{m=1..., m} \qquad (19)$$

For the factors influencing exposure, parametric estimation of ATE reduces to a standard probit estimation restricted to the exposed sub-sample. The estimation was done in STATA using STATA routine developed by Diagne (2007). Table 3.2 shows the variables used in econometric analysis of objective 2.

Table 3.2: Variables used in Econometric Analysis of Objective 2

Variable	Description	Measurement	Expected Sign
Dependent:			
Adoption	Climate resilient potato varieties uptake	Dummy (1=adopters, 0=otherwise)	
Exposure	Exposure to climate resilient potato varieties	Dummy (1=Exposed, 0=otherwise	
Independent:			
Socio-economic			
AGE	Age of the household head/ farmer	Discrete	+/-
GENDER	Gender of the household head/ farmer	Dummy (Male=1, 0=Female)	+/-
EDUC	Education level of the farmer	Dummy	+
H/SIZE	The number of people residing in that household	Discrete	+/-
DECISIONMAKER	Decision maker of the household	Nominal	+/-
FARMSIZE	Total size of the farm owned	Continuous	+/_
LANDPOT	Total land under potatoes	Continuous	+/-
SOILFERT	Level of farm's soil fertility	Dummy	+/-
Institutional			
EXTN	Number of times a farmer gets access to extension services in a year	Discrete	+
DISTMKT	Distance to the input and output markets (Walking time)	Continuous	-
DISTAGOFFICE	Distance to the nearest agricultural office	Continuous	-
CREDIT	Access to credit services by the farmer	Dummy (1=Yes, =0 Otherwise	+
GRPMEMBERSHIP	Membership in any farmers' group or any agricultural partnership	Dummy (1=Yes, 0=Otherwise)	+
CLIMATEINFOR	Access to information on climate change	Dummy (1=Yes, 0=Otherwise)	+
SEEDACESS	Access to clean potato seeds	Dummy (1=Yes, 0=Otherwise)	+
TRAINING	Number of trainings on climate resilient potato varieties	Discrete	+

Climate change related shocks			
RAINFALL	Whether the household experienced rainfall shocks in the last 3 years	Dummy	+/-
TEMP	Whether the household experienced temperature shocks in the last 3 years	Dummy	+/-
FROST	Whether the household experienced frost shocks in the last 3 years	Dummy	+/-
PESTDIS	Whether the household experienced pests and diseases in relation to potato production in the last 3 years	Dummy	+/-
Ward Dummies	1= Kibirichia 2= Kiirua/Naari 3= Abogeta West 4= Abothuguchi West	Dummy	+/-

Objective 3: To evaluate farmers' preferences and willingness to pay for the various attributes of climate resilient potato varieties in Meru County.

Revealed and stated preference methods are the two main approaches in eliciting individual preferences for priority setting in economic evaluation. Revealed preference approach involves analysis of individual preferences revealed by real market behavior. This approach is limited in that attributes are usually collinear in market data, making it difficult to predict the effect of independent variation in an attribute. On the other hand, stated preference approach involves asking consumers to state their preference for hypothetical scenarios that comprise different attributes with different levels. Stated preference approach is usually preferred as it addresses the multicollinearity problem of the revealed preference approach by allowing for sufficient variation in the data. Some of the stated preference methods include Contingent Valuation Method (CVM) and Discrete Choice Modelling (DCM).

Among all the variants of DCM, Discrete Choice Experiment (DCE) is the most popular due to its validated economic theory. It is based on the Lancaster theory of consumption which states that consumers derive utility from characteristics or attributes of a product rather than the product as a whole (Lancaster, 1966). In this study, DCE method was used to determine the key attributes preferred by farmers for climate resilient potato varieties and willingness to

pay for each attribute. First order interactions for attributes and socio-economic characteristics of farmers were analyzed to account for sources of preference heterogeneity.

In DCE, farmers were presented with various hypothetical scenarios where they were supposed to choose different attributes described by their levels as presented in choice sets. The experiment involved various stages. In the first stage, potential attributes and the attribute levels were identified based on the characteristics of climate resilient potato varieties and literature. A Focus Group Discussion comprising of 30 experienced farmers, decentralized seed multipliers, village-based potato advisors, Agricultural extension officers and researchers was conducted to validate the attributes and attribute levels proposed for the experiment. Table 3.3 shows the potential attributes and their levels based on literature and validated by FGD.

Table 3.3: Attributes and Attribute Levels of Climate Resilient Potato Varieties

Attributes	Description	Levels
Resistance to pests and diseases	Whether the variety is resistant to pests and diseases or not	Yes No
Water Requirements	The amount of water the variety requires to grow	High Low
Yield per Hectare	Yield in Tonnes per Hectare	High (40T/Ha) Low (20T/Ha)
Maturation Period	How long it takes for the potato to be ready for harvest	Short (<3 months) Long (>3 months)
Input Price (50kg bag)	Input price for every 50kg bag of potato seeds	2000, 2500, 3000

One of the negative effects of climate change is increased emergence of pests and diseases. Climate change factors such as higher humidity, increased temperatures and unseasonal rainfalls are said to increase the severity of potato diseases such late blight, bacterial wilt, potato leaf roll virus and potato virus Y (Quiroz *et al.*, 2018). Therefore, resistance of CRPVs to pests and diseases was included as a potential attribute and was described by two levels; whether the variety preferred is resistant or not. The amount of water required to grow CRPVs was also included as a potential attribute and was described by two levels; high or

low water requirements. Reduced precipitation due to climate change has necessitated use of irrigation as an adaptation practice by farmer (Esayas *et al.*,2019). However, most smallholder farmers lack enough resources to invest in irrigation equipment. More so, lack of access to adequate farming water limits smallholder farmers from adopting irrigation as an adaptation strategy.

The yield attribute was also included to capture the preferred yield per hectare by farmers. It was described using two levels; High yields (40T/Ha) and Low yields (20T/Ha). Mukherjee *et al.* (2017) reported that the average potato productivity in India is 23T/Ha whereas International Potato Center in its 2017 annual report argued that the average productivity of quality seeds was 35-45T/Ha. To ensure food security through increased productivity without increasing the size of farming land, there is need to breed improved varieties that have high yield. Previous studies show that some farmers preferred varieties with short maturation period while others preferred varieties that mature late to ensure food security and sustainable income. Kolech *et al.* (2015) reported that farmers preferred potato varieties that are drought resistant, resistant to pests and diseases and mature early. Maturation period was included as a potential attribute described by two levels; short (<3months) and long (>3months) to determine the preferred maturation duration for CRPVs by smallholder potato farmers in Meru county.

The last attribute was the price attribute. This is the input price or buying price for every 50kg bag of CRPVs seeds. The input price was set around the mean of the buying price for the most popular variety in the county named *Shangi*. The price for the certified *Shangi* variety is around 2500 Kenya shillings per 50Kg bag seed as reported from FGD. The input price had three levels; 2000, 2500 and 3000 Kenya Shillings. The price attribute was an important attribute used in obtaining willingness to pay a premium for the other attributes (Sánchez *et al.*, 2017).

The second stage involved designing of choice cards whereby choice cards were constructed based on their attributes and attribute levels. Each choice card had two unlabeled scenarios of climate resilient potato varieties and one opt-out option showing a farmer who is not willing to uptake a climate resilient potato variety. D-efficient design was used to reduce the number of choice cards. The SAS software was used to generate the design as is the most widely applied package for experimental designs (Kjær, 2005). The design had a D-efficiency of

96.85% which was a relatively good measure of D-Optimality. A design is said to be D-Optimal if it yields data that enables estimation of parameters with low standard errors and the design can extract the maximum amount of required information from the respondents. The A-efficiency was 93.10% implying that variance matrix generated estimates that were sufficiently reliable. The G-efficiency was 100% which makes precise response predictions for choice experiments (Alemu *et al.*, 2017; Kessels *et al.*, 2006; Otieno *et al.*, 2019;Oyinbo *et al.*, 2019).The design generated 12 choice situations which were blocked into 4 profiles as shown in Appendix 1 and each farmer was presented with 3 choice cards each representing a choice set. An example of a choice set/card is presented in Figure 3.2.

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Drought and Disease Resistant	Not	Resistant	
Water Requirements	Low	High	
Yield	40T/Ha	20T/Ha	
Maturation Period	Long (> 3 months)	Short (<3 months)	
Input Price per 50kg bag	2500	2000	
Which option would you prefer?			

Figure 3.2: Choice set sample

The final stage involved econometric analysis of DCE which was based on the Random utility theory (Louviere *et al.*, 2010). This means that the total utility derived from adopting CRPVs can be decomposed into a deterministic and unobservable stochastic error components depending on the attributes preferred by farmers. Mixed logit model using 100 Halton draws was used in the estimation of farmers' preferences. Lecocq (2008), argued that 100 Halton draws were sufficient to yield unbiased estimates considering accuracy and time factors. The mixed logit model was used because it accounts for preference heterogeneity by allowing for variations across respondents for coefficients of variables that enter the model. The model also does not exhibit the restrictive IIA (Independence of Irrelevant Attributes) property as in the conditional logit model and accounts for correlation in unobserved utility over repeated choices (Van den Broeck *et al.*, 2017). The utility (U_{ijk}) derived by farmer *i*from choosing alternative j in the choice card k was given by: -

$$U_{ijk} = \alpha_i ASC + \beta_i X_{ijk} + \varepsilon_{ijk}$$
$$\beta_i = \delta_i \beta + \gamma \eta_i + \delta_i \eta_i \quad (20)$$

Where;

X_{ijk}= Vector of attributes

β_i=Vector of individual specific parameters

ε_{ijk}=idiosyncratic error

β= Vector of mean attribute utility weight

δ_i= Person-specific scale heterogeneity of the idiosyncratic error

η_i= Vector of individual specific deviation from the mean

γ= Scalar parameter governing variance of residual taste heterogeneity

ASC= Alternative Specific Constant

ASC accounts for when a farmer opts out and it captures attributes not included in the choice experiment hence catering for non-response bias. It is usually a dummy variable; 0=uptake of climate resilient variety and 1=otherwise.

The specification of the choice probability equation was;

$$P_{ijk|l} = \frac{\exp(\beta_i X_{ijk})}{\sum_{j=1}^{ji} \exp(\beta_i X_{ijk})} \quad (21)$$

To identify sources of heterogeneity, interactions between preferences and farmer characteristics were computed.

Values of Willingness to Pay (WTP) for different varietal attribute levels were derived as: -

$$Marginal\ WTP = -\frac{\beta_{attribute}}{\beta_{price}} \quad (22)$$

STATA Version 15 was used to estimate parameters for the mixed logit model. The variables used in analysis of objective 3 and how they enter the model are shown in Table 3.4. All the variables entered the model as random parameters assuming a normal distribution except for the price attribute that was specified as fixed and assumed to have a lognormal distribution in order to facilitate estimation of WTP. Hole *et al.* (2012) argued that restricting the sign of coefficients to be either positive or negative for all respondents maybe desirable in some cases and thus, lognormal distribution acts as an alternative to normal distribution.

Table 3.4: Variables used in Econometric Analysis of Objective 3

Variable	Description
Resistance	Variety is resistant to pests and diseases (1=Yes, 0=Otherwise)
Water Requirements	The amount of water the variety requires to grow (1=Yes, 0=Otherwise)
Yield	Yield of the variety in Tonnes per Hectare (1=Yes, 0=Otherwise)
Maturation Period	How long it takes for the potato to be ready for harvest (1=Yes, 0=Otherwise)
Price	Input price for every 50kg bag of potato seeds (2000, 2500, 3000)

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter provides discussion of results and is sub-divided into sections. In the first sub-section, characterization for all variables used in econometric analysis is reported and discussed. Sub-section two addresses the first objective whereby climate adaptation practices among smallholder farmers in Meru county were established and a regional comparison was done using Chi-square. Sub-section three presents the results for objective two where true population adoption rates were estimated using the Average Treatment Effect (ATE) Framework that controlled for exposure. Finally, in the last sub-section, farmers' preferences for climate resilient potato varieties and their willingness to pay is determined using discrete choice experiment and mixed logit model was used for analysis.

4.1 Descriptive Statistics

4.1.1 Socio-economic Characteristics

Table 4.1presentsthe differences in percentage distribution for gender and decision maker of the household for potato farmers in Meru county. The data was disaggregated by the adoption status for 384 sampled farmers. Adopters were defined as households that planted at least one climate resilient potato variety in the 2018/2019 cropping season.

Table 4.1: Gender and decision maker in the household (%)

Variables	Adopters n=24 (6.25%)	Non-Adopters n=360 (93.75%)	Pooled Sample n=384	Chi^2Test
Gender of farmer (%Male)	79.17	63.89	64.84	2.30
Decision maker (%)				8.71***
Household Head	12.50	41.39	39.58	
Spouse	0.00	1.67	1.56	
Both	87.50	56.94	58.85	

***=level of significance at 1%.

From the pooled sample, 6.25% grew climate resilient potato varieties in the reference period while64.84% of the sampled farmers were males. In decision making, 39.58% of the sampled households relied on the household head, 1.56% on the spouse whereas 58.85% of the households made decisions jointly.Results further show thatthere was no significant

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter provides discussion of results and is sub-divided into sections. In the first sub-section, characterization for all variables used in econometric analysis is reported and discussed. Sub-section two addresses the first objective whereby climate adaptation practices among smallholder farmers in Meru county were established and a regional comparison was done using Chi-square. Sub-section three presents the results for objective two where true population adoption rates were estimated using the Average Treatment Effect (ATE) Framework that controlled for exposure. Finally, in the last sub-section, farmers' preferences for climate resilient potato varieties and their willingness to pay is determined using discrete choice experiment and mixed logit model was used for analysis.

4.1 Descriptive Statistics

4.1.1 Socio-economic Characteristics

Table 4.1presentsthe differences in percentage distribution for gender and decision maker of the household for potato farmers in Meru county. The data was disaggregated by the adoption status for 384 sampled farmers. Adopters were defined as households that planted at least one climate resilient potato variety in the 2018/2019 cropping season.

Table 4.1: Gender and decision maker in the household (%)

Variables	Adopters n=24 (6.25%)	Non-Adopters n=360 (93.75%)	Pooled Sample n=384	Chi^2Test
Gender of farmer (%Male)	79.17	63.89	64.84	2.30
Decision maker (%)				8.71***
Household Head	12.50	41.39	39.58	
Spouse	0.00	1.67	1.56	
Both	87.50	56.94	58.85	

***=level of significance at 1%.

From the pooled sample, 6.25% grew climate resilient potato varieties in the reference period while64.84% of the sampled farmers were males. In decision making, 39.58% of the sampled households relied on the household head, 1.56% on the spouse whereas 58.85% of the households made decisions jointly.Results further show thatthere was no significant

4.1.2 Institutional Characteristics

Table 4.3 shows the household institutional characteristics of potato farmers in Meru county for categorical variables. The statistics were disaggregated by their adoption status where adopters were defined as households that grew at least one climate resilient potato variety in the 2018/2019 cropping seasons.

Table 4.3: Institutional Characteristics for Categorical Variables

Variables	Adopters n=24 (6.25%)	Non-Adopters n=360 (93.75%)	Pooled Sample n=384	Chi^2 Test
Climate infor (%Yes)	95.83	99.72	99.48	6.57***
Attended training (%Yes)	83.33	36.11	39.06	21.08***
Extension services (%Yes)	41.67	18.33	19.79	7.72***
Group membership (%Yes)	79.17	51.67	53.39	6.84***
Credit access (%Yes)	37.50	30.64	31.07	0.49
Exposed to CRPV (%Yes)	100.00	9.17	14.84	146.86***
Soil fertility test (%Yes)	33.33	15.83	16.93	4.90**
Irrigation (% Yes)	70.83	43.89	45.57	6.59***
Kibirichia	41.67	44.44	44.27	0.07
Kiirua/Naari	4.17	29.17	27.60	7.04***
Abogeta West	33.33	13.61	14.84	6.92***
Abothuguchi West	20.83	12.78	13.28	1.27

***, ** =level of significance at 1% and 5% respectively.

Results show that almost all farmers (99.48%) in the sample had access to information on climate change. The information was sourced from government extension officers, NGOs, social media, radio, television and other farmers. However, there was a slight difference in information access between adopters and non-adopters with non-adopters having the higher proportion 99.72% in comparison to the adopting counterparts with a proportion of 95.83%. With rising temperatures, changing precipitation patterns and greater risk on farmers, climate change discussions have facilitated availability of information through various media outlets such at television, radio, mobile applications and extension officers. Tambo *et al.* (2012) reported that climate change awareness was an important determinant for adoption of

adaptation measures such as improved varieties as it had a positive and significance effect on adoption. Access to adequate information on climate change enabled farmers to seek for ways to adapt to climate change to minimize its adverse impacts on them (Gebre *et al.*, 2019).

Majority of all those who attended training on CRPVs were adopters (83.33%). This is in comparison to non-adopters who comprised of 36.11%. The association between attending training and adopting CRPVs was significant at 1% level of significance. Attending trainings enlightened farmers on existence of CRPVs and merits of adopting them and its during training that demonstrations are carried out to reinforce learning. This is in line with literature for instance Feleke *et al.* (2019) who found similar results and argued that training forums presented learning opportunities for farmers about improved varieties.

Among the adopters, 41.67% had access to extension services in the reference period whereas only 18.33% of the non-adopters had received extension services. This shows that majority of farmers who had access to extension services adopted CRPVs. The association between extension services and adoption was significant at 1% level of significance. Farmers who had access to extension services gain better understanding of these varieties and hence adopted them (Kapalasa *et al.*,2019). Similar results were reported by Mmbando *et al.* (2016) who showed that farmers with access to extension services were over six times likely to adopt improved maize varieties as compared to those who did not have access to extension services. More than half, 79.17% of the farmers who planted CRPVs were a member of one or more farmers' groups whereas 51.67% were non-adopters. The association between adoption and membership in a farmers' group was significant at 1% significance level. Farmer group enables farmers to exercise the power of collective action in lobbying for external support in terms of credit access and information on climate and market trends (Wekesa *et al.*, 2017). Farmers organized in groups were also able to consolidate and assert their opinions on the merits and demerits of improved potato varieties (Wabwile *et al.*, 2016).

All the adopters, 100% were aware of at least one or more CRPVs, however only 9.17% of non-adopters were aware of these varieties. Farmers are exposed to CRPVs through trainings, agricultural shows and accessing information through print or mainstream media. This shows that exposure is necessary for adoption and hence everyone who had adopted the varieties was aware of them (Simtowe *et al.*, 2019; Simtowe *et al.*, 2016).

A significantly higher proportion (33.33%) of the adopters had conducted soil fertility tests whereas only 15.83% of non-adopters had conducted soil fertility test. The association between soil fertility tests and adoption was significant at 5% level of significance revealing that most farmers who had conducted soil fertility tests adopted CRPVs. Out of all the adopters, 70.83% were practicing irrigation whereas only 43.89% of non-adopters were practicing irrigation. The association between irrigation and adoption was significant revealing that most farmers who had access to water for farming adopted CRPVs. Access to adequate water supply acted as an incentive for farmers to explore different varieties in pursuit for increased productivity and income since irrigation minimizes the adverse effects of rainfall variability caused by climate change. This is in line with previous literature as shown by Ebrahim *et al.* (2019) who reported a positive and significant effect of irrigation on adoption arguing that irrigation enabled farmers to avoid effects of change of precipitation patterns.

In terms of geographical location of farmers, from the pooled sample, 44.27% of the farmers were from Kibirichia ward. The proportions between the adopters and non-adopters in the wards were almost the same with non-adopters being slightly higher at 44.44% as compared to 41.67% for the adopters. From the pooled sample 13.28% comprised of farmers from Abothuguchi west with adopters being more than non-adopters by 8.05%.

Associations between Kiirua/Naari, Abogeta West and adoption were significant at 1% level of significance. This could be explained by differences in agro-ecological zones. According to literature, potato is said to be a cool season crop. It grows in areas with temperatures between 15^0C and 18^0C (Muthoni *et al.*, 2017). Abogeta West falls in the upper highlands characterized by temperatures between 10.90^0C-14.90^0C whereas Kiirua/Naari falls in the lower midlands with temperatures falling in between 20.90^0C-24.0^0C. Therefore, farmers in Abogeta West are more likely to adopt CRPVs unlike farmers in Kiirua/Naari ward which is drier. Similar results were reported by Tambo *et al.* (2012) who emphasized on the importance of agro-ecological zones and added that they should be considered in the development, promotion and dissemination of CRPVs.

Table 4.4: Farm size, land under potatoes and distance to seed source

Variables	Adopters n=24 (6.25%)	Non-Adopters n=360 (93.75%)	Pooled Sample n=384	t-test
Farm size(Acres)	1.46	1.56	1.55	0.28
Land under potatoes (Acres)	1.02	1.53	1.50	1.46
Distance to seed source (Km)	7.62	3.51	3.77	-2.41**

**= level of significance at 5%.

Table 4.4presents the mean differences for farm size, land under potatoes and distance to seed source. From the pooled sample, 1.55 acres was the average farm size whereas 1.50 acres was the average land under potatoes and 3.77km was the average distance to the seed source. Adopters were reported to own less land 1.46 acres, hence dedicated a smaller portion to potato growing 1.02acres on average as compared to their non-adopting counterparts.

The results also showed that there was a significant mean difference in distance to the seed source between adopters and non-adopters. For adopters, the average distance to the seed source (7.62Km) was higher than for non-adopters (3.51Km). This revealed that adopters travelled longer distances to acquire seeds for climate resilient varieties. The t-statistic for distance to seed source was negative and significant implying that long distances made it difficult for farmers to acquire CRPV seeds and hence preferred recycling the readily available seeds. This conforms to previous literature as shown by Feleke *et al.* (2019) who reported a negative and significant effect of distance to seed source on adoption. Further, shorter distances to seed source reduce transaction costs and improve timely access to information on seed availability as shown by (Abubakar *et al.*, 2016; Chandio *et al.*, 2018).

4.1.3 Exposure rates for CRPVs

Table 4.5 shows the distribution of exposure rates for CRPVs in the study area. Frequency results shows that Unica variety was the most popular with 14.84%of all sampled farmers being aware of it. It was followed by Lenana with 4.42% farmers being aware of the variety, then Wanjiku and Chulu with 4.17% farmers each and finally Nyota was the least popular with only 0.52% farmers aware of the variety.

Table 4.5: Exposure rates for CRPVs in different wards in Meru County

CRPVs	Kibirichia	Kiirua/Naari	Abogeta West	Abothuguchi West	Total
Unica	56.14%	12.28%	15.79%	15.79%	14.84%
Wanjiku	50%	18.75%	12.75%	18.75%	4.17%
Lenana	52.94%	17.65%	11.76%	17.65%	4.42%
Chulu	43.75%	18.75%	12.50%	25.00%	4.17%
Nyota	50.00%	0%	0%	50.00%	0.52%

4.2 Regional Comparison of Adaptation Practices among Smallholder Potato Farmers

Results for objective one are presented in this sub-section. Table 4.6shows a comparison of different adaptation practices against climate change by farmers from different wards randomly selected in Meru County. The wards represent various agro-ecological zones in Meru county. Proportions of farmers using the identified practices were compared among the selected wards using Chi square tests. The results showed that adaptation practices varied significantly in relation to different agro-ecological zones.

Table 4.6: Comparison of Adaptation Practices by Agro-ecological zones

Adaptation Practice	Kibirichia n=170	Kiirua/Naari n=106	Abogeta West n=57	Abothuguchi West n=51	Chi square Chi2
Climate resilient varieties (%Yes)	5.88	0.94	14.04	9.80	12.13***
Crop rotation (%Yes)	86.47	92.45	98.25	96.08	9.93**
Irrigation (%Yes)	28.82	19.81	96.49	98.04	163.77***
Intercropping (%Yes)	77.06	78.30	71.93	86.27	3.33
Organic fertilizers (%Yes)	71.76	79.25	94.74	98.04	25.94***
Soil conservation (%Yes)	12.94	7.55	52.63	60.78	91.35***
Increased use of pesticides (%Yes)	9.41	0.94	12.28	5.88	9.99**

***, ** =level of significance at 1% and 5% respectively.

In the 2018/2019 cropping seasons, the adoption rates of CRPVs as an adaptation measure was geographically distributed as follows; 5.88% in Kibirichia, 0.94% in Kiirua/Naari, 14.04% in Abogeta West and 9.80% in Abothuguchi West. Abogeta West had the highest adoption rate whereas Kiirua/Naari had the least adoption rate. This finding revealed that farmers from Abogeta West adopted CRPVs as an adaptation practice more than farmers from all the other wards whereas farmers from Kiirua/Naari were least adopters of CRPVs. This can be explained by the fact that Abogeta West has better infrastructure than Kiirua/Naari hence easy flow of information and extension services. CRPVs can be used as adaptation measure to cope with the adverse effects of climate because of their attributes of resistance to drought, heat stress, pest and diseases; high yield and early maturation (International Potato Center, 2017). Similar findings were reported by Asrat *et al.* (2018) who reported that despite farmers in dry lowland perceiving more change in climate than farmers in wet lowland, better awareness and use of adaptation measures was revealed in wet lowland.

The distribution of farmers practicing crop rotation as an adaptation practice was as follows, 86.47% in Kibirichia, 92.45% in Kiirua/Naari, 98.25% in Abogeta West and 96.08% in Abothuguchi West. Majority were in Abogeta West. Crop rotation reduces the rate at which pests and diseases spread in the agricultural land hence reducing the negative effects of climate variability (Fadina & Barjolle, 2018). Irrigation was majorly practiced by farmers from Abogeta West and Abothuguchi West whose proportions were 96.49% and 98.04% respectively unlike the lower proportions reported in Kibirichia and Kiirua/Naari which were 28.82% and 19.81% respectively. Kiirua/Naari had the lowest proportions of irrigation because it is relatively a drier location, has harsh climatic conditions and low water access. Issahaku *et al.* (2019) argued that irrigation could play a positive role in minimizing the adverse effects of rainfall variability. Therefore, increased access to irrigation facilities can increase farmers' resilience to climate change and variability.

Proportions of farmers using intercropping as an adaptation measure were almost the same with majority being in Abothuguchi West. Intercropping is said to reduce soil erosion which is as a result of adverse weather conditions. It also acts as form of preserving food and nutrition security of the household since farmers argue that if one crop fails another one will at least produce significant yield (Fadina & Barjolle, 2018). Most farmers in the study area intercropped potatoes with maize. Proportions of farmers using organic fertilizers for planting

were significantly different with almost all farmers in Abogeta West (94.74%) and Abothuguchi West (98.04%) adopting the practice. Use of organic fertilizers could help with adapting to climate change since fertilizers tend to replenish soils of nutrients that have been depleted over time due to continuous cropping. This finding is consistent with Tambo *et al.* (2012) who argued that fertilizers used in recommended proportions increased crop productivity.

Soil conservation was practiced by 12.94% in Kibirichia, 7.55% in Kiirua/Naari, 52.63% in Abogeta West and 60.78% in Abothuguchi West. The soil conservation measures considered in this study include terracing and tree planting in the farms. Soil conservation is an important adaptation measure as it helps preserve fertile soils that are crucial for crop growth and productivity. Asrat *et al.* (2018) reported that farmers were more likely to adopt soil conservation measures in areas that were more susceptible to the risks of climate change. Association of different geographical locations and use of pesticides was statistically significant at 5%. Highest proportion was accounted by farmers from Abogeta West. Pesticides use helps farmers adapt to climate change by controlling for pests and diseases (Fadina & Barjolle, 2018). Climate change causes various adverse effects on agricultural sector which includes increased occurrence of pests and diseases that reduce crop productivity (Sinelle, 2018).

The results on comparison of adaptation practices by geographical locations reveal that agro-ecological conditions are location-specific and the probability of adoption of adaptation practices varies across these zones. Farmers from Abogeta West were found to be better adapted to climate change than other areas probably because there was better awareness and use of adaptation measures in the area. More so, Abogeta West had better infrastructure compared to other areas making it an easy and convenient target for extension services for climate change adaptation strategies and promoting easy flow of information on climate change. This finding conforms to that of Asrat *et al.* (2018) who argued that spatial variations play an important role in explaining different climate change adaptation rates among farmers.

4.3 Estimation of Population Adoption Rates of Climate Resilient Potato Varieties and its Determinants

4.3.1 Preliminary Diagnostic Tests for Variables in Econometric Analysis

This section presents econometric results of the study. Prior to conducting econometric analysis, diagnostic tests for heteroscedasticity and multicollinearity were carried out for different variables. Heteroscedasticity happens when standard errors of a variable monitored over a specific period of time are not constant. On the other hand, multicollinearity occurs when independent variables are highly inter-correlated. These statistical problems could result into biased parameter estimates if not corrected for the data. Multicollinearity was tested using Variance Inflation factor (VIF) for continuous variables and results were presented in Table 4.7. The results revealed that there were no serious linear relationships among continuous independent variables tested since VIF values were less than 10 (Arabameri *et al.*, 2018; Gujarati, 2004).

Table 4.7: Variance Inflation Factor test results for continuous independent variables

Variable	VIF	1/VIF
Total land owned	1.370	0.732
Household size	1.360	0.737
Household head Age	1.240	0.810
No. of groups	1.190	0.841
No. of trainings attended	1.180	0.849
Total Land under Potatoes	1.170	0.852
No. of extension visits	1.120	0.891
Distance to Seed source	1.110	0.898
Distance to Output market	1.060	0.946
Distance to Agricultural office	1.030	0.971
Mean VIF	1.180	

Contingency coefficients test was conducted for categorical variables whereby contingent coefficients were calculated and results presented in Table 4.8. The contingent coefficients were less than 0.75 confirming that there was no serious linear relationship among categorical independent variables. By the rule of thumb, there was no strong inter-correlations among the hypothesized independent variables and therefore they were all used in econometric analysis.

Table 4.8: Contingency coefficient test results for categorical independent variables

	Gender	Education	Decision Maker	Climate information	Training	Extension services	Group leadership	Credit
Gender	1							
Education	0.242	1						
Decision	0.469	0.115	1					
Climate Inf	-0.053	-0.012	-0.060	1				
Training	0.028	0.081	0.086	-0.016	1			
Extension	0.008	0.124	0.061	-0.055	0.419	1		
Group lead	0.030	0.146	0.150	-0.063	0.116	0.120	1	
Credit	-0.040	0.052	0.080	-0.030	0.062	0.076	0.306	1

To test for heteroscedasticity, White test was used and results presented in Table 4.9. White test is more preferred to Breusch-pagan test because it includes both the magnitude and direction of change for non-linear forms of heteroscedasticity. On the other hand, Breusch-pagan test only tests for linear forms of heteroscedasticity (Dunn, 2018; Williams, 2015). The results revealed presence of heteroscedasticity since Chi^2=108.50 was significantly large. To counter this statistical problem, robust standard errors were reported in econometric analyses (Wekesa *et al.*, 2018).

Table 4.9: Test for Heteroscedasticity

Source	Chi^2	Df	P
Heteroscedasticity	108.500	65	0.001
Skewness	40.720	10	0.000
Kurtosis	32.330	1	0.000
Total	181.550	76	0.000

$Chi^2(65)=108.50$

$Prob>Chi^2=0.0006$

4.3.2 Determinants of Exposure to CRPVs

This section presents results for the parametric (probit) estimation of the exposure model which was estimated using the ATE framework. Exposure/awareness was considered as a binary variable with an exposed farmer being one aware of one or more of climate resilient potato varieties. The fitness results of the model are presented in the lower panel of Table 4.10. The number of observations was 384. The log likelihood for the fitted model was -124.902 whereas the log likelihood chi-squared was 68.92 and significant at 1% level of significance indicating that the model had a strong explanatory power. Pseudo R^2 of 21.6% was above the statistical threshold of 20%Ayuya (2010) confirming that effects on exposure to CRPVs was attributed to covariates considered in the model. From the entire sample, 14.6% were exposed to either one or more CRPVs. The empirical results in Table 4.10 showed that education, land owned, group leadership, number of trainings attended, number of groups, credit access and Kiirua/Naari location were statistically significant in determining exposure to CRPVs.

Table 4.10: ATE Parametric (Probit) Estimation of Exposure Model

CRPV Aware	Coefficients	Robust Std. Errors	P>|z|	dy/dx
Socio-economic factors				
Household head age	0.073	0.051	0.155	0.012
$HHAge^2$	-0.001	0.000	0.204	-0.000
HH gender	0.297	0.205	0.147	0.048
HH education	0.163***	0.061	0.007	0.028
Institutional factors				
Farm size	-0.208***	0.081	0.010	-0.035
Group leadership	0.585**	0.282	0.038	0.126
No. of groups	-0.243**	0.121	0.044	-0.041
No. of trainings attended	0.286***	0.067	0.000	0.048
Soil fertility level	-0.356*	0.183	0.052	-0.060
No. of extension visits	0.161	0.129	0.212	0.027
Credit used for farming	0.491**	0.219	0.025	0.098
Locations				
Kibirichia	0.262	0.267	0.326	0.045
Kiirua/Naari	-0.591*	0.336	0.078	-0.085
Abogeta West	0.167	0.347	0.630	0.031
Goodness of fit				
No. of observations	384			
Log likelihood	-124.902			
Likelihood Ratio (Chi^2)	68.92***			
Pseudo R^2	0.216			

***, **, * =level of significance at 1%, 5% and 10% respectively. Abothuguchi West is the reference ward.

The effects of the household head's level of education was positive and statistically significant at 1%. This means that an increase in household head's education level by 1% increases the propensity of being exposed to CRPVs by 2.8%. Higher education increases the ability of a farmer to seek information on farming challenges. It also enhances the ability of farmers to acquire, synthesize and respond quickly to change hence increasing their

probability of being exposed. Further, education enhances reasoning capability and awareness of a farmer placing them in a better position to recognize risks associated with climate change and therefore in search for coping strategies, the propensity of being exposed to CRPVs becomes higher. The finding is similar to Chandio *et al.* (2018) and Kumar *et al.* (2016) where level of farmer's education is reported to have a positive and significant influence on exposure to farm technology.

Farm size had a negative and significant effect on propensity of exposure. An increase in farm size by 1% reduced the probability of being exposed to CRPVs by 3.5%. This could be attributed to the fact that a farmer who owned less land was more likely to be exposed to CRPVs because land pressure on small plots obligates farmers to find solutions to increase farm productivity. Thus, in search of high yielding varieties, these farmers are more likely to get exposed to CRPVs. On the contrary, Baiyegunhi *et al.* (2019) and Kabunga *et al.* (2012) reported a positive and significant influence of land size on awareness and argued that land size can be used as a proxy for wealth whereby farmers with larger land plots were considered to be wealthier and hence were more likely to afford the cost of knowledge acquisition. Amengor *et al.* (2018) also reported that farmers with more plots had a higher propensity of being exposed to CRPVs because with more plots, farmers were likely to search for more vines increasing their chances of exposure to improved varieties.

Leadership in a farmers' group increases the chances of being exposed to CRPVs. At a 5% level of significance, being a leader increased the propensity of exposure by 12.6%. Group leaders tend to have more contacts with extension officers, experts and access more training forums than the members. They are also entry points for various farm innovations as in most cases, their farms are used as demonstration plots. From the focus group discussion, most group leaders were referred to as Decentralized Seed Multipliers (DSMs) as they were responsible for multiplying seeds for other group members. This was an arrangement between farmers and non-governmental organizations such as International Potato Center (CIP) and Farm Inputs (FIPS) Africa who are key disseminators of improved seed varieties to farmers in Meru County. Wossen *et al.* (2015) reported similar findings and argued that holding a leadership position can be used as a measure of social capital since it provides the household with formal and informal support and information dissemination.

There was a negative and significant effect of number of groups a farmer was in, on exposure. The higher the number of groups, the lower the propensity of being exposed to

CRPVs. This could possibly be explained by the fact that not all farmer groups are based on potato farming whereas CRPVs are mainly discussed only in potato-based farmer groups. Most groups in the study area are dairy and welfare-based while other farmer groups were based on perennial crops such as coffee and tea. The results were contrary to Hunecke *et al.*(2017) and Kabunga *et al.* (2012) who found a positive effect of group membership emphasizing on the role of social networks and social capital in dissemination of information. The effect of number of trainings attended by a farmer was positive and significant at 1% significance level whereby, an increase in the number of trainings attended by 1% increased the probability of being exposed by 4.8%. Farmers who attend more trainings on potato farming are more likely to get exposed to CRPVs because they acquire knowledge and information on climate change adaptation using improved varieties. More so, trainings are offered by different stakeholders who comprise climate change adaptation experts, seed providers among others. Trainings also come with field demonstrations hence increasing the propensity of exposure to CRPVs for farmers who attend such trainings. These results are in line with literature for instance Mwololo *et al.* (2019) who argued that improved varieties are usually introduced and promoted through training of farmers in organized groups. Similar results were also reported by Arya (2019) and Arya *et al.* (2018).

Soil fertility level had a negative and significant effect on exposure. Farmers whose farms were acidic or less fertile were less likely to seek information on CRPVs. A 1% change in soil fertility level to the negative side resulted reduced propensity of a farmer being exposed by 6%. Farmers with fertile lands had a higher propensity for exposure. This could be because soil fertility acted as an incentive for farmers to seek more information on sustainable farming including the use of CRPVs. Moreso, during testing farmers are advised of various sustainable farming measures such as use of CRPVs. These results are consistent with previous assertions from farmers in the study area where farmers who had conducted soil tests and found their farm soil fertile showed more interest in learning about adapting to climate change through use of improved varieties (Abdulai, 2016; Chandio *et al.*, 2018; Tadesse *et al.*, 2017).

Access to credit for farming had a positive effect on propensity of being exposed that was significant at 5% level of significance. Farmers who had access to credit had a higher probability of being exposed to CRPVs. An increase in credit used for farming by 1% results to an increase in the propensity of exposure by 9.8%. Access to credit is usually accompanied

by extension services including risk management which involves climate change adaptation practices such as the use of CRPVs. Credit access also increases the purchasing power of farmers and hence can afford to buy quality CRPVs. This increases the propensity of farmers with access to credit of being exposed to CRPVs. This was in line with Mwololo *et al.* (2019) who argued that access to credit acted as an incentive for farmers to seek more information about CRPVs to maximize on returns. Further, Aryal (2019) reported similar results and argued that farmers with access to credit are more likely to adopt resource saving agricultural practices such as drought-resistant varieties hence are more likely to be exposed to CRPVs.

The effect of a farmer being located in Kiirua/Naari on exposure to CRPVs was negative and significant at 10% level of significance. The probability of a farmer in Kiirua/Naari being exposed to CRPVs decreases by 8.5%. This could be explained by various reasons such as the climatic conditions of Kiirua/Naari in relation to climatic conditions of Abothuguchi West. According to literature, potato is a cool season crop which grows in areas with temperatures between 15^0C and 18^0C (Muthoni *et al.,* 2017). However, Kiirua/Naari is characterized by higher temperatures falling in between 24.0°C-20.90°C. This negatively affects the growth of potato varieties discouraging farmers from growing potatoes. This lowers farmers' propensity of being exposed to CRPVs which have the ability of doing well in such harsh climatic conditions due preferred attributes of resistance to heat stress. These findings were similar to Amengor *et al.* (2018) and De Groote *et al.* (2016) who argued that awareness of CRPVs is location specific.

4.3.3 Adoption rates for CRPVs

Table 4.11 presents results of Average Treatment Effect (ATE) corrected adoption rates including the actual Joint Exposure and Adoption (JEA) and potential ATE adoption rates and the adoption gap which is given by the difference between JEA and ATE, that is, (GAP=JEA-ATE). Adoption gap originates from incomplete exposure to climate resilient potato varieties among the sampled farmers. ATE is the effect of a treatment on a randomly selected person from the population. In this study, "treatment" is the exposure to one or more CRPVs whereas the average treatment effect(ATE) on adoption outcomes is the potential adoption rate which is the rate of adoption when all farmers are exposed the CRPVs.

Table 4.11: ATE Estimated CRPV Adoption rates

CRPV Adopt	Parameter	Std. Err.	P>z
ATE (Potential adoption rate)	0.307***	0.033	0.000
ATE1 (Adoption rate among exposed sub-sample)	0.433***	0.038	0.000
ATE0 (Adoption rate among non-exposed sub-sample)	0.285***	0.035	0.000
JEA (Joint exposure and adoption rate)	0.063***	0.006	0.000
GAP (Adoption gap)	-0.244***	0.029	0.000
PSB (Population selection bias)	0.126***	0.025	0.000
Observed			
Ne/N	0.146***	0.018	0.000
Na/N	0.063***	0.012	0.000
Na/Ne	0.429***	0.085	0.000

***, **, * =level of significance at 1%, 5% and 10% respectively.

The results indicate that 14.6% of all the farmers sampled were aware of at least one CRPV. This incomplete exposure to CRPVs restricted the Joint Exposure and Adoption rate (JEA) to 6.3% which was the actual adoption rate whereas the potential adoption rate (ATE) was at 30.7%. The adoption rate of CRPVs could have been 30.7% in Meru County if the whole population was exposed instead of the Joint Exposure and Adoption rate of 6.3%.

The difference yields an adoption gap of 24.4% which is attributed to the incomplete exposure. The estimated adoption gap was negative and statistically significant at 1% level of significance. This means that there is a potential of increasing the actual adoption rate by 24.4% if all farmers are made aware of one or more climate resilient potato varieties (Simtowe *et al.*, 2016). Furthermore, the joint exposure and observed adoption rates are considered to be inaccurate indicators of adoption due to non-exposure bias. The true population adoption rate corresponds to ATE which is the potential adoption rate after correcting for heterogeneous exposure (Muthini, 2018).

ATE1 which can be defined as the adoption rate among the exposed sub-sample or the treated sample, shows that 43.3% of the farmers exposed to CRPVs grew at least one of them in the reference period. The mean potential adoption rate among the non-exposed sub-population (ATE0) was estimated at 28.5%. The population selection bias (PSB) which was estimated at 12.6% is a measure of the difference between the potential adoption rate in the exposed sub-population and the actual population adoption rate.

The population selection bias is highly significant at 1% implying that the probability of adoption for a farmer from the exposed sub-population is different from the probability of adoption of CRPVs for a farmer randomly selected from the entire population. According to literature, positive PSB could occur due to either self-selection of farmers into exposure or progressive farmers being targeted by extension workers or both(Diagne & Demont, 2007).

4.3.4 Determinants of Adoption of CRPVs

Table 4.12 presents results on the determinants of climate resilient potato varieties uptake for the classical "adoption" model and the ATE parametric (probit) adoption model. The results of model fitness are presented in the lower panel of Table 4.12. The number of observations for the ATE corrected parametric model was 57. The log pseudo likelihood for the fitted model was -16.549 whereas the Wald chi-squared was 32.60 indicating that all parameters were jointly significant at 1% and the model had a strong explanatory power. Pseudo R^2 of 56.7% was above the statistical threshold of 20% confirming that effects on adoption to CRPVs was attributed to covariates considered in the model.

Consistent with theoretical expectation, there was a notable difference in the magnitude of the coefficients between the two models. The magnitude of the marginal effect of a factor determining adoption without controlling for exposure computed from the classical adoption model is always between 0 and 1 and is very small in most cases when few farmers are aware of the improved technology. This is because the magnitude of the marginal effect is calculated from multiplying the marginal effect of the true adoption model by the conditional probability of awareness (Diagne & Demont, 2007). It is also important to note that some coefficients maybe significant in either one model or both.

Table 4.12: Parametric Estimation of Determinants of Adoption (restricted to the exposed sub-population) Vs Classical Estimation

	ATE Corrected Adoption		Classical Adoption	
CRPV Adopt	Coefficient	dy/dx	Coefficient	dy/dx
Gender (male)	-1.981 (0.996)	-0.211**	-0.303(0.332)	-0.007
Age of household head	0.465(0.233)	0.021**	0.244(0.101)	0.005**
$HHAge^2$	-0.004(0.002)	-0.000**	-0.002(0.001)	-0.000**
Size of household	-1.009(0.654)	-0.047	-0.196(0.109)	-0.004*
Decision maker	1.871(0.794)	0.086**	0.538(0.192)	0.011***
Farm size			-0.083(0.121)	-0.002
Distance to agricultural office	0.044(0.079)	0.002	-0.009(0.019)	-0.000
Credit access			-0.482(0.521)	-0.008
Total land under potatoes	-0.053(0.304)	-0.002		
Information on climate change	1.489(0.650)	0.019**	0.904(0.578)	-0.027
Soil fertility level			-0.129(0.157)	-0.003
No. of trainings attended	0.234(0.084)	0.011***	0.309(0.068)	0.006***
No. of extension visits			0.426(0.319)	0.008
No. of farmer groups	0.922(0.460)	0.043**	0.085(0.146)	0.002
Extension services			-0.610(0.590)	-0.008
Lack of seeds	-1.069(0.612)	-0.041**	-0.119(0.303)	-0.002
Household education			0.081(0.092)	0.002
Credit used for farming			0.306(0.517)	0.007
Information from other farmers	2.492(0.883)	0.119***	0.905(0.415)	0.016**
Kibirichia	2.415(1.200)	0.230**	-0.490(0.338)	-0.010
Kiirua/Naari[a]			-1.708(0.618)	-0.023***
Abogeta West	5.408(1.975)	0.992***		
Abothuguchi West	3.537(1.641)	0.833**	-0.303(0.378)	-0.005
_cons	-19.290(6.909)***			
Number of Observations	57		384	
Wald chi2	32.60***		82.90***	
Log pseudo likelihood	-16.549		-54.360	
Pseudo R2	0.567		0.394	

***, **, * =level of significance at 1%, 5% and 10% respectively.

Figures in parenthesis represent robust standard errors.

[a] is the reference ward.

Results show that gender of the household head had a negative and significant effect on the uptake of climate resilient potato varieties at 5% level of significance. Female-headed households had a higher propensity to adopt CRPVs than males. The probability of adopting

at least on variety of climate resilient potatoes decreases by 21.1% with being a male farmer. Women farmers are responsible for half of world's food production and usually produce around 60-80% of food in developing countries (Doss, 2014). Therefore, they are more concerned with varieties (climate resilient varieties) that ensure consistent production despite the prevailing climatic shocks. Potato is also referred to as a female crop where most females are engaged in potato growing whereas males mostly grow perennial crops such as coffee and tea in the study area. This is consistent with previous literature as shown by Simtowe *et al.* (2016) who found out that women farmers preferred cultivation of improved pigeon pea due to its high protein content.

Age of the farmer had a positive and significant influence on adoption indicating that the older the farmer, the higher the propensity to adopt. An increase in age by 1% increases the probability of adoption by 2.1% which was significant at 5% level of significance. This could be attributed to the reasoning that the older a farmer gets, the more experience they gather with the potato crop, acknowledging the benefits associated with growing an improved variety of such a crop. Similar results were reported by Fadina and Barjolle, (2018) who argued that experience with a technology is a critical factor for affecting its adoption and age can be used as a proxy for experience where such information on how long a farmer has been using the technology cannot be accessed. Simtowe *et al.* (2016) also found a positive relationship between age and adoption and argued that older farmers are less constrained in terms of financial capacity to adopt improved technologies such as CRPVs as compared to younger farmers. However, age had a quadratic pattern in uptake of CRPVs whereby as age increased, propensity to adopt increases up to a certain level and then starts to decline in line with the life cycle hypothesis. This is indicated by the square of age (Age^2)which had a negative effect on adoption of CRPVs at 5% level of significance. The findings suggest reduced commitments of the farmers hence low incentive to adopt innovations. This is consistent with Kapalasa *et al.* (2019) who found a decreasing effect of age on adoption of improved potato varieties.

The effect of decision making unit (decision maker) on adoption of CRPVs was positive and significant at 5% level of significance. Households whose decisions were made jointly had a higher propensity of adopting CRPVs by 8.6% than households with individual decision-making. Households with joint decision making units are able to share ideas and convince each other of adoption of certain innovations that enhance adaptation to climate change such

as CRPVs. Similar results emphasizing on the role of joint or participatory decision making on adoption of improved varieties were reported by previous studies Acosta *et al.* (2020), Bjornlund *et al.* (2019) and Shiferaw *et al.* (2008) who argued that joint decision making allows for consensus forming on merits of agricultural technologies.

The results show that access to information on climate change and its impacts had a positive and significant effect on uptake of CRPVs. An increase in access to information on climate change and its impact by 1% increased the propensity to adopt by 1.9% at 5% level of significance. A farmer with access to information on climate change and its impact was more likely to adopt CRPVs as a climate adaptation practice because of awareness of the adverse effects of climate change on potato crop. Awareness of the impact of climate change is a necessary condition for climate change adaptation among smallholder farmers. Knowledge of impact prompts farmers to seek for measures to cope with the situation. This explains why farmers with such knowledge have a higher propensity to adopt CRPVs. The variable 'Other farmers' used as a proxy for source of information was also positive and significant emphasizing on the importance of access to climate information on adoption of CRPVs (Simtowe *et al.*, 2019). These results are in line with previous literature as shown by Aryal *et al.* (2018) and Nzeadibe *et al.* (2011) who reported that farmers aware of the impact of climate change was more likely to uptake adaptation innovations such as CRPVs because they understood the risks associated with climate change. Other sources of information revealed by farmers in Meru county include television, radio, mobile phones, print media, non-governmental institutions and government extension officers.

The number of trainings attended by a farmer in a cropping season had an effect on adoption of CRPVs that was positive and significant at 1% level of significance. This shows that farmers who had attended more trainings on potato farming had a higher propensity to adopt CRPVs than farmers who had attended lesser training sessions. A 1% increase in number of trainings attended increased farmers' propensity to adopt by 1.1%. Through training, farmers acquire knowledge, skills and better understanding of CRPVs and their role in adapting to climate change. The knowledge gained could also capacitate farmers with the technical know-how required for adoption of CRPVs. Number of training sessions attended highlights the importance of human capital development. These results are consistent with previous studies (Ahmed *et al.*, 2016; Feleke *et al.*, 2019;Kapalasa *et al.*, 2019) since training exposes farmers to practical and technical knowledge required in adopting agricultural technologies.

There was a positive and significant effect of number of farmer groups a farmer was engaged in on adoption of CRPVs. Membership in many groups increased the propensity of adopting CRPVs by 4.3%. Farmers who were in more farmer groups had a greater chance of adopting CRPVs. This could be because farmer groups offer platforms for trainings, information access and even credit access through pooling of resources. Similarly, Wabwile *et al.* (2016) found a positive and significant relationship between adoption and farmer groups and argued that, groups presented an opportunity for farmers to ascertain their decision on the relevance of new technologies being introduced to them. Further, Muthini (2018) argued that groups as proxies for social networks increased channels for access to information. Climate change information from other farmers had a strong positive effect on adoption emphasizing on the importance of social capital on adoption (Hunecke *et al.*, 2017).

Lack of clean potato seeds had a negative and significant effect on adoption of CRPVs. Farmers whose access to seeds was constrained or difficult had a lower propensity to adopt. This was as expected since farmers cannot adopt a variety they had no access to its seeds in terms of availability, affordability and timely delivery. Similar results were reported by Asante *et al.* (2017) who argued that availability and affordability of seeds was a necessary condition for adoption. Awotide *et al.* (2016) also argued that some farmers were seed dealers and not only sold potato as ware but also as seed and therefore lack of access encouraged them to deal in traditional varieties that were readily available.

Out of the four locations considered in the study, Kibirichia, Abogeta West and Abothuguchi West had positive and significant influence on adoption of CRPVs. Farmers from these locations were more likely to adopt CRPVs than farmers from Kiirua/Naari.This could possibly be explained by variations in climate conditions. Kiirua/Naari is relatively drier compared to the other three locations hence comprising potato growth which is a cool season crop. The probability of adoption in Abogeta West (0.992) and Abothuguchi West (0.833) was higher than Kibirichia (0.23) probably because Kibirichia has poor infrastructure as compared to the two locations hence make flow of information and extension services difficult. The results were similar to (Mansaray *et al.*, 2019)who argued that areas with high propensity of adoption had higher targeted extension effort and development of local seed systems. Similarly, De Groote *et al.* (2016) and Kaliba *et al.* (2018) argued that farming systems with favorable soils and climatic conditions were more likely to have farmers with high propensity to adopt improved varieties.

4.4 Evaluation of Farmers' Preferences and Willingness to Pay for CRPV Attributes

This section presents results for farmer preferences and willingness to pay for various potential climate resilient potato attributes. The first and second sub-sections presents farmers' preferences and possible sources of preference heterogeneity whereas the last sub-section presents willingness to pay premiums for improved CRPVs. Farmers' preferences were analyzed using the Discrete Choice Experiment (DCE) approach. Mixed logit model was used to account for preference heterogeneity. The price attribute entered the model with the expected negative sign (Hole *et al.*, 2012). The maximum likelihood simulation procedure was used to estimate the models with 100 Halton draws using STATA Version 15 software. The response rate was 100% with 384 farmers participating in the choice experiment making a total of 3456 observations included in the econometric model.

4.4.1 Farmers' Preferences for Improved CRPVs

Table 4.13 shows results for farmers' preferences for improved CRPVs. The log likelihood was -417.018 whereas chi-square was 108.83 and statistically significant at 1% level of significance. This shows that all the variables included in the econometric model were statistically sufficient and the model had a good fit. All the variables included in the model were positive and significant at 1% except for input price which was negative and significant at 10% level of significance. This further reveals that the attributes and attribute levels considered in the model were essential in determining farmer preferences for CRVPs. The standard deviations for all parameter estimates were statistically significant at 1% level of significance with the exception of the standard deviation for High yield which was significant at 5% level of significance. This shows the presence of preference heterogeneity among farmers who participated in the experiment validating the suitability of mixed logit model for analysis of this objective.

Table 4.13: Farmers' preferences for improved CPRVs

Variable	Coefficient	Standard error	*p*-Value
Resistant to pests and diseases	7.755	1.933	0.000***
Low water requirement	2.341	0.661	0.000***
High yield (30T/Ha)	2.061	0.540	0.000***
Short maturation period(<3 months)	2.017	0.546	0.000***
Input price (per kg)	-0.024	0.014	0.085*
Derived standard deviations of parameter distributions			
Resistant to pests and diseases	5.275	3.90	0.000***
Low water requirement	2.455	0.700	0.000***
High Yield	-1.787	0.761	0.019**
Short Maturation Period(<3 months)	-1.488	0.537	0.006***
Goodness of fit			
Log Likelihood	-417.018		
LR Chi2 (4)	108.83***		
n (respondents)	384		
n (choices)	3456		

***, **, * =level of significance at 1%, 5% and 10% respectively.

Farmers not only consider productivity of potato varieties when making decision on whether to adopt or not, but they also consider the adaptability of potato varieties to the changing factors of climate that have adverse effects on potato crop. Results indicate that farmers preferred CRPVs that were resistant to pests and diseases. The estimated coefficient for resistant was positive and significant at 1% significance level. The magnitude of the coefficient was high (7.755) and almost thrice the magnitude of all other attributes. This reveals that even though farmers preferred potato varieties with high yield, short maturation period and low water requirements; resistance to pests and diseases was their most preferred attribute. This can be explained by changes in climatic conditions for instance, increased temperature and humidity which increase the severity of pests and diseases such as late blight and bacterial wilt. Therefore, in attempt for farmers to adapt to climate change and increase

resilience, they seek for potato varieties that are highly resistant to pests and diseases. This finding is consistent with previous studies Gamboa *et al.* (2018), Kassie *et al.* (2017) and Sánchez *et al.* (2017) who reported that farmers preferred varieties that were resistant to pests and diseases to reduce yield loss amid climate change.

The estimated coefficient for low water requirement was positive and significant at 1% level of significance. The magnitude of the coefficient (2.341) indicate that low water requirement was the second most preferred attribute after resistance to pests and diseases. Due to the negative effects of factors of climate change such as unseasonal rainfall and reduced precipitation, farmers prefer potato varieties that require less water to grow so as to ensure yield stability even in seasons of poor rainfall. More so, farmers from drier agro-ecological zones are usually limited in terms of access to water hence varieties with low water requirements were more favorable. Similar results were reported by Asrat *et al.* (2010) who highlighted that farmers preferred varieties that were tolerant to environmental stress factors such as poor rainfall.

The coefficient of high yield (2.061) was positive and significant at 1% level of significance revealing that potato farmers from Meru County preferred varieties that were high yielding (30T/Ha). This finding was as expected for a rational decision maker trying to maximize utility. High yielding varieties are preferred by farmers as they ensure food security, increased income from sales and hence reduced household poverty. Climate change leads to yield loss and reduced productivity. Kivuva *et al.* (2014) argued that farmers preferred high yielding varieties in order to counter production constraints. The attribute of short maturation period (<3 months) had a positive and significant coefficient at 1% level of significance and a magnitude of 2.017. This indicates that potato farmers preferred varieties that matured faster. Varieties that mature fast are usually less affected by adverse effects of climate change such as poor rainfall, frost, potato blight and drought (Gamboa *et al.*, 2018).

The price attribute was negative and significant at 10% significance level. This indicates that farmers preferred lower prices for CRPVs holding all other factors constant. This finding was as expected since the sign of the price attribute was actually imposed by choosing log normal distribution. Similar results were reported by Pambo *et al.* (2014) and Van den Broeck *et al.* (2017). However, the absolute magnitude of the price coefficient was relatively small revealing that potato farmers in Meru county were low-price responsive. A small change in

price did not affect their preferences for other CRPV attributes. This was contrary to Wanyama *et al.* (2019) who reported high-price responsiveness for low income consumers. The contrast shows that farmers in Meru county valued environmentally adaptable potato varieties despite the price mark up.

4.4.2 Sources of Preference Heterogeneity

The middle part of Table 4.13shows significant values for the standard deviations of the random estimates which reveals presence of preference heterogeneity. This means that preferences for CRPV attributes were allowed to vary across different farmers with similar observed characteristics. To show possible sources of preference heterogeneity, interactions between random parameters and farmer characteristics were estimated using mixed logit model (Pambo *et al.,* (2014). After iterative process of model estimation and comparison using simulated log likelihood procedure, interactions that were significant and produced a good fit for the model were reported in Table 4.14. These included; gender_HY which represented the interaction between gender of the farmer and High Yield (HY) attribute, Age_Lwr which was the code for interaction between age and low water requirement attribute, Educ_HY which was the code for education and high yield, and finally Educ_Res which represented the code for education and resistant attribute.

The top part of Table 4.14 shows the mean estimates for preferred CRPV attributes (discussed in Table 4.13), the middle part shows the interactions whereas the third part shows the standard deviations for the parameter estimates. The lower panel of Table 4.14 shows the goodness of fit for the model. Comparing results of the two tables (Table 4.13 and 4.14), inclusion of interactions improves the overall model fit since the log likelihood reduces to -425.380.

Table 4.14: Potential Sources of Preference Heterogeneity

Variable	Coefficient	Standard error	*p*-Value
Resistant to pests and diseases	5.240	0.935	0.000***
Low water requirement	2.858	0.728	0.000***
High Yield (30T/Ha)	0.054	0.643	0.933
Short Maturation Period(<3 months)	2.336	0.715	0.001***
Seed Price (per kg)	-0.024	0.013	0.057*
Interactions			
gender_HY	0.513	0.297	0.085*
Age_Lwr	-0.020	0.012	0.081*
Educ_Res	-0.221	0.118	0.061*
Educ_HY	0.222	0.092	0.015**
Derived standard deviations of parameter distributions			
Resistant to pests and diseases	2.788	0.327	0.000***
Low water requirement	1.333	0.275	0.000***
High Yield	0.248	0.174	0.155
Short Maturation Period(<3 months)	2.037	0.695	0.003***
Goodness of fit			
Log Likelihood	-425.380		
LR Chi2 (4)	87.40***		
n (respondents)	384		
n (choices)	3456		

***, **, * =level of significance at 1%, 5% and 10% respectively.

The interaction between gender and high yield denoted by gender_HY had a positive and significant coefficient at 10% level of significance. This shows that being male increased the preference for high yielding potato varieties by 51.3%. This can be explained by the fact that most male farmers are business-oriented and practice agribusiness unlike female farmers who in most cases farm potato for household food and nutrition security. Male farmers prefer potato varieties with higher yield so as to boost their income levels from increased sales. This

finding is consistent with Patel-Campillo *et al.* (2018) who argued that females majored in potato farming mainly for the food security of the household.

The interaction between age of the farmer and low water requirement attribute denoted by Age_Lwr had a negative and significant coefficient at 10% significance level. Age reduced the preference for potato varieties requiring low water to grow by 2%. Older farmers shifted their preference from low water requirements. This can be explained by the fact that older farmers are usually more endowed in terms of resources than younger farmers and therefore can afford to acquire irrigation equipment making water requirements a less preferred attribute. Simtowe *et al.* (2016) argued that older farmers are less constrained in terms of financing farming practices.

The interaction between education and resistant to pests and diseases denoted as Educ_Res yielded a negative and significant coefficient at 10% level of significance. Farmers' preference for resistant varieties shifted downwards by 22.1% with increase in education level. More educated farmers did not place much importance to the resistance attribute besides the attribute being the most preferred generally. A possible explanation is that educated farmers are more knowledgeable in terms available pesticides suitable for use and are aware of their appropriate application. More so, educated farmers have alternative sources of income and therefore are able to afford such recommended pesticides hence do not place much importance on the resistance attribute. This finding is contrary to Chandio *et al.* (2018) who argued that education enhanced farmer ability to recognize risks associated with climate change such as severity of pests and diseases hence preferring varieties that are resistant. Further, results show that the interaction between education and high yield had a positive and significant coefficient at 5% level of significance revealing that preference for high yielding varieties increased by 22.2% with higher level of education.

This study revealed that gender, age and education level of the farmer were significant sources of preference heterogeneity for preferred CPRV attributes including resistant to pests and diseases, yield and water requirements. However, the derived standard deviation for the maturation period attribute was still significant at 1% implying that heterogeneity in preference for maturation period was caused by other factors other than the socio-economic factors included in the model.

4.4.3 Willingness to Pay for Improved Climate Resilient Potato Varieties

This sub-section presents results for the estimation of Willing To Pay (WTP) for CRPVs. The price attribute represented the purchasing price for CPRV seeds and was captured as price per 50kg bag which is the most popular recommended packaging method for potato seeds in Kenya. However, for purpose of favorable econometric modelling, the price variable entered the model as Kenya Shillings per Kilogram implying that the WTP values should be multiplied by 50 since the price variable was divided by 50 during estimation.

The price coefficient enabled estimation of Marginal Rate of Substitution (MRS) between improved CPRVs attributes and money interpreted as marginal willingness to pay for a change in each attribute. The effect of each attribute was not predetermined and therefore, the willingness to pay values could take any sign. Positive values show the amount farmers would be willing to pay to acquire preferred attributes whereas negative values indicate the discount farmers would demand for accepting less preferred attributes for CRPVs. Table 4.15 shows the estimated WTP values for each of the CPRV attributes.

Table 4.15: WTP Values for CPRV Attributes

Variables	Marginal WTP	Lower CI	Upper CI
Resistant to pests and diseases	327.740	-88.740	741.221
Low water requirements	98.954	-33.167	231.075
High Yield (30T/Ha)	87.083	-29.208	203.373
Short Maturation Period(<3 months)	85.256	-28.913	199.424

CI, Confidence Interval at 95% confidence level

The willingness to pay estimates highlight the extent to which potato farmers value CRPV attributes. A first observation is that WTP values for CRPV attributes average around the same value except for the resistant to pests and diseases attribute whose WTP value was over three times more than all other attributes. This means that farmers were willing to pay more for the resistant to pests and diseases attribute than for any other attribute despite the price mark up. This is justified as pests and diseases comprise of the most important challenge facing potato production in Kenya. Kivuva *et al.* (2014) and Maligalig *et al.* (2018) reported

that the main factors constraining potato production include occurrence of pests and diseases and limited access to quality seeds.

Looking further into the details of Table 4.15, potato farmers in Meru County would be willing to pay an average of Ksh 327.740 per Kg for varieties resistant to pests and diseases, Ksh 98.954 per Kg for varieties that have low water requirements, Ksh 87.083 per Kg for high yielding varieties (30T/Ha) and above, and Ksh 85.256 per kg for varieties with short maturation period (<3 months). However, it should be noted that this analysis was based on stated preference data which is subject to hypothetical bias. Thus, WTP values should be interpreted as high preferences rather than a strategy to develop feasible price mark-up for CRPVs (Gamboa *et al.*, 2018).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the analyses of the three objectives, three conclusions were made respectively:

i. Results indicate that adaptation practices adopted by potato farmers in Meru county varies with agro-ecological zones. Farmers from Abogeta West and Abothuguchi west are more adapted to climate variability as compared to farmers from Kibirichia and Kiirua Naari regions. The major adaptation practices identified in Meru County include; irrigation, intercropping, crop rotation, soil conservation, use of organic fertilizers and use of climate resilient potato varieties.

ii. Results also reveal that considering exposure the adoption rate for climate resilient varieties is still low at 6.3%compared to the potential adoption rate of 30.7%. The adoption gap of 24.4% is due to incomplete exposure of farmers to CRPVs. Ensuring that the entire population is exposed to CRPVs could increase adoption rate from 6.3% to 30.7%. Socio-economic and institutional variables influence the exposure and adoption of CRPVs.

iii. Farmers have a strong preference for CRPVs with high resistance to pests and diseases as the most important potato crop trait as indicated by the high value of willingness to pay. Preference heterogeneity varies by socioeconomic characteristics.

5.2 Recommendations

To increase the adoption rate of CPRVs as an adaptation practice against climate variability, farmer exposure to and knowledge of climate resilient potatoes should be increased. This can be achieved through organizing more trainings on climate change adaptation and encouraging farmers to attend through enhanced mobilization. Stakeholders should also organize participatory variety selection events for potato farmers to increasing their understanding of CRPV traits. Farmers should also be encouraged to acquire membership in farmer groups that address issues in potato farming. This will boost farmers' exposure to CRPVs which is a necessary condition for adoption.

Differences in agro-ecological zones should be put into consideration when promoting adoption of CRPVs. The government should establish more training centers and deploy more trained extension officers in Meru County to avail information on climate variability

adaptation practices such us use of CRPVs. Information can also be made available to farmers through electronic and print media.

Breeding efforts should embed traits for CRPVs preferred by farmers. Results indicate that CRPVs have a high potential for diffusion should ongoing breeding programs focus on development of potato varieties that are highly resistant to pests and diseases, have high yielding potential with low water requirements and short maturation period (<3months).

5.3 Areas of Further Research

Following the high preferences exhibited for various CRPV attributes in this study, it would be important to estimate adoption rates for CRPVs under joint seed access, affordability and exposure. This is because despite exposure and availability of seeds, households for whom the seed is not affordable are unlikely to adopt the variety of their choice. This analysis would further inform on the current bottlenecks in the potato value chains and scaling up of CRPV adoption efforts by various stakeholders. Further analysis on preference-variations across social classes of potato farmers would provide additional insights on affordability of CRPVs for different social classes of farmers and different pathways of increasing adoption of climate resilient potato varieties.

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APPENDICES

Appendix I: Questionnaire

PREFERENCES FOR AND EXPOSURE TO CLIMATE RESILIENT POTATO VARIETIES: CASE OF SMALLHOLDER FARMERS IN MERU COUNTY, KENYA

Date.....

Questionnaire No.....

My name is Sally Mukami Kimathi, a student from Egerton University. I am conducting a study on the above named topic and you are one of our randomly selected farmers to participate in this survey. Your participation is voluntary and the information we get from you will be treated confidentially. The findings of this study will help us better understand how potato farmers are adapting to climate change, their preferences and constraints to the uptake of climate resilient potato varieties.

With your permission/consent, I would like to start the interview.

Enumerator's name: .....

SECTION 1: HOUSEHOLD PROFILE

Screening Question: A1) Did you grow any Potato in the last two seasons? 1=Yes, 0=No ------ If no, discontinue the Interview. **PotGrow**

1.1 GEOGRAPHIC LOCATION

1) Ward ..... **Ward**

1=Kibirichia

2=Kiirua/Naari

3= Abogeta West

4= Abothuguchi West

1.2 SOCIO-ECONOMIC CHARACTERISTICS

1) What is the name of the Household Head (HH)? ..... **HHName**
2) Mobile Number..... **HHMobNo**
3) Gender of HH 1=Male 0=Female [ ] **HHGen**
4) Age of HH..... **HHAge**
5) Education Level of HH (Code below) ..... **HHEduc**

Education Level (Educ) Codes: *0= None, 1= Btwn STD 1-7 2= Primary Certificate 3= Btwn Form 1-4 4= Secondary Certificate 5=College certificate 6= University degree & above, 7= Adult education.*

6) What is the name of the Respondent? ..... **ResName**
7) Gender of the Respondent 1=Male 0=Female [ ] **ResGen**
8) Relationship of the Respondent to the HH..... **RlshpHH**
9) What is the Household Size?..... (members above 18 years old) **HHSize**
10) Does the HH participate in off-farm employment? 1=Yes 0=No [ ] **OffFarmAct**

If yes,

I. What is the Occupation of HH?..... **HHOcc**

II. What is the average monthly income from off-farm employment?.....KES **OffFarmInc**

11) Who is the key decision maker? 1=HH 2=Spouse 3= Both [ ] **DecMaker**

SECTION 2: POTATO PRODUCTION

2.1 ACCESS TO LAND

2.2 POTATO Seed	Size in acres S1	Size in acres S2
Total land owned		
Land size under lease		
Total land under crops		
Total land under potatoes (Including leased)		

If leased, what is the leasehold cost for area under potato? ***S1****.....KES,* ***S2****.....KES*

2.2 POTATO PRODUCTION

Season 1 2	**Field No.**	**Crop variety code** *(See variety codes below)*	**Field size in acres**	**Seed type planted** 1=Certified seed 2=DSM/VPA seed 3=Farmers 'own seed 4= Others specify	**Quantity of Seed Used**			**Quantity harvested** *-777=not yet harvested*		**Quantity Sold**		
					Quantity	Unit	Cost per unit (KES)	Qty	Unit (Codes)	QTY	UNIT	Price Per Unit
Season	**Field#**	**Variety**	**acres**	**sdtype**								

Unit codes1: 1=90 kg bag, 2=50 kg bag, 3=110kg bag, 4=70kg bag, 5=25kg bag, 6=10kg bag, 7=kgs 8=tonnes, 9=Other (Specify)

Variety codes: 1. *Unica,* 2. *Wanjiku* 3. *Lenana*, 4. *Chyulu* 5. *Nyota* 6. *Sherehekea* 7. Shangi 8. Asante 9. Others (Specify)

2.3: Distance to Input and Output Markets

Distance to the nearest agricultural office (walking time) ..... **DistAgric**

Distance to the seed source (walking time) ..... **DistSeed**

Distance to the potato output Market (walking time) ..... **DistOutput**

SECTION 3: CLIMATE INFORMATION

1.1 Did the household experience the following climate related shocks in the last 3 years in relation to potato production? 1= Yes 0= No

a) Rainfall/Floods .....

b) Temperature.....

c) Frost.....

d) Pests and diseases.....

If yes, for (a) how long was the rainfall in months?.....

1.2 Has soil fertility test been conducted in the reference period?..... 1=Yes 0=No **SoilFerTest**

If yes, what is your soil fertility level?..... **SoilFertLevel**

1.3 What Climate change adaptation practices have you adopted? Check where appropriate. **AdaptStrat**

1=Climate Resilient Varieties [ ] 2=Crop Rotation [ ] 3=Irrigation [ ] 4=Intercropping [

] 5=Organic Fertilizer [ ] 6= All [ ]

6=Others (Specify).....

1.4 Do you have any access to information on climate? ..... 1=Yes 0=No **InforAccess**

If yes, what are your sources?..... **InforSource**

1= Radio, 2= Government Extension Officers, 3= NGOs, 4=TV, 5= Social media, 6= Other farmers, 7= Others (Specify).....

1.5 Have you attended any training on climate resilient potato varieties? ..... 1= Yes 0=No **TrainAttend**

If yes, how many trainings have you attended?..... **TrainNo**

1.6 a) Did you receive any extension services in the last one year?..... 1= Yes 0= No **ExtnAcc**

b) If yes, how many times in the last one year? ..... **Nextn**

1.7 Is the household head a member of any formal farmers' group?..... 1= Yes 0=No **FarmerGrp**

If yes,

a) How many groups is he/she in?..... **GroupNo**

b) Does the household head have any leadership roles in the groups?..... **FarmerLeadership**

c) What benefits does he/she derive from membership in the groups?..... **GrpBenefits**

1=Information on credit 2=General advice on farming 3=Information on climate change 4=Help in credit access 5=Others (specify).....

1.8 Do you have access to credit?..... 1=Yes 0=No **CreditAccess**

a) If yes, received during the reference period ..... KES **CreditAmt**

b) Is the credit used in farming of climate resilient potato? **CreditFarm**.....

1=Yes 0=No

1.9 Question on Social influence

Social Influence	Please tick the box that represents your opinion in matters access to climate adaptation information and Climate Resilient Potato Varieties					
		1=Strongly Agree	2=Agree	3=Neutral	4=Disagree	5=Strongly Disagree
Those in my social circle influence my access	**Sinfl1**					

to climate change information						
Those in my social circle influence the choice of adaptation practices	**Sinfl2**					
Those in my social circle influence my access to quality seeds	**Sinfl3**					
Those in my social circle influence my use of climate resilient potato varieties	**Sinfl4**					

1.10 What Assets do you own? **AssestsOwned**

Asset	Units	Approx. Unit Value
1. Cow		
2. Goat		
3. Sheep		
4. Motorcycle		
5. Car		
6. Water Pump		
7. Farm Plough		
8. Land		
9. Irrigation equipment		
10. Television		
11. Radio		
12. Tractor		

13. Donkeys
14. Others (Specify))

SECTION 4: FARMERS' PREFERENCES

1.1 Are you aware of any of these Climate resilient potato varieties?..... **CRPVAware**

1= Yes 0=No

(1. *Unica,* 2. *Wanjiku* 3. *Lenana*, 4. *Chyulu* 5. *Nyota 6. Asante)*

1.2 If Yes, have you planted any of the above named varieties in the reference period? ..... 1= Yes 0=No **CRPVPlant**

If yes,

a) Which ones? .....

(1. *Unica,* 2. *Wanjiku* 3. *Lenana*, 4. *Chyulu* 5. *Nyota 6. Asante)*

b) Why do you use the above mentioned variety?..... **CRPVUseReason**

1= Resistance to pest and diseases 2= Tolerance to drought and heat stress 3= Early Maturity 4= High yield 5= Others (Specify).....

1.3 What constraints do you face in using Climate Resilient potato varieties? ..... **CRPVConstraints**

1= Lack of capital, 2=Lack of information, 3= Lack of access to water, 4= Lack of quality seeds, 5= Lack of access to associated inputs, 6= Others (Specify).....

1.4 What Benefits do you enjoy in using Climate Resilient potato varieties?..... **CRPVBenefits**

1= Increased Climate resilience, 2= Increased farm productivity, 3= Wider markets due to value addition, 4= Others (Specify).....

1.5 Do you have information on any of these attributes of climate resilient potato varieties? 1=Yes 0= No **CRPVInfor**

a) Resistance to pests and diseases.....
b) Tolerance to heat stress.....
c) Yield .....
d) Maturity period.....
e) Water requirements....
f) Resistant to drought....

1.6 If you were to buy for a new variety with attributes of your choice, how much would you pay for it? ..... **NewVarPrice**

1=2000-2500 2=2600-3500 3= above 3500

SECTION 5: CHOICE EXPERIMENT

The following choice cards are constructed based on the attributes and attribute levels of climate resilient potato varieties. Each choice card has two unlabeled options of the improved variety, and an opt-out option that will indicate when a farmer is not willing to uptake any of the improved varieties. A farmer can select only one option from each of the 3 choice sets. The aim of this experiment is to be able to determine the optimal option for the improved potato varieties. The choice situation will be repeated 4 times. At each repetition, the attributes of the potato varieties will be slightly different.

Attributes and Attribute Levels of Climate Resilient Potato Varieties

Attributes	Description	Levels
Resistant to Pests and Diseases	Whether the variety is resistant to pests and diseases or not	Resistant Not
Water Requirements	The amount of water the variety requires to reach maturation	High, Low

Yield	Yield in Tonnes per Hectare	20T/Ha, 40T/Ha
Input Price in KES (50kg bag)	Input price for every 50kg bag of potato seeds	2000, 2500, 3000
Maturation Period	How long it takes for the potato to be ready for harvest	Short (<3 months) Long (>3 months)

Profile 1

Choice set 1

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Not	Resistant	
Water Requirements	Low	High	
Yield	40T/Ha	20T/Ha	
Maturation Period	Long (> 3 months)	Short (<3 months)	
Input Price per 50kg bag	2500	2000	
Which option would you prefer?			

Choice set 2

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Not	Resistant	
Water Requirements	Low	High	
Yield	20T/Ha	40T/Ha	
Maturation Period	Short (<3months)	Long (>3months)	
Input Price per 50kg bag	3000	2500	
Which option would you prefer?			

Choice set 3

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Resistant	Not	

Water Requirements	Low	High	
Yield	20T/Ha	40T/Ha	
Maturation Period	Long (>3months)	Short (<3months)	
Input Price per 50kg bag	2000	2500	
Which option would you prefer?			

Profile 2

Choice set 1

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Not	Resistant	
Water Requirements	High	Low	
Yield	20T/Ha	40T/Ha	
Maturation Period	Long (>3months)	Short (<3months)	
Input Price per 50kg bag	3000	2500	
Which Climate resilient potatoes attributes option would you prefer?			

Choice Set 2

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Resistant	Not	
Water Requirements	High	Low	
Yield	40T/Ha	20T/Ha	
Maturation Period	Long (>3months)	Short (<3months)	
Input Price per 50kg bag	3000	2000	
Which option would you prefer?			

Choice Set 3

Climate resilient potatoes attributes	Option A	Option B	Neither A nor B
Resistant to Pests and Diseases	Resistant	Not	
Water Requirements	High	Low	
Yield	20T/Ha	40T/Ha	
Maturation Period	Long(>3months)	Short (<3months)	
Input Price per 50kg bag	2500	3000	
Which option would you prefer?			

Profile 3

Choice set 1

Climate resilient potatoes attributes	Option A	Option B	Neither A nor B
Resistant to Pests and Diseases	Resistant	Not	
Water Requirements	High	Low	
Yield	40T/Ha	20T/Ha	
Maturation Period	Short (<3months)	Long (>3months)	
Input Price	2000	2500	
Which option would you prefer?			

Choice set 2

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Not	Resistant	
Water Requirements	High	Low	
Yield	40T/Ha	20T/Ha	
Maturation Period	Long (>3months)	Short (<3months)	
Input Price	3000	2500	
Which Climate option would you prefer?			

Choice set 3

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Not	Resistant	
Water Requirements	High	Low	
Yield	20T/Ha	40T/Ha	
Maturation Period	Short (<3months)	Long (>3months)	
Input Price	2500	2000	
Which option would you prefer?			

Profile 4

Choice set 1

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Resistant	Not	
Water Requirements	Low	High	
Yield	40T/Ha	20T/Ha	
Maturation Period	Short (<3months)	Long (>3months)	
Input Price	3000	2000	
Which option would you prefer?			

Choice Set 2

Climate resilient potatoes attributes	**Option A**	**Option B**	**Neither A nor B**
Resistant to Pests and Diseases	Resistant	Not	
Water Requirements	High	Low	
Yield	20T/Ha	40T/Ha	
Maturation Period	Short (<3months)	Long (>3months)	
Input Price	3000	2000	
Which option would you prefer?			

Choice Set 3

Climate resilient potatoes attributes	Option A	Option B	Neither A nor B
Resistant to Pests and Diseases	Not	Resistant	
Water Requirements	High	Low	
Yield	40T/Ha	20T/Ha	
Maturation Period	Short (<3months)	Long(>3months)	
Input Price	2000	3000	
Which option would you prefer?			

Appendix II: Estimation of Marginal effects for ATE Joint Exposure and Adoption

Variable	Dy/dx	RSE	P-Value

HH Education	0.001	0.001	0.646
Total Land Owned	-0.001	0.001	0.646
Group Leadership	-0.003	0.005	0.561
HH Age	0.002	0.004	0.525
Train No	0.002	0.004	0.586
Soil Fertility Level	-0.001	0.003	0.650
Extension No	0.001	0.001	0.662
Group No	0.003	0.005	0.478
HHAge2	-0.000	0.000	0.521
Credit Farm	0.002	0.001	0.048**
HH Gender	-0.014	0.016	0.386
HH Size	-0.004	0.006	0.429
Distance to Agric	0.000	0.001	0.732
Climate Information	0.002	0.004	0.638
Decision Maker	0.008	0.013	0.514
Total Land Potatoes	-0.000	0.002	0.887
Lack of seeds	-0.004	0.007	0.571
Other Farmers	0.011	0.013	0.371
Kibirichia	-0.018	0.014	0.202
Kiirua/Naari	-0.035	0.020	0.081*
Abogeta West	0.001	0.001	0.653
Abothuguchi West	-0.003	0.006	0.583

**, * =level of significance at 5% and 10% respectively.

Appendix III: Potential Sources of Preference Heterogeneity

Variable	Coefficient	Standard error	*p*-Value
Resistant	5.240	0.935	0.000***
Low water requirement	2.858	0.728	0.000***

High Yield (30T/Ha)	0.054	0.643	0.933
Short Maturation Period(<3 months)	2.336	0.715	0.001***
Seed Price (per kg)	-0.024	0.013	0.057*
Interactions			
gender_HY	0.513	0.297	0.085*
gender_Res	-0.359	0.390	0.358
gender_Lwr	-0.193	0.333	0.562
gender_Short	-0.336	0.316	0.287
Age_HY	0.008	0.011	0.481
Age_Res	0.000	0.013	0.979
Age_Lwr	-0.020	0.012	0.081*
Age_Short	-0.015	0.011	0.189
Educ_HY	0.222	0.092	0.015**
Educ_Res	-0.221	0.118	0.061*
Educ_Lwr	-0.093	0.094	0.319
Educ_Short	-0.007	0.090	0.939
Derived standard deviations of parameter distributions			
Resistant	2.788	0.327	0.000***
Low water requirement	1.333	0.275	0.000***
High Yield	0.248	0.174	0.155
Short Maturation Period(<3 months)	2.037	0.695	0.003***
Goodness of fit			
Log Likelihood	-425.380		
LR Chi2 (4)	87.40***		
n (respondents)	384		
n (choices)	3456		

***, **, * =level of significance at 1%, 5% and 10% respectively.

Appendix IV: Potato Varieties in Meru County with their Characteristics

Potato Variety/ Characteristics	Maturity	Yield	Disease Resistance/Tolerance
Shangi	<3 months	30-40T/Ha	Moderately susceptible to Late blight.

Asante	3-4 months	35-45T/Ha	Moderately tolerant to Late blight but can suffer late season infections and tolerant to PLRV.
Sherekea	3-4 months	>40T/Ha	Sherekea is resistant to Late blight and Potato Virus X.
Kenya Mpya	3-4 months	>40T/Ha	Resistant to Late blight and PLRV.
Kenya Karibu	3-4 months	35-45T/Ha	Tolerant to Late blight and most of the potato viruses.
Kerr's Pink	<3 months	<30T/Ha	Susceptible to Late blight.
Tigoni	3-4 months	35-45T/Ha	Moderately tolerant to Late blight and extremely resistant to potato Virus X.
Purple gold	3-4 months	<30T/Ha	Moderately resistant to Late blight, PLRV and resistant to Potato Virus X (PVX).
Dutch Robijn	3-4 months	<30T/Ha	Highly susceptible to Late blight.

Source: NPCK Catalogue (2019)

Appendix V: NACOSTI Research Permit

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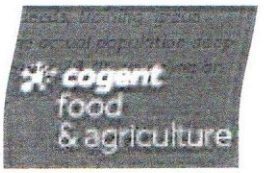
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Appendix VI: Publication Abstract Page

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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Adoption of climate-resilient potato varieties under partial population exposure and its determinants: Case of smallholder farmers in Meru County, Kenya

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Additional information is available at the end of the article

Abstract: Production of Potato (Solanum tuberosum. L) has been declining over the years in Sub-Saharan Africa due to climate change resulting into low food supply and low income among smallholder farmers. Despite Climate-Resilient Potato Varieties (CRPVs) having the potential of increasing farmers' resilience to climate change, previous studies show that uptake of these varieties is still significantly low. More so, standard techniques such as Tobit and Probit models yield biased adoption rate estimates despite existence of vast literature on technology adoption. This study sought to determine true population adoption rates under partial exposure and their determinants using the modern Average Treatment Effect (ATE) framework. Multistage sampling technique was used to sample 384 farmers from Meru County. Focus group discussions and structured questionnaires through household survey were used to collect primary data. Results revealed that the main factors affecting adoption were access to information, quality seeds, training, group membership and variations in agro-ecological zones. The actual population adoption rate was 6.3% whereas the potential adoption rate was 30.7% revealing an



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PUBLIC INTEREST STATEMENT

Potato (Solanum tuberosum. L) is an important food crop doubling up as a major source of income and a staple food. The adverse effects of climate change and variability have resulted into a decline in production in Sub-Saharan Africa. This has prompted development and dissemination of Climate Resilient Potato Varieties (CRPVs) by various research institutions characterized by

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