

**EVALUATING FARMERS' PREFERENCES FOR SWEET POTATO
VARIETY TRAITS IN WESTERN KENYA**

BY

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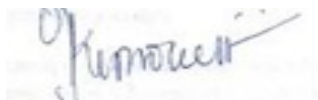
JULY, 2024

DECLARATION

Declaration by the candidate

I, William Bett Kiprotich, declare that this doctoral research Thesis that I submitted, was entirely my original work and has not been submitted for the award of any degree in any other university.

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DEDICATION

I would like to dedicate this thesis to my late Father George Kibet Chumoh. This is a gift for his undying love for education and researched knowledge. I cannot forget the wonderful and inspirational encouragement by the late rector of St. Joseph's Seminary Molo-Kenya (where I schooled), Brother Austin Dolan. I dedicate this to him and to all alumni of the seminary. Brother Dolan was a pillar to all of us when he lived and even now when he has long departed from us. I dedicate this work to my family including Kipchumba George William, Kipsuge Alexander William and Cherop Tapranje William, my sons and daughter respectively, for their tireless prayers and support. God Bless you abundantly.

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ABSTRACT

Despite the high investment put in place so far in developing high-yielding sweet potato varieties, their uptake by farmers in the country has been low. While both farm and farmer characteristics have influenced farmers' choice decisions for different crop varieties, the role of varietal traits has only received limited attention in the empirical literature. This study investigated farmers' preferences towards sweet potato variety traits in western Kenya (i.e., Busia, Bungoma Kakamega, and Vihiga Counties). More specifically, the study sought to assess farmers' willingness to pay (WTP) for better quality sweet potato varietal traits; evaluate farmers' preference certainty and consistency in their choice decisions for sweet potato varietal traits; explore the role of preference variation in the choices made by farmers towards sweet potato variety traits and; finally, ascertain attribute non-attendance of the farmers in their choice decisions for sweet potato variety traits in the study area. The discrete choice experiment (DCE) approach was used to investigate these objectives. The empirical analysis was based on primary data collection from 400 randomly selected farmers in western Kenya (Busia, Bungoma, Kakamega, and Vihiga Counties). Functional estimations followed several models, namely: the multinomial logit (MNL), mixed multinomial logit (MXL), scaled multinomial logit (S-MNL), generalized multinomial logit (G-MNL), generalized mixed logit (G-MXL) and the equality constrained latent class (ECLC) models, which were estimated using Nlogit V software. Farmers, in the first objective, were willing to pay the highest amount for sweetness of the flesh attribute (KES 334.70, $P < 0.01$) followed by tolerance attribute (KES 187.09, $P < 0.05$), yield level attribute (KES 137.58, $P < 0.05$), color of the flesh attribute (KES 100.85, $P < 0.1$) and maturity period attribute (KES 100.28, $P < 0.05$) respectively. As for the second objective, results showed that farmers were considerably specific about their preferences, with an average certainty score of 7.0 on a scale of 0-10. They were also consistent in their choice behavior since they chose the same option on the second occasion as on the first occasion in 65.9% of the cases. Results of the third objective show significant preference variation in farmers' affinity towards Sweet Potato traits such as yield level, sweetness of the flesh, color of the flesh, maturity period, and price change. Similarly, the final fourth objective show survey results that ranked flesh color as the most ignored attribute from both stated (61.8%) and inferred (59.2%) attribute non-attendance. In conclusion, due to solid statistical evidence, all four null hypotheses of the study were rejected. The Kenya Agriculture and Livestock Research Organization (KALRO) should consider the production of improved seed varieties (sweet potato breeding programs in Western Kenya) since sweet potato farmers were willing to pay positive amount of money to get sweet potatoes with high-quality attributes. At the National and County level, the Ministry of Agriculture (MoA) should provide regular agricultural extension services to sweet potato farmers in Western Kenya. Respondents in the survey did not pay attention to all attributes when selecting sweet potato varietal traits, implying a need for researchers to take note of this phenomenon in future undertakings involving farmers. Sweet potato breeding research institutions, such as KALRO should use the findings of this study to support development of high-quality sweet potato varieties in Kenya by employing discrete choice approach; ostensibly choice certainty, choice consistency, preference variation, and attribute non-attendance of individual farmers.

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ACRONYMS AND ABBREVIATIONS

CIDP	County Integrated Development Plan
DCE	Discrete Choice Experiment
ECLCM	Equality constrained latent class model
FAOSTAT	Food Agricultural Organization Statistics
G-MNL	Generalized multinomial logit
G-MXL	Generalized mixed logit
GOK	Government of Kenya
IV	Improved varieties
LV	Local varieties
MNL	Multinomial logit
MXL	Mixed logit
RUT	Random Utility Theory
S-MNL	Scaled multinomial logit
SP	Sweet potato
WTA	Willingness to Accept
WTP	Willingness to Pay

CHAPTER ONE

INTRODUCTION

1.0 Overview

The introduction of this chapter included background data on sweet potato. The problem description, study objectives, hypotheses, importance, and the study's scope were listed after this, followed by a statement about the discrete choice experiments utilized in the study. Finally, the chapter provided the thesis' organization, laying the groundwork for the second chapter.

1.1 Background of the Study

1.1.1 Sweet potato, varieties and traits

Sweet potato (*Ipomoea batatas* L. Lam) is a member of the morning glory family (e.g., Kays, 2004). It is one of the most significant crops for food, feed, and vegetables in majority of poor countries, which account for around 97 percent of global production (e.g., Kays, 2004; Westby *et al.*, 2003). Developing nations generate around 131 million tonnes per year on about 9 million hectares and obtain yields of approximately 13.7 tonnes per hectare on average (e.g., FAOSTAT, 2009: 2015). It is also the fifth economically significant crop after rice, wheat, maize, and cassava, the sixth in dry matter output, the seventh in digestible energy production, and the ninth in protein production among emerging countries (e.g., Thottappilly and Loebenstein, 2009; Kidmose *et al.*, 2007).

Sweet potato is a source of Energy, proteins, minerals, and vitamins (e.g., Stathers *et al.*, 2005; Kidmose *et al.*, 2007). Its store roots are composed of 25-30% carbohydrates and 2.5-7.5% protein. In addition, it contains 200-300 mg per 100g of potassium (K), 0.8 mg per 100g of iron (Fe), 11 mg per 100g of calcium, (Ca), and

20-30 mg per 100g of vitamin C of its dry matter (e.g., Stathers *et al.*, 2005; alifikan *et al.*, 2007), as well as copper, zinc, manganese, vitamin B2, B6 and E, and provitamin A, particularly (e.g. Kidmose *et al.*, 2007). All of its plant components and culms are utilized as livestock feed (e.g. Clark, 1988; Duvernaya, *et al.*, 2013). In addition to being a cover crop that decreases soil erosion, it increases soil fertility through nitrogen fixation and humus production (e.g., Woolfe, 1992). Additionally, the fresh storage roots are sold on the market to generate cash (e.g., Githunguri *et al.*, 2007).

Approximately 4.7 million hectares are devoted to the cultivation of sweet potatoes in China, which accounts for 52 percent of the global harvest (e.g., FAOSTAT, 2009, 2015; Stathers *et al.*, 2005). Africa is the second greatest sweet potato producer, accounting for 10.6 percent of total production. It is second to Asia, which accounts for 86.5% of global production. In sub-Saharan Africa (SSA), where around 9.9 million tonnes of storage roots are produced on an estimated 2.1 million hectares, sweet potato is the most extensively cultivated root crop (e.g., FAOSTAT, 2009: 2015; Kays, 2004).

The plant can adapt to a variety of agro-ecological settings and thrives in low-input agriculture and at altitudes between 800 and 2200 meters above sea level (e.g., Gichuki *et al.*, 2006; Nungo *et al.*, 2007). East Africa, specifically the Great Lakes region, accounts for the majority of Africa's output (e.g., Odondo, 2013; Gichuki *et al.*, 2006). Its existence and adaption to tropical regions, where per capita incomes and nutritional statuses are typically low, make it a crucial crop for agricultural output and domestic consumption (e.g. Kidmose *et al.*, 2007; Westby *et al.*, 2007). In fact, sweet potato has become an increasingly essential crop for food security and famine

relief in recent years, particularly during crop failure seasons (e.g. Aywa *et al.*, 2013; Kibwage *et al.*, 2009; Opiyo, 2011).

According to studies, farmers cultivate various sweet potato cultivars based on their preferences for varietal features (e.g. Makini *et al.*, 2018; Momanyi *et al.*, 2016). A preference simply means a greater liking for one alternative over another or others. In this study, farmers were perceived to derive more utility from improved sweet potato attributes than the local vines given their superior traits. Varieties are distinguished based on morphological, botanical, and agronomic characteristics, such as differences in the vines, leaves, flowers, and storage root characteristics (e.g. Callie, 2008; Ekanayake, 1990; Makini *et al.*, 2018). Typically, sweet potatoes are herbaceous perennial plants with branching and creeping vines that grow alternate heart-shaped leaves and medium-sized, multi-coloured flowers. Generally, storage roots are long and tapering, with a smooth, white, brown, purple, or red skin. Some species' flesh colours range from white, yellow, orange, purple, and even cream/beige. Regarding growth, sweet potatoes may be upright, semi-erect, or spreading, with quickly developing horizontal vine systems. The most widely grown and consumed sweet potato types are yellow (YFSP), white (WFSP), orange (OFSP), and purple fleshed (PFSP). Yellow, orange, and white fleshed variants are quite popular among farmers, but the purple fleshed form is also gaining favour due to the anti-oxidant and cancerpreventative properties of Anthocyanins compounds (e.g. Callie, 2008; Ekanayake, 1990; Huaman, 1991; Odendo and Ndolo, 2002).

Sweet potato has been planted in Kenya since the late 19th century and is the second most important and commonly consumed food security crop after maize (e.g., Kibwage *et al.*, 2009; Momanyi *et al.*, 2016; O'Brien, 1972). It is cultivated between sea level and 2200 meters above sea level, with around 80% of the area being either

arid or semi-arid (e.g. Gichuki *et al.*, 2006; Kaguongo *et al.*, 2010). Although it is farmed for subsistence by smallholder farmers, its attractiveness as a source of revenue is growing (e.g. Kibwage *et al.*, 2009; Odendo and Ndolo, 2002; Opiyo, 2011). Its ability to produce excellent yields despite unfavourable climatic and soil conditions as well as with minimal or no external inputs has made it popular among numerous smallholder farmers in Kenya (e.g. Kibwage *et al.*, 2009; Nungo *et al.*, 2007; Odendo and Ndolo, 2002; Opiyo, 2011). In addition, its adaptability in mixed farming systems and ability to mature rapidly, hence providing food security for households, has made it an essential method of subsistence for small-scale farmers (e.g. Momanyi *et al.*, 2016; Nungo *et al.*, 2007; Odendo and Ndolo, 2002; Westby *et al.*, 2002).

In terms of food security, the sweet potato plays a significant role in Kenya since it is drought-resistant and a relatively short-term crop with a flexible harvest schedule, allowing for a great deal of flexibility in food security strategies (e.g. Momanyi *et al.*, 2010). Additionally, crop rotation increases the yield of maize compared to continuous maize production (e.g. Westby *et al.*, 2002). In addition, research demonstrates that rotating sweet potatoes and maize increases farmers' incomes through increased maize yields and sweet potato income (e.g. Odendo and Ndolo, 2002). It may be harvested and kept in pieces, making it an ideal crop for food security (e.g. Ekanayake, 1990; Makini *et al.*, 2018; Stathers *et al.*, 2005).

The storage roots are boiled and consumed, or chopped, dried, and ground into flour and used to produce snacks and infant weaning foods (e.g. Kidmose *et al.*, 2007). It is also dried and ground into flour, which is used to make porridge, or combined with wheat flour and baked to make bread. In addition to pies, puddings, biscuits, cakes, chips, crisps, mandazis, and chapatis, the flour is used to manufacture snacks and

desserts such as chips, crisps, mandazis, and chapatis (e.g. Kidmose *et al.*, 2007; Momanyi *et al.*, 2016). Additionally, fresh storage roots are sold in open marketplaces for profit and/or preserved for export markets. Additionally, sweet potato roots are utilized to synthesize starch and vines that are used as livestock feed (e.g. Claessens *et al.*, 2008). Consumption of yellow and orange flesh Sweet Potatoes which are rich in pro-vitamin A also aids in preventing vitamin A insufficiency (e.g. Kidmose *et al.*, 2007; Ishiguro *et al.*, 2007; Stathers *et al.*, 2005). Error! Reference source not found..1 was adopted and modified from Mwololo *et al.* (2012) which outlines several of the most prominent sweet potato cultivars grown in Kenya. The table describes the name, variety, flesh and skin colours for improved and local sweet potato varieties mainly grown in Western Kenya.

Table 1.1: List of sweet potato varieties grown in Kenya

Name	Variety	Flesh Colour	Skin Colour
Jonathan	Improved	Light cream	Cream white
Japanese	Improved	Orange	Cream white
Zapallo	Improved	Orange	Cream white
Stokes	improved	Purple	Light purple
Kemb10	Improved	Cream	Cream white
Jewel	Improved	Orange	Orange
Mugande mom	Local	White	Red
Marooko	Local	Light cream	Brown
Ex-shimba	Local	White	Red
Jubilee	Local	Orange	Orange
Okinawa	Improved	Purple	Cream white
Ejumula	Local	Orange	Orange
SPK004	Improved	Orange	Red
440015	Improved	Orange	Red
Charleston	Local	Purple	Cream white
K135	Improved	Orange	Cream
Salyboro	Local	Orange	Cream white
Muibai	Local	White	Red
Bungoma	Local	Yellow	Red
Sponge	Local	Orange	Red

Source; Mwololo et al. (2012).

Annually, around 592,000 hectares of land are devoted to the production of sweet potatoes, in Kenya, which represents only 4% of the area in East Africa where sweet potatoes are grown (e.g., Momanyi *et al.*, 2016). In economic terms, attributes denote quality, character, or characteristic ascribed to someone or something. In this study, attributes referred to the quality of seed/vine varieties which make farmers to have heterogeneous choices when selecting sweet potato variety to be planted during a given production season. In relation to sweet potato, such a package of traits may include both production traits such as disease and pest resistance, early maturity, and

adaptability to harsh environments (e.g. Manu–Aduening *et al.*, 2005; Opiyo, 2011) and consumption traits such as flavor, color, and seed quality (e.g. Manu–Aduening *et al.*, 2005; Opiyo, 2011). (e.g. Wale *et al.*, 2005).

Smale *et al.* (2001) also contend that farmers select crop types based on a set of features that best responds to production restrictions, ensures consumer preferences, and fits certain market requirements. Some researchers (e.g. Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Adesina and Seidi, 1995) highlight the cropspecific attributes hypothesis, which suggests that farmers' choice decisions of a particular crop variety are not solely driven by profit maximization, but rather by complex decision-making processes that are influenced by crop, agronomic, socioeconomic, and psychological variables (e.g. Willock *et al.*, 1999). In addition, farmers cultivate crops that meet their needs, and once there is congruence between those needs and variety characteristics, varietal preference and land allocation decisions result (e.g., Wale and Mburu, 2006).

All of this research, however, may be insufficient (e.g., Sanchez-Toledano *et al.*, 2017; Gamboa *et al.*, 2018; Teeken *et al.*, 2018; Sanou *et al.*, 2019) for informing policy decisions regarding crop variety improvements. Individual preferences for product characteristics may be unstable due to their tendency to alter with crop, location, and time period under consideration (e.g., Sanou *et al.*, 2019; Tsusaka *et al.*, 2018). In addition, the study followed Gamboa *et al.* (2018), Mansaray *et al.* (2018), Sanchez-Toledano *et al.* (2017), and Skreli *et al.* (2017) by employing the discrete choice experiment approach to achieve its aims (2017). The method was selected because of its robustness in permitting respondents to make trade-offs between different varietal features of the investigated crop (e.g., Sanchez-Toledano *et al.*,

2017). Choice experiments are rooted in Choice decisions which entail choosing an action given one's preferences, the actions one could take, and expectations about the outcomes of those actions. Choosing can be resulting from ways such as supporting one outcome and rejecting others, expressed through active responses such as choosing to use certain products or services through purchases, or through passive responses such as supporting particular views over an issue of interest.

Many societies in the developing countries around the world depend on agricultural innovation processes for their daily livelihoods, particularly food supply. Crop genetic resources, embodied in the diversity of seeds/vines planted by farmers, are important to secure food production and supply (e.g., Mendis, *et al*, 2013). Different stakeholders such as farmers and breeders as well as gene-bank managers and crop scientists draw on diverse crop genetic resources to innovate, support and benefit society as a whole (e.g., Scarpa, *et al.*, 2003).

The basic component of crop genetic starts with seed/vines which is a vital input in crop production and is also an important source of all food and agricultural production. Vines and seeds are genetic resources that carry plant genetic diversity that is vital for breeding and crop improvement. The genetic diversity is also critical for enhancing resilience of agricultural production systems, giving them the capacity to cope with adverse conditions such as climate change and climate variability (Louwaars & de Boef, 2012). Seeds/vines are valuable assets not only for farmers but for the global society as a whole due to interdependence on genetic resources. Seed/vine systems, as determined by the users, – the inter-related set of breeding, management, replacement and distribution of seeds/vines (Thiele, 1999) – serve as a means to attain food and nutrition security, income generation and the preservation of

genetic heritage. Therefore, efforts towards a world without hunger must inevitably target seed/vine systems.

Since time immemorial, humans have been exploiting the wide genetic diversity from the earliest domestication of crops for food, fibre and fodder. Natural selection and human management of wild plants allowed the domestication and cultivation of a wide range of crops and varieties with higher yields, making it possible for an increasing human population to live on smaller areas of land. The sowing, harvesting and sharing of propagation material was and remains crucial to human development as well increasing crop productivity. Additionally, traditional on-farm seed/vine saving has been responsible for the establishment and conservation of diverse gene pools of plant genetic materials (GTZ, 2015).

In the 1970 and 80s, public seed/vine sector programs targeted the development of formal propagation material systems and hence the dissemination of certified seed/vine of improved varieties, including hybrids, assuming the informal propagation material system would gradually disappear. In the 1990s, in many countries, public sector involvement in the formal propagation material system was withdrawn and privatization and liberalization promoted. However, in most developing countries, the informal systems have remained dominant (Louwaars & de Boef, 2012). Farming and cropping systems vary according to agro-ecologies and in their objectives including livelihood, food supply, and/or income generation. The structure of the seed/vine systems, therefore, varies accordingly. The majority of small scale and subsistence farmers largely rely on informal seed/vine systems for their needs as they operate in areas where complex environmental stresses challenge agricultural production, a scenario where the propagation systems adequately respond to their food security, household as well as market needs. In developing countries, it

is estimated that 80% of all propagation material planted are provided through informal seed/vine systems (Duttfield, 2007). On the other hand, formal systems are predominantly embedded into large scale, high input agricultural production schemes with advanced mechanization in which the principles of the market are the determinants (Louwaars & de Boef, 2012).

1.1.2 Formal propagation systems

The formal propagation systems are normally characterized by off-farm (*ex-situ*) conservation strategies namely gene banks supported by research and development in form of breeding and crop improvement programs. Consequently, the system is very knowledge and technology driven. It is also intensive and has a high degree of specialization (GTZ, 2015). Target oriented breeding is placing emphasis on **D**istinct, **U**niform and **S**table varieties (DUS characteristics). Hybrids, which take advantage of heterosis, are a common feature in formal systems. They are also characterized by certification schemes that reduce the risk of diseases transmission, guaranteeing a reliable germination, seed purity and uniformity. There are various international regulatory frameworks that protect the intellectual property rights (IPR) of breeders in order to stimulate innovation and recover investments costs. The formal propagation systems focus on main commodities and their high yielding varieties. This facilitates production in large schemes and helps to meet demand with regard to product prices and quality. Commercial seed/vine multiplication allows for the production of a large quantity of propagates, supported by distribution and marketing capabilities and actors in formal seed systems can operate all the way from local to global levels (GTZ, 2015).

Farmers relying on formal systems largely depend on a highly centralized and oligopolised propagation material market. In these systems, re-sowing of propagates is economically not feasible due to high potential of disease transmission, loss of hybrid vigour and sometimes strong IPR restrictions (GTZ, 2015). In addition, the separation of production, multiplication and the use of propagates lead to a loss of traditional knowledge and skills of farmers. As the activities of the propagate industry concentrate on a low number of species and varieties, genetic diversity is constantly reduced and even threatened depending on the scale of the introductions. Formal seed systems aligned farming systems are characterized by homogenous cropping and as a result, ecosystem services are severely reduced and the resilience of agro-ecological systems put at risk (GTZ, 2015). Negative externalities such as adverse effects due to the use and production of fertilizers and pesticides required by high performance propagates are not included in the cost of production. Formal propagate systems are normally embedded in formal institutions such as existing legislations and policy schemes supporting commercial systems and input reliant agriculture.

1.1.3 Informal propagate systems

In the informal seed/vine systems, farmers have little or no access to formal seed systems and institutions and mostly operate outside the legal provisions, policies and laws governing seeds/vines. Moreover, farmers lack financial resources for buying seeds and inputs and as a result, about 80% of farmers in the developing countries depend on the harvest season to select propagation material for the next growing season. In these systems, farmers have few opportunities to benefit from decades of crop improvement that have taken place around the world (Walpole *et al.*, 2013). The propagate material that is used in informal systems is produced, stored and re-used on farms. Planting material management has a strong local and decentralized character

such as basic breeding, artisanal multiplication, and selection. Normally, planting material storage takes place on-farm or at community level on a small-scale, with women undertaking the bulk of the tasks. Storage facilities are often poorly developed and planting material production techniques are rather simple, with the transfer of knowledge being based on informal channels.

The seed used in informal seed systems is characterized by a wide diversity at both variety and crop levels. Formal certification and quality control mechanisms are largely absent in these systems. Crop improvement is mostly done through recurrent selection and by integration of new varieties into local gene pools via crossing or physical mixing and is based on farmers' preferences. The main drivers for farmers' crop conservation strategies in informal systems are natural conditions, a desire to maintain diversity and poor access to formal system channels. Farmers usually draw from a relatively high number of landraces which are better adapted locally and are more resilient, but usually low yielding (IAASTD, 2009). The exchange and distribution of material are dependent on geographical boundaries, cultural systems and social networks. In case of planting material shortages due to economic, social or natural shocks, small and remote located communities are vulnerable with regard to seed/vine supply. For the greater majority of most farmers in developing countries, informal systems are a source of economic independence and resilience in the face of threats, such as pests, diseases or climate change (Schutter, 2009).

1.1.4 Development of Planting Material Industry in Kenya

The seed/vine industry development in Kenya started in the early 20th century, when the government of Kenya realized the importance of high quality seed in agricultural production. This was supported by research on food, industrial and export crops,

which supplied planting material, for the farming community. Kenya's seed industry comprises of the formal and informal seed sectors with the latter accounting for approximately 80% of the seed planted (Wakhungu *et al.* 2004). The formal sector started with the establishment of Kenya Seed Company (KSC) in 1956 in Kitale to produce pasture seed to serve the then dairy farmers. Later, the company diversified to other crops. KSC continued to play a predominant role until the industry was liberalized in the mid-1980s to 1996. Several companies entered the formal sector and by 2005, there were 50 registered seed companies largely dealing in seeds of maize, wheat, barley, oats, triticale and sorghum; rapeseed, sunflower; pulses; pastures; horticultural crops and Irish potatoes.

The Seed/vine industry is governed by the Seeds and Plant Varieties Act (Cap 327) of 1972, which became operational in 1975. Regulations to guide seed operations were made in 1977 and revised in 1991 to incorporate plant variety protection (plant breeder's rights) regulations. The liberalization of the industry in the mid 1990's resulted in the entry of new players in the seed market, resulting in the over 100 seed companies having been officially registered to date. These companies are now dealing with crops neglected previously, due to their low profitability. These include, Sweet Potato, horticultural crops, rice, cotton, pastures seeds, sorghum, millet, pigeon peas, cow peas, groundnuts and chickpea among others (Wakhungu *et al.* 2004).

Planting material production and marketing in Kenya was liberalized through the Ministry of Agriculture's Seed and Plant Varieties Act Cap 326, which allowed private seed companies to cover all stages of the seed/vine value chain (Wakhungu *et al.* 2004). The Act regulates testing, certification and procedures relating to the introduction of improved and new varieties bred locally or imported. All crop

varieties fall under Schedule II of the Act requiring mandatory inspection before official registration and varietal release. Seed laws are harmonized with the relevant international conventions. Imported planting material requires phytosanitary certificates as well as International Seed Testing Association (ISTA) certificates. Local seed/vine is considered to be over-regulated as production and distribution is subject to stringent regulations. This is coupled with long varietal release processes which make the seed/vine expensive and contributes to their shortages (Wakhungu *et al.* 2004).

Propagation material traded and used in Kenya is made up of local production and imported planting material. As part of the trade business there are exports of seed to Kenya's neighbours in the region. The movement of seed within and between these countries is normally restricted by regulations governing planting material certification and standards, phytosanitary measures, variety testing and release procedures, plant variety protection and import and export requirements.

Kenya Agricultural and Livestock Research Organization (KALRO) employs 61% of all the trained crop breeders followed by national universities (23%), private companies (9.6%) and international organizations (6%) (Wakhungu *et al.* 2004). The majority (90%) are trained in conventional breeding methods and crop improvement programs. KALRO, the International Agricultural Research Institutes (IARCs), the Coffee and Tea Research Foundations are the most active organizations producing improved varieties. KALRO's practice of non-exclusive rights over the distribution of certain varieties has created some conflicts and led to a shortage of breeder seed for varieties of orphan crops and legumes which are pivotal food security crops.

The liberalization of the seed industry has seen a rapid expansion of seed companies.

To date, there are 100 private seed companies in Kenya. Five are public, including the KALRO seed units and have supported a strong public research capacity with competing private sector entities for the genetic material. The Kenya Seed Company controls 75% of market share of maize seed and also has a substantial share of seeds of other crops. Foundation seed bulking and commercial seed multiplication are constrained by limited stocks of basic seed (Wakhungu *et al.* 2004). The procurement of seed produced by the public seed system involves lengthy processes that delay the availability of seed to farmers at the appropriate planting times.

There is heavy government involvement in enforcing local and international planting material regulations in seed testing, registration, release, certification and marketing through the Kenyan government regulatory body, KEPHIS (Wakhungu *et al.* 2004). The current regulatory and legal framework of the national formal seed and vine system limits the development of the informal seed/vine system. The existing seeds and plant variety legislation are not supportive of the informal seed sector relative to on-farm seed production, exchange, maintenance, development and registration of landraces. The stringent legal criteria for distinctiveness, uniformity and stability (DUS) as well as other quality aspects are difficult to implement in the informal system. The testing, registration, release and certification systems have been designed to handle new varieties from commercial or conventional breeders (Wakhungu *et al.*, 2004). One school of thought postulates that state monopoly in seed inspection and certification has sometimes hampered production of certified planting material and seed growers have lost their crops due to late inspection by an overstretched, under-resourced seed inspection service (RohrBach and Howard, 2003). The stifling regulatory system also raises barriers to the dissemination of modern/improved

varieties due to long periods of testing required before a variety is officially approved and released for commercial purposes.

The Kenya Health Inspectorate Services (KEPHIS) which was established by the 1966 State Corporate Act (Cap 446) is the National Regulatory Authority responsible for variety evaluation, release, registration, plant protection and the implementation and development of seed standards. KEPHIS conducts propagation material certification services but is overwhelmed by the demand for material inspection and certification services and sometimes leads to rejection of crop under trials. The fees charged are considerably high and contribute to high costs of propagates. Donors,

NGOs and CBOs play a crucial role in filling the unmet demand for planting material. These organizations promote the collection, multiplication and distribution of seed/vine using various strategies, including working with farmer groups that they train and provide with seed/vine capital to boost their seed business. They also import planting material and disseminate it to farmers using direct distribution of relief seed, the voucher system and seed/vine fairs.

It is a regulatory requirement that all planting material agents and stockists be registered by KEPHIS to promote traceability of seed movement and enforce quality standards (inspections etc). KEPHIS registers them as outlets and distributors of seed/vine at a charge of US\$1,600 per agent and US\$600 per stockist. This is factored into the wholesale and retail price of seed/vine and tends to increase the cost of planting material. Most of the stockists/agents benefit from training on product knowledge, technical aspects of agronomic practice, financial literacy and business skills. KEPHIS also trains some to serve as effective disseminators of information on plants. They have limited access to micro-finance due to limited availability and high cost of

capital. Farmers play a very significant, if not the most significant role in the seed industry. They obtain seed/vine through both formal and informal channels; with the latter source constituting the largest source for smallholder farmers. There is, however, a growing concern about potential loss of crop biodiversity associated with social and economic change. The common challenge now is to develop strategies that enable crop genetic resources to be managed in ways that satisfy the needs of farmers and consumers at present and in the future. Crop biodiversity is a quasi-public good (Bezabih, 2008) and its conservation also benefits society as a whole, including future generations. The provision of crop biodiversity is largely on-farm, in particular in low-input agricultural systems in developing countries, and therefore the level of conservation is highly dependent on the preferences and decisions of farmers.

In most of the developing countries worldwide, agricultural sector is the backbone of their economies in terms of GDP contribution, employment, raw materials and source of food; especially in Sub Saharan Africa. In this continent, farming is carried out by both small-scale and large-scale farmers whose rate of uptake of improved agricultural technologies remains very low. Surprisingly, the low adoption rate of improved planting material varieties has led to some studies that have identified several factors that influence the adoption or non-adoption of improved seed varieties (Manu-Aduening, 2005; Dankyi and Agyekum, 2007; Owusu and Donkor, 2012; Acheampong *et al.*, 2012). Factors normally enumerated to influence adoption are farmers' socio-demographic characteristics (e.g., household heads' gender, age, education, household size) and institutional factors (e.g., access to extension services, credit and infrastructure). The farmers' preferences for improved seed/vine varieties traits are hardly looked into. This study fills this gap by analyzing farmers' seed/vine varieties attributes preferences. Farmers' acceptance of technologies and their ability

to use them properly depend to a large extent on their preferences for the attributes of that technology. Farmers adopt technologies for different reasons, one of which is the overall satisfaction of their household consumption needs. The successful adoption of technologies by farmers is based on personal assessment of the characteristics of the technology (Ouma *et al.*, 2007).

To enhance the likelihood of adoption of improved seed varieties, it is necessary to identify and focus contemporary crop research on traits that significantly contribute to utility while de-emphasizing insignificant plant attributes (F *et al.*, 2008). This study provided important information for seed/vine varieties researchers such as KALRO so as to provide improved seed varieties which take into account the farmers' preferences for different seed/vine varieties attributes, with an extensive study of choice preference for Sweet Potato vine preference in western Kenya. It was aimed at improving understanding of farmers' preferences for variety traits and to enable a reasonable adoption and use of improved crop varieties for increasing yields in Kenya.

The study was also important in the following way: it provided exceptional empirical case study about the relationship between farmers' demand for crop varieties traits and farmers' related household characteristics. Although some studies have explored the determinants of adoption of improved crop varieties by farmers in Kenya, (Okuthe, *et al* 2000; Wekesa *at al.*, 2003; Salasya *et al.*, 2007; Katengeza *et al.*, 2012 and Abdulai and Huffman 2014) and other developing countries (Conley and Udry, 2002; Mather *et al.*, 2003; Faturoti *et al.*, 2006; Badal *et al.*, 2007), the preferences of farmers for crop variety traits have not received much attention. Using choice experimental technique, this study explored the Kenyans farmers' preferences for

improved seed varieties traits and the values (willingness to pay) that farmers place on different traits. Most studies in Africa that employed choice experiments have focused on livestock (Scarpa *et al.*, 2003a; Ouma *et al.*, 2007; Ruto *et al.*, 2008; Zander and Drucker, 2008; Girma *et al.*, 2009) with few studies on crop varieties traits in East Africa (Asrat *et al.*, 2009; Wale *et al.*, 2005). The application of choice experiment to elicit farmers' preferences in Kenya is not well studied and therefore not fully known. Therefore, the study contributes to literature on farmers' crop varieties preferences in Kenya and also expands the literature on crop variety traits in Africa by employing choice experiment to elicit farmers' preferences.

This study provided pertinent information to seed breeders such as KALRO so as to provide improved Sweet Potato variety attributes which took into account the diverse farmers' preferences for different improved variety attributes. This aimed at improving the understanding of farmers' preferences for improved Sweet Potato variety traits so as to enable a reasonable adoption, growing and use of improved attributes of the crop in order to increase yield of the tuber crop in Kenya.

The study assisted the government through the ministry of agriculture to establish vine development policies based on the farmers' preferences as opposed to the breeders' perspectives in Kenya. The initiative aided in the adoption of improved agricultural technologies which are farmer oriented.

The application of choice experiment to elicit farmers' preferences for crop traits in Kenya was not known. Therefore, the study contributed to literature by examining the farmers' preferences for improved sweet potato varieties in Kenya and also expanded the literature on crop variety traits in Africa by employing choice experiment to elicit farmers' preferences.

1.1.5 Discrete Choice Experiments

Since crop varietal advances are quasi-public in nature, the conventional markets measurement tools cannot appropriately be used to measure their economic worth (e.g., Gamboa *et al.*, 2018; Sanou *et al.*, 2019). The use of the non-market measurements of value is consequently a widespread practice among researchers. One of the strategies used to obtain these non-market measurements of worth is the Discrete Choice Experiment (DCE). It is a member of the wider family of expressed preference methods - a range of statistical approaches – that are used to obtain data by surveying individuals' intentions to undertake specified behavior in certain statistically constructed hypothetical situations. Thereafter, they evaluate the gathered data using discrete choice models that are developed from random utility theory (e.g., Ben-Akiva and Lerman 1985). Discrete choice experiments explain choices of decision makers among alternatives. Examples of decision makers are people, households, firms, or any other decision-making unit, and instances for the alternatives represent competing products, courses of action, or any other options over which choices must be made. The DCE methodology distinctively falls under choice modelling, which contains four variants: the choice experiment, contingent ranking, contingent rating, and paired comparison procedures (Bateman *et al.* 2002) all of which are based on the random utility theory.

It was first introduced by Louviere and Woodworth in 1983, and over the years, it has been improved substantially to become an important statistical method in the social sciences sphere with applications in marketing, environment, agriculture, transportation, and health related studies, among others (e.g., Louviere *et al.* 2000; Bennett and Blamey 2001; Bateman *et al.* 2002; Hensher *et al.* 2005; Kanninen 2007; Ryan *et al.* 2008). The approach has also been used to extract useful information on

public and private sectors of developed (e.g., Birol and Koundouri, 2008) and developing countries (e.g. Bennett and Birol, 2010) such as public's willingness to pay for local environmental improvements and consumers' preferences for product attributes.

In a typical DCE, survey respondents are shown a series of options that have been sorted into distinct groups of choices and described by different features at different levels and then asked to choose their most favored alternative from each choice set. The organization of the option sets lets the probability of an alternative being picked to be represented in terms of their properties. As a result, larger levels of a desirable feature in an alternative, *ceteris paribus*, are projected to have greater value associated with a particular option and are hence more likely to be picked by respondents and vice versa. It consequently allows researchers to learn how individuals value the particular qualities of a product above other hypothetical alternatives depending on individual values placed on each attribute. One useful characteristic of the DCE approach is that it allows for the calculation of the marginal rates of substitution (MRS) between distinct attributes of the good under investigation. These marginal rates of substitution provide an implicit ranking of the traits, which may subsequently be utilized to decide attributes that are valued most. Therefore, researchers are able to compel respondents into scenarios in which they must make trade-offs among many features of alternatives (e.g., Boxall *et al.*, 2009; Colombo and Glenk, 2013; Day and Pinto, 2010).

Despite its popularity among academics and widely distributed application in practically all social science disciplines, the method still suffers from various unresolved challenges that largely originate from its hypothetical market approach to public and quasi-public good analysis. Some of the unresolved difficulties were

ostensibly intended to be treated in this work and they include: preference certainty, preference consistency, preference variation and attribute non attendance (e.g., Colombo *et al.*, 2015; Dellaert *et al.*, 2007). Available empirical research (e.g., Brouwer *et al.*, 2010; Hensher *et al.*, 2011; Scarpa *et al.*, 2011) demonstrates that failing to account for these concerns in DCE analysis might lead to erroneous and biased policy recommendations.

Notably, DCEs are founded on a crucial assumption that respondents are rational decision-making units with well-defined and stable preferences. Therefore, individuals are clear about their preferences and can always perfectly expose them by choosing an option from a number of alternatives through a trade-off process (e.g., Brown *et al.*, 2008; Hanemann, 1984). However, this is not the case in practice because several studies have now revealed that respondents may not after all be certain about their choices (e.g., Alberini *et al.*, 2003; Brouwer *et al.*, 2010) owing to the unfamiliar hypothetical marketplaces commonly deployed in DCEs (e.g., Brouwer *et al.*, 2010). As a result, researchers (e.g., Hensher *et al.*, 2011) have underscored the need to evaluate the influence of response preference certainty in DCEs so as to improve the credibility of policy outcomes and also provide a foundation for developing refined economic models that can be used to analyze the choice behavior of individuals. This study consequently evaluated the influence of preference certainty on farmers' decision behavior for sweet potato varietal features in Western Kenya and thereby, contributed to DCE literature on preference certainty.

While DCEs have also the potential to yield greater information on individual preferences, that has tended to come at a cost since respondents are required to employ a considerable amount of cognitive effort in making their choices across different choice tasks (e.g. Boxall *et al.*, 2009; Fiebig *et al.*, 2010; Swait and

Adamowicz, 2001a). The difficulty thus met is that individuals may fail to make consistent choices in otherwise nearly identical decision situations, thus decreasing the credibility of the policy outcomes coming from a DCE survey (e.g. Saelensminde, 2002; Hess *et al.*, 2010; Cameron and DeShazo, 2011). As such, this study purposed to examine the consistency of preferences of sweet potato farmers in western Kenya towards crop varietal attributes to understand its meaning in the conclusions of the DCE survey and also contributed to the already existent DCE literature on choice consistency.

As for preference variety, it basically implies a situation where individuals tend to derive varied marginal utility from distinct product attributes. It therefore requires looking for diversity in the preferences of individuals for product features. Evidence (e.g. Keane and Wasi, 2009) suggests that when provided with similar or roughly identical choice tasks, individuals may often respond in a heterogeneous fashion in terms of the choices they are observed to make. The two basic categories of preference variation studied in individual decision behavior are taste and the scale variation. While taste variation is systematic and individual based, scale heterogeneity is random and arises from differences in the variance of the error terms in the decision-making process between individuals. Researchers (e.g. Keane and Wasi, 2009; Greene and Hensher, 2010; Christie and Gibbons, 2011; Scarpa *et al.*, 2011, 2012) have also emphasized the importance of analyzing the role of taste and scale variation in the choice behavior of individuals so as to understand their implications in the policy conclusions arising from DCE surveys. This study thus tried to model the influence of both taste and scale factors in the choice decisions of sweet potato farmers for varietal features in western Kenya and correspondingly, contributed to enrichment of DCE literature on preference variation.

Conventionally, DCEs have also assumed that preferences are continuous and so, respondents would base their choice decisions on all the qualities offered in a choice set, trading off gains in one attribute to losses in another (e.g., Kragt, 2013). However, new empirical research reveals that respondents may not necessarily weigh up all the features and their levels, but base their choice decision on a selection of a few traits (e.g., Campbell *et al.*, 2008, Hensher *et al.*, 2005, Rose *et al.*, 2005). This is the behavior that is referred to as attribute non-attendance (ANA), which in DCEs is viewed as discontinuous preference ordering, a sort of irrational choice behavior (e.g., McIntosh and Ryan 2002; Salensminde 2002). Though ANA is a possible concern in many DCE investigations, it is usually neglected in practice. This study therefore intended to investigate ANA from DCE data on farmers' preferences for sweet potato varietal traits in western Kenya using the Equality Constrained Latent Class (ECLC) modelling framework and made contributions to literature on attribute non-attendance.

1.2 Statement of the problem

Sweet potato can play a very important role in the food security strategy for Kenya because it is drought resistant, and also since it is a relatively short-term crop with a flexible time of harvest allowing a high degree of flexibility in food security strategy. Kenya has an estimated 65,973.00 hectares under sweet potato cultivation with an approximated production of 893,656 tons and an estimated annual yield of 9.53 tons per hectare which is below the global average of 14 tons per hectare (GTZ, 2015). It is believed that an increase in the crop's yield can create income for the farmers as well as food and nutritional security for countless homes across the country (Momanyi *et al.*, 2016). However, sweet potato farmers have faced several challenges

including pests, diseases, low yield, storage, value addition, and clean seed (Sumbele *et al.*, 2018).

While research and extension initiatives have been commissioned to produce and disseminate new sweet potato varieties to address some of these issues, adoption of the improved varieties has remained largely low and attributed to the fact that sweet potato varieties lack crop-specific traits that farmers value, as crops are composite bundles of multiple attributes (Kibwage *et al.*, 2009, Donkor, 2012; Kibwage *et al.*, 2009). Moreover, the development, release and accessibility of various sweet potato varieties with farmer-preferred traits also play an important role towards motivating farmers to devote substantial amounts of resources towards cultivation of sweet potatoes. Despite the high investment put in place so far in the development of high-yielding sweet potato varieties, their uptake by farmers in the country has been low. While both farm and farmer characteristics have been important in influencing farmers' choice decisions for different crop varieties, the role of varietal traits has only received limited attention in the empirical literature.

As for sweet potatoes, only a few studies have explored farmers' preferences and their willingness to pay for sweet potato varietal traits (e.g. Dibi *et al.*, 2017). In addition, the use of decision choice experiment methodology, which is robust in allowing respondents to make trade-offs between different varietal traits of crops under investigation, has also received limited application (Mansaray *et al.*, 2018). Except for preference variation, there is also no study known to the author that has explored the implications of key DCE methodological issues - preference certainty, consistency, and attribute non-attendance - in the analysis of discrete choice data for crop variety traits.

To fill these research gaps, this study evaluated farmers' preferences for sweet potato variety traits in western Kenya (i.e., Busia, Bungoma, Kakamega and Vihiga Counties). Western Kenya was in this case purposively chosen because of its importance in sweet potato production in the country and for the fact that farmers in the region are known to grow different varieties of sweet potato. The DCE was used to evaluate farmers' trade-offs for six sweet potato varietal traits, namely: yield level, flesh sweetness, flesh color (orange, white, yellow or purple), tolerance to pests and diseases, maturity period and price. These traits, which were derived from the empirical literature and discussions with experts, were broadly evaluated based on whether they were local or improved varieties so that farmers could express their preferences.

1.3 General objective of the Study

The general objective of this study was to analyze preferences of farmers towards sweet potato variety traits in western Kenya (i.e., Busia, Bungoma Kakamega and Vihiga Counties).

1.3.1 Specific objectives of the study

The specific objectives of the study are:

- a) To assess farmers' willingness to pay (WTP) for better-quality sweet potato varietal traits in western Kenya.
- b) To evaluate farmers' preference certainty and consistency in their choice decisions for sweet potato varietal traits in Western Kenya.
- c) To explore the role of preference variation in the choices made by farmers towards sweet potato variety traits in Western Kenya.

- d) To assess attribute non-attendance of the farmers in their choice decisions for sweet potato variety traits in Western Kenya.

1.4 Hypotheses of the study

The study comprised of four null hypotheses as stated below:

H₀₁: That farmers are not willing to pay more amount of money to acquire improved sweet potato varietal traits in western Kenya.

H₀₂: That farmers are not certain and consistent in their preferences towards sweet potato variety traits in Western Kenya.

H₀₃: That preference variation (taste and scale factors) plays no significant role in the choice decisions of the farmers towards sweet potato variety traits in Western Kenya.

H₀₄: That there is no attribute nonattendance among farmers in their choice decisions for sweet potato variety traits Western Kenya.

1.5 Significance of the study

Numerous studies have been undertaken focusing on farmers' preferences towards crop varietal traits. There are those that have focused on beans (e.g Tekalign *et al.*, 2016), cassava (e.g. Acheampong *et al.*, 2013; Teeken *et al.*, 2018), chickpea (e.g. Goa *et al.*, 2017), cotton (e.g. Sanou *et al.*, 2019), cowpea (e.g. Alidu *et al.*, 2019; Ishikawa *et al.*, 2019), maize (e.g. Sanchez-Toledano *et al.*, 2017; Tadesse *et al.*, 2014; Ajambo *et al.*, 2017), sweet potato (e.g. Dibi *et al.*, 2017), finger millet (e.g. Owere *et al.*, 2014), onion (e.g. Tadesse, 2008), pigeon peas (e.g. Otieno, 2008; Tsusaka *et al.*, 2018), quinoa (e.g. Gamboa *et al.*, 2018), rice (e.g. Hanis *et al.*, 2012;

Mansaray *et al.*, 2018; Joshi and Bauer, 2006), strawberry (e.g. Yue *et al.*, 2014), sugarcane (e.g. Sumbele *et al.*, 2018), tomatoes (e.g. Skreli *et al.*, 2017) and yams (e.g. Dansi *et al.*, 2013).

Of interest, however, is that none of these studies has evaluated farmers' preferences for crop varietal traits taking into account important issues such as preference certainty, consistency, variation and attribute non-attendance that might be inherent in the preference data of individual farmers. Therefore, this research was significant because it evaluated these issues along with their implications on policy outcomes of the DCE survey with a case example of sweet potato farmers in western Kenya.

1.6 Scope of the study

The study aimed at analyzing the preferences of farmers towards sweet potato variety traits in Busia, Bungoma, Kakamega and Vihiga Counties of western Kenya. As such, the unit of analysis was the smallholder farmers growing sweet potatoes in the four counties, who were asked questions on their knowledge about sweet potato varieties, their preferences for the different varieties available and their socioeconomic and demographic profiles. While the study did not seek to develop any theory for analyzing farmers' preferences for sweet potato varietal traits, it however contributed to policy enrichment in terms of farmers' desirability for different sweet potato varietal traits in the counties, and also methodologically in terms of the role of preference certainty, consistency, variation and attribute non-attendance on policy outcomes of the DCE survey. The information sought was expected to be useful to all relevant stakeholders and especially crop breeding scientists in their response to specific varietal demands by farmers.

1.7 Layout of the Thesis

The first chapter of the thesis discusses background information, statement of the problem, study objectives, hypotheses, significance and the scope of the study. In the second chapter, the thesis presents the theoretical and analytical framework of the study together with the review of the relevant empirical literature. In chapter three, the thesis presents the methodology for the study by discussing the study area, study population and sample, data needs and sources, data collection and analysis. Chapter four presents the results and discussions emanating from the study while Chapter five gives summary, conclusions and recommendations arising from this study followed by a list of references and appendices.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

The purpose of the study was to evaluate the preferences of the farmers towards sweet potato variety traits in Busia, Bungoma, Kakamega, and Vihiga Counties of western Kenya. In this chapter, therefore, information on the theoretical framework for exploring farmers' preferences for varietal traits was presented followed by the analytical framework of the study objectives and finally, a review of the related empirical literature.

2.2. Theoretical Framework

This study was firmly grounded in the Attribute Theory of Consumer Choice (Lancaster, 1966) and the Random Utility Theory (McFadden, 1974). Both theories argue that individuals derive utility not from goods themselves but from the attributes they provide. In this context, it implied that the utility that farmers derive from choosing a given sweet potato variety is a function of the attributes of the sweet potato, price, farm, and farmer characteristics. Attributes refer to those intrinsic characteristics that are frequently used by farmers to value the quality of sweet potato varieties they choose to grow on their farms.

The underlying framework for choice experiment is choice decisions, which are usual activities in all societies either at an individual, group or organizational level. Choice decisions entail choosing an action given one's preferences, the actions one could take, and expectations about the outcomes of those actions. Choosing can result from ways such as supporting one outcome and rejecting others, expressed

through active responses such as choosing to use certain products or services through purchases, or through passive responses such as supporting particular views over an issue of interest (Louviere *et al.*, 2000). There are three theories of choice: Lancasterian consumer theory, discrete choice theories, and random utility and probabilistic choice theories.

These are described below.

2.2.1 Lancasterian Consumer Theory

The theoretical framework of choice experiments is derived from Lancasterian consumer theory and discrete choice random utility theory. The classical economic theory models consumer behaviour as maximization of a utility function subject to a budget constraint. The point of departure of Lancasterian consumer theory from classical consumer theory to choice experiments is the assumption that utility is derived from traits or attributes of goods rather than the good (Lancaster, 1966). This is the basic point of departure from the traditional economic theory of demand which assumes that goods are the direct objects of utility. This implies that goods are either used singly or in combination to produce the attributes that are the source of a decision maker's utility.

The implication is that the utility function has been defined on a trait or attributes space and the budget constraint has been defined on a goods space. The relation represents a transformation between the goods space and the traits space. In this model, utility can only be related to the budget constraint after both have been defined on the same space. According to Lancaster the primary interest of economists is in how consumers will react to changes in prices or traits of the goods that produce a good and not how the preference function is formed. Lancaster's main assumption is

that goods are infinitely divisible. Yet many goods are not perfectly divisible, especially goods relevant to discrete choice applications. Although Lancaster's models provide important frameworks for choice experiments, they have some shortcomings as they emanate from the traditional economic theory of consumer behaviour. For example, these models would not hold when individual choice behaviour is stochastic because the models are basically static and deterministic, and do not address the question of how preferences for attributes are formed. They link utility directly to attributes of goods, yet utility may possibly be linked to attributes through complex functions due to the complex nature of choice decision making process which is also linked to behavioral theory (Louviere *et al.*, 2000; Ben-Akiva *et al.*, 2002).

2.2.2 Discrete Choice Theories

In discrete choice framework, the set of alternatives (goods), called the choice set, are naturally discontinuous and must exhibit three characteristics. First, the alternatives must be mutually exclusive from the decision maker's perspective. Secondly, the choice set must be exhaustive, in that all possible alternatives are included, and thirdly, the number of alternatives must be finite. A universal set of alternatives denoted C is assumed to exist. The constraints, for example the budget constraint, faced by an individual decision maker n determines his or her choice set. The third characteristic is restrictive and is the defining characteristic of discrete choice models which distinguishes their realm of application from that of regression models (Train, 2003). Regression models have continuous dependent variables, assuming an infinite number of possible outcomes. The mutual exclusivity characteristic implies a set of discrete choices, which consider the use of maximization techniques of calculus to derive demand functions (Ben-Akiva and Lerman, 1985). This necessitates the maintenance of the discrete choice assumptions. Rationality implies that when decision makers are

faced with a set of possible consumption bundles of goods, they assign preferences to each of the various bundles and then choose the most preferred bundle from the set of affordable alternatives. Consistency and transitivity of preferences is assumed (Train, 2003). Describing the underlying framework of choice experiments necessitates linking the Lancasterian consumer theory with discrete choice theory. The function $U(\cdot)$ which maps the attributes values and socio-economic characteristics to a utility scale is an ordinal utility function. The utility function $U(\cdot)$ can usually take several forms but is often assumed additive to simplify it (Ouma, 2007).

2.2.3 Random Utility Theories

The random utility theory, originated by Thurstone (1927) and further developed by Luce, (1959), forms the framework for discrete choice modelling. Whilst classic consumer theory assumes deterministic behaviour, random utility theory establishes the concept that individual choice behaviour is essentially probabilistic. Probabilistic choice theory in its random utility form implies that the individuals' reports of their preferences or utilities are not always the same under identical conditions, owing to measurement error or to random variation in the assessment of preference/utility by individuals. The notion behind random utility theory is that while the decision maker may have perfect information regarding his/her utility function, the analyst lacks precise knowledge about the decision maker's decision processes and therefore uncertainty must be taken into account in equation (1). In addition, the deterministic discrete choice framework does not take into consideration existence of unobserved heterogeneity in preferences among decision makers with identical choice sets, attributes of alternatives and socioeconomic characteristics. The random variation may be resulting from unobserved attributes, unobserved taste variation, measurement errors and proxy variables (Manski, 1977).

Similar to the consumer theory, the random utility theory assumes that an individual derives utility by buying or choosing an alternative from a set of alternatives. A utility maximizing behavior is assumed, that is, a decision maker is assumed to buy or choose the utility maximizing alternative. The utilities are latent to the analyst and the actual choice which is what can be observed is a manifestation of the underlying utilities (Ouma, 2007).

The deterministic component consists of the attributes of the alternatives and the socioeconomic characteristics of the decision maker as presented in equation (1); for the analyst, is a random variable with some joint density function, denoted as

$f_{\varepsilon}(\varepsilon_1 \dots \varepsilon_m)$ which induces a density on utility function, The distributional

assumptions on and parameterization of the utility function lead to various choice models and the model outputs represent the probabilities of individuals selecting each alternative.

Simplifying assumptions are often made in discrete choice models in order to maintain a prudent and tractable structure (Hensher *et al.*, 2005). Such assumptions include utility maximizing behavior, deterministic choice sets, easily measurable characteristics of decision makers and simple error structures (ε_n) such as Gumbel (or extreme value type 1) distributions leading to conditional logit (CL), nested logit, among others.

Due to the strong assumptions and simplifications in discrete choice models, there has been much debate among behavioral researchers and economists regarding the validity of such models. A major limitation often raised regarding the conditional logit models is the property of independence of irrelevant alternatives (IIA) which results from the assumption of identically and independently distributed (IID) random terms ε_n . The IIA property states that, for a given individual, the ratio of his choice probabilities of any two alternatives is independent of the presence or absence

of any other alternative in a choice set. An important behavioral implication of the IIA property is that all pairs of alternatives are equally similar or dissimilar. Hensher *et al.* (2005) indicate that for the unobserved sets of attributes, this property assumes that all the information in the random components are identical in quantity and relationship between pairs of alternatives due to the identical and independent distribution assumption. The conditional logit model (multinomial model) has often formed the framework for discrete choice modelling because it is fairly robust and has a tractable closed form solution, leading to its wide application in discrete choice literature. The main disadvantage of the IIA property is that the conditional logit model would perform poorly when there are some alternatives that are similar and highly correlated. This is especially pronounced when there are cases of repeated choices by a single decision maker, common in discrete choice studies such as choice experiments. The conditional logit model cannot represent random taste variation and exhibits restrictive substitution patterns (Revelt and Train, 1998). Conditional logit models enable the measurement of the effect of each choice-specific explanatory variable on the individual choices. The conditional logit however assumes homogeneous preferences.

There are a number of ways to relax the IIA assumption and many variations of discrete choice models have been developed to accommodate more general random utility model-consistent behavior. The nested logit model, initially derived by BenAkiva (1973), is an extension of the conditional logit (MNL) model and a special case of the generalized extreme value (GEV) model designed to partially accommodate violations of IIA. The nested logit model allows the possibility of different variances across the alternatives and correlations in unobserved factors across sub-sets of mutually exclusive alternatives (Train, 2003). The model also has closed forms for the choice probabilities and is relatively robust. However, its

limitation is mainly centered on the fact that it does not accommodate complete relaxation of the IID assumption and the fact that it does not allow for overlaps between nests or sub-sets.

The other major group of discrete choice models that relax the IID assumptions is the probit family, derived under the assumption of jointly normal unobserved utility components. The multinomial probit model is highly flexible, because it allows for an unrestricted covariance matrix (Train, 2003). However, it is difficult to estimate and it does not easily converge as it lacks a closed form solution. The mixed logit model is a powerful and highly flexible model that relaxes the IIA property and combines the advantages of probit and the GEV models by allowing for an unrestricted substitution pattern while still maintaining global concavity.

It accounts for unobserved, unconditional heterogeneity which should be used in order to account for preference heterogeneity in pure public goods. The model does not exhibit IIA (independence of irrelevant alternatives) and can explicitly account for the repeated nature of the choices made, and they explicitly allow for a distribution of preferences within the population. Early applications of mixed logit have been in the fields of transportation research and consumer behavior (Revelt and Train, 1998).

The mixed logit model has been known for many years but has only become fully applicable since the advent of simulations. Recent studies have shown that when the paradigms are combined in modelling technology adoption by farmers the explanatory power of the model improves (Langyintuo and Mekuria, 2005b; Morris *et al.*, 1999).

The sweet potato attributes considered in this study included the yield level, the sweetness of the flesh, the color of the flesh, tolerance to pests and diseases, maturity period, and price. It was expected that farmers' preferences for different sweet potato

varieties (either local or improved varieties) were an increasing function of varietal traits such as yield level, the sweetness of the flesh, the color of the flesh, and tolerance to pests and diseases, but a decreasing function of maturity period and price traits. It was also posited that farm (e.g., acreage and soil fertility) and farmer (e.g., age and gender) characteristics will have significant contributions to the choice decisions of the farmers. Since farmers were most likely to have diverse preferences towards sweet potato variety traits owing to the hypothetical nature and design of the discrete choice experiment, this study, as mentioned earlier on, also endeavored to examine the roles of preference certainty, consistency, variation, and attribute nonattendance on policy outcomes of the DCE survey.

Since farmers' preferences were observed in terms of the choices they made, the study, therefore, employed the random utility framework to analyze farmers' responses to different choice sets in the discrete choice experiment. Assuming a linear indirect utility function, the utility for an alternative in a choice situation for the farmer was decomposed as the sum of two components, the systematic (observable) and the random (non observable) components (McFadden, 1974), thus:

$$U_{ijt} = \beta_i' x_{ijt} + \varepsilon_{ijt} \quad (1)$$

where x_{ijt} is a vector of explanatory variables including traits of the sweet potato variety profiles, interactions of traits, and socioeconomic characteristics, and ε_{ijt} is the unexplained utility assumed to be independently and identically distributed (iid) across individuals, alternatives, and choice sets with extreme value type 1 distribution.

β_i is a conformable vector of the unknown utility weights that were assigned to the explanatory variables. Nevertheless, the development of the Conditional Logit (CL) model by McFadden (1974) to analyze individual preferences provided the statistical

framework for modeling how varying preference attributes contribute to the probability of choice. The model has been widely used in applied economics owing to its computational simplicity and closed-form model specification. It assumes that choices are consistent with independence from irrelevant alternatives (IIA) property such that for any individual, the ratio of choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternative (e.g. Louviere *et al.*, 2010). The CL model is based on an indirect utility function where the indirect utility derived from alternative i in choice situation j for farmer t in choice set C_i is:

$$U_{ijt} = V_{ijt} \{Z_{ijt}, S_i\} + \varepsilon_{ijt} \quad (2)$$

where V_{ijt} is the observable deterministic component and ε_{ijt} is the unobserved stochastic component. V_{ijt} is a function of both the attributes of the alternative options and the status quo in choice set (Z_{ijt}) and the characteristics of the respondent

(S_i). Respondent t chooses alternative i in a choice situation j if $U_{ijt} > U_{ikt}$ for all

$j \neq k$ in C_i . As such, the probability of choosing alternative i by respondent t is:

$$\begin{aligned} Prob_i(j|C_i) &= \{V_{ijt} + \varepsilon_{ijt} > V_{ikt} + \varepsilon_{ikt}\} \\ &= \{V_{ijt} - V_{ikt} > \varepsilon_{ikt} - \varepsilon_{ijt}\} \end{aligned} \quad (3)$$

The estimation of Equation (3) requires that the assumptions over the distributions of the error terms to be made. For MNL model, the errors are assumed to be independently and identically distributed (*iid*) with a Type 1 extreme value (Weibull) distribution (McFadden, 1974). This suggests that the probability of choosing alternative j by respondent t is:

$$Prob_i(j|C_i) = \exp\{\mu V_{ijt}\} / \sum_{k \in C_i} \exp\{\mu V_{ikt}\}$$

This parameter is not separately identified and thus, it is generally assumed to be equal to one, which implies constant error variance (e.g. Ben-Akiva and Lerman, 1985). As such, the log-likelihood function takes the form:

$$\ln LL = \sum_{i=1}^N \sum_{j=1}^M \{Y_{ijt} * \ln [Prob_i(j|C_i)]\} \quad (5)$$

where the value of Y_{ijt} is one if the t^{th} respondent chooses alternative j and zero otherwise. Equation (5) is estimated by maximum likelihood procedure (e.g. Hensher *et al.*, 2015). The final conditional indirect utility (MNL) model, with attributes only, will be of the form:

$$U_{ijt} = ASC_{local} + ASC_{improved} + \beta_1 yield_{ijt} + \beta_2 tolerance_{ijt} + \beta_3 sweetness_{ijt} + \beta_4 colour_{ijt} + \beta_5 maturity_{ijt} + \delta price_{ijt} + \varepsilon_{ijt}$$

where ASC is the alternate specific constant representing the utility of local and improved sweet potato varieties relative to 'none' option, respectively. The betas (β) and the delta (δ) refer to the vector of coefficients related to yield, sweetness, colour, tolerance, maturity and price traits. From the equation above, the average implicit prices or mean willingness to pay (WTP) for any given varietal trait relative to 'none' will be computed as: $WTP_i = -(\beta_i/\delta)$ while the marginal willingness to pay

(MWTP) for any two traits will be given by:

$$MWTP = (WTP_1 - WTP_2)/\delta = (\beta_1 - \beta_2)/\delta \text{ (e.g. Hanneman, 1984).}$$

Furthermore, the standard errors of the estimated WTP values will be generated using the parametric bootstrapping method developed by Krinsky-Robb using 1,000 halton draws from the estimated parameter distribution.

2.3 Parametric and Non-Parametric Analytical Approaches on Preference

Variation

Several analytical approaches have been developed to analyze uptake and diffusion of agricultural innovations. Non-parametric and parametric approaches have been used to investigate adoption. Count data methods (Isgin *et al.*, 2008), the use of index numbers (Kiani *et al.*, 2008) and data envelopment analysis (DEA) (Seiford and Thrall, 1990) are non-parametric methods that have so far been used to study adoption of agricultural technologies. More recently, Isgin *et al.* (2008) examined the number of precision of farming technologies adopted by farmers using count data methods. They employed Poisson and Negative Binomial count data models. Isgin *et al.* (2008) found education to be positively related to the number of technologies adopted whereas age or other variables measuring experience did suggest a lower number of adoptions. This argument is based on the premise that there is a reduced time period over which a new technology will be rewarded. Also farmers with greater experience with existing technologies may be willing to continue their reliance on existing methods and as such there may be a status quo bias.

Kiani *et al.* (2008) applied the Tornqvist-Theil index (TTI) approach to measure total factor Yield (TFP) using outputs and inputs for 24 fields and horticulture crops in Pakistan. Empirical evidence showed attractive marginal rates of return to investments in agricultural research in Punjab. The study concluded that investment in agricultural research has resulted in attractive returns and recommended that supporting and further strengthening research and extension system of the province should be continued. Ehui and Jabbar (2002) argue that superlative-index based total factor Yield measures are a more appropriate technique for assessing the performance of

agricultural production technologies and systems. This was based on three case studies from sub-Saharan Africa in which this approach was applied.

Data envelopment analysis (DEA) or non-parametric frontier estimation dates back to Farrell (1957). It was operationalized by Charnes *et al.* (1978) and an overview of the method with applications can be found in Seiford and Thrall (1990). No particular production function is assumed. Instead, Yield is defined as the ratio of a linear combination of outputs over a linear combination of inputs. The main advantage of DEA is the absence of functional form or behavioral assumptions. The underlying technology is entirely unspecified and allowed to vary across firms.

Parametric approaches commonly used to analyze adoption are the logit, probit, Tobit, the linear probability model and multinomial logit models. In the case of dichotomous dependent variable such as improved Sweet Potato variety adoption or non-adoption measured in nominal dummy variables, the linear probability model, the logit model and the probit model are applied. The linear probability cannot be constrained between 0 and 1 and thus cannot be used (Amemiya, 1981; Collett, 1991). The binary decision also produces a non-linear response and thus violates the assumptions of the linear regression model. As a result, a probability model based on a cumulative frequency distribution is used.

The probability functions used for the probit and logit models are based on the normal distribution and on the logistic distribution functions respectively and they are bounded between 0 and 1 and they exhibit a sigmoid curve, conforming to the theory of adoption. The logit and probit models are however quite similar as the cumulative normal and logistic distributions are very close to each other. The choice between the two parameters is somewhat difficult since both models yield equally

efficient parameter estimates using an iterative maximum likelihood approach (Demaris, 1992).

However, the tails of a logistic model are flatter than the probit model (Amemiya, 1981). The results produced by either model are similar, unless the samples are very large and many observations fall near the tails (Maddala, 1983). But the logistic transformation is more convenient to compute. Unless there are other theoretical reasons for preferring a distribution function to the logistic cumulative distribution function, the logit model is preferred when repeated observations are available (Judge *et al.*, 1980; Pindyck and Rubinfeld, 1981). The logistic model also has a direct interpretation (as does the probit model) in terms of the logarithm of the odds in favour of success (Collet, 1991). Being based on the cumulative logistic probability function, the logit model can be used for transforming the dependent variable to predict probabilities within the bound (0, 1).

The dependent variable becomes the natural logarithm of the odds when a positive choice is made. When the objective is to identify the socio-economic variables that influence both adoption and intensity of adoption, the probit and the Tobit models are preferred (McDonald and Moffit, 1980). Thus, when the dependent variable is continuous, a censored regression model is appropriate as the probit or logit models fail to differentiate between limit (zero or censored) and non-limit (continuous or uncensored) observations (Langyintuo *et al.*, 2005). In this study, Logit Models are adopted since dependent variables are binary, measured as improved Sweet Potato variety use or non-use, in principle, while the independent variables are the combination of both continuous and discrete variables.

2.4 Revealed and Stated Preference Methodologies

Economic value is usually expressed in monetary terms, however it is taken to mean by economists as difference in preference or utility levels (Freeman, 2003). It is generally assumed that individuals are the best judges of what they want. Economic valuation is therefore based on individual preferences and choices. Even though utility cannot be directly observed, it is possible to observe the choices of individuals, or to ask individuals to state their preferences between alternatives, and in both cases it is assumed that individuals choose the option that yields the highest utility (MerinoCastello, 2003). People express their preferences through the choices and trade-offs that they make, given the constraints faced, such as personal, income or available time. Therefore, for economists, the economic value of a trait is measured by the maximum amount that someone is willing to sacrifice in other traits in order to obtain a particular trait (Ouma, 2007) or the maximum amount an individual is willing to pay in order to secure a change (Hanemann, 1994).

This is often referred to as “willingness to pay” for a good. Measuring preferences assist in quantifying individuals’ economic valuation or willingness-to-pay (WTP) and or willingness to accept (WTA) for public and private initiatives (Hensher *et al.*, 2005). Utility theory provides a useful framework for valuing traits without market value or price since preferences are measured directly, and trade-offs between traits can be evaluated. One drawback of utility theory is the fact that individual utilities or preferences are not observable. Revealed and stated preference approaches overcome this limitation by linking utilities to observe (revealed) or stated choices. Revealed and stated preference approaches, which are grounded in preference or utility theory, have been widely applied in economics literature for the valuation of attributes of goods.

In revealed preference methodology it is assumed that consumer preferences can be revealed by their purchasing behavior. Revealed preference methods draw statistical inferences on values from actual choices people make within markets (Boyle, 2003). More often than not, the method is applied to the demand for existing products where data is available on consumers' actual choice behavior in the real market (Zou, 2011). As such, it represents events that have been observed to have actually occurred. Data is collected on real trait levels and alternatives chosen and not chosen. There are two main methods under the revealed preference method: hedonic pricing and travel cost method. Travel cost models are based on decisions to visit recreation sites that differ in travel cost and quality. Hedonic price models assume that a good is heterogeneous and its component traits yield utility (Rosen, 1974). These models assume a competitive market where the price of a good is a function of the traits of the goods. The marginal values of the traits then give the implicit prices of the traits.

The main advantage of revealed preference approach is that preference is based on actual choices made by individuals. The major disadvantage is that the valuation is conditioned on current and previous levels of the non-market good and it is impossible to measure non-use values such as existence value, altruistic value and bequest value (Alpizar *et al.*, 2001). Given that revealed preference data is based on actual behavior, the use of this technique proves difficult when forecasting demand for new services or products. It neither takes into consideration new candidates in the form of new products/brands nor innovations which may suggest new attributes, which equate to new alternatives within a market which can have significant impact on choice behavior (Ouma, 2007).

The stated preference technique came about as a result of the difficulties of the revealed preference method to predict the demand for new products yet to come to the

market. The stated preference method, involves asking individuals to make a hypothetical choice between different crop varieties offered in a choice set and differentiated by their attributes using carefully worded survey questions. The method seeks the decision maker's choice behavior among alternative products (Alpizar *et al.*, 2001). This approach is especially useful when revealed preference data are absent, typical of non-market goods or when a good is not traded in the real market. With stated preference approach, the attributes and their levels are pre-specified by the analyst and given to the decision maker as determined by some statistical design in the form of hypothetical scenarios (Hensher *et al.*, 2005). Stated preference methods use a variety of approaches for asking valuation questions; from the straight forward request for maximum willingness to pay amounts of open-ended contingent valuation method, to indirect methods using choice experiments or rankings and ratings in conjoint analysis (Louviere *et al.*, 2000).

Contingent valuation is a direct survey approach which is used in estimation of preferences. In contingent valuation methodology, respondents are asked whether or not they would be willing to pay a certain amount of money for realizing the level of the non- market good, well described or, more precisely, the change in the level of the good (Bateman and Willis, 1999).

Contingent Valuation Methods are the most commonly used methods for valuation of non- market goods. By means of well-structured or open-ended questionnaire, a hypothetical market is described where the good or service in question can be traded. This contingent market defines the good itself, the context in which it would be provided and the way it would be financed. Respondents are then asked to express their maximum willingness to pay for, or their minimum willingness to accept, a hypothetical change in the level of provision of the good. The assumption here is that

willingness to pay (WTP) amounts is related to respondents' underlying preferences in a consistent way (Hanley *et al*, 2001).

The open-ended contingent valuation is the original form of contingent valuation and constitutes an open-ended question, in which respondents are asked to state their willingness to pay (or accept compensation) for a specified change or improvement (Merino-Castelló, 2003). In this manner respondents find it difficult answering for goods that are not traded in the market. This major disadvantage led to the development of closed ended referendum or dichotomous choice elicitation method. This provided incentives for truthful revelation of preferences and also simplified the cognitive tasks faced by respondents (Hanley *et al*, 2001). However, an increasing number of empirical studies reveal that dichotomous choice results seemed to be significantly larger than open-ended values, possibly due to “yeah saying” (Hanley *et al*, 2001).

Both approaches have some limitations for estimating values. Firstly, only one attribute or scenario can be presented to a sample of respondents for valuation.

Secondly, it is a poor method for estimating a person's values because respondents are unlikely to provide an accurate response when presented with a hypothetical scenario. A third weakness of contingent valuation is that it may induce some respondents to behave strategically, particularly when public goods are involved (Merino-Castelló, 2003).

In response to the above problems, alternative stated preference techniques such as the conjoint analysis (preference-based approach) and choice modelling (choice-based approach) have been developed. The preference-based approaches require the individual to rate or rank each alternative product whilst the choice-based approaches

allow the consumer to choose one among several alternative products. In preference based approach the consumers are asked to assess a series of hypothetical and real products, defined in terms of their characteristics. Choice-based approach differs in that individuals are asked to view a series of competing products and select one or, in some cases, more than one. Therefore, choice-based approaches are based on a more realistic task that consumers perform every day, the task of choosing a product from among a group of competitors whereas preference-based approaches do not require respondents to make a commitment to select a particular option (Merino-Castelló, 2003).

Bateman *et al.* (2003) further enumerate some advantages of conjoint and choice modelling that resolves the weaknesses of contingent valuation. They report that: (i) the only way that a contingent valuation study can estimate more than one attribute is to design different valuation scenarios for each attribute level; however, this is very costly. Conjoint and choice modelling provide a natural way to do this because they look at more than two alternatives at a time; (ii) since conjoint analysis and choice modelling designs are based on the attribute theory of value, they are much easier to pool with cost models or hedonic price models than contingent valuation; (iii) conjoint and choice modelling designs can reduce the extreme multicollinearity problems because attribute levels are usually designed as orthogonal; and (iv) conjoint and choice modelling may avoid some of the response difficulties that appear in contingent valuation.

The major difference between contingent valuation method and choice modelling is that contingent valuation method focuses on a single scenario to collect the precise information from each respondent choice, while choice modelling tends to examine a respondent preference by providing an excellent description of the attributes tradeoffs

in the overall scenarios (Adamowicz *et al.*, 1998). Choice experiments apply the probabilistic theory of choice, where the choices made by decision makers from a discrete set of alternatives are modeled in order to reveal a measure of utility for the traits of the choices (Ben-Akiva and Lerman, 1985).

The stated preference methods have two main advantages over revealed preference methods. First, the methods allow the estimation and prediction of demand of new products with non-existing attributes. Secondly, they are able to introduce variability in cross sectional data (Louviere, *et al.*, 2000). The main drawback of the stated preference method is its hypothetical nature. The temptation to providing unrealistic statements about cost if no cost is provided and overstating their willingness to pay (WTP) is inevitable (Morikawa, *et al.*, 2002). Also, if consumers are unfamiliar with the product their stated WTP may be inaccurate, because this method asks respondents to state their WTP values but does not record an actual choice action as is the case with revealed preference studies. “The fact that stated preference methods are based on what people say rather than what people do, is the source of its greatest strengths and its greatest weaknesses compared with revealed preference” (Zou, 2011).

In terms of methodology, both stated and revealed preference methods have advantages and drawbacks. As a result of the criticisms of both stated preference and revealed preference methods, studies have gone to the extent of comparing the two by using stated preference method to estimate revealed preference data. They then conducted convergent validity test and their results show preference consistency for both stated preference and revealed preference estimates (Scarpa *et al.*, 2003a; Adamowicz *et al.*, 1994). Carson *et al.* (1996) compares estimates from revealed and stated preference methods and finds out that results from both methods are highly correlated, with a rank correlation coefficient of between 0.78 and 0.92. The argument

is that both methods can be relied on (Adamowicz *et al.*, 1994) and therefore must be seen as complementary sources of information.

2.5 Accounting for Taste and Scale Heterogeneities in Discrete Choice

Experiments

Conventionally, the Conditional Logit (CL) or MNL models have all a long been used by researchers to analyze discrete choice data (e.g. Bennett and Blamey 2001; Scarpa *et al.* 2007). Even though the CL model provides a computationally convenient choice model, it is known to be restrictive in its parameter estimation (Kataria, 2009). Besides the restrictive Independence of Irrelevant Alternatives (IIA) property, CL models have limited ability to capture individuals' preference variation. While socioeconomic variables can be included in the specification of the utility function, this approach has tended to rely on the observable differences between respondents. Recent modelling approaches such as the mixed logit (MXL) and latent class (LC) models relax the IIA assumption and account for the unobserved individual heterogeneity in the systematic component of utility (Hensher and Greene 2003). A number of authors (e.g. Louviere *et al.* 2002; Louviere and Eagle 2006; Boeri *et al.* 2011) have identified the additional importance of accounting for the differences in variance between individuals, which requires models that can represent unobserved individual heterogeneity in the random error component of utility. There are two models that are not yet widely published but can account for scale heterogeneity, that is: the scaled multinomial logit (S-MNL), generalized multinomial logit (G-MNL) and the generalized mixed logit (G-MXL) model.

Notwithstanding the huge number of research evidence regarding heterogeneity in the systematic and random components of utility, there are surprisingly few studies that have compared the different approaches to modelling unobserved individual

heterogeneity. Keane and Wasi (2009) compare the performance of CL or MNL, MXL, G-MNL and G-MXL models using ten empirical choice data sets for marketed consumer goods. The authors find that G-MXL and G-MNL model specifications outperform the MXL and CL models. Greene and Hensher (2010) estimate MXL, GMNL and G-MXL models for a study of transport choices. They find that accounting for scale heterogeneity in the G-MNL model is of limited interest in the presence of unobserved preference heterogeneity that is accounted for in the MXL and G-MXL models.

In the context of valuing environmental goods, Scarpa *et al.* (2011) investigate the effects of increasing the number of choice alternatives and preference elicitation method (best-worst questions) on the scale parameter for a study of Alpine pastures in Europe. They compare models of scale heterogeneity to models that account for preference heterogeneity and models that include both. They find significant effects of the number of alternatives in the choice context on scale. However, once taste heterogeneity is addressed in a MXL specification, the scale effect is no longer significant for choice tasks with five alternatives. Best-worst ranking is associated with lower variance than a single most preferred choice format.

In a study on preference for tap water attributes, Scarpa *et al.* (2012) conclude that a G-MXL model fits their data best, but find issues related to WTP estimation using the model. Christie and Gibbons (2011) also compare models of scale and preference heterogeneity for environmental goods. Similar to Scarpa *et al.* (2011), they find that preference heterogeneity is more important than scale heterogeneity in their case studies, with MXL and G-MXL models outperforming CL and G-MNL models. The authors argue that G-MXL models have the potential to improve the rigour of valuation studies for unfamiliar grounds in environmental goods and services. They

however call for additional research work so as to shed more light on how these models compare. As such, this paper follows up on the identified need for additional studies that compare approaches to modelling individual heterogeneity (Keane and Wasi, 2009; Greene and Hensher 2010).

2.6 Empirical studies

Empirically, studies have been conducted by researchers to understand the preferences of the farmers toward crop variety traits. This has been done using four main methodological approaches, namely: the farmers' participatory method, the mixed approach, the conjoint method, and the discrete choice experiments. For instance, using the participatory assessment method, Alidu *et al.* (2019) evaluated farmers' preferences for cowpea variety traits in Northern Ghana.

They found that most farmers preferred varieties with large grain size, early maturing, and drought-tolerant traits. Ishikawa *et al.* (2019) while examining farmers' preferences for cowpea varieties in Burkina Faso found that farmers preferred cowpea varieties with early maturity, drought tolerance, large seed size, and good seed color traits. In Southern Ethiopia, Goa *et al.* (2017) assessed farmers' preferences for chickpea varieties and found that most farmers preferred traits that included earliness, diseases and pest resistance, seed color, branch number and length, and seed size.

In Côte d'Ivoire, Dibi *et al.* (2017) also studied farmers' preferences for orange-fleshed sweet potato varieties for consumption and commercial purposes. They found that farmers' mostly preferred orange-fleshed sweet potato varieties based on their color, dry matter content, and taste. Tekalign *et al.* (2016) in their study on farmers' varietal preferences for Faba beans in Ethiopia discovered that the majority of the farmers preferred local varieties for their adaptability to the environment, tolerance to frost,

early maturity, good food taste, and straw yield, while improved varieties were preferred for their high grain yield and bigger grain size. Tadesse *et al.* (2014) while analyzing farmers' criteria for maize variety traits in Chilga, North West of Ethiopia established that earliness, drought tolerance, grain yield, vigorously, husk cover, cob size, grain color, and grain size were the most preferred maize variety traits among farmers. Finally, Dansi *et al.* (2013) also used the participatory assessment approach to assess farmers' cultivar preference criteria for cultivated yams in Togo. They found that high productivity, good quality of pounded yam, resistance to drought, and adaptability to all types of soils were the most important varietal traits.

On the use of the conjoint analysis method, Skreli *et al.* (2017) in their assessment of consumers' preferences for organic tomatoes in Albania found that the most important attributes were production type (biological vs. conventional), production system (open field vs. greenhouse), origin and price. Moreover, Hanis *et al.* (2012) also evaluated consumers' preferences for rice variety traits in Malaysia. They found that the most important attributes of rice varieties were food safety, taste, and size of the grain. As regards the DCE method, Mansaray *et al.* (2018) used it to provide empirical insights into farmers' preferences for seed rice variety attributes in Sierra Leone.

The results showed that potential yield, maturity, seed viability, and tolerance to pests and diseases were the most important traits driving farmers' choice decisions for the seed rice varieties. In addition, Gamboa *et al.* (2018) analyzed farmers' preferences for improved quinoa varieties in Peru.

They found that farmers generally preferred improved varieties over traditional varieties, with larger grain sizes, higher yield levels, lower levels of saponin, and a reduced maturation period as the most preferred varietal traits. In another study, Sanchez-Toledano *et al.* (2017) in their study on farmer preferences for improved corn

seeds varieties in Chiapas, Mexico found that farmers' willingness to pay was a key determinant for selecting the improved varieties of maize seeds and landraces in Chiapas, Mexico.

They also found that the improved seed varieties were preferred over the local varieties, thereby ensuring higher yields, resistance to diseases, and larger ear size. In Burkina Faso, Sanou *et al.* (2019) while trying to gain insight into farmers' preferences towards varietal attributes for cotton cultivation established that farmers had more preference towards high-yielding varieties. In Ghana, Acheampong *et al.* (2013) evaluated farmers' preferences for cassava variety attributes and found that in-soil storage and disease resistance were the most important attributes for farmers' choice of cassava varieties.

Furthermore, farmers were found more willing to forgo extra incomes and yields to obtain more disease and pest-resistant varieties and increased in-soil storage of the matured roots. Finally, Callie (2008) also used the DCE method to evaluate consumer preferences for several watermelon traits in Alabama, USA and found that most consumers preferred red-fleshed watermelons compared to yellow-fleshed ones. Moreover, flesh color was the most important attribute followed by form, price, seed content, and lycopene sticker possession.

In studies using mixed methods, Teeken *et al.* (2018) examined trait and varietal preferences of men and women cassava farmers and processors in Nigeria. They established that high yield, early maturity, and root size were the most important traits across both genders, though women mostly preferred cooking traits while men placed a higher priority on agronomic traits. In Uganda, Ajambo *et al.* (2017) in their study on important non-yield productive and consumptive attributes in new maize varieties established that maize farmers were willing to pay more for seeds of short-medium

height, short-medium maturity period, and high-yielding maize varieties. Still, in Uganda, Owere *et al.* (2014) analyzed finger millet varieties and varietal preferences among farmers and found that high grain yield, brown seed color, compact head shape, tolerance to blast disease, high tillering ability, moderate plant height, early maturity, tolerance to shattering and ease of threshing without compromising quality were the most preferred traits. Tadesse (2008) also looked into farmers' selection criteria for improved onion varieties in Ethiopia and found that early maturity, good yield, large bulb size, and good bulb color were the most important traits of the improved onion varieties.

In Kenya, Otieno (2008) examined the role of varietal traits in the adoption of Pigeon peas in Taita Taveta County, Kenya and the study established that the major pigeon pea variety attributes driving rapid adoption were drought tolerance, pest tolerance, yield, ease of cooking, taste and the variety's ability to fetch a premium price in the market. Joshi and Bauer (2006) in their attempt to identify factors that condition the adoption of selected modern varieties of rice and found that both production and consumption attributes significantly conditioned the demand for specific rice varieties. While analyzing farmers' preferences for strawberry fruit quality and plant traits, Yue *et al.* (2014) found that fruit firmness, fruit flavor, and fruit shelf life at retail were the most important traits influencing farmers' choice decisions for strawberry fruits and plants. Finally, Sumbele *et al.* (2018) in their study on sugarcane production in Cameroon established that farmers prioritized early maturity and marketability of the cane, the sweetness of the cane, and cultural and medicinal values as the top preferred traits for sugarcane varieties.

Just like in many developing countries settings, in Kenya, production decisions are mainly subsistent-oriented and production and consumption decisions are

nonseparable, Yield attributes become important considerations for all farm households (net-buyers, net-sellers, and the self-reliant). On the other hand, the price attribute is most relevant for farm households with better access to output markets and those selling most of their agricultural products. In this study, as expected price and Yield attributes played very pertinent roles in determining farm households' preferences for different crop varieties and in designing appropriate incentive-based policies. The attributes that the farmers should, take into account when selecting a new variety for crops such sweet potatoes are sweet taste, crispy, crunchy, mealy textures, dry texture, flavor, attractive color, flavor and possibly softer textures desired by different consumer groups (Derry *et al.*, 2021).

According to Hayati *et al.* (2020), industrial properties that are highly desired to assist easy processing of sweet potato, are the selection of cultivars, the size, and the shape of the tubers. The shape attribute influences peeling and trimming efficiency during processing. Stable morphological attributes that are nevertheless considered sometimes by farmers and consumers, but to a lesser degree are leaf shape, leaf color, petiole, leaf bone and stem, sweet potato skin color and sweet potato flesh. Some morphological attributes are highly determined by climate conditions and environmental elements, such as tendrils length, leaf stalk length, leaf size, and tubers yield. Product price is another important extrinsic attribute affecting the purchase decision and certainty of farmers when choosing a specific improved crop variety attributes (Lockshin *et al.*, 2006).

2.6.1 Farmer Willingness to Pay for Crop Variety Attributes

Recent literature has increasingly focused on the monetary value of traits by including a monetary price as one of the traits. Willingness to pay (WTP) measures are considered useful as they can directly inform policy makers by providing information about how much people value some goods and can thus inform the pricing of these goods and also as a tool to make relative comparisons and rankings of the desirability of the good (Hanley *et al.*, 2003). Dalton, (2004) evaluated farmer willingness to pay for rice traits in West Africa. He found high willingness to pay for plant traits such as plant length, grain elongation and tenderness. Yield was not a significant explanation factor for farmer willingness to pay for rice traits.

Asrat *et al.*, (2010) estimated farmer willingness to pay for sorghum and teff traits in their study of farmer preferences for sorghum and teff traits in Ethiopia. The estimated willingness to pay from the random parameter logit model revealed high willingness to pay values for environmental stability and yield stability traits of both crops. The results revealed that for a 100kg of sorghum and teff, farmers were willing to pay Ethiopian Birr 292 and 255 for environmental stability and yield stability trait of sorghum and only Ethiopian Birr 16 for productivity trait of sorghum. Similarly, for teff, farmers were willing to pay Ethiopian Birr 564 and 379 for environmental stability and yield stability traits and only Ethiopian Birr 28 for productivity traits.

Mendis and Edirisinghe (2013) analyzed farmers WTP for rice traits in Sri Lanka using hedonic pricing and found positive WTP for yield and disease resistance. In these studies, real market prices were assigned to traits and that made it easy to apply hedonic pricing. The results showed that farmers were willing to pay Rs 5.92 for yield trait compared with Rs 3.31 for disease resistance trait and Rs 0.03 for stem vigor trait.

2.6.2 Postulations on Farms and Farmers' heterogenic preferences for variety attribute

There are differences in the preferences for attributes based on economic status of farmers, geographic locations and their farming objective. Variety preference has been shown to be influenced by area of residence (Birol *et al.*, 2006). Birol *et al.* (2006) applied a stated preference choice experiment approach to study farmers' demand for agricultural biodiversity in the home gardens of Hungary's transition economy. They employed conditional logit model in their analysis of demands for agricultural biodiversity. The authors found that farmers' preferences depended on settlement development. Farmers that have access to markets and developed settlements relied less on their home-produced goods for food and the maintenance of agricultural biodiversity reduced.

On the other hand, farmers residing in the most isolated and economically marginalized settlements value the agricultural biodiversity and food produced in their home gardens most. In a similar study to investigate farmers' preferences for Milpa Diversity and Genetically Modified Maize in Mexico, Birol *et al.* (2007) used choice experiment data and applied latent class model to estimate farmers' preferences.

The results revealed that farm households that resided in the most economically and geographically marginalized locations preferred the intercrop diversity attribute (i.e. crop species diversity in the *milpa*, which consists of intercropping of maize, beans and squash) and intra crop diversity (i.e. maize seed variety diversity) attribute was preferred by farmers who also valued maize genetic diversity embodied in maize landraces regardless of the market integration level of the households.

Small holder farmers have limited access to extension services, inputs and output markets, and face high farm-to-market transaction costs largely due to inadequate road infrastructure (Obare *et al.*, 2003). Levels of market access for inputs and outputs influence farmers' preferences for high yield traits. Baidu-Forson *et al.* (1997) reported that farmers preferred high yielding varieties only if there were reliable markets for their produce in their study on farmer preferences for socio-economic and technical interventions in groundnut production systems in Niger. Wale and Mburu (2006) in a study on farmers' preferences for coffee variety traits discovered that farmers' preferences depended on several factors such as market access, access to inputs, access to extension and the opportunity cost of resources such as land and labor. The results revealed that farmer in more accessible areas and those who are less concerned with satisfying subsistence income preferred yield and marketability traits of coffee. In contrast, farmers in less accessible areas and those more concerned with subsistence needs preferred adaptability and yield stability traits of coffee.

Farmer preferences for variety traits are influenced not only by profit motives; rather it is the result of a complex process that is affected by several socio-economic and psychological variables. Household characteristics such as gender, education level, income and experience are important factors that can influence a decision maker's perceptions, attitudes and preferences. Results from a study of farmers' choice of the modern rice varieties in Nepal showed sources of seed, education and experience as farm and farmer characteristics influencing farmer demand for improved rice varieties (Joshi and Bauer, 2006). Asrat *et al.* (2010) found that farmers with large households and large livestock population preferred high yield trait and vice versa in analyzing farmer preferences for teff and sorghum varieties traits in Ethiopia.

In estimating farmers' valuation of agro biodiversity, Birol *et al.* (2006) employed choice experiment to Hungarian farm households and found that age is a significant factor in agro biodiversity development. Their results indicated that the elderly and experienced home gardeners preferred landraces whilst the younger and more educated families preferred organically produced home gardens.

2.6.3 Preference Heterogeneity on Crop and Livestock Attributes

Farmers' preferences for variety traits have gained increased attention in recent economic literature. In their choice of production technology, farmers have preferences not only regarding productivity but also for various attributes of crops, or farming practices. Dalton, (2004) investigated farmer rice trait preferences in West Africa (Sierra Leone, Cote d'Ivoire, and the Senegal) using hedonic pricing model and drawing upon the input characteristics and consumer good characteristics model. Results indicated farmers' preferences for production characteristics such as plant cycle length and plant height and consumption characteristics such as grain elongation/swelling and tenderness.

In an analysis to quantify farmers' demand for rice varietal attributes in the *Terai* Region of Nepal using an ordered probit model, Joshi and Bauer, (2005) found that farmers preferred production stability, tolerance to stress and consumption traits of rice. Farmers therefore prefer varietal diversity and since no single variety produces all the desired attributes, they mix several varieties of a crop. Applying multinomial logit model and analysing farmers' choice of the modern rice varieties in the rain fed ecosystem of Nepal, Joshi and Bauer (2006) found farmers' preferences for rice variety attributes such as easy threshability, usage of grains for preparing special

products (such as *murahi* fried rice and *chiura*-beaten rice), early maturity, and less irrigation requirement.

Ndjeunga *et al.* (2010) applied an ordered probit model in assessing farmer preferences for groundnut traits and varieties in West Africa (Mali, Niger and Nigeria). They found high farmers' preferences for traits such as colour of the leaves, short maturity period, yield, pod bead and taste. Using choice experiment and employing random parameter logit model, as Ndjeunga *et al.* (2010) analysed farmers' preferences for crop variety traits in Ethiopia. They established that Ethiopian farmers demonstrated high preferences for environmental adaptability (tolerance to drought and frost) and yield stability traits of teff and sorghum varieties. They therefore recommended the inclusion of these traits in future breeding programs.

Mhike *et al.* (2012) assessed farmers' selection of varieties for planting under drought stress in two droughts prone districts of Zimbabwe. Results from the study revealed farmers' preferences for high yield potential, drought tolerance, early maturity, and good performance even under poor soil conditions traits.

In their study of farmers' desired traits and selection criteria for maize varieties in KwaZulu-Natal Province, South Africa, Sibiyi *et al.* (2013) found farmers' preferences for the following maize varieties traits: high yield, disease resistance, early maturity, white grain colour, and drying and shelling qualities. These traits were embedded in local maize varieties. They concluded that breeding opportunities existed for improving the farmers' local varieties and maize breeders could take advantage of these preferred traits and incorporate them into existing high yielding varieties. Ward *et al.*, (2013) examined farmer's preferences for abiotic stress tolerance in hybrid versus inbred rice from Bihar, India using discrete choice

experiments and employing mixed logit model. Their results showed that rice farmers preferred short duration rice varieties, low seeding rates varieties and seed reusability, a trait available only in self-pollinating inbred rice varieties.

Many of the studies of farmers' preferences in the field of agriculture have concentrated on the search for preferences for livestock traits. Tano *et al.*, (2003) analysed the economic values of traits of indigenous breeds of cattle in West Africa focusing on trypanotolerance by employing conjoint ranking and ordered probit model. The results revealed that farmers have more utility towards resistance, fitness for traction and reproductive performance. Meat and milk yields, parameters often used as the basis for development of a selection index for breed improvement by animal breeders, were found to be relatively unimportant in their study, despite their being the focus of traditional economic analyses. Using choice experiments and mixed logit model, Scarpa *et al.*, (2003a) quantified the economic values of different traits of a Creole (local) pig in Yucatan, Mexico. Their results revealed high preferences for traits associated with weight gain, low feed costs, disease resistance and low bathing frequency. Scarpa *et al.*, (2003b) later employed the same method to estimate the values for the traits of indigenous cattle in Northern Kenya. Ouma *et al.*, (2007) also employed choice experiments to elicit preferences and mixed logit and latent class models to determine the relative values of traits and heterogeneities in trait preferences in the pastoral areas of Northern Kenya and South-Western Ethiopia. They find that good traction potential, fertility, trypanotolerance and reproduction performance are preferred most by farmers. Findings suggest more emphasis on nontradable traits, defeating the main objective of breeding for increase beef and milk yield.

Roessler *et al.*, (2008) employed choice experiments and multinomial logit model to investigate the relative economic weights of pig traits in Vietnam. The findings indicate that smallholder farmers who are more subsistence oriented highly value both adaptive traits (frequency of illness and feed requirement) and performance traits (live weight and litter size) and farmers who are integrated more into the market have high utility towards performance traits. Ruto *et al.*, (2008) examined the relative values of cattle traits and preference heterogeneities in Northern Kenya using choice experiments and latent class modelling. In their analyses three segments were identified and results revealed that all three segments have high preferences for exotic breeds and thus posing danger to conservation of indigenous breeds. Recently, Faustin *et al.*, (2010) applied choice experiment and mixed logit model to estimate preferences for chicken traits in Benin. Contrary to the findings above, farmers in Benin prefer traits that are found in indigenous chickens. The authors thus advocate for village chicken breeding programs to support conservation.

Choice experiment studies aimed at investigating trait preferences of plant genetic resources have mostly utilized mixed logit model to empirically model preference behaviour (Asrat *et al.*, 2009; Asrat *et al.*, 2010). Mixed logit model is a recent advancement in discrete choice analysis that overcomes the constraints of the conventional logit/multinomial logit and ordered probit models by accounting for preference heterogeneity by allowing taste parameters to vary randomly over individuals (Train, 2003). This study follows the work of Asrat *et al.*, (2010) and uses choice experiments and mixed logit model to assess farmers' preferences for improved seeds variety traits in Kenya.

2.6.4 Farmers' Choice Certainty and Consistency

It is usually a key assumption in stated preference methods that respondents are able to assess without any error the utility they may derive from the good presented to them, and hence can answer any valuation question with absolute certainty. There are numerous arguments why this assumption may not be valid, and recognizing this, several Contingent Valuation (CV) studies have investigated the causes of respondent uncertainty, as well as ways to handle it (Alberini *et al.*, 2003).

However, so far this issue has been given little attention in Choice Experiments (CE) studies, which have in recent years been increasingly used for environmental valuation. While it may be perfectly reasonable for respondents to feel uncertain about their stated responses and choices, the problem is that failing to accommodate for such uncertainty in the modelling of data may bias, if not the valuation estimates, then at least the variance estimates and hence the inference and conclusions made (Samnaliev *et al.*, 2006).

Several studies have tried to obtain opinions felt by the respondent when answering CV questions. The approaches taken can roughly be classified into two groups. The first approach is to make respondents choose among answers to the payment question, which explicitly incorporates some level of uncertainty, e.g. 'Don't Know', 'I will definitely pay' or 'I most probably will not pay' (Alberini *et al.*, 2003). The second approach is to have respondents first answer the payment question ('Yes'/'No') and then state their degree of certainty regarding the answer just provided, either in the form of a numeric scale or as text statements (Blumenschein *et al.*, 2008).

There are pros and cons of both approaches. For example, the latter has the advantage that it does not directly interfere with the valuation task, yet it hinges to some degree on researcher interpretation concerning the stated certainty in order to handle it in

estimations. This study took this approach, asking respondents to indicate their certainty post choice. This stated certainty may of course differ from true certainty, which limits how far one can make conclusions on true certainty from the observed stated certainty. However, our focus here was the evaluation of different approaches to using respondents' stated certainty in choice to improve estimations, which is a relevant objective even if it does not coincide perfectly with the unobserved true certainty in choice. How the researcher handles respondents' stated certainty will depend on what is assumed to be the reasons for the stated certainty.

Samnaliev *et al.*, (2006) summarized four such assumptions or hypotheses, which we briefly present and discuss here in a slightly different order and wording. One hypothesis is that certainty levels indicated by respondents will reflect only their attempt to appear consistent in answers: Once they have chosen 'Yes' or 'No', they indicate some degree of certainty to signal consistency. The main objection to this hypothesis is that if such behavior dominates, we should find a fairly constant level of certainty across alternatives but in fact stated certainty varies systematically with, e.g. the bid (Campbell, 2008).

A second and related hypothesis is that certainty levels may be susceptible to protesting and strategic behavior such as respondents exaggerating certainty along with stated WTP (Samnaliev *et al.*, 2006). This sort of behavior is usually screened for in quality studies and samples. While it may be a source of noise, it should not be dominant. A third hypothesis concerning preference uncertainty is that when respondents are allowed to state uncertainty, they use this option to scale down their stated WTP, i.e. an asymmetric effect on WTP reducing hypothetical bias is assumed. A fourth hypothesis is formulated by Wang, (1997) and maintains the assumption that respondents are rational, truth-telling and non-strategic, but may for different reasons assess the value of the environmental change with some degree of uncertainty and,

therefore, they may be quite uncertain as to their answer ('Yes'/'No') when the bid price is close to their maximum WTP but quite certain when very different from it. The implication is that the response itself may be subject to error which in a CE setting translates into a probability that the respondent does not choose the utility maximizing alternative.

If the third assumption is preferred, it is relevant to apply some sort of asymmetric method to correct for the signal sent by respondents stating uncertainty about their 'Yes'. A direct recoding of these answers from 'Yes' to 'No' has been applied by several authors (e.g. Champ *et al.*, 1997; Welsh and Poe, 1998), whereas Loomis and Ekstrand, (1998) propose an asymmetric uncertainty model incorporating stated uncertainty levels of 'Yes' answers into the likelihood function. Not surprisingly, the first approach implies an often-dramatic downward adjustment of WTP estimates, whereas the effect on WTP is somewhat less with the second approach. If the fourth assumption is preferred, it follows that respondents can also be uncertain about voting 'No'. This calls for a symmetric approach and several studies have suggested ways to incorporate uncertainty for all responses directly in the likelihood function, be the uncertainty level implied by the chosen answer (as in Wang, 1997 and in Alberini *et al.*, 2003), or stated on some sort of scale post decision (Loomis and Ekstrand, 1998). As noted by both Loomis and Ekstrand, (1998) and Alberini *et al.*, (2003) the symmetric approach tends to increase the estimated WTP, even if it also provides a better performing model.

Recent studies have investigated biases in respondents' processing of the different attributes in CE studies and their use of heuristics in response, as an underlying cause of uncertainty and heterogeneity (Campbell, 2008; Hensher, 2008), and found that such biases can be severe. These findings are important and its bearings on the present study had to be taken into account, if respondents were in fact not processing all

attributes as assumed. This limitation was ostensibly kept in mind as we proceeded to address our objective here: to determine the farmers' choice certainty and consistency for improved sweet potato variety attributes in Kenya. Following (Braga and Starmer, 2005) approach, this study went on to apply the use of RUM where farmers' preference uncertainty was specifically treated as a source of random behaviour instead of systematic violation of model prediction. The farmers were also required to indicate their level of certainty at the end of each choice task.

Choice certainty among respondents has for a long time been debated by researchers though the focus has varied from time to time. For instance, in the elicitation process, Manski (1995) suggests the use of direct questions to allow respondents to elicit their probabilistic assessment of hypothetical preferences. On the other hand, Bemmaor (1995) argues for a qualitative assessment of choice certainty among respondents involving ordinal measures such as "very certain" "probably not" and "certainly not." Li and Mattsson (1995) suggest yet another procedure of using a continuous certainty measure (0% to 100%) in the elicitation of respondent certainty, especially in contingent valuation choices studies. While Loomis and Ekstrand (1998), Reddy *et al.* (1995) and others suggest the use of qualitative measures for certainty rating elicitation in WTP studies, F *et al.* (1999) recommend procedures of collecting respondent's perception of certainty in the form of interval scale rather than in the form of strict numbers.

On the treatment of certainty data in the final analysis, both qualitative and quantitative information on certainty ratings has been included directly or indirectly in the final investigation of the choice data. Some researchers (Champ *et al.*, 1997; Ethier *et al.*, 2000; Champ and Bishop 2001; Lundhede *et al.*, 2009) have argued for the inclusion of elicited certainty ratings into the choice models by creating a threshold of certainty to screen out similar response data to the model. Such a practice of creating

thresholds to screen out similar response data is intended to eliminate choices that have very low certainty.

However, Norheim (2001) and Rose *et al.* (2015) have argued that the practice of scrapping low-certainty choices to remove outliers from the choice data is counterproductive and leads to loss of data since the low-certainty responses may not necessarily be wrong choices. They observe that the low-certainty choices may be a reflection of respondents' ambivalence to the choice tasks due to task complexity and should therefore not be scrapped off. As Hensher *et al.* (2012) note, the elicited certainty rating on any choice task may be essentially a function of choice task complexity arising from the number of alternatives, attributes, and their levels in the choice tasks.

As for the nature of the final results after the integration of choice certainty in the final analysis, Shaikh *et al.* (2007) report that accommodation of certainty in a choice model may not only result in better goodness-of-fit of the choice model but may also introduce some additional variance. Lundhede *et al.* (2009) also find that the incorporation of the elicited certainty in the choice analysis may not necessarily improve the performance of the choice model, but rather provide a structurally stable way of accommodating such additional information into individual preference investigation.

While Beck *et al.* (2013) observes that the lack of a proper theoretical background of accommodating the elicited certainty ratings into choice modeling could be the main reason for serious difficulties in explaining the influences of such ratings on individual choices, Dekker *et al.* (2016) find that innovative models such as their own integrated latent variable choice model designed to exploit the elicited certainty ratings into the DCE model estimation process may pose several challenges in the estimation of the

choice model with even no prove to show improved model fit or statistical significance of the parameter estimates.

Notably, the present paper however does not explore how to incorporate the elicited choice certainty into the discrete choice model, but rather on the intuitive way of handling the elicited choice certainty data to yield information that could inform further research on incorporating such certainty data into the DCE models. For the first time, the paper applies a procedure initially used by Chang *et al.* (2007) and Wang and Whittington (2005) to estimate welfare estimates corrected for response uncertainty to analyze the kind of certainty scores generated by the 0–10-point certainty scale and further establish the empirical relationship between choice certainty and consistency. Following Chang *et al.* (2007) and Wang and Whittington (2005), suppose that individual choice certainty associated with a given choice task is so that all have a mean value of μ_i and standard variance is σ_i , then the choice certainty model can be represented as:

$$C_i = \mu_i + \varepsilon_i \quad (7)$$

Where ε_i is a random term with a mean of zero. Assuming that individual i well knows her preferences and the choice certainty over any given choice task c , then μ_i and σ_i can be derived and estimated for each individual i and thereafter, used to construct linear models to analyze relevant explanatory factors for the elicited certainty scores. A choice consistent variable can also be added to the model to assess the statistical relationship with choice certainty. A functional form that can be used to relate μ_i and σ_i with relevant explanatory factors and the choice consistent variable is:

$$\mu_i = \beta_0 + x_i' \beta + z \delta + \varepsilon_1 \quad (8)$$

$$\sigma_i = \alpha_0 + w_i' \alpha + z \delta + \varepsilon_2 \quad (9)$$

Where x'_i and w'_i are personal specific variables, z is the choice consistent variable, β , α and δ are coefficients to be estimated while ε_1 and ε_2 are random errors.

2.6.5 Inferred and Stated Attribute Non-Attendance

Past empirical research on ANA can be largely categorized into two categories: stated ANA and inferred ANA. The former consisted of asking respondents explicitly if they had examined all criteria defining the alternatives in the choice tasks or if they had overlooked one or more attributes when making their selections. Alternately, nonattendance questions may be posed after each decision set (e.g., Scarpa *et al.*, 2009), and the responses to these questions are then utilized to impose specific constraints on Random Utility models. Despite this, there is a consensus among researchers (e.g., Scarpa *et al.*, 2009; Hensher *et al.*, 2005, 2011; Hole, 2011) that disregarding ANA can lead to significantly erroneous estimates of policy outcomes in a DCE survey.

The initial research to examine ANA (e.g., Hensher *et al.*, 2005) employed the responses to a binary stated non-attendance question to design a mixed logit model in which respondents who claimed that they disregarded a particular characteristic were anticipated to have zero utility. Estimating distinct coefficients for each characteristic, one for the set of respondents who indicate that they did not disregard the attributes and one for those who state that they ignored the attributes, has also been employed to address the declared non-attendance issue (Hess and Hensher, 2010; Scarpa *et al.*, 2013; Colombo *et al.*, 2013). Nevertheless, declared ANA's trustworthiness has been called into question for several reasons.

First, it has been argued that respondents may assign low importance to an attribute but state that they completely ignored it (e.g. Hess and Hensher, 2010), resulting in an overestimation of ANA (e.g. Carlsson *et al.*, 2010). Second, the direct incorporation of

non-attendance question replies into the RUM may pose significant endogeneity bias issues (e.g. Hess and Hensher, 2010). Thirdly, further material raises doubt about dependability of supplementary questions regarding absenteeism (e.g. Hensher and Rose, 2009; Hensher and Greene, 2010). With these constraints of stated nonattendance inquiries, there has been a growing interest in the literature on econometrically inferring ANA from the stated preferences of persons. In addition, some research has incorporated the examination of both declared and inferred nonattendance within the same study. The overall finding, however, has proven that findings from inferred and stated ANA are inconsistent, and that inferred ANA gives a higher model fit and, therefore, more believable policy outcomes than stated ANA.

Researchers (e.g. Hensher *et al.*, 2005; Hess and Hess, 2010; Scarpa *et al.*, 2013) have found that accounting for ANA improves the model fit and policy conclusions of the DCE survey, regardless of the angle used to analyze ANA. They have also found that accounting for ANA may tend to under-exaggerate (e.g. Hensher, 2006; Campbell *et al.*, 2008; Scarpa *et al.*, 2009) or exaggerate (e.g. Hensher *et al.*, 2005; Hensher and Rose, 2009; Hensher and Greene, 2010; Lagarde, 2013) the policy conclusions deriving from a DCE survey in comparison to when ANA is not accounted for in the analysis of choice data. Moreover, studies have also proven that indeed the DCE respondents utilize various information processing processes in their choice behavior for product features.

As such and with all the afore facts in mind, this study aimed to infer ANA from the stated choices of individuals using a prominent latent class modeling approach known as the Equality Constrained Latent Class (ECLC) model. It assumes that a discrete number of classes or segments of respondents are sufficient to account for preference heterogeneity among classes. The ECLC allows the choice attribute data and

individual consumer personal characteristics to simultaneously explain choice behavior. In this modeling framework, ANA is operationalized by allowing some respondents to belong to latent classes with zero utility weights for selected attributes, while non-zero parameters are assumed to take the same values across classes (e.g., Scarpa *et al.*, 2009, 2013; Hensher and Greene, 2010; Campbell *et al.*, 2011; Hess *et al.*, 2013).

2.6.6 Modelling of Crop Varietal Attributes with Farmers Socioeconomic Characteristics

Considerable evidences have been gathered concerning farmers' adoption behaviour including technology specific characteristics, farm and farmer-associated characteristics and farming objectives (e.g., Feder *et al.*, 1985; Kaliba *et al.*, 1998; Badal *et al.*, 2007; Faturoti *et al.*, 2006). In studying improved varieties adoption, age has been found to be one of the human capital characteristics frequently associated with non-adoption of improved varieties in many adoption studies (Gould *et al.*, 1989; Polson and Spenser, 1991; Simtowe *et al.*, 2009; Badal *et al.*, 2007; Etounde and Dia, 2008; Langyintuo and Mekuria, 2008). In Tanzania Kavia *et al.*, (2007) analyzed the determinants of the extent of adoption of improved cassava varieties using Logit and Tobit models. They found that age positively affected the extent of adoption.

By employing negative binomial model in an analysis of adoption rates, variety attributes and speed of adoption, Abele *et al.*, (2007) found positive influence of age on adoption of improved cassava varieties in Uganda. Owusu and Donkor, (2012) used Tobit model in their study of factors influencing adoption of improved cassava varieties in southern Ghana and reported of negative relationship between age and extent of adoption. In a study of economics of improved and local cassava varieties in

Nigeria, Mohammend-Lawal *et al.*, (2012) found age to be positively associated with households' adoption of improved cassava varieties.

The gender of household head has also come out strongly as influencing the adoption of improved varieties. The general assertion is that women are generally discriminated against in terms of access to external inputs and information (De Groote and Coulibaly, 1998; Doss, 2001; Langyintuo and Mekuria 2005a; Quisumbing and Pandolfelli, 2009; Peterman *et al.*, 2010; Ragasa, 2012). Studies by Dankyi and Agyekum, (2007), Abele *et al.*, (2007) and Kavia *et al.*, (2007) in Ghana, Uganda and Tanzania on determinants of improved cassava adoption found no significant effect of gender on adoption. A study of large scale adoption of improved cassava varieties in southern Nigeria by Tarawali *et al.*, (2012) found positive effect of gender on adoption and suggested that males are more likely to adopt improved cassava varieties. Nwakor *et al.*, (2011) analysed factors affecting adoption of improved cassava varieties in Nigeria and found positive effect of gender on adoption. They found that males are more likely to adopt improve cassava varieties. Njine, (2010), who analysed social and economic factors hindering adoption of improved cassava varieties in Kenya, found no effect of gender on adoption.

The influence of household size on the decision to adopt improved agricultural technologies is vague. Whilst some empirical studies find positive effect of household size on adoption of improved varieties (Teklewold *et al.*, 2006), others find negative effect of household size on improved varieties (Amaza *et al.*, 2007). Many studies on determinants of adoption of improved crop varieties have found household size important in decision to adopt improved cassava varieties. In Nigeria, Udensi *et al.*, (2011) found negative and significant relationship between household size and adoption of improved crop varieties and Mohammend-Lawal *et al.*, (2012) found positive effect of household size on adoption. Abele *et al.*, (2007) found positive

influence of household size on adoption of improved cassava in Uganda. In Ghana, Owusu and Donkor, (2012) found that household size related positively to extent of adoption of improved cassava varieties. The importance of education and experience in enhancing human capital through acquisition and learning of skills has been well documented (Feder *et al.*, 1985; Asfaw and Admassie, 2004). Education enhances the ability of human beings to perceive, to interpret correctly and to undertake actions that will appropriately reallocate their resources (Adegbola and Gardebroek, 2007). In improved crop adoption, education and experience have been found to explain adoption decisions. In Nigeria, many authors (Imoh and Essien, 2006; Nwakor *et al.*, 2011; Tarawali *et al.*, 2012) have found education and experience to positively influence adoption of improved seed varieties. In Ghana and Tanzania, Owusu and Donkor (2012) and Kavia *et al.*, (2007), found that level of education has positive influence on adoption of improved seed varieties.

Farm size has also been influential in improved varieties adoption studies (Morris *et al.*, 1999; Simtowe *et al.*, 2009; Langyintuo and Mekuria, 2008). These studies assert that farmers with larger farm holdings are more likely to try new technologies as they can afford to devote part of their field to try out the new technology. Improved seed varieties adoption is of no exception. Farm size is found to influence adoption of improved seed varieties positively in most adoption studies in Nigeria (Imoh and Essien, 2006; Udensi *et al.*, 2011; Mohammend-Lawal *et al.*, 2012; Madu *et al.*, 2008). Kavia *et al.*, (2007) also found significant relationship of farm size with adoption of improved seed varieties in Tanzania.

Land tenure and access to credit are institutional factors often considered to influence the acceptance of new technologies (Feder and Onchan, 1987; Basely, 1995). In improved seeds adoption, Tarawali *et al.*, (2012) and Udensi *et al.*, (2011) found negative relationship of land ownership with improved seeds adoption in Nigeria.

Onyemauwa, (2012) however found positive relationship of land ownership with improved seed varieties participation in Nigeria. Kavia *et al.*, (2007) and Dankyi and Agyekum, (2007) in their study of extent of adoption of improved cassava varieties in Tanzania and Ghana found positive and significant effect of land ownership on adoption.

Kagya-Agyeman, (2001) and Owusu and Donkor, (2012) found credit access to be positive and significant in decisions to adopt improved seed varieties in Ghana. Orebiyi *et al.*, (2005) and Okpukpara, (2010) analyzed determinants of contract farmers' adoption of improved seeds technologies in Nigeria. They found that credit access played significant role in the adoption of the improved seeds technologies.

Distance to input and output market is another important factor affecting adoption of agricultural technologies. The observation has been made' that long distances to markets decreased the probability of adoption of new technologies while short distances increase adoption probability of improved technologies (Salasya *et al.*, 2007; Langyintuo and Mekuria, 2008). Udoh and Kormawa, (2009) analysed the determinants for cassava production expansion in the semi-arid zone of West Africa and reported that distance to nearby urban markets is a major influence on cassava adoption in Ghana, Chad, Nigeria and Burkina Faso.

The importance of agricultural extension systems in agricultural technology adoption cannot be underestimated. Many empirical studies, (Wozniak, 1993; Feder *et al.*, 1995; Adesina and Baidu Forson, 1995) have identified agricultural extension as being the most efficient source of information of improved technologies to farmers. Abele *et al.*, (2007) reported positive impact of access to extension on adoption of improved seed varieties in Uganda. In Nigeria, many studies, (e.g., Omonona *et al.*, 2006; Madu *et al.*, 2008; Onyemauwa, 2012; Omoregbee *et al.*, 2013) on

determinants of improved variety adoption have found extension access as very influential in farmers' decision to adopt improved seeds varieties. Farmers contact with extension was found to affect cassava varieties adoption in a study conducted in five semi-arid regions of Africa (Ghana, Chad, Nigeria, Burkina Faso and Niger) (Udoh and Kormawa, 2009). The number of times of extension visit and participation in field days and demonstrations are also found to be very influential in improved cassava adoption. Dankyi and Agyekum, (2007) reported of frequency of extension visits having effect on improved cassava adoption in Ghana. Number of times of extension visit was significant and positive in studies of determinants of farmers' participation in improved cassava varieties in Nigeria (Orebiyi *et al.*, 2005; Onyemauwa, 2012).

2.7 Uptake of planting materials of Improved Crop Varieties (Improved Sweet Potato Cultivars)

Adoption is simply the use of a technology and it is part of a decision-making process (Rogers, 1995). Adoption of an innovation is the decision to apply the innovation and continue to use it. The process consists of a series of actions and choices over time and through that an individual evaluates a new idea and decides whether to integrate the idea into an ongoing practice. Feder *et al.* (1985), define individual adoption, as the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the new technology and its potential. Information therefore is necessary in the adoption process. As noted by Rogers (1995), four factors influence adoption of an innovation and these include 1) the innovation itself, 2) the communication channels used to spread information about the innovation, 3) time, and 4) the nature of the society to whom it is introduced. There are four main postulations that deal with the adoption of agricultural technologies. These are the

innovation-diffusion outlook, the economic constraint outlook, the central source of innovation outlook and the multiple source of innovation case. Economic constraint postulation assumes that, in the short run, inputs such as access to credit, land, labor or other critical inputs are fixed. These actually limit production flexibility and condition technology adoption decisions.

2.7.1 The Innovation-Diffusion Outlook

The innovation-diffusion outlook consists of four processes. These are the innovation decision process, the individual innovativeness process, the rate of adoption and the perceived attributes processes (Rogers, 1985). The innovation-decision process case is based on time and five distinct stages. The first stage is knowledge. Potential adopters must first learn about the innovation. Second, they must be persuaded as to the merits of the innovation. Third, they must decide to adopt the innovation. Fourth, once they adopt the innovation, they must implement it. Fifth, they must confirm that their decision to adopt was the appropriate decision. Once these stages are achieved, then diffusion results.

The individual innovativeness outlook is based on who adopts the innovation and when. A bell-shaped curve is often used to illustrate the percentage of individuals that adopt an innovation. The first category of adopters is innovators (2.5% of the potential adopting population). These are the risk-takers and pioneers who lead the way. The second group is known as the early adopters (13.5%). They climb on board the train early and help spread the word about the innovation to others. The third and fourth groups are the early majority and late majority. Each constitutes 34% of the potential adopting population. The innovators and early adopters convince the early majority. The late majority waits to make sure that adoption is in their best interests. The final group is the laggards (16%). These are the individuals who are highly skeptical and

resist adoption until absolutely necessary. In many cases, they never adopt the innovation (Rogers, 1995).

The postulation of rate of adoption suggests that the adoption of innovations is best represented by an s-curve on a graph. The argument holds that adoption of an innovation grows slowly and gradually in the beginning. It will then have a period of rapid growth that will taper off and become stable and eventually decline.

The case of perceived attributes is based on the notion that individuals will adopt an innovation if they perceive that the innovation has the following attributes. First, the innovation must have some relative advantage over an existing innovation or the status quo. Second, it is important the innovation be compatible with existing values and practices. Third, the innovation cannot be too complex. Fourth, the innovation must have triability. This means the innovation can be tested for a limited time without adoption. Fifth, the innovation must offer observable results.

The innovation diffusion outlook assumes that innovations are well developed but the individual's inability to adopt is due to improper communication (Feder and Slade, 1984; Shampine, 1998; Smale *et al.*, 1994). To encourage adoption, the use of extension, experiment station visits, on-farm trials and other means of expression to transmit technical information are emphasized. The innovation diffusion model has a number of limitations. One of the major limitations of the model is that it generally assumes that the most important variable is information and the willingness of the individual to change. An individual is characterized according to his behavior without considering factors that influence his behavior. In actual fact many other factors are known to influence the adoption of an agricultural innovation. These include the farmer's objectives, the level of the resource endowments of the individuals, access to

resources, availability of support systems and the characteristics of the innovation (Adesina and Zinnah, 1993, Shiyani *et al.*, 2003).

2.7.2 Economic Constraint Postulation

The economic constraint postulation assumes that, in the short run, inputs such as access to credit, land, labor or other critical inputs are fixed. These actually limit production flexibility and condition technology adoption decisions (Smale *et al.*, 1994; Shampine, 1998). Economic argument perceives farm households as decision makers whose concerns are how much to devote to the cultivation of each crop, whether or not to use purchased inputs, which crops to grow on which fields, and so on. These they do depending on their goals or objectives and the resource constraints of the individual farming household. The economic constraint model makes various assumptions. The model assumes that the household acts as a unified unit of production and consumption that aims to maximize utility subject to its production function, income and total time constraint. Utility is described as the satisfaction an individual derives from a set of commodities, which is attained from consumption. The main characteristic of the model is the use of a single decision maker and the implicit assumption is that there is no inconsistency within the household and that all members have the same utility function so that maximizing the household utility would yield similar results as maximizing individual functions.

2.7.3 The Central Source of Innovation Argument

Another important argument that has been used for a long time to explain agricultural research and technology diffusion is the central source of innovation postulation. The model is also known as the transfer of technology technique. In this model, innovations are seen to move gradually from the international agricultural research

institutions, national agricultural systems, to national extension systems and finally to farmers (Biggs, 1990). This model's emphasis is placed on the transfer of knowledge and technology from research institutions to farmers. The key feature of the model includes assignment of clear-cut roles to specific institutions and groups of people. Research institutions have either an international or national mandate to conduct research, extension agents are only supposed to pass on the results, whereas farmers are seen as technology adopters or people who have problems that are fed back to extension advisers and researchers. The process of technology generation and transfer is seen as a linear process where scientists develop technology, demonstrate it to farmers through the extension agents, and the farmers adopt it in the final stage. The research institutions are the only source of information. Thus, farmers' experience, knowledge and resources are ignored and farmers are seen as passive receivers of technology (Leeuwis and van den Ban, 2004). But even with full technical information, farmers may subjectively evaluate the technology differently than scientists (Adesina and Zinnah, 1993, Shiyani *et al.*, 2003; Norris and Batie, 1987). As farmers are the eventual decision makers in the adoption process, understanding whether or not their perceptions of a given technology are important in the adoption process is critical to designing information dissemination programs.

2.7.4 Multiple Source of Innovation Case

This case suggests that there are diverse needs and resources of beneficiaries of innovations and views the users not merely as adopters but as active participants in the process of technology development and adoption. This is an outlook that builds on the central source of innovation argument by highlighting the active participation of all beneficiaries instead of agricultural institutions. Therefore, agricultural innovations are derived not only from agricultural research institutions but from multiple sources.

These sources include farmers, innovative research practitioners, non-governmental organizations, private corporations and extension agents (Biggs, 1990). In the multiple source models, perceptions of the users of technology are seen as important in helping to develop and transfer locally usable innovations (Nguthi, 2007). The multiple source of innovation model includes the use of participatory approaches that have evolved from efforts to improve technology development and dissemination. Participatory methodologies are often characterized as being reflexive, flexible and interactive, in contrast with the rigid linear central source model (ibid).

2.8 Assessment of Improved Seed Variety Attributes: The Crop Breeders’

Perspective

Plant breeders have often used selection index to assign values to traits before coming up with varieties (Sölkner *et al.*, 2007). Index selection involves simultaneous selection of multiple traits in the same generation. The breeder creates a single new “trait,” the index, which is a function of the multiple traits that are under selection. Selection among genotypes or lines is then performed based solely on the index value rather than the values of the individual traits. Index selection is essentially a method for weighting the individual traits based on their perceived importance and the opportunity for improvement (Luby and Shaw, 2009). Relative economic value is predicted on a combination of genetic and economic information in a regression equation for the prediction of the value of a genotype. Economic value is usually expressed in monetary terms; however, it is taken to mean by economists as difference in preference or utility levels. It is generally assumed that individuals are the best judges of what they want. Economic valuation is therefore based on individual preferences and choices. The assumption is that each genotype has an

aggregate genetic value that is a function of its performance for the multiple traits being considered. Luby and Shaw, (2009) defined relative economic value as:

$$Y = E_1G_1 + E_2G_2 + \dots + E_iG_i \quad (2.9)$$

Where; Y =Relative economic value, E_1 = Economic value of the first trait and G_1 is the corresponding genetic value of the first trait.

The large amount of genetic variability continuously created is then drastically reduced through selection and surviving lines and spread among farmers. Formal breeding tends to focus on "broad adaptability and, therefore, candidate genetic material that yields well in one growing zone, but less in another, is quickly eliminated from the breeder's gene pool (Cecarelli, 1997).

No end-users' involvement is realized at this stage implying that breeders make assumptions that are supposed to fit end-users' objectives. Bhandari (1997) states the following assumptions as underlining conventional breeding: 1) farmer participation is unnecessary as farmer involvement is costly, cumbersome and farmers are less knowledgeable than university-trained plant breeders; 2) varieties with high local adaptation are less desirable than varieties with wider adaptation - breeders should select from multi-locational trials only those varieties that perform well across locations; 3) selection must be done under optimal conditions where heritability, and hence responses to selection, are assumed to be higher; 4) any low adoption of modern varieties is due to ineffective extension, or to the insufficient supply of quality seed, or to the inefficient agronomic practices employed by farmers, and not due to deficiencies in the released crop varieties; 5) seed supply should only be in the domain of the formal sector, which is far more efficient than farmer-led systems and the only possible source of quality seed; the informal seed supply system involves farmers in unnecessary risks as they have limited capacities and expertise (Ceccarelli

et al., 1996). As a result, farmers' participation has been very low in varietal testing and release systems. Farmers' participation is limited to the final steps: evaluating and commenting on few near finished or advanced varieties just prior to their official release (Thiele *et al.*, 1997; Fukuda and Saad, 2000; Manu-Aduening *et al.*, 2006).

It is clear from the economics of plant breeding theory that genetic improvement should be on traits of economic importance. However, formal breeding systems have emphasized too much on yield, measured a limited number of traits, and rarely if ever, have employed a system of trade-offs between those traits (Witcombe *et al.*, 1998). Formulating breeding objectives that incorporates crop sector objectives, farmers preferred traits and needs, environmental constraints and social concerns may encourage the adoption and use of improved crop technologies such as high yielding and disease-resistant varieties.

2.9 The Agriculture sector in Kenya

Agriculture is the mainstay of Kenya's economy and the growth of this sector is crucial to the country's overall economic and social development. The sector directly contributes about 26% of Gross Domestic Product (GDP) and a further 27% through linkages with manufacturing, distribution and service-related sectors. The sector accounts for 65% of the country's total exports and supports 18% of formal employment and more than 60% of informal employment in the country (Vision 2030, 2010). Therefore, this sector is not only the driver of Kenya's economy, but also the means of livelihood for the majority of the Kenyan people (MOA, 2009).

Kenya's agricultural sector is currently guided by Vision 2030 which is an umbrella economic development strategy that was developed in 2007. At the sector level, development is currently guided by the Agricultural Sector Development

StrategyASDS (2010-2020) (GoK, 2010). The thrust of the ASDS, which is the overall national policy document for the sector ministries and all stakeholders in Kenya, is to increase agricultural productivity, commercialization and competitiveness of the agricultural commodities to enable the sector towards contributing to achievement of the goals of attaining national food security, increased exports for foreign exchange earnings and employment creation. The Government has therefore developed subsector/commodity-specific policies to address key challenges and constraints. These include Food and Nutrition Policy (2007); National Seed Industry Policy and the National Agricultural Sector Extension Policy among others.

Kenya's agriculture is predominantly rain-fed and its performance is mainly influenced by weather conditions from one year to another. With the deteriorating climatic conditions, and primarily due to global warming, annual growth rate in agricultural value addition has been on the decline. This clearly points to the need to promote irrigation-based agriculture and more drought tolerant crops such as sorghum. Sweet potato cultivars of all types are essentially drought tolerant. Smallholder farmers are the dominant producers accounting for 70% of total marketed agricultural production, with average farm sizes of 1.6 hectares. Although there is no recent trend analysis of national household land holding size, the average farm size is believed to be declining rapidly with continued sub-division of household farms resulting in uneconomical landholdings. Therefore, enhancing the performance of smallholders through promotion of intensive mixed farming is critical to future agricultural growth. This should include the provision of quality and timely support services including extension to promote appropriate agricultural practices, optimal usage of modern inputs as well as the use of well adapted crop varieties. Kenya has a dynamic national agricultural research system which provides improved varieties and appropriate

farming technologies. The problem lies in the low rate of adoption among smallholder farmers. The private sector plays a key role in distribution of agricultural inputs through the numerous input supply systems.

2.10 Analysis of Seed System in Kenya

The Kenyan seed industry structure comprises the formal and informal systems and these two systems differ in their magnitude and importance, depending on the commodities they support. It is apparent that commodities that have been supported by massive research efforts tend to have more formal than informal seed system, whereas those regarded as orphan crops are governed more by informal rather than formal seed system (Ayieko and Tschirley, 2006). Table 2.1 shows the plurality of seed systems in Kenya with examples of crops in the various systems.

Table 2.2: Plurality of seed systems in Kenya

Seed system	Description	Examples of crops in the system
Farmer-based	Seed saved, used, exchanged and sold between individual farmers.	Sweet potato; Irish potato; bananas; beans; cowpea; millet; sorghum
Community based	Seeds produced, multiplied and either sold or shared within a community	Cassava
Relief seed	Civil society organizations, non-governmental organizations and relief agencies purchase seed either from the public and private sector and distribute to farmers	Hybrid maize; OPV maize; tomatoes; kale; onions
Public formal	Breeding, seed production, multiplication and distribution by public sector only	Wheat; hybrid maize
Mixed public/private	Breeding undertaken by public sector; seed production, multiplication and distribution by private sector	Hybrid maize; OPV maize; beans
Closed value chains	Breeding, seed production, seed multiplication and seed distribution all undertaken by private sector only	Pineapples; flowers; tobacco

(Source: Munyi and De Jonge, 2015)

About 80% of all the seeds used in Kenyan farming systems come from the informal sector; though despite this, the importance of the informal seed system has been largely underplayed and unappreciated as a distinct and expanding system (Ayieko and Tschirley, 2006). Table 2.2 below shows the proportion of seed that passes through the formal and informal systems for selected commodities.

Table 2.3: Proportion of seed made available from different sources in Kenya

Informal System			Formal System				
Crops	Farm-Saved seeds	Community based schemes	Public Comp local	Pvt	Private Foreign Comp	Gov.Distribution Schemes	Donors/NGOS
Bananas	80	0	20	0	0	0	0
Beans	80	0	5	0	10	0	5
Wheat	93	2	5	0	2	0	0
Cow-pea	75	8	10	2	0	0	5
Ground-nut	80	3	0	10	0	0	7
Maize	32	6	40	15	5	5	1
Millet	90	3	1	2	0	0	4
Pigeon-pea	80	0	6	4	0	0	10
Rice	15	0	85	0	0	0	0
Sorghum	87	0	4	5	0	2	2
Soy-bean	99	1	0	0	0	0	0
Sweet potato	96	3	1	0	0	0	0
Overall	76	2	15	3	1	1	3

(Source: Ayieko and Tschirley, 2006)

With the exception of maize and rice, the seed of other commodities are mainly sourced from the informal seed systems. By comparing the formal and informal seed systems in terms of value shares, formal seed sources account for more than half (52%) of all seed used in the country, compared to 40% from retained sources and only 8% from informal seed purchases (Table 2.3). The wide disparity in shares could be explained by the high cost of seed from formal sources compared to those from informal purchases.

Table 2.4: Value share of seed and planting materials sources

Seed Type	Share of total value of seed used in country	Share of total value of crop production in country
Retained Seed	40	42
Informal seeds purchased	8	10
Formal seeds purchased	52	48

(Source: TAMPA, 2004)

The formal seed source is dominated by cereals, pulses and industrial crops. Among the cereals and pulses, more than half (52%) of the seed by value is from formal seed purchases, while another one-third (34%) of the seed is farm-retained. Among the cereals and pulses, maize dominates the formal seed purchases (87%). This is due to widespread use of hybrids since maize is the most important cereal in Kenya and serves as the staple food for more than 90% of the population (ISAAA, 2001). Vegetables and other non-tree fruits are also mainly grown from retained seed sources (43%) and informal sources (34%), while the tree fruits are mainly produced from retained seedlings (**Table 2.4**) (Muthoni and Nyamongo, 2008).

Table 2.5: Value share of seed source by commodity group

Commodity group	Informal Sources	Formal Sources Purchase	
		Informal	Formal
	Farm retain		
Cereals and pulses	34	14	52
<i>Of which: Maize</i>	10	3	88
Others	58	24	17
Tubers	84	16	0
Veg & non-tree fruits	43	34	22
Industrial crops	1	0	99
Tree crops	93	7	0
Fodder	98	1	1
Overall	40	8	52

Source: TAMPA (2004)

In terms of value, formal seed sources are important for all agro-ecological zones, except in the Eastern and Coastal Lowlands. Over 40% of all seed purchases from the formal channels are for maize in the high potential maize zone. But retained seed use is spread across a wider geo-graphical area and more crops. Four-fifths of all seed used in Eastern Lowlands by value is retained seed. This may be attributed to the fact that the Eastern and Coastal lowlands are generally arid and semi-arid areas (Table 2.5).

Table 2.6: Value share of seed sources by agro regional zones in Kenya

Zone	Informal sources	Formal sources purchase		Total
		Informal	Formal	
	Farm retain			
% value				
Central highlands	49	10	41	100
High potential maize zone	31	7	61	100
Eastern lowlands	80	11	9	100
Western lowlands	45	7	48	100
Western transitional	11	4	85	100
Western highlands	35	6	60	100
Coastal lowlands	55	36	19	100

Source: TAMPA (2004)

The informal seed sector has been in operation in Kenya for a long time, particularly for the small scale farmers. The National Seed Policy reveals that the source and quality of most of the planting materials and seed purchased, multiplied and marketed by the informal seed sector may not be known, yet this is the major source of planting material for the Kenyan farmers. Informal sources of seed include farm-saved seed, farmer-to-farmer exchange, local markets, Non-Governmental Organizations (NGOs) and Community Based Organizations (CBOs). Growers of flowers and ornamental plants do import and/or locally multiply planting material for their own use or sale to other local growers, yet they are not registered as seed dealers. Moreover, some Relief Agencies who supply emergency seed, do not always obtain such planting material from registered seed dealers, and so such seed may not be of known quality. However, the informal seed sector sometimes voluntarily uses KEPHIS seed testing services to determine quality status of their seed for own use. As farming becomes more

commercial, the focus is shifting towards formal seed though (Muthoni and Nyamongo, 2008).

The informal seed sector in Kenya can be divided in at least three different categories: farmer-based seed systems, community-based seed systems, and relief seed systems.

These categories are not absolutely distinct but sometimes overlap depending on the types of crops and seed value chains operating. The farmer-based seed systems are normally characterized by individual farmers saving seed from harvests, exchanging seed with their neighbors or purchasing grain from the local market and using the same as seed for planting in subsequent seasons (Almekinders & Louwaars, 1999). In many instances, it may involve individual farmers selling excess farm produce to other farmers as seed. The bulk of seed and planting material for vegetative propagated crops such as sweet potato (96%), cassava (93%) and bananas (80%) is mostly obtained from farm- saved sources (Ayieko & Tschirley, 2006). For legumes and small- grain cereals Ayieko & Tschirley, (2006) have found the scenario as similar, as 80% of bean seed, 75% of cowpea seed, 90% of millet seed and 87% sorghum seed is obtained from farm-saved sources. Hybrid maize is the least, with only 15% of seed being farm- saved (Ayieko & Tschirley, 2006). Ayieko and Tschirley, (2006) estimate that for all crops cultivated in Kenya, 78% of seed used comes from informal seed sources. Smallholder farmers, whose farm size averages 0.2-3 hectares, account for 75% of the total agricultural output and 70% of marketed agricultural produce (GOK, 2010). As such, seed from farmer-based seed systems contributes substantially towards the total agricultural output in Kenya (Munyi and De Jonge, 2015).

Community-based seed systems normally involve associations of individuals, that are usually organized as a group or cooperative through the support of non-governmental organizations or state agents that assist them in entrepreneurial forms of seed multiplication and the marketing of seeds. These systems are established either to

support other farming systems recovering from systemic stress such as drought, pests or diseases or to strengthen farmer-based systems with improved varieties or seed quality enhancing techniques. These systems are characterized by unregulated (informal) seed quality control mechanisms (Munyi and De Jonge, 2015). However, an intermediate category of seed systems in which farmer associations or cooperatives go into commercial seed production does exist in Kenya. The associations produce Quality Declared Seed or Standard Seed which is sold in local markets and as such does not necessarily compete with national varieties and the seed companies that market them (Ayieko & Tschirley, 2006).

Relief seed, which is different from subsidies, comprises another critical seed system especially in times of disaster. Like other countries in the Horn of Africa, Kenya experiences drought from time to time (Sperling *et al.*, 2004). Seed aid programs started emerging as early as the 1990s with the aim of assisting the afflicted farmers overcome acute stress and seed shortages. Seed aid programs have been initiated by the government in certain areas as a result of drought or internal displacement of farming populations. Non-governmental organizations such as CRS have also been engaged in seed aid activities since 1992, distributing both certified and farmerproduced seed. Official and unofficial maize seed aid, followed by vegetable seed aid (tomatoes, kale and onions) has dominated in relief seed recipient areas. Sperling *et al.*, (2004) have found that seed aid has been delivered on a fairly large scale about every other season, and across a large number of districts in Kenya.

The formal seed sector in Kenya is multi-faceted in nature, comprising three main categories that can be classified as the public formal seed systems, mixed public private seed systems and closed value chains. In public formal seed systems, the public sector undertakes all the activities in the seed value chain - from breeding to seed distribution. The wheat seed system in Kenya is one example of a public formal

seed system. It is not the only mode of delivery of seed to farmers for this crop but it is the second most important source of seed for wheat after farmer-based seed sources (Mahagayu *et al.*, 2010). Currently, all wheat-breeding activities are undertaken by KALRO, which also undertakes seed production, multiplication and distribution through its own Seed Unit and contracted seed growers. Furthermore, it also contracts the Agricultural Development Corporation (ADC), a state agent for seed multiplication. Wheat seed distribution is also undertaken through the National Cereals and Produce Board, another government agent. Distribution of seeds of other crops is also undertaken through ADC and the KALRO Seed Unit (Munyi and De Jonge, 2015).

Mixed public private seed systems are characterized by participation of both the public and private sector in the seed value chain. The public sector usually undertakes breeding research while the private sector multiplies and distributes seed to farmers. Private sector participation in seed value chains in Kenya is vibrant albeit to varying degrees. There are around 100 registered seed companies in Kenya. Most of the 100 registered private seed companies undertake seed multiplication and distribution, leaving plant-breeding research, which is capital intensive and risky to KALRO. Thus, most seed companies obtain breeder material, mainly maize but also beans and other legumes, from KALRO and these are multiplied under supervision by the Kenya Plant Health Inspectorate Service (KEPHIS) (Munyi and de Jonge, 2015). However, some private seed companies have registered their own varieties and do maintain them, while others import and resell seed from other countries.

Closed value chain seed systems refer to those seed systems that are entirely controlled by the private sector from plant breeding to distribution of seed to farmers and the marketing (and processing) of their produce. They are characterized by minimal government involvement in the value chain except in seed quality control and

certification, mainly to prevent introduction of pests and diseases. This is the dominant seed system for fruit crops, vegetable crops, flowers and tobacco. The closed value chain seed systems are effectively governed by and utilize plant breeders' rights. For example, in the 2010/2011 financial year, of the 69 applications for plant breeders' rights made in Kenya 30 were in respect of roses (KEPHIS, 2011).

2.10.1 Nature of Commercial Availability of Planting Material

Seed marketing plays an important role in availing quality and improved planting material though it is prone to pertinent challenges. These challenges are experienced in the seed industry because of the nature of planting materials. Planting materials are essentially living organisms and are therefore often subjected to inherent quality deterioration at a high rate; thus, their shelf life is limited and must therefore be marketed within a short period, often one season. Another peculiar feature of seed is that it requires two to three years lead time to meet specific farmer and farm requirements in order to be availed in the market. This means that production of any propagates has to be organized at least two years in advance. Changes in the weather, price of crop, and price of competing crop, may alter prospects of demand for seed of any particular required variety at the commencement of a sowing season (e, g., Singh 2004).

The nature of seed/vines demanded for planting by farmers differs. Large- and medium-scale farmers use markets to purchase uniform genetic materials that are highly responsive to chemical inputs and embody specific characteristics (e.g., color, uniformity of grain size) rewarded by the market. By contrast, more subsistence oriented smallholders may value characteristics such as drought tolerance, early maturity or good storage; more than fertilizer responsiveness. Because of the small

size of their land holdings, mixed cropping practices, and strategy of minimizing production risks by diversifying the variety base, smallholders also demand relatively small quantities of seed. They often demand a number of varieties of the same crop and more often recycle seed over more seasons than the larger commercial farmers. High demand of planting by different farming households can be met by inducing a widespread sourcing from different seed organizations with affordable cost implications towards supplying seeds of distinct characteristics to the different farmer groups. For example, multinational seed companies can meet seed needs of largescale commercial farmers whose quality requirements and willingness to pay are higher than their smallholder counterparts. The seed needs of the latter group can be met more effectively by small-scale firms or community-based seed multiplication and distribution schemes such as farmers' seed groups and co-operatives (Maredia *et al.*, 1999). The largest problem faced by seed multiplication program elsewhere in Africa is in difficulty of building sustainable seed market. Small quantities of seed are profitably sold within village communities. Sales are strongest for newly introduced varieties. But most small-scale farmers are unwilling to pay premium price to their neighbors for seed they can obtain from their own harvests (Rohrbach *et al.*, 2002).

According to Tsigedingli (2002) analysis of wheat seeds, as an example, out of the total seed produced by farmers in 1998/99 in the SNNPR (Southern Nations Nationalities and Peoples' Regional State) only 10.7% was purchased as seed WTC (Wondo Trading Company), 6.8% exchanged through informal system as seed to neighbors and relatives, 26.6% was used for home consumption and 55.9% sold as grain. Similarly, from 1999/2000 produced wheat seed, 40.6% was purchased by WTC the rest used as own seed and sold as grain to the market.

To increase the sales of seed produced by farmers, promotional activities should be conducted to raise awareness of all farmers in villages under smallholder seed production programs (Kibibiy *et al.*, 2001). Promotional activities should focus on the advantage of improved seed and the quality of seed produced in their own villages by small holder seed producers. As posited by this study, henceforth more efforts should be expended towards producing crop planting materials that are desired by the farmers and end user consumers. A primary objective of these promotional activities would be to increase the willingness of farmers to purchase seed from small producers. A study done by Abdisa *et al.* (2001) stressed on the need of farmers to find sustainable and dependable markets for their newly adopted propagates, otherwise they would feel restrained from production activities. This will lead farmers to be suspicious and reluctant to adopt any technology presented to them. Hence market information; on where and when to sell is quit essential, if informal seed production is to be sustainable.

One important factor that influences farmers' seed multiplication is the performance of the existing market channel, according to (Montshwe, 2006). The choice of the marketing channel depends on a number of aspects in the chain. This include availability of markets, prices offered, distance to the market and the potential of the market and its participants to absorb the stock on sale. A commonly used measure of market performance is the marketing margin or price spread. A marketing margin is the percentage of the final weighted average selling price taken by each stage of the marketing chain. A wide margin usually implies high prices to consumers and low prices to producers. This conclusion was arrived at after a study done on cattle marketing by Getachew, (2002)

2.11 Modelling of Study Objectives

2.11.1 Preference certainty Handling

One of the important assumptions underlying DCEs is that respondents are certain about their indifference curves and can perfectly reveal their preferences by choosing an alternative from a variety of alternatives through a trade-off process (e.g. Brown *et al.*, 2008; Hanemann, 1984). However, this assumption does not seem to hold in practice because past empirical studies have now shown that respondents may not after all be certain in their choice behavior (e.g. Alberini *et al.*, 2003; Brouwer *et al.*, 2010). One main reason for this is that DCEs are often abstract and involve stating monetary values regarding hypothetical product changes. Thus, based on the existing preferences, respondents are assumed to be able to compare, rank, and trade-off the benefits of different product changes against the costs involved in terms of personal money income they are willing to sacrifice (e.g. Akter *et al.*, 2008; Bateman *et al.*, 2008; Brouwer *et al.*, 2010).

As earlier alluded, several methods have so far been developed to capture preference uncertainty among survey respondents (e.g. Morrison *et al.*, 1996; Mitchell and Carson, *et al.*, 2008; Brouwer *et al.*, 2010). 1989; Brown *et al.*, 2008), and they include the use of polychotomous choices (where preference certainty is captured through ordinal measures such as 'Don't Know/Not Sure' or 'Definitely Yes, Probably Yes, Unsure, Probably No, Definitely No'), numerical certainty ratings (where respondents are asked to rate their preference certainty on a scale of 0 to 10) as well as a post-decisional confidence rating, which have been treated by recoding or incorporating uncertainty measures in the likelihood function (e.g. Ready *et al.*, 1995; Li and Mattson, 1995; Champ *et al.*, 1997). In addition, ordered and mixed logit

formulations have also been developed to capture response certainty in the choice behavior of the respondents (e.g. Whelan and Tapley, 2006; Whelan *et al.*, 2008).

Of much interest is that the subsequent incorporation of preference certainty information into the analysis of choice data has yielded inconsistent outcomes regarding its effect on model fit, efficiency, and credibility of the derived survey outcomes. Lundhede *et al.* (2009) focusing on the evaluation of different approaches using respondents' stated choice certainty to improve model estimation note that effects on model fit, efficiency, and credibility of the derived survey outcomes depend on the way a researcher handles respondents' stated choice certainty and what is assumed to be the reasons for the stated certainty. Still as enumerated earlier, Samnaliev *et al.* (2006) summarize these reasons by stating that i) certainty levels indicated by respondents may reflect their attempt to appear consistent in answers ii) certainty levels may be susceptible to protesting and strategic behavior such as respondents exaggerating certainty iii) respondents may use stated uncertainty to scale down their stated WTP and iv) though rational, respondents may assess the value of a product change with some degree of uncertainty and thus give responses that may be subject to error, which translates into a probability that respondents do not choose the utility-maximizing alternative.

The undeniable implication by Samnaliev *et al.* (2006) is that response choice uncertainty, which can be tested empirically, is still a contested issue and prevalent (e.g Akter *et al.*, 2008; Brouwer *et al* 2010; Hensher *et al.*, 2011) in stated preferences. Moreover, Hensher *et al.* (2011) note that little is known about the influence of response choice certainty in DCEs whose further understanding can provide a foundation for refined economic models for analyzing choice behavior. This study, therefore, investigated the role of preference certainty in the choice behavior of the

farmers towards sweet potato varietal traits in western Kenya. The analysis involved assessing the relationship between respondents' responses to preference certainty questions as demarcated on a numerical scale of 0-10 points of certainty (e.g., Hensher *et al.*, 2011, 2012; Beck *et al.*, 2011). An attempt was also made to control for exogenous effects such as farm, farmer, and attitudinal characteristics of individual respondents, which may have a bearing on the degree of certainty placed on stated choices.

2.11.2 Modelling of choice certainty

The respondents in this study were presented with alternative descriptions of a hypothetical policy scenario comprising of different combinations of variety attribute levels. Respondents were then asked to choose their preferred alternative and also rate their level of certainty on a 0-10-point numerical certainty scale. For each choice made, the alternative selected was assumed to yield a higher level of satisfaction than that rejected. It was also possible to collect information on response choice certainty of the respondents from the presented numerical certainty scale. This enabled the probability of an alternative being chosen to be modeled both in terms of the attribute levels used to describe the policy intervention and on any systematic influence on variations in individual responses.

Following Hensher *et al.* (2012), the study was anchored on a 10 point numerical certainty scale with a natural ordering from 0 (very uncertain) to 10 (very certain) to capture the systematic influences on variations in individual responses along the scale bearing in mind that the 10 points had an underlying continuous distribution. The study assumed that the cut-off levels on the scale was likely to be perceived differently by each respondent and even possibly between the choice sets that each respondent assessed. As such, fixed cut-offs or thresholds that were not able to adjust for

preference heterogeneity, both random and systematic, were in this case deemed inappropriate. Besides, there was a real possibility that different variances in unobserved effects (or heteroscedasticity) were defined through the random error component of the utility expression, including the possibility of systematic sources of influence.

In the past studies, and previous conventions, sources of explanation of the differences in subjective response choice certainty were tested for in a generalized ordered choice model of the logit form exposited in Greene and Hensher (2010). The model, is a behaviourally richer representation of ordered choice, extending beyond simple ordered logit and probit with fixed thresholds and preference homogeneity in attribute parameter estimates.

2.11.3 Preference consistency and Time Aspects

One dilemma encountered in DCEs concerns the amount of cognitive effort it takes respondents to make their choice decisions and this mainly owes to the design of the DCEs (e.g. Boxall *et al.*, 2009; Fiebig *et al.*, 2010). Thus, researchers have to tradeoff between thorough descriptions of the choice alternatives in the survey and the ability of respondents to understand and make consistent choices on the attributes presented (e.g. DeShazo and Fermo, 2002; Cameron and DeShazo, 2011). Notably, the consistency with which individuals make their choices has been shown to have important consequences for survey outcomes derived in DCEs since whenever individuals fail to make the same choices in otherwise identical choice tasks, the credibility of the policy outcomes emanating from DCE surveys is lowered (e.g. Saelensminde, 2002; Hess *et al.*, 2010).

Although respondents in DCEs state their choices in hypothetical markets with minimal scope for them to familiarize themselves with the choice attributes they are

asked to consider, establishing whether or not individuals are consistent in their choice decisions has received limited attention (e.g. Brouwer *et al.*, 2008; Czajkowski *et al.*, 2014; Liebe *et al.*, 2012; Sælensminde, 2001). This has prompted studies to be carried out in which respondents repeat a choice process after some interval and the consistency of the values derived is investigated. While the results of these choice consistency analyses have largely been consistent and robust in terms of the survey outcomes, it is not well known whether they are typical of the time aspect and hence, reliable to inform relevant policy narratives.

Most studies analyzing preference consistency among individuals have focused on the intertemporal approach where outcomes are assumed to be stable and reliable (e.g. Brouwer and Logar, 2014). In practice, this may not be the case since outcomes derived from the intertemporal analysis may be prone to significant amounts of variation in the behavioral as well as the socio-demographic characteristics of the respondents over the period under consideration. Therefore, this study addressed this issue through a different approach where a choice task in a sequence of 10 choice tasks was repeated and then used to assess the sequential preference consistency of farmers in their choice for sweet potato varietal traits.

2.11.4 Preference Heterogeneity Models

Preference variation refers to the situation where individuals derive different marginal utility from product characteristics owing to relative individual profiles (e.g. Revelt and Train 1998; Boxall and Adamowicz, 2002) or the error variance in the choices made by individuals (e.g. Fiebig *et al.* 2010). In the traditional discrete choice analysis, the Conditional Logit (CL) or Multinomial Logit (MNL) model of McFadden (1974) has all along been used by researchers to analyze preference data (e.g., Bennett

and Blamey, 2001; Scarpa *et al.* 2007). While this choice model is behaviorally and computationally appropriate, it is however known to be restricted by the Independence of Irrelevant Alternatives (IIA) property in its parameter estimation (e.g., Kataria, 2009; Keane and Wasi, 2009). Besides, the model has a limited ability to capture preference variation in the choice behavior of individuals. As a result, researchers have opted to include the socio-demographic variables in the specification of the utility function relying heavily on the observable differences between respondents.

Recent modeling approaches that are extensions of the standard CL model such as the latent class logit (LCL) model (Kamakura and Russell, 1989); mixed logit (MXL) model (Ben-Akiva and McFadden, 1997); scaled multinomial logit (S-MNL), generalized multinomial logit (G-MNL) and generalized mixed logit (G-MXL) models (e.g. Fiebig *et al.*, 2010) have nonetheless been developed to relax the IIA assumption and/or account for the unobserved preference variation in both systematic and random components of individual respondents' utility functions (e.g. Fiebig *et al.*, 2009; Hensher and Greene 2003; Hole 2008). The two main types of preference variation studied in discrete choice behavior are taste and scale variances. While taste variance arises from the systematic component of the utility function (i.e., the diverse decisions made by individual respondents), scale variance arises from the random component of the utility function (i.e., differences in the error terms of decisionmaking processes across individual respondents). Since preference variation can have important implications on policy outcomes of a DCE survey, several researchers (e.g., Boeri *et al.*, 2011; Keane and Wasi, 2009; Louviere *et al.*, 2002; Louviere and Eagle, 2006) have underscored the importance of analyzing the importance of both taste and scale factors on individuals' utility functions. While there is more research evidence in this area, only a few studies have looked into the importance of both taste and scale factors

in the choice behavior of individuals for crop varietal traits (e.g. Kragt, 2013). As a result, this study intended to fill this research gap by estimating MNL, MXL, SMNL, G-MNL, and G-MXL using choice data on farmers' preferences for sweet potato varietal traits in western Kenya.

2.11.5 Accounting for Attribute Non-Attendance (ANA)

Following Kragt (2013), different kinds of models were estimated in this study so as to account for both stated and inferred attribute nonattendance. To begin with, a set of mixed logit (MXL) models were first estimated to account for unobserved individual preference heterogeneity in the sampled population (e.g. Hensher *et al.*, 2005). Heterogeneity is, in this case, accounted for by specifying random parameters β_{ik} for the k^{th} attribute faced by the i^{th} individual as:

$$\beta_{ik} = \beta_k + \sigma_k v_{ik} \quad (1)$$

Where β_k is the unconditional population parameter of the preference distribution; and v_{ik} are random, unobserved variations in individual preferences that are distributed around the population mean with standard deviation σ_k . Individual taste differences in the population are represented by density function $f(\beta_i|\theta)$ (e.g. Hensher *et al.*, 2005), where θ is a vector of parameters characterizing the density function that captures individual deviations from the mean. The researcher specifies a distributional form for θ (e.g. Hensher *et al.*, 2005; Hensher and Greene, 2003). In the present study, the sweet potato varietal attributes were defined as random, normally distributed parameters while the cost attribute was treated as a random parameter with a constrained triangular distribution. In the MXL model, the unconditional probability of observing choice j by the i^{th} individual in choice situation t is equal to the expected value of the logit probability over the parameter values. This is the integral over all possible values of β_i , weighed by the density of β_i (e.g. Hensher *et al.*, 2005), that is:

$$E(Prob_{ijt}) = \int Prob_{ijt}(\beta_i) \cdot f(\beta_i|\theta) d\beta_i \quad (2)$$

Since equation (2) lacks a closed form solution, the model is best estimated using the simulated maximum likelihood approaches (e.g. McFadden and Train, 2000). The MXL models in this study were estimated in a panel format, and included an additional latent error component that was common between the two change alternatives. This error component allows for cross-correlation between the stochastic components of the utilities derived from those alternatives. It can capture unobserved heterogeneity that is alternative- rather than individual-specific (e.g. Greene and Hensher, 2007). The error component appears as $M \leq J$ additional random effects:

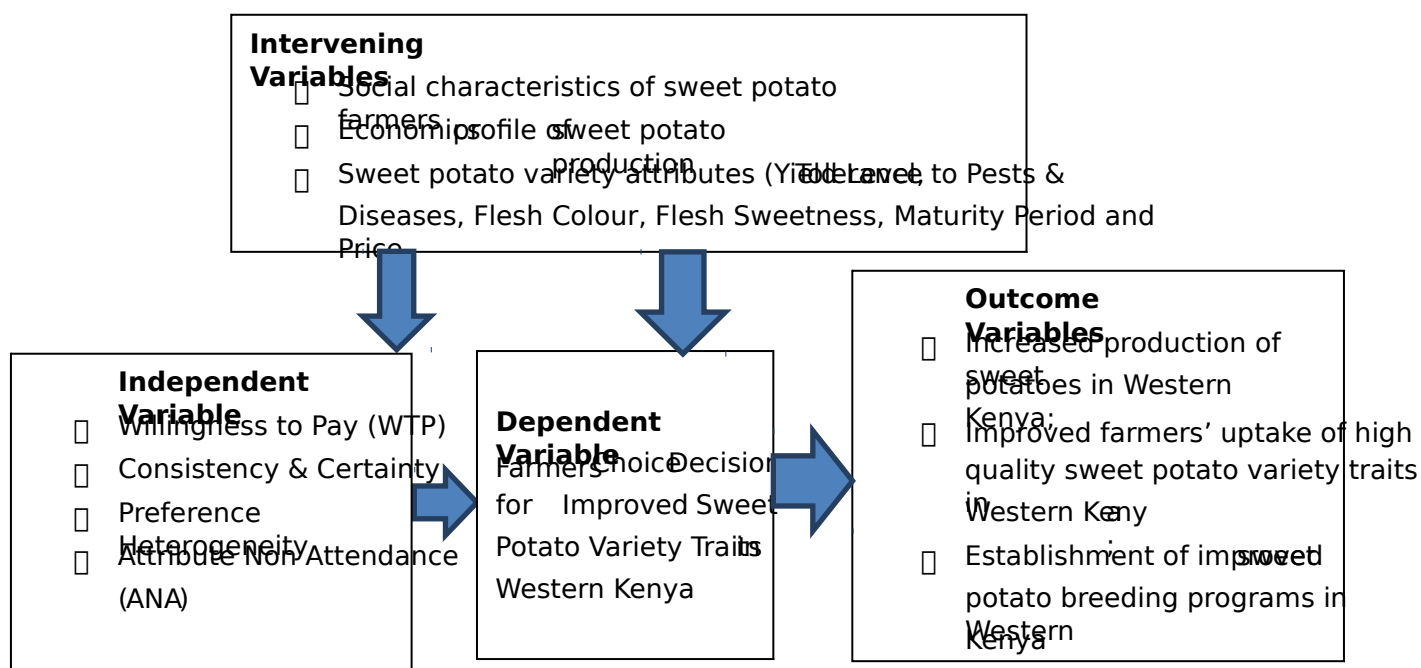
$$U_{ijt} = \beta_i' X_{ijt} + \varepsilon_{ijt} + d_{jm} w_{im} ; \quad m = 1, \dots, M \leq J \quad (3)$$

Where w_{im} are normally distributed latent effects with zero mean; and $d_{jm} = 1$ if the random error component appears in the utility function for j . As for ANA, it is accounted for by restricting the attribute coefficients to zero if an attribute was ignored by the respondent as captured through the supplementary questions. This is readily implemented in the NLOGIT software coding the attributes as appropriate if respondent did not attend to the attribute. It is an important part of the underlying theory that the attribute coefficients, rather than the attribute levels, are constrained to zero (e.g. Hensher *et al.*, 2012). Although some authors have claimed that the two approaches are essentially the same, setting attribute levels to zero if ignored will still result in estimated taste parameters, whereas setting coefficients to zero means that the respondent did not attach any weight to that attribute in evaluating the utility derived from an alternative (see Hensher *et al.*, 2005) for a more detailed description of the MXL model that incorporates ANA.

2.12 The conceptual framework of the study

The conceptual framework for discrete choice models was derived from Lancaster's approach and the random utility framework. The primary emphasis of this framework was to discover the underlying elements that influence an individual or group's choice actions for sweet potato variety features. A choice decision can be considered as a decision-making process tied to elements which are both external and internal to the decision maker. Figure 2.1 illustrates this.

Figure 2.1: Conceptual framework showing relationship between the study variables



Source: (Researcher's conceptualization, 2021)

Pertinent variables, such as yield, play an important primary role in determining decision outcomes that affect the objectives of the study directly and also through the influence of such factors such as literacy levels; for example, willingness to pay, through gender via flesh color will affect the choice for farmers for sweet potato traits. Given that improved Sweet Potato variety attributes are a discrete choice good with

varying traits with potentials to meet several objectives, the decision maker's problem is the choice of variety profile that best maximizes his utility from preferred traits and trait levels from a choice set of alternative profiles with different levels of traits. These profiles can be viewed as representing different varieties with varying trait levels. The universal set of alternative vine varieties is determined by the decision maker's environment as it influences the options available to him/her. This may include factors such as properly functioning markets and personal characteristics. However, the decision maker n is faced by personal constraints such as household income and information access that determine the feasible choice set, which is a subset of the universal set of alternatives, represented as $C_n \in C$ (Langyintuo *et al.*, 2005).

Following Lancaster (1966), the utility derived from alternative Sweet Potato vine profiles within the choice set of the decision maker was perceived to be determined by the attributes of the alternatives. The decision maker was assumed to form a utility function for the alternatives and assigned a utility value for each alternative by valuing and trading off the attributes that were important in his/her choice decision. A utility maximizing behaviour was assumed to be exhibited, resulting in preference and choice of an alternative with the highest positive utility value. Though the sources of utility were strictly linked to the attributes of the alternatives, the contextual characteristics and socio-economic characteristics of the decision-maker were included since they influence preference and choice behaviour. These descriptors are not sources of utility of an alternative *per se*, but can condition the role of unobserved attributes and can be considered as influences on the parameter estimates of observed attributes. The inclusion of socio-economic characteristics of decision makers is one way of explicitly accounting for observed preference heterogeneity as explained by specific observable characteristics.

The attitude and perception of the decision maker of the attributes and attribute levels are unobserved by the analyst; however, they influence choice. Attitudes reflect the decision maker's needs, values, and tastes and are influenced by external factors as well as socioeconomic characteristics. Perception of the attribute levels is influenced by the decision maker's past experience, culture and other socio-economic factors such as age, level of education, household size and gender. High levels of education enhance a decision maker's capacity and influence his/her ability to conceptualize and comprehend the effects of different trait levels. An example of perception of attributes in vine trait preference choice context is disease resistance while an example of attitude may be the importance of disease resistance.

The economic model for the discrete choice framework for improved Sweet Potato variety attributes in Figure 2.4 that considers unobserved heterogeneity is presented as follows. Each individual's choice set C_n , is assumed to have a finite set of J mutually exclusive and exhaustive alternative improved vine variety attributes profiles to choose from in each choice situation. For each choice situation, a sampled decision maker is assumed to have full knowledge of the factors that influence his/her choice decision when asked to choose the most preferred improved sweet potato variety attributes profile from the competing J alternatives subject to the budget constraint (Boxall and Macnab, 2000).

Following the random utility theory, an individual n receives utility U from choosing an alternative equal to $U_{njt} = U(X_{njt})$ from a finite set j alternative in a choice set t , if and only if, this alternative generates at least as much utility as any other alternative, with denoting a vector of the attributes of j . According to Random Utility Theory, the utility of a good is composed of (1) an observable or deterministic component, which

is a function of a vector of attributes, and (2) an unobservable or random error component (Boxall and Macnab 2000). The following equation for an individual's utility formalizes the basic relationship where (V_{njt}) is the observable component and (ε_{njt}) represents the error component of utility.

$$U_{njt} = V_{njt} + \varepsilon_{njt}$$

The equation below disaggregates the systematic component of choice further, where respondent (n) derives utility (U_{njt}) from the alternatives (j) in choice set (C); utility is held to be a function of the attributes of the relevant good (Z_{njt}) and the characteristics of the individual (S_n), together with the error term (Rolfe *et al.*, 2000).

$$U_{njt} = V(Z_{njt}, S_n) + \varepsilon_{njt}$$

Due to the inherent stochastic or random error component of (U_{njt}), a study can never hope to fully understand and predict preferences, hence, choices made between alternatives are expressed as a function of the probability that respondent (n) will choose (j) in preference to other alternatives if and only if $U_{njt} > U_{njh}$. Based on this, the probability that the n th individual chooses the j th alternative can be expressed as:

$$P_{njt} = P(U_{njt} > U_{njh}, \forall j \neq h)$$

From this equation, we can now derive the condensed equations as:

$$P_{njt} = P_{rop}(V_{njt} + \varepsilon_{njt} > V_{njh} + \varepsilon_{njh}) \quad \forall j \neq h$$

And also,

$$P_{njt} = P(\varepsilon_{njt} - \varepsilon_{njh} > V_{njh} - V_{njt} + \varepsilon_{njh}, \forall j \neq h)$$

And this equation is a cumulative distribution, namely the probability that each random term is below the observed quantity (Train, 2003).

2.13 Summary and Literature Review Gaps

Out of the above review of literature, it is evident that multiple studies have analyzed farmers' preferences for crop variety traits. Numerous crops have been analyzed to understand farmers' preferences for their varietal traits and they include maize, beans, yams, rice, cotton, strawberry, millet, chickpeas, pigeon peas, quinoa, sweet potato, watermelon and tomatoes among others. Moreover, different approaches have been used to analyze the preferences of the farmers for crop traits and they include the participatory assessment methods, conjoint analysis, discrete choice experiments, and the mixed methods approach. The empirical results from most of these studies are consistent in establishing that farmers tend to prefer certain crop varietal traits over others.

The results are however inconsistent on whether farmers prefer local varieties over the improved ones or the vice versa. The studies are also limited in the way they address potential methodological challenges that may be inherent in the approaches employed to evaluate farmers' preferences. Besides, the information sought on farmers' preferences for sweet potato varietal traits is also sparse. Therefore, with a case application to western Kenya, this study used the discrete choice experiment method to evaluate farmers' preferences for sweet potato variety traits in Kenya. An additional evaluation was also undertaken in exploring the implications of preference certainty, consistency, variation, and ANA on the policy outcomes of this study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter developed the general methodological framework that was followed to achieve the objectives of the study. It began by presenting the study area, study population, and study sample. This was followed by the experimental design where data needs; data sources, data collection, and data analysis was discussed.

3.2 Study area, population and sample

This study was conducted in western Kenya, which has four counties namely: Busia, Bungoma, Kakamega, and Vihiga Counties. As earlier mentioned, western Kenya was purposively chosen for this study owing to its importance in sweet potato production in Kenya. Notably, Busia County covers an area of 1,694.5 Km² and has seven sub-counties, namely Teso North, Teso South, Funyula, Nambale, Matayos, Budalang'i and Butula with a population of 816,452 persons and a population density of 437 people per Km². The ecological zones in the county range from upper midlands to lower midlands with an annual rainfall pattern ranging between 760-2000mm. Agriculture is the backbone of the county as it accounts for over 64 percent of the total earnings. The main food crops grown include maize, cassava, finger millet, beans, sorghum, rice, sweet potatoes, cowpeas, groundnuts, bananas, green grams, sesame, soya beans, cotton, tobacco, sugarcane, oil palm, and pepper. Horticultural crops are also grown in the county that includes pineapples, tomatoes, kales, cabbages, watermelons, local vegetables, papaya, amaranth, onions, and, mangoes, among others (CIDP - Busia, 2018-2022).

As for Bungoma County, it covers an area of 3,032.4 Km² and has nine sub-counties, namely Mt Elgon, Sirisia, Kabuchai, Bumula, Kanduyi, Webuye East, Webuye West, Kimilili and Tongaren with a population of 2,040,343 persons and a population density of 3,700 people per Km². Ecological zones in the county range from upper highlands to lower midlands with an annual rainfall pattern that ranges between 400-1800mm.

Agriculture is also the backbone of the county as it accounts for over 66 percent of the total earnings. The main food crops grown include maize, beans, finger millet, sweet potatoes, bananas, sorghum, Irish potatoes, and assorted vegetables. Sugar cane, cotton, palm oil, coffee, tea, sunflower, and tobacco are grown as cash crops (CIDP - Bungoma, 2018-2022).

Kakamega County covers an area of 3,051.3 Km² and has twelve sub-counties, namely Likuyani, Lugari, Malava, Navakholo, Lurambi, Ikolomani, Shinyalu, Mumias East, Mumias West, Matungu, Butere and Khwisero with a population of 1,660,561 persons and a population density of 544 people per Km². There are two main ecological zones in the county, namely, the upper medium and the lower medium with an annual rainfall pattern of between 1200-2200mm. Agriculture is the backbone of this county as it accounts for over 65 percent of the total earnings. The main crops grown are maize, beans, sweet potatoes, cassava, bananas, sorghum, finger millet, local vegetables, rice, tea, sugarcane, and some horticulture crops (CIDP - Kakamega, 2018-2022). As for Vihiga County, it covers an area of 531.0 Km² and has five sub-counties, namely Hamisi, Emuhaya, Luanda, Sabatia, and Vihiga with a total population of 554,622 persons and a population density of 1,033 persons per Km². The county is characterized by two main agro-ecological zones, the upper and lower midlands with an annual rainfall pattern of between 1800-2000mm that supports a variety of crop farming and livestock rearing. Crop farming is however the mainstream of the county's

economy and contributes about 64 percent to the county's income. The main food crops produced are maize, beans, sorghum, millet, cassava, sweet potatoes, and bananas and the cash crops include tea, and coffee (CIDP - Vihiga, 2018-2022). In the above counties' information, it is evident that the entire region experiences a good amount of rainfall all year-round supporting farming activities of various crops including sweet potato for both subsistence and commercial purposes. Data for the study was collected from each of the four counties for comparative statistical reasons. Each county was expected to generate a representative sample of sweet potato farmers, to make a total sample of 400 respondents. Ultimately, this generated a total of 12,000 (3 choice options x 10 choice sets x 400 respondents) observations that were subjected to econometric analysis to provide answers geared towards finding objectives of the study.

Figure 3.2 Map of Western Kenya



(Source: Murere & Were, 2019)

3.3 Data types and sources

Data is acknowledged as any piece of information, quantitative and qualitative that has been generated through application of logic and objectivity. In survey data collection, data is classified into primary and secondary data as well as quantitative and qualitative data set.

3.3.1 Primary data and sources

The main type of data for this study was primary data. The primary data was obtained directly from respondents in the field by use of semi-structured questionnaires. Both qualitative and quantitative data was sourced from household survey. The qualitative surveys adopted a more open, unstructured and flexible style, which allowed new leads to be followed or additional data to be gathered in response to changes in ideas. By contrast, the quantitative surveys used structured questionnaires to collect data from a pre-determined sample.

3.3.2 Secondary data and sources

This is data that has been collected earlier, recorded and stored. The secondary data was obtained from the western Kenya, year 2017, annual reports together with FAO statistical reports. This data was used by the researcher as a guideline on areas that have been documented in relation to this study.

3.3.3 Methods of data collection

This study used questionnaire guided survey technique. The researcher with the help of eight trained enumerators administered research questionnaires to collect information from sweet potato farmers from the four counties of Western Kenya. This technique was chosen since it helped the interviewers to clearly explain to potential

respondents all the variables required for the study, assisted respondents who did not know how to read and write to fill research questionnaires, enabled the researcher to obtain first-hand information and also motivated respondents to participate in the exercise of data collection.

3.3.4 The quantitative survey

The quantitative approach survey involved the development of structured questionnaires and administration of the questionnaires. The survey was conducted from the beginning of August, 2020 to the end of October, 2020. Surveys in all the sub counties were carried out by administering research questionnaires through face-to-face interviews with farmers. All household activities (farm and non-farm), enterprise types, crop area and production levels, inputs and expenditures were recorded during the survey. Socio-economic and institutional data such as household characteristics, land size and tenure arrangements, farm characteristics and investment in assets were also captured. Other questions entailed farmers' management capacity and demographic characteristics such as the supply of on-farm family labor and educational status. Two types of questionnaires (the farm level questionnaire and the choice experiment questionnaire) were prepared and administered. A draft farm level questionnaire was prepared before the beginning of the fieldwork based on the theoretical framework. This draft was later revised to reflect the experiences gained from the reconnaissance survey, focus group discussions, key informant interviews and the pretesting of the questionnaire. The farm level questionnaire (Appendix II) contains specific questions and efforts were made to avoid generalizations as much as possible. Efforts were also made to maximize the relationship between the answers recorded and what the study aimed to measure in the questionnaire, and measurement indicators were specific and precise (Fowler, 1994). The questionnaire preparation

took into account factors which minimized non-sampling errors, such as clarity of expression, potential for respondent recall, cultural specific conceptions, sensitive questions and the time required to complete an interview (Nicholas, 1991). The responses from the focus group discussions and informant interviews provided a background of specific questions to include in the farm level questionnaire for the study's specific objectives of identifying specific improved Sweet Potato variety attributes preferred by relevant farmers, determining the adoption of the already available improved Sweet Potato variety attributes and assessing the factors that influence farmers' adoption and preferences for improved Sweet Potato variety cultivars.

3.3.5 The qualitative survey

The qualitative data was sourced in two phases. The first phase was composed of the orientation phase while the second phase involved focus group discussions. The orientation phase involved reconnaissance visits to the study area. The objectives of the visits were to help in exploring the proposed study area, gain insights into the agricultural production activities, and establish contacts with key informants on the ground. It involved collection of secondary information on improved Sweet Potato varieties and other relevant Western Kenya province information; such as data on topography and drainage, climate and vegetation, and geology and soils. During the visits discussions were held with relevant extension staff from the Ministry of Agriculture (MoA) on concerning contemporary trends on improved sweet potato vine varieties over the recent-last years. The major improved sweet potato variety attributes preferred by the farmers in the study area were then identified in consultation with the relevant Agricultural Officers in order to select pertinent specific locations for the study. Visits were also made to some farmers that grow both improved and local seed

varieties, an undertaking which led to easier establishment of key contacts that later proved very useful during survey administration process.

The focus group discussions phase involved organization of three focus group discussions in each of the four counties of Bungoma, Busia, Kakamega and Vihiga. When conducting the discussions, three important aspects were carefully considered; starting with careful selection of prospective participants, representative composition of the focus groups and reasonable size of the groups. Equitable size of groups estimation was guided by recommendations of experienced scientists such as (Russell, 2002; Ritchie, 2003) who recommended a minimum of four to ten members as being adequate to make up a representative group in focus group discussions. This definitely ensured free discussions and ample time for participants to productively contribute. There was a conscious effort to include both male and female in the focus groups.

Agricultural Extension Staff from the Ministry of Agriculture were asked to mobilize farmers; both male and female, for the focus group discussions on agreed dates, venues and occasions. Checklists were developed and used to guide the discussions with the farmer groups. The objectives of the study were explained and communication procedures were established to ensure that farmers and resource persons were in alignment and therefore in tandem with issues under discussions. These discussions were organized from May 2020 to June 2020. During the discussions, farmers were asked to mention both local and improved Sweet Potato varieties grown in their communities and their key associated characteristics. They were also asked to give ratings on five main improved Sweet Potato variety attributes (yield, Taste of flesh, color of flesh, disease tolerance and Maturity period) on a Likert-type scale, ranging from 1 (very important) to 3 (somewhat important). The sources of these traits were findings the previous reconnaissance surveys to western

and past research outcomes on improved Sweet Potato variety traits preferred by farmers. The selection of the traits above was based on scientific need to consider attributes that were expected to greatly affect farmers' choices, as well as those that are policy relevant.

3.4 Experimental design of the study

To determine farmers' relative preferences for different sweet potato traits, the study employed the DCE approach (e.g., Louviere *et al.*, 2000). In a DCE, people make a series of repeated choices between different products defined by multiple traits. In this case, the DCE was described by six traits: yield level, tolerance to pests and diseases, the sweetness of the flesh, color of the flesh, maturity period, and price. These traits were obtained from an extensive literature review and through interviews with relevant experts in the wider agricultural sector. The essence of the DCE was to create choice scenarios in which farmers were asked to make repeated choices between three alternatives that differ along the six traits mentioned afore. As such, the DCE required the construction of choice sets in which the traits of each alternative were varying for every choice task. Table 3.1 shows traits that were considered in this study and the levels that were used to vary each of the traits. In designing the choice sets, the study respondents were presented with three choice options, one of which was the *local varieties* option and the other was the *improved varieties* option. There was also the "status quo" "opt-out" or "no choice" option to take care of those respondents who were indifferent towards *local* and *improved variety* alternatives. Thus, the two alternatives of sweet potato (*local* and *improved*) varieties represented fixed-choice options or alternatives, but the levels of yield, tolerance to pests and diseases, the sweetness of the flesh, the color of the flesh, maturity period, and price were varied across options and choice questions. Because there were two options (*local* or

improved) each with six traits varying at three levels; there were $2^6 \times 3^6 = 46,656$ possible choice sets or scenarios that had to be presented to the respondents. From this full factorial of 46,656 possible choices, it was impossible to show the survey respondents all these possible combinations. Hence, the DCE for this study was designed using fractional factorial design so that only a few of these combinations were generated based on A-efficiency and D-efficiency statistical efficiency considerations. While A-Efficiency attempts to minimize the sum of the variances of estimated coefficients, D-Efficiency maximizes the determinant of the information matrix, (e.g. Hensher *et al.*, 2005; Kuhfeld, 2010; Rose and Bliemer, 2004). Therefore, an efficient design containing 10 choice sets with 3 choice alternatives each was obtained using the *Ngene* software (Institute of Transport and Logistics Studies, 2007). Besides, in the 10 possible choice questions selected, the price of *local* and *improved* sweet potato varietal traits was expected to be completely uncorrelated across the 10 choice options.

Experimental levels of five improved sweet potato variety attributes were identified through focus group discussions, expert interviews and literature review. A monetary attribute in terms of purchase of Sweet potato was included in order to estimate farmers' willingness to pay for improved variety attributes. The improved variety attributes and their levels used in this study are explained below:

Yield: The total output per unit of total area of crop in hectares was very important to farmers. Given the fact that farmers depend solely on output for their yearly incomes it was expected that high yield variety led positively to increased choice of that variety. In the choice experiment, yield was accounted for by analysing three levels: (1) 6t/ha; (2) 10t/ha; and (3) 14t/ha. The yield levels were set based on farmers' current yields without extension and current yields from research managed fields. In order to arrive

at the actual values for these levels, Yield levels were reviewed from the Ministry of Agriculture's data file on current improved vine yields and the Crops Research Institutes' (KALRO) latest existing field data files under research managed conditions.

Disease tolerance: Pests and diseases are very important since they can reduce production by 20 to 100 percent depending on the level of infestation and therefore farmers are expected to be concerned. The most common diseases comprise of the rust, leaf blight and various viral diseases among many others. Various pests were also included in this consideration. Pest and Disease tolerance was accounted for in the choice experiment as having three levels: (1) High tolerance; (2) medium tolerance; and (3) low tolerance. Pest and disease tolerance Sweet Potato cultivars automatically mean high utility to the prospective farmer.

Taste of Sweet Potato: Taste of Sweet Potato to a large extent determines selection of relevant types of Sweet Potato to grow. The study used three levels of sweet potato taste, namely: (1) Good taste (2) Average taste and (3) Bad taste

Flesh Color of Sweet Potato: Sweet Potato is one of the global leading sources of energy, protein and fiber. Color of sweet potato is a good indicator of desired quality of the tuber. According to (e.g., Neela *et al.*, 2019) scientific studies reported on the relevant diversities in Sweet Potato flesh color in connection with nutritional and sensory acceptability. Amongst all, orange-fleshed sweet potato (OFSP) has been attracting admiration food technologists and nutritionists due to its high content of carotenoids and pleasant sensory characteristics which corresponds to the color. Other colors, especially white have less attraction because of this reason. This study rated the properties of color consequently in the choice experiment, of this attribute on three levels as follows: (1) Orange color (2) Yellow color and (3) White color.

Maturity Period of Sweet Potato: The ability of improved Sweet Potato variety attributes to mature early is taken as a positive phenomenon. Early maturing Sweet Potato improves on food security situation and translates to higher productivity per unit area annually, which not only leads to more available food for the often-needy households, but also some improved income earnings. In the choice experiment, this attribute was accounted for in the choice experiment on three levels; namely: (1) Sweet potato variety which matures in 3 months (2) Sweet potato variety which matures in 5 months, and (3) Sweet potato variety which matures in 7 months.

Price of traits: The purchase price of the traits was based on prevailing market prices of 100 vines of improved Sweet Potato varieties in the study area. Three levels that were used to account for purchase prices in the choice experiment were: (1) KSH 100; (2) KSH 200; and (3) KSH 300. The three levels were used to represent the minimum, average, and maximum prices corresponding to relevant four counties. Farmers were expected to insist on lower costs of the attributes; or demand lower prices as a way of maximizing their utilities.

Table 3.7: Descriptions and levels of the chosen attributes

Attribute	Description	Levels	Coding
Yield	The amount of sweet potato output per hectare	Level 1:6 tons/hectare Level 2:10 tons/hectare Level 10:14 tons/hectare	Actual values
Tolerance	Forbearance to common crop pests and diseases	Level 1: High Level 2: Medium Level 3: Low	Effect coding
Sweetness	Taste of the sweet potato flesh.	Level 1: Good Level 2: Average Level 3: Bad	Effect coding
Colour	Colour appearance of the sweet potato flesh.	Level 1: Orange Level 2: Yellow Level 3: White	Effect coding
Maturity	Period sweet potato takes to mature.	Level 1: months Level 3 2: months Level 5 3: months Upto 7	Actual values
Price	Change in price per unit of output.	Level 1: 100 Level 2: 200 Level 3: 300	Actual values

Source: Author's Compilation (2021)

Moreover, all correlations between other traits within a variety (*local* or *improved*) were zero, and the traits were completely balanced within each variety, i.e., each trait level appeared exactly four times across the 10 choices in the *local* and *improved* varieties. In summary, each farmer was asked to answer 10 choice questions, where each question posed a choice between two sweet potato options that vary by yield level, tolerance to pests and diseases, the sweetness of the flesh, color of the flesh,

maturity period and price, and a third "*status quo*" or "*opt-out*" or "*no choice*" option. Those respondents who persistently chose the "no choice" option in all the 10 choice tasks were asked a follow-up question to understand their underlying reasons. Table 3.1 presents one of the 10 DCE choice card questions presented.

Farmers purchase sweet potato vines per piece. The price ranges from Ksh 1 per vine mainly from nearby farms, Ksh 1 for vines sourced from Egerton University, Ksh 2 from KEPHIS, Ksh 8 from KALRO, and Ksh 38 per from specialized breeders per piece. Because farmers tend to source from their farms and nearby farms, Ksh 1 per piece was generally used as a base when letting farmers conceptualize price changes. The price of 100 vines emanating from this was used to set the base level price of Ksh 100 in the DCE cards and the related Ksh 200 and Ksh 300 for the other levels.

A questionnaire including the choice experiment was prepared and pretested on 50 randomly selected sweet potato farmers to assess the extent to which they understood the survey questions in general and the DCE, in particular. The final version of the questionnaire employed in the study was therefore based on the inputs from the pretest as well as the guidance provided by the interviewed experts in the sweet potato subsector. The final version of the survey questionnaire had three sections. The first section measured respondents' general knowledge of sweet potato farming, sweet potato varieties, and traits to acquaint them with the traits of interest. The second section contained the DCE and was to elicit respondents' preferences for sweet potato variety traits by allowing trade-offs between price change for the different varieties (*local or improved*) and their characteristics.

Since respondents were likely to experience some uncertainty in their choice decisions, this study chose to capture such uncertainty in the choice tasks. As such, respondents were asked to rate their level of uncertainty surrounding each choice on a

scale of 0 to 10, where 0 was used to show that they were completely uncertain while 10 showed that they were completely certain. Preference consistency was also explored in the study by asking respondents to answer the same choice card on two occasions. For instance, in a given choice set, the first-choice card was repeated either as the 6th, 7th, 8th, 9th, or 10th card and then preference consistency across two choice occasions was assessed directly by comparing the choices made by each individual on both choice occasions.

Figure 3.3: Example choice card for the survey

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	6	6	
	TolerancePD	Low	Low	
	Flesh sweetness	Bad	Bad	
	Flesh colour	Orange	Orange	
	Maturity period	3	3	
	Price change	100	100	None of the two

I prefer: ☐ ☐ ☐

How certain are you about your choice? *Completely Uncertain* 0 1 2 3 4 5 6 7 8 9 10 *Completely Certain*

Source: Author's Compilation (2021)

The final part of the questionnaire involved questions about the socio-demographic characteristics of the respondents, such as age, gender, and income. The survey was done between the months of August and October 2020 through 400 in-person (face-to-face) interviews with respondents above the age of 18 who were growing sweet potatoes. The Survey CTO, an online interactive means of capturing data using the smartphone, was employed. Since there was an outbreak of one of the most contagious viral disease, called COVID19, the use of this mode of phone platform to administer

all questionnaires was very convenient. Interviews were conducted by eight well-trained local interviewers who initially participated in the pre-test interviews and were carefully instructed to adhere exactly to all wordings used in the introduction of the DCE questionnaire to minimize any interviewer bias. Both text and pictograms were used to represent key information in the choice cards to enhance understanding and conceptualization of all respondents, including those with low literacy rates on issues concerning sweet potato traits. Moreover, respondents were given adequate time to understand and answer each question so as to enhance validity of the responses obtained. Interviews also involved a random selection of sweet potato farmers' right on their farms and doorsteps. The results are presented in Chapter Four.

3.5 Sample Size Determination and Sampling Design

The target population of the study was the smallholder sweet potato farmers in western Kenya. Four counties were purposively selected because of the huge concentration of sweet potato farming. The counties included; Busia, Kakamega, Bungoma, and Vihiga. The total population of the four counties amounted to 362,530 sweet potato farmers (KNBS, 2019). The required sample size was established using

Kothari's (2004) formula as shown below;

$$n = N * \frac{\frac{z^2 * p * q}{e^2}}{[N - 1 + \frac{(z^2 * p * q)}{e^2}]}$$

$$n = 362530 * \frac{\frac{1.96^2 * 0.5 * 0.5}{4.9^2}}{362530 - 1 + \frac{(1.96^2 * 0.5 * 0.5)}{4.9^2}} \cong 400$$

Where; n = sample size, p = population proportion with the characteristic of interest is taken to be (0.5), $q = (1 - p) =$ Proportion of the target population (0.5),
 N = size of the population (362,530),

e = margin of error (0.049),

Z =critical value at the desired confidence interval=1.96.

The study used the proportionate sampling and simple random sampling techniques to select the respondents from the four counties in western Kenya as illustrated in the Table 3.2.

Table 3.8: Sampling frame for Smallholder Sweet Potato Farmers in Western Kenya

County	Sweet Potato Farmers	Proportion	Sample Size
Kakamega	146,673	0.405	162
Bungoma	102,940	0.284	114
Busia	61,973	0.171	68
Vihiga	50,944	0.140	56
Total	362,530	1.000	400

Source: Author's compilation (2021)

As has already been mentioned, the selection of the attributes was exclusively guided by attributes that were expected to affect farmers' choice, as well as those attributes that were policy relevant. Once attributes and levels had been determined, experimental design procedures were used to construct the choice tasks or profiles that were presented to the respondents (Hanley *et al.*, 2001).

There are several different design types in the literature to obtain choice sets. One is a full factorial design which consists of all possible choice situations (Bennett and Blamey, 2001). With this, all possible effects (main and interaction effects) can be estimated. However, for a practical study the number of choice situations in full factorial design is too large. Therefore, most researchers rely on **fractional factorial designs**. A fractional factorial design is the orthogonal design, which aims at minimizing the correlation between the attribute levels in the choice situations

(Kuhfeld *et al.*, 2004). However, these orthogonal designs have limitations and cannot avoid choice situations in which a certain alternative is clearly more preferred over the others (hence not providing much information).

More recently, several researchers have suggested another type of fractional factorial designs, the so-called efficient designs (Hensher *et al.*, 2005; Scarpa and Rose, 2008). Instead of merely looking at the correlation between the attribute levels, efficient designs aim at finding designs that are statistically as efficient as possible in terms of predicted standard errors of the parameter estimates. Essentially, these designs attempt to maximize the information from each choice situation. In case any information about the parameters is available, then efficient designs will always outperform orthogonal designs (Kessels *et al.*, 2006). This is because efficient designs use prior knowledge of parameters to optimize the design in which the most important information is gotten from each choice situation.

While efficient designs can outperform the orthogonal designs, prior parameter estimates need to be available (Hensher *et al.*, 2005). The efficient design thus relies on the accuracy of the prior parameter estimates. As the prior parameter values for the estimation in this study were not available, the orthogonal (fractional factorial) design were used to generate the number of choice situation in this study. Two reasons can be given for using orthogonal design in this study. Firstly, it allowed use of independent estimation of the key influence of each design attribute on choice. Secondly, with the absence of prior parameters, there was no reasonable justification for applying efficient design in this study.

A full factorial design achieves perfect orthogonality and balance. For a full factorial design, all main effects, all two-way interactions, and all higher-order interactions are

estimable and uncorrelated. Hensher *et al.*, (2005) define a main effect as the direct independent effect of each trait on a dependent variable. It is the difference in the means of each level of a trait and the overall mean. An interaction effect, on the other hand, is the effect on a dependent variable by combining two or more traits which would not have been observed had each of the traits been estimated separately. The problem with a full-factorial design is that, for most practical situations, it is too costly and may place a significant level of cognitive burden on respondents, which is likely to result in response unreliability. Several strategies have been employed to reduce the number of choice sets given to respondents. These include reducing the number of levels used within the design, using fractional factorial designs, blocking the design or using a fractional factorial design combined with a blocking strategy.

Fractional factorial designs are generated by selecting subsets of choice sets from the full factorial design. To choose the subsets of choice sets from the full factorial design, an analyst may randomly select a number of treatment combinations without replacement. The limitation in doing this, however, is the likelihood of producing statistically inefficient or sub-optimal designs. An alternative strategy to select optimal combinations is to select the smallest orthogonal main effects design from the full factorial, which is determined by the total degrees of freedom required to estimate all implied main effects (Louviere *et al.*, 2000). The total degrees of freedom are determined by summing the separate degrees of freedom in each main effect. The use of fractional factorial design has been popular amongst employers of choice experiment. Adamowicz *et al.* (1998) and Revelt and Train (1998) utilized fractional factorial designs to generate choice sets using orthogonal main effects only designs. In a main effect only design, a sub-set of the full factorial design is selected such that all main effects are identifiable and completely orthogonal with each other (Lusk and

Norwood, 2005). Main effects only-designs significantly reduces the number of treatment combinations though its limitation arises due to the fact that only a fraction of the total number of possible combinations are used, resulting in possible information loss.

In this study, a full factorial design as indicated will have led to $2^6 \times 3^6 = 46,656$ generic choice sets. A full factorial design is, in fact, very large and not easy to manage in a choice experiment. Since it would not have been practically feasible to work with such a large number of choice sets, a partially orthogonal main effect only design was generated from the full factorial design to create feasible choice sets using experimental design techniques in LOGIT V to obtain an orthogonal design, which consisted of only the main effects. The design results in 6 fractional factorial profile plans or alternatives.

The choice sets that resulted from this design were used to construct profiles describing the differences in traits and levels of improved sweet potato attributes and these were presented to respondents in terms of hypothetical settings. The profile plans (alternatives) were then consequently grouped into 10 types of questionnaires with three profile plans (alternatives) forming a choice set. Table 3.2 provides an example of one of the choice sets that was used in the choice experiment.

The generic choice sets did not refer to any particular variety or label, but rather were members of a class of alternatives. The alternatives are simply bundles of traits and the objective was to assess which traits were important drivers of choice.

Generally, there are two types of choice experiments: labelled and unlabeled choice experiments (Louviere *et al.*, 2000). Unlabeled choice experiments use nonspecific titles for the alternatives (e.g., improved variety “A” or “B”) whilst labelled choice

experiments use alternative-specific titles for the alternatives (e.g., “H627, H626, H625”). From a theoretical view point, the number of alternatives, whether labelled or unlabeled, in a choice set is unrestricted (Hensher *et al.*, 2005). Unlabeled choice experiments are known to have some advantages over labelled choice experiments and they include: (1) there is no need to identify and use all alternatives within the universal set of alternatives, that is, the attribute levels are sufficiently broad to represent all alternatives; (2) they encourage respondents to choose an alternative by trading-off attribute levels, which may be desirable from a nonmarket valuation perspective (Mitchell and Carson, 1989); and (3) respondents are required to consider differences in alternatives and not base their responses on the more attractive label.

Generally, unlabeled choice experiments generate estimates of the relative importance of the attributes of the products themselves and prevent respondents from resorting to decision-making ‘shortcuts’ if the number of attributes and/or choice alternatives is too large (Blamey *et al.*, 1997). One extreme shortcut will be to consider improved seeds/vines variety name that appeals to him/her only. In that case, respondents’ perceptions of the improved Sweet Potato variety rather than the attribute descriptions in the choice scenario will determine the stated choices. Although labelling choice experiments provides information about the alternatives and makes choices less demanding, they may encourage discriminating responses (Blamey *et al.*, 2000). Instead of the respondents focusing attention on the attributes of the improved seed or vine variety they will be focusing on the names or brands of the improved crop variety. This action will compromise the estimation of the tradeoffs between the attributes in the choice model which is the main aim of this studies.

Presenting generic unlabelled Sweet Potato variety labels like “A” or “B” focused the attention of the respondent on the attributes and presented each choice scenario differently without the known names or brands.

The presentation to the respondents of profiles or alternatives in a choice experiment can be carried out in the following three ways: verbal descriptions, paragraph descriptions, and pictorial representations (Cattin and Wittink, 1982). Verbal descriptions use cards in which each trait level is described in a brief line item fashion, while paragraph descriptions give a more detailed description of each level. Pictorial representations use some graphical images to present the levels of traits. This study resorted to the use of both paragraph and pictorial presentations. These were deemed to be plausible due to the high illiteracy rates and language differences in the study communities. Holbrook and Moore (1981) found that visual materials aid respondents to process the information in a more accurate way, thereby facilitating the interpretation and rating of the profile or alternative.

Cards with pictorial representations of the differences in the levels of traits were used to demonstrate each improved sweet potato variety profile to the survey respondents. Figure 3.2 presents an example of a choice card that was consequently presented to sweet potato farmers. Overall, a total of 12000 choices were elicited from 400 farmers who took part in the choice experiment. The choice experiment administration was conducted in the following ways: the respondents were introduced to ten choice sets and were asked to choose one out of the three alternative variety profiles from each choice set. Unlike the traditional choice experiment, an “opt-out” was included in the choice sets. The farmer had to choose amongst one of the alternatives. The reasons being that the study focused on finding the willingness to pay for improved sweet

potato traits and not just marginal willingness to pay for the sweet potato attributes and, therefore, it was necessary to include an opt-out alternative (Carlsson *et al.*, 2007).

3.6 Analytical framework

The standard MNL model described above has several important restrictions. First, the model structure assumes that taste parameters (β_s) are constant within the population. Secondly, the model also assumes that utilities derived by individuals from the choices they make are independent and homoscedastic. Thirdly, the model formulation is unable to account for preference variation (i.e random taste and scale heterogeneity) in the choices made by individuals. Because of these restrictions, the standard MNL model has been extended to formulations that have more flexible error structures, namely: the mixed logit (MXL), scaled multinomial logit (S-MNL), generalized multinomial logit (G-MNL) and generalized mixed logit (G-MXL) models. In this study, all these models were estimated to capture the objectives of the study as well as test the study hypotheses.

Nowadays, the MXL model has generally replaced the MNL model in analyzing the preference behavior of individuals. The model was developed to account for the intuitive fact that decision agents differ from each other. Thus, it can account for random taste variation, unrestricted substitution patterns, and correlation in unobserved preference factors of individuals (e.g. Hensher *et al.*, 2015). Subsequently, the utility farmer receives from a choice alternative would algebraically be formulated

as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (10)$$

Where V_{ij} is the deterministic component of the utility function observable to the researcher while ε_{ij} is the random component of the utility function known only by the

individual farmer as respondent. The deterministic component V_{ij} is a linear function of the product attributes in vector x_{ij} and the vector (β) of utility weights for each attribute, hence:

$$U_{ij} = \beta'_i x_{ij} + \varepsilon_{ij} \quad (11)$$

However, β_i is partitioned into a mean part ($\bar{\beta}$) and individual i^{th} deviation (η_i), thus:

$$U_{ij} = \beta'_i x_{ij} + \varepsilon_{ij} = (\bar{\beta}' + \eta'_i) x_{ij} + \varepsilon_{ij} \quad (12)$$

Following Train (2009), the probability of choosing alternative j by respondent i expressed by a vector of product attributes x is obtained by integrating the distribution density over the range of parameter values, thus:

$$Prob(j|x_i, b, w) = \int \exp(\bar{\beta}'_i x_{ij}) / \sum_{j \in k} \exp(\bar{\beta}'_{ij}), \Omega(\bar{\beta}|b, w) d\beta \quad (13)$$

The utility function of each consumer therefore has some random taste parameters $\bar{\beta}'_i$ with values that depend on the values of the parameters b and w of an underlying distribution $\Omega(\bar{\beta}|b, w)$. As Hensher and Green (2003) note, the choice of the distribution strongly affects the properties of the model. As such, random taste parameters $\bar{\beta}_i$ induce correlation across choices made by the same respondent but, maintains the advantageous logit probability. In effect, ε_{ij} is *iid* Gumbel and therefore, the choice probability remains logit conditional on the parameter draw. The MXL formula is thus a weighted average of the MNL probability calculated at different values of β . The weight is the probability density (Ω) of β over respondents with mean b and variance-covariance matrix w . Since Equation (13) does not have a closed form solution, it is estimated by simulated maximum likelihood method (e.g., McFadden and Train, 2000). Because the MXL formulation still maintains the MNL model assumption that the idiosyncratic error term is *iid*, it is unable to account for scale variation.

In order to account for the potential effects of scale variation, the S-MNL model that relaxes the *iid* assumption was developed (e.g., Fiebig *et al.*, 2010). Notably, the

MXL model only accounts for the unobserved taste variation in the deterministic component of utility. As a result, the scale factor μ , which is inversely associated with the error variance σ_ε^2 is normalized to one to allow for the estimation of the model. Past research (e.g., Louviere and Eagle, 2006) suggests that such a constant scale of error distribution may not be appropriate in explaining individual choice behaviour. Thus, Fiebig *et al.* (2009) developed other modelling methods that could accommodate variance across respondents in the random component of utility, namely, the S-MNL and G-MNL. For S-MNL model, the error variance σ_ε^2 is allowed to vary in the population so that the utility U_{ij} that respondent i derives from alternative j is:

$$U_{ij} = (\beta\sigma_i)'x_{ij} + \varepsilon_{ij} \quad (14)$$

where β denotes a vector of averaged attribute parameters of the population; σ_i refers to the individual's specific standard deviation of the idiosyncratic error term that captures scale heterogeneity, x_{ij} denotes a vector of the observed explanatory variables, and ε_{ij} is as before the stochastic error that is *iid* over the alternatives and individuals (Fiebig *et al.*, 2009). The individuals' scaling factor has to be restricted to be positive and this is attained through the use of an exponential transformation (e.g., Fiebig *et al.*, 2009; Greene and Hensher, 2010), that is:

$$\sigma_i = \exp(\bar{\sigma} + \tau w_i) \quad (15)$$

Where, $\bar{\sigma}$ denotes the mean parameter related to the error variance; τ is the coefficient associated with the unobserved scale variation; and w_i refers to the unobserved individual variation related to the scale that is standard normally distributed. Since $\bar{\sigma}$ is unidentified separately from τ , σ_i is normalized as $\bar{\sigma} = \tau^2/2$. Thus, larger parameter values for τ show a greater degree of scale variation (Fiebig *et al.*, 2009). The S-MNL model is estimated by way of simulated maximum likelihood procedure. The need to account for both taste and scale variation in one and the same model led to the

development of the G-MNL model (e.g., Keane *et al.*, 2006; Fiebig *et al.*, 2010; Greene and Hensher, 2010). Notably, the G-MNL model nests both MXL and SMNL. First operationalized by Fiebig *et al.* (2010) and subsequently by Greene and Hensher (2010), the marginal utility for attribute j for the G-MNL model is represented as:

$$U_{ij} = \sigma_i \bar{\beta}_j + \gamma \theta_{ij} + (1 - \gamma) \sigma_i \theta_{ij} \quad (16)$$

where γ takes any value between 0 and 1 and:

$$\sigma_i = e^{\bar{\sigma} + \tau v_i} \quad (17)$$

In Equation (17), $\bar{\sigma}$ denotes a mean parameter of scale variance, τ is a parameter of unobserved scale variation and v_i is a standard normal distribution representing the unobserved scale variation. Ignoring σ_i and in the extreme case where γ takes the value 0, Equation (16) collapses to:

$$U_{ij} = \sigma_i (\bar{\beta}_j + \theta_{ij}) \quad (18)$$

suggesting that scale impacts equally upon both the mean and standard deviation parameters. Fiebig *et al.* (2010) refer to this model as G-MNL II. On the other extreme, when γ equals 1, Equation (16) collapses to:

$$U_{ij} = \sigma_i \bar{\beta}_j + \theta_{ij} \quad (19)$$

suggesting that scale impacts only upon the mean parameter. Fiebig *et al.* (2010) refer to this model as G-MNL I. Values of γ between 0 and 1 suggest that scale impacts both the mean and standard deviation parameters but, to different extents. Returning to σ_i , if $\sigma_i = 1$ and all $\theta_{ij} = 0$, then the model collapses to the standard MNL model. If σ_i is estimated to take the value 1, then the marginal utilities obtained from the model would collapse to the MXL model estimates. Similarly, if all θ_{ij} simultaneously equal 0, then the model collapses to S-MNL model (Fiebig *et al.*, 2010) such that the marginal utilities obtained from the model would algebraically be given as:

$$U_{ij} = \sigma_i \bar{\beta}_j \quad (20)$$

Finally, a more flexible G-MXL modelling approach accommodating individual taste as well as individual scale variation was also proposed by Fiebig *et al.* (2009). The GMXL model specification thus accounts for the unobserved variation both in the deterministic and in the random components of the individual utility function. In this model, utility, U_{ij} , is given by:

$$U_{ij} = \{\sigma_i\beta + \gamma\eta_i + (1 - \gamma)\sigma_i\eta_i\}'x_{ij} + \varepsilon_{ij} \quad (21)$$

where σ_i denotes the respondent specific standard deviation of the idiosyncratic error term that captures the scale variance, η_i is respondent specific deviations from the mean, capturing individual variance in taste; and γ is a weighting parameter between 0 and 1, that captures how the variance of the individual taste varies with scale.

While estimating the G-MXL model, several normalizations are however required. σ_i is again normalized as $\bar{\sigma} = -\tau^2/2$ to enable identification of $\bar{\sigma}$ so that $E[\sigma_i] = 1$. In addition, to ensure that $\tau \geq 0$, the model is fit in terms of λ , where $\tau = \exp(\lambda)$ and 1 is unrestricted (e.g., Hensher *et al.*, 2011). τ is the parameter that captures scale variance. If τ approaches 0, then the G-MXL model approaches the MNL model (Fiebig *et al.*, 2009).

As regards ANA, it was inferred from respondents' observed choices and thus, allowed for the estimation of the ECLC model. In the ECLC model, the population of interest was divided into a discrete number of classes, with the number of classes being determined endogenously by the choice data under investigation. Preferences of individuals are assumed to be homogeneous within a class but can vary between classes. Following Kragt (2013), the utility that individual i derives from choice alternative j in choice situation t may algebraically be defined as:

$$U_{ijt} = \beta_c'X_{ijt} + \varepsilon_{ijt} \quad (22)$$

where a class specific parameter vector β_c is estimated in the model. The probability of choosing alternative j is now conditional on belonging to a certain class c algebraically given as:

$$Prob(j_{it}|c) = \frac{\exp(\mu_c \beta_c' X_{ijt})}{\sum_{j=1}^J \exp(\mu_c \beta_c' X_{ijt})} \quad (23)$$

where μ_c is a class specific scale parameter. The error terms are assumed to be *iid* across individuals and classes with a type 1 extreme value distribution and scale factor ϕ . Class probabilities can be specified by the logit formula:

$$Prob(j_{it}|c) = \frac{\exp(\phi \gamma_c' Z_i)}{\sum_{s=1}^C \exp(\phi \gamma_s' Z_i)} \quad (24)$$

where Z_i is a vector of choice invariant individual-specific characteristics; γ_c is a vector of parameters to be estimated in the model; and C is the total number of classes specified by the researcher. To account for ANA, there are specified a number of classes in which some attribute coefficients were restricted to zero. Respondents whose choice strategies matched that of the specified pattern of non attendance are said to have a higher predicted probability of belonging to that class. The model infers class probability, and consequently the probability of non attendance, from the respondents' observed choices (e.g., Scarpa *et al.*, 2009; Campbell *et al.*, 2010; Hensher *et al.*, 2012). In this study, ANA was inferred by identifying the number of latent classes for the ECLC model, which were associated with all possible different combinations of ANA to the six choice attributes used in the study.

Another issue in the ECLC concerns how to choose the number of classes, S . The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to decide the number of classes, S (Louviere *et al.*, 2000; Boxall and Adamowicz, 2002). The criterion indicates that the preferred number of C classes were found where the values of AIC and BIC had been minimized (Louviere *et al.*, 2000).

3.7 The calculation of willingness to pay

The choice modelling results can be used to estimate implicit prices or willingness to pay (WTP) values of the different attributes. The simple random utility function as earlier alluded can be re-written as:

$$U_{njt} = \alpha_j + X_j\beta_n + P_j\beta_p +$$

Where most terms are as earlier defined, P_j denotes the cost parameter or price of alternative j which is often included as one of the attributes of the choice alternative. X_j denotes the other observed attributes of choice alternative, j . The constant, α_j denotes individual n 's choice-specific intercept for alternative j , β_p is the coefficient for the cost parameter and $j X$ represents the coefficient vectors for the other traits, for individual n . β_p and $j X$ are assumed to be random. The implicit prices for the traits $j X$ can then be estimated as the rate of change in the trait divided by the rate of change of the cost parameter (marginal rate of substitution) represented as:

$$\frac{\frac{\partial y}{\partial x_j}}{\frac{\partial U}{\partial P_j}} = - \frac{\beta_j}{\beta_p}$$

As mentioned above, the calculated willingness to pay estimate represented the marginal rate of substitution between prices and traits, and is a simple point estimate, assuming that the parameters are non-random.

3.8 Measurement of variables and hypothesized relationships

Adoption of improved Sweet Potato variety was taken as the dependent variable. It was equals 1 if the farmer planted improved Sweet Potato variety during the 2020 cropping season and 0 if it had been otherwise. The hypothesized relationship of these dependent variables to the explanatory variables is discussed in detail in the section on

factors affecting technology adoption under the literature review. The farmer's decision to adopt or not to adopt improved Sweet Potato variety was hypothesized to depend on the explanatory variables of age, gender, education, household size, farm size, credit access, membership to farmer organization, Sweet potato variety grown, Frequency of growing sweet potatoes, Source of sweet potato vines, Sweet potato income, Sweet potato use, extension access, Distance to reliable input/output market, amongst others. These were represented as both continuous and categorical variables in the analysis section. The continuous variables took any numerical value in form of real values. Categorical variables took a numerical value of either one or zero and are also called binary or dummy variables.

The age variable (AGE), was ostensibly measured in number of years. This is a continuous variable and it was expected a priori to negatively (Bekele and Drake, 2003) or positively (Langyintuo and Mekuria, 2008) influence the decision to grow new sweet potato varieties. It may be that older farmers are more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new varieties. It could also be that older people have more experience and are in a better position to assess characteristics of new varieties than younger farmers, and hence a higher probability of adopting the new and improved sweet potatoes.

The gender (GENDER) of the household head was a dummy variable that took the value of 1 if the head of the household was male, and 0 if female. The general assertion is that women are generally discriminated against in terms of access to external inputs and information. Gender of the household head has been found to influence the decision to adopt new technologies (Langyintuo and Mekuria, 2005a). GENDER was therefore hypothesized to have a positive or negative sign.

The Education (EDUCN) variable was measured as the number of years of schooling. The importance of education (EDUCN) and experience in enhancing human capital through acquisition and learning of skills has been well documented (e.g., Feder *et al.*, 1985, Asfaw and Admassie, 2004). More educated farmers are typically assumed to be better able to process information and search for appropriate technologies to alleviate their production constraints. Therefore, education was expected to positively influence the decision to adopt improved sweet potato varieties.

Number of times of growing sweet potato in a season was expected to increase the probability of uptake of new and improved varieties because it normally leads to higher income for farmers and therefore higher utility for them with more frequencies of growing sweet potato. Farming experience is measured as the number of years one has spent in farming. Other variables that are more likely to affect adoption of sweet potato are sources of sweet potato vines, with own source positively affecting adoption; and sweet potato use, with growing the crop for commercial purposes having a positive impact.

Farm size (FARMSIZE) was measured in hectares. Farmers with larger farm sizes are more likely to try new technologies as they can afford to devote part of their field to try out the new technology (Simtowe *et al.*, 2009; Langyintuo and Mekuria, 2008). It was therefore hypothesized that larger land holdings will positively influence adoption of improved sweet potato varieties.

Farmers contacts with extension agents (EXTENSION) was measured as a binary variable: 1 if the farmer has been in contact with any extension, 0 if otherwise. Agricultural extension (EXTENSION) enhances the efficiency of making adoption decisions. Contact with extension agents was expected to have a positive effect on adoption of improved seed varieties. Contacts with extension agents expose farmers to

necessary information concerning agricultural technologies and are likely to stimulate adoption (Polson and Spencer, 1991).

Knowledge (AWARENESS) was ostensibly measured as dummy variable: 0 = unaware, 1 = aware. Knowledge (AWARENESS) about the existing technologies have also been found to influence adoption positively (Asfaw *et al.*, 2011) as lack of awareness of end users may hinder potential adoption. Knowledge of the various improved Sweet Potato varieties was hypothesized to positively influence their adoption.

Sweet potato income was expected to have a positive impact in motivating farmers towards growing better and improved varieties. The higher the income from growing and selling of sweet potato, the higher the propensity of adopting improved sweet potato varieties. Sweet potato income was measured as a continuous variable. Based on the innovation diffusion theory, it is hypothesized that farmers who earn high income from commercially disposing sweet potato were more likely to accept to grow improved sweet potato varieties (e.g., Feder and Slade, 1984; Shampine, 1998; Smale *et al.*, 1994). Sweet potato income was hypothesized to positively affect adoption.

Land tenure (LANDT) has been found to contribute to adoption, because landowners tend to adopt new technologies more frequently than tenants. Land tenure was measured as dummy variable: 1 = owner, 0 = not the owner. Land ownership was likely to influence adoption if the innovation requires investments tied to land and whether the investment is long term or short term (Feder and Onchan, 1987; Basely, 1995). The adoption of improved seeds varieties is short term (usually one crop cycle) which may not be affected if farmers do not have property rights as farmers can rent and or sharecrop land for agriculture. Therefore, the relationship between land tenure and the decision to adopt improved seeds varieties can be positive or negative.

Another variable that has received attention is access to credit (CREDIT), which commonly has a positive effect on adoption behaviour. Access to credit (CREDIT) was measured as dummy variable and was expected to positively influence the adoption of improved sweet potato varieties as farmers would have access to more funds for increased input use among others. Credit plays important role in technology adoption when the initial outlay requires cash investment, mainly for smallholder farmers without readily available cash (Feder *et al.*, 1985).

Distance to input and output market (DISTANCE) measured in kilometres was expected to negatively influence adoption of improved seeds varieties. Input markets allow farmers to acquire the inputs they need such as pesticides and herbicides whilst access to output markets provides farmers with positive incentives to produce more for sale. The general perception is that the shorter the distance from the household to the nearest market, the higher the probability of adoption (Salasya *et al.* 2007; Langyintuo and Mekuria, 2008).

Concerning technology specific characteristics, farmers were asked to compare improved seeds variety with their choice of the best traditional variety in terms of pests and diseases (TOLERANCE), productivity (YIELD), and Maturity Period (MATUEPRD). The perceived superiority of improved sweet potato varieties over the traditional in terms of yield and disease resistance was expected to positively influence adoption. If an improved variety was perceived to better meet desirable maturity period and had more productive attributes compared to traditional varieties, then it would naturally be highly demanded by farmers. A positive relationship was therefore expected for improved varieties that could mature faster as a matter of fact. Higher yielding sweet potato varieties were also expected to attract favor from farmers.

Table 3.9: Measurement of variables and expected signs

VARIABLE	Description	Measurement	Expected sign
AGE	Age of a farmer	Years	+ve or -ve
GENDER	Sex of the farmer	Dummy (0=Male; 1=female)	+ve or -ve
EDUCATION	Number of years in school	Years	+ve
SINCOME	Income from sale of sweet potato	Kenya Shillings	+ve
EXTENSION	Extension contact	Dummy (1=contact; 0=otherwise)	+ve
CREDIT	Access to formal credit	Dummy (1=yes; 0=otherwise)	+ve
ACCESS TO MARKETS	Access to input and output market	Dummy (1=yes; 0=otherwise)	-ve
SOURCEVINES	Source of sweet potato vines	Dummy (1=perceived that improved sweet potato vines are from own source; 0=otherwise)	+ve
Quantity of Sweet Potato (Yield)	Perception of high yielding of improved seeds variety	Dummy (1=perceived that Improved Sweet Potato is high yielding)	+ve
Sweet potato use	Perception that improved seeds variety can be commercially sold	Dummy (1=perception that improved Sweet Potato has commercial use; 0=otherwise)	+ve

Source: Researcher's Tabulation, (2020)

Table 3.3, previously shown presents the improved sweet potato trait levels that finally entered the deterministic portion of the utility functions, ostensibly random utility models like the Multinomial logit and the mixed logit models and their expected direction of influence on the utility function. Random utility theory establishes the concept that individual choice behavior is essentially probabilistic.

Random utility (Probabilistic choice theory) in its form implies that the individuals' reports of their preferences or utilities are not always the same under identical conditions, owing to measurement error or to random variation in the assessment of individuals' preference/utility. The data was essentially coded according to the levels

of the attributes used in the choice experiment. Attributes with two levels were entered to the utility function as binary variables that were effects coded (Louviere *et al.*, 2000). All attributes in this study had three levels.

For Pests and Diseases resistance (tolerance) variable, not resistant to pests and diseases was entered as High for highly resistant, Moderate for moderately resistant and low for poorly resistant to pests and diseases. For Sweetness variable, improved seeds varieties that are Sweet were entered as Good whilst those that are moderately sweet were entered as Average. Those that had poor taste were entered as bad.

For maturity attribute, improved seeds varieties that are early maturing, were entered as “Up to 3 months” those that are middle maturity were entered as “up to 5 months” and for those that are late maturity, entered “up to 7 months”. The levels used for purchase price and productivity were correspondingly entered as ascribed in the previously ascribed levels. As a result, the purchase price attribute consequently the predetermined levels of 100, 200, and 300 for values measured in Kenya Shillings. In the same way, the productivity attributes similarly took levels 6, 10 and 14 respectively; being measures of sweet potato productivity in tonnage per hectare. However, the coding for costs were ostensibly multiplied by 100 to make it easy for coding purposes; since the base value was value of a dozen vines of sweet potato planting materials.

What was deduced from the farmer was taken to constitute the choice made by the respondent, and rightfully assumed to be the utility maximizing alternative. Choice was binary dependent variable if it took the value of 1 for the chosen alternative and 0 for the non-chosen alternatives. From a priori perspective, the trait levels ‘high productivity’, ‘shorter maturity period’ ‘high resistance to diseases’, ‘yellow colour’, ‘low cost of Ksh 100’, ‘sweet taste’ and ‘early maturity’ were expected to increase a

producer's utility. High productivity was expected to increase production per hectare and thus increase farmers' food stock and income. Therefore, high productivity was expected to influence farmers' utility positively. A high resistance to pests and diseases normally has a positive impact on productivity and thus on utility. Since agricultural production of sweet potato is constrained with colour of the flesh, improved seeds variety which were Orange in colour were highly desirable due to expected nutritional benefits to the farmers and consumers of sweet potato. Similarly, maturity period in normal case expected to influence utility of the farmer positively as early maturity results into faster return of capital investment. Finally, the trait coefficients associated with purchase price that is, selling price of improved sweet potato variety traits was expected to have a negative sign due to the negative marginal utility for cost generally exhibited by most individuals. It also conforms to economic theory of demand which usually has a negative coefficient among all rational consumers.

Most important socio-demographic variables that were generally considered included gender, age, experience and education of the decision maker, average household size, farm size and market access factors. Human capital theory suggests that education and experience are important factors in enhancing human capital through acquisition and learning of skills. It enhances the efficiency of human beings to perceive, to interpret correctly and to undertake actions that will appropriately reallocate their resources (Schultz, 1975). This implies that farmers who are highly literate will easily conceptualize and comprehend the effects and trade-offs of different trait levels better in their choice decisions. Household size and composition reflect labour availability and constraints which impact on the utility derived from certain traits that may be labour intensive (e.g. high productivity that would need labour for harvesting). The household size variable has often been used in crop technology adoption studies such

as Kaliba *et al.*, (2000) and Amaza *et al.*, (2007) as an indicator of availability of labour resource.

Gender of the household head is important because female headed households may be labor constrained, especially if some of the improved seeds traits require special type of labor. For instance, a trait such as high productivity often requires lots of hired labor during harvesting and the cost of hired labor may be unable to be realized by female headed households. Lack of market access for the products may adversely affect utilities for high productivity traits and early maturity traits. It was therefore hypothesized that farmers who are closely located to a market or an urban center were most likely be interested in increasing their production due to an assured and secured degree of opportunity to market their produce easily.

3.9 Estimation of farmers' preferences

From an econometric viewpoint, data for an individual had as many observations as choice questions she or he had been asked to answer (i.e., there were $T = 10$ observations per individual). The multinomial logit model was used to estimate choice specific data through maximum likelihood. The MXL, S-MNL, GMNL, GMXL and to a large extent ECLC also followed the same procedure. Suppose that our sample was made of I individuals, each making T choices. Each choice set was made of $J = 3$ alternatives. Let us define δ_{njt} as being a dummy variable such that:

$$\delta_{njt} = \begin{cases} 1 & \text{if the individual } n \text{ choose alternative } j \text{ from the choice set } t \\ 0 & \end{cases}$$

and 0 if otherwise

Hence, the likelihood function corresponding to the conditional logit model can be written as:

$$LL(\beta_x \beta_p) = \prod_{n=1}^I \prod_{t=1}^T \prod_{j=1}^J \left\{ P(y_n = \frac{j}{t}) \right\}^{\delta_{njt}}$$

Then, taking the logarithm of L gave us the log-likelihood function associated with the conditional logit model. With the mixed logit model, or indeed other described models, taking maximum likelihood estimation which required integrating over V_n . This amounted to computing a high-dimensional integral. Hence, the log-likelihood was approximated by a simulator that was based on S draws of V_n from the normal given current estimates of $\sum \beta_x$. The maximum simulated likelihood estimator then led to a situation that maximizes the logarithm of:

$$L(\beta_x \beta_p) = \prod_{n=1}^I \prod_{t=1}^T \prod_{j=1}^J \left\{ P(y_n = \frac{j}{t}) \right\}^{\delta_{njt}}, \text{ where } P(y_n = \frac{j}{t}) \text{ is a}$$

simulator for $P(y_n = \frac{j}{t})$. Here the frequency simulator was a smooth simulator. In this study, the log-likelihood function was maximized directly using N-LOGIT's general optimization package.

3.9.1 The empirical model specification of farmers' preference heterogeneity

The Multinomial logit model, mixed logit and S-MNL, GMNL, GMXL and ECLC, discussed above were used in this study to investigate farmers' preferences and the existence of improved Sweet Potato vine variety attributes and preference heterogeneity amongst farmers in Western Kenya. Estimation of the models required a specification of the functional form of the utility function. In this study, a linear in parameters utility function was assumed. The vector in equation contains improved Sweet potato vine variety attributes and trait levels of improved variety attributes profiles from the choice experiment. The choice experiment was designed with the assumption that the observable utility function was to follow a strictly additive form (Birol, 2004). The model was specified so that the probability of selecting a particular improved sweet potato variety attributes was a function of attributes of that variety.

That is, for the population represented by the sample, indirect utility from improved variety attributes took the form;

$$U_{ijt} = ASC_{local} + ASC_{improved} + \beta_1 yield_{ijt} + \beta_2 tolerance_{ijt} + \beta_3 sweetness_{ijt} + \beta_4 colour_{ijt} + \beta_5 maturity_{ijt} + \delta price_{ijt} + \varepsilon_{ijt}$$

Where β_{1-5} refer to the vector of coefficients associated with the vector of attributes describing improved Sweet Potato variety attributes. Estimated coefficient β , may be interpreted in terms of the relationship between the explanatory variables and the probability of choice. The constant term was not dropped in the above specification of the indirect utility function because the choice sets included a status quo or an opt-out option (Bateman *et al.*, 2003). Had this been the case, then the opt out option will not have been possible to consider. This is a base model which clearly specified the utility function with the main effects variables in the choice experiment. Besides the mean coefficients of variables from the sample population, mixed logit, and indeed the other five or so models, were also able to estimate the amount of spread that exists around the mean of the random parameter and provided estimates of individual specific parameter estimates. Each farmer made repeated choices for six improved sweet potato variety attribute profiles.

Several socio-economic factors influencing preference and choice behavior as presented in the choice model framework were therefore made relevant. These factors entered into the models as interactions with the X 's in the utility function in the preference equation. The indirect utility function was as presented in the equation below.

$$U_{ijt} = ASC_{local} + ASC_{improved} + \beta_1 yield_{ijt} + \beta_2 tolerance_{ijt} + \beta_3 sweetness_{ijt} + \beta_4 colour_{ijt} + \beta_5 maturity_{ijt} + \delta price_{ijt} + \alpha_1 (X_{PT} * GENDER) +$$

$$\alpha_2(X_{MTP} * GENDER) + \dots + \alpha_n(X_{nj} * K_{nj}) + \varepsilon$$

Where; V_{nj} =choice of the farmer, $\beta_i X_i$ and $\alpha_n(X_{nj} * K_{nj})$ are the deterministic terms

while ε represented the stochastic term.

3.10 Pre-testing of research instrument

Eight enumerators were trained to carry out the farmer survey in the four counties. The principal investigator doubled both as an enumerator and a supervisor. The criteria for the selection of the enumerators was based on the level of education; fluency in spoken and written English; and good knowledge of the local languages. The training involved explaining the goals and objectives of the study, imparting specific skills for effective interviewing and motivating the interviewers. The training also included reaching a consensus among the interviewers concerning the right interpretation of questions ostensibly because the interview process involved translating the questionnaire into local languages. The need for interviewers to keep sensitive information confidential was also particularly emphasized during the training.

Pre-testing of the questionnaires was done in five sub counties of Trans Nzoia county. The questionnaires were pre-tested with 50 Sweet Potato farmers (ten from each sub counties of Trans Nzoia) who were not part of the main study. Pre-testing was essential so as to determine the strengths and weaknesses of the survey concerning question clarity, format, wording, flow, order and timing. After pre-testing, the study went through the questionnaires with the interviewers to find out whether the questions were comprehensible to both the respondents and the interviewers. The questions that were not clear were rephrased in a manner that was easily understandable to both the interviewers and the respondents without changing the original meaning and themes of the relevant questions.

3.11 Limitations of the Study

The study was not able to use genetic information, as recognized by geneticists, which are used to differentiate improved varieties from local varieties. There were no real measurements (e.g. DNA testing) but physical appearances were mainly used to detect whether an improved seed variety is local or improved. Another problem involved use of questions that required the respondents to recall events from the past. These comprised questions such as the amount of produce harvested, quantity sold and consumed. A third challenge was the interpretation of the questions from English language into the local language. The interviewers however, were thoroughly trained before starting the survey, so as to minimize possible lack of clarity. The study was done during the peak of the outbreak of COVID 19, a very virulent disease. This posed a great risk to the health of all those involved, especially during the administration of questionnaires. To mitigate for this, SurveyCTO platform was used to gather data from respondents.

3.12 Data analysis

This study employed both descriptive and inferential statistical analysis techniques. Descriptive statistics (e.g., mean, median, standard deviation) were used to summarize and describe the survey results. Inferential statistics were used to arrive at conclusions based on probability. Choice experiment was used to investigate and measure preferences and willingness to pay for improved Sweet potato variety attributes.

Farmers' preferences and willingness to pay for the selected sweet potato attributes were analyzed using the multinomial logit model, Scaled Multinomial logit model, Generalized Multinomial logit model, generalized mixed multinomial logit model and the mixed logit models among others. Details of the theoretical and analytical

frameworks of the above mentioned models are as presented in Chapter 2 and 3 respectively. Analyses were carried out using N-Logit.

3.13 Ethical and Philosophical Considerations

The researcher obtained an introduction letter from the University before the massive data collection exercise. The administrative authorities including the ministry of agriculture, sub-county agricultural officers and ward agricultural staff, as well as area administrative chiefs were contacted for consent before administering the choice experiment questionnaires in their respective regions. Finally, a written informed consent letter was presented to the farmers after a brief oral description of the objectives of the study. Permit from National Commission for Science, Technology and Innovation was also obtained. The confidentiality of the information provided by the respondents was guaranteed through access restriction to all third parties and through the use of strong passwords for electronically stored data. All respondents also participated in the study voluntarily without providing their contacts addresses and names.

Philosophical approach was anchored on positivism. Indeed, we believed that knowledge is revealed from a neutral and measurable or quantifiable observation of activity, action or reaction.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This section presents tabulated and critically presented discussions on the pertinent results of the study. The results shown in the chapter were obtained using both descriptive and inferential statistics. The multinomial logit (MNL), mixed logit (MXL), scaled multinomial logit (S-MNL), generalized multinomial logit (G-MNL), generalized mixed logit (G-MXL) and the equality constrained latent class (ECLC) models were therefore estimated to understand key relationships among variables.

4.2 Descriptive Statistics on Preference Variation and Willingness to Pay Estimates

Regarding willingness to pay and preference variation, Table 4.1 presents descriptive statistical results that primarily capture the socio-demographic and economic characteristics of the survey sample. As indicated, the mean age of the respondents was 45 years, and the majority of respondents (78%) were men. The majority of respondents (93%) had primary and post-primary education, but only 11% and 14% had access to farm credit and agricultural extension services, respectively. The average distance to a reliable input/output market center was approximately 3 kilometers, and 16% of the interviewed farmers were members of farm organizations. 62% of respondents grew improved sweet potato varieties, and 36% of respondents said they grew sweet potatoes more than once per year, according to the study. In addition, the study revealed that 95% of the farmers interviewed produced sweet potatoes for commercial purposes. According to the study, 35% of the farmers

obtained planting vines from their farms. The average sweet potato yield was 1.91 tons per acre (4.775 tons per hectare), yielding a revenue of approximately KES 11,702 per acre.

Table 4.10: Socio-demographic and farm characteristics of the survey sample

Variable	Mean/prop ortion	Std error	Min	Max
Age (years)	45	13.31	20	85
Gender (1=male)	0.78	0.41	0	1
Education (1=educated)	0.93	0.25	0	1
Access to farm credit (1=access)	0.11	0.31	0	1
Access to agricultural extension (1=access)	0.14	0.35	0	1
Membership to farm organizations (1=member)	0.16	0.37	0	1
Sweet potato variety grown (1=improved)	0.62	0.48	0	1
Frequency of growing sweet potatoes (1=more than once)	0.36	0.48	0	1
Sweet potato use (1=commercial purposes)	0.95	0.22	0	1
Source of sweet potato vines (1=own farm)	0.35	0.77	0	1
Quantity of sweet potato harvest (tonnes)	1.91	15.23	0	300
Sweet potato income (KES)	11,702	2,114	0	180,000
Distance to reliable input/output market (Kms)	3.07	0.71	0.1	7

Source: Author's Compilation (2021)

In a bit to understand more issues about descriptive data on preference variation and willingness to pay for various Sweet Potato varietal traits information, Table 0.2, further shows farmer's perceptions about the severity of challenges faced in sweet potato production. As shown in the table, 81% of the farmers felt that lack of extension services is a major problem facing sweet potato farming in the study area. This was followed by the unavailability of farm credit (76%), yield variability (67%), input quality (58%), input availability (54%), and price variability (50%). However, low incidences of flooding (18%) and drought (22%), exploitation by middlemen (22%), and theft of produce were some of the least challenges faced by farmers in production.

Table 4.11: Severity of challenges faced in sweet potato farming among the survey respondents

Variable	Proportion	Std error	Min	Max
Labour scarcity	0.31	0.46	0	1
Yield variability	0.67	0.47	0	1
Frequent droughts	0.22	0.41	0	1
Frequent floods	0.18	0.38	0	1
Extension services	0.81	0.39	0	1
Input quality	0.58	0.49	0	1
Input availability	0.54	0.50	0	1
Credit availability	0.76	0.43	0	1
Market for produce	0.30	0.46	0	1
Price variability	0.50	0.50	0	1
Road network	0.30	0.46	0	1
Theft of produce	0.29	0.45	0	1
Middlemen	0.22	0.41	0	1

Source: Author's Compilation (2021)

Further to information in Table 4.1 and Table 4.2, the results shown in Table 0.3 further expands pertinent data on preference variation and willingness to pay. The study found that friends (91%) were the most important source of information, followed by relatives (87%), and radio (68%). However, farmers' associations (31%), television (30%), input dealers (30%), extension agents (27%), and newspapers (23%) were the least important sources of information in sweet potato production.

Table 4.12: Important sources of information used in sweet potato farming in the study area

Variable	Proportion	Std error	Min	Max
Friends	0.91	0.29	0	1
Relatives	0.87	0.34	0	1
Newspaper	0.23	0.42	0	1
Radio	0.68	0.47	0	1
Television	0.30	0.46	0	1
Input dealer	0.30	0.46	0	1
Farmer association	0.31	0.46	0	1
Extension agent	0.27	0.44	0	1

Source: Author's Compilation (2021)

Data on Willingness to Pay and Preference heterogeneity descriptive statistics will not be complete without considering choice shares across the three alternatives (i.e., for local variety, improved variety, and the status quo option). These were analyzed and presented in Table 4.4 extensively.

Table 4.13: Choice shares across the alternatives in the discrete choice experiment

Description	Proportion	Standard Error	95% Confidence Interval	
Local variety	0.340	0.007	0.326	0.355
Improved variety	0.624	0.008	0.609	0.639
Status quo	0.036	0.003	0.030	0.041

Source: Author's Compilation (2021)

As shown in Table 4.4, there was a positive attitude among respondents towards improved sweet potato variety since the alternative was chosen in 62% of the cases compared to the local variety option which was chosen in 34% of the cases. The majority of those who chose none of the two (3.6%) explained that they did not mind any of the sweet potato varieties.

4.3 Econometric results On Preference Variation and Willingness to Pay

The first objective of the study was to assess farmers' willingness to pay (WTP) for better-quality sweet potato varietal traits in western Kenya. This discussion also relates to the third objective which explicitly sought to explore the role of preference variation in the choices made by farmers towards sweet potato variety traits in the region. As previously mentioned, five utility models, namely, MNL, MXL, S-MNL, G-MNL, and the G-MXL were estimated to assess preference variation in the choice data. Since the MNL model does not implicitly account for either taste and/or scale variation in the discrete choice decisions, researchers have in the past used interaction terms so as to capture taste variation. As for the MXL model, taste variation is captured directly in the systematic component of utility and accounted

for by specifying the choice attributes as random parameters. In the S-MNL model, scale variation is implicitly accounted for in the random component of utility. For G-MNL and the G-MXL models, both taste and scale variations are accounted for in both the systematic and the random components of the utility models.

In this study, estimations of the five behavioral models (MNL, MXL, S-MNL, GMNL, and G-MXL) were conducted with choice attributes as the random parameters to assess the significance of taste and scale variation in the choices made by sweet potato farmers in western Kenya. The utility functions were specified as linear functions of the choice attributes with an alternate specific constant (ASC), also included in the utility functions to represent the difference in utility between respondents' choice of the provided choice alternatives (local variety or improved variety) and the status quo option when all attributes are equal. Relevant choice data to accomplish these objectives were therefore obtained and the appropriate utility functions were specified. The utility functions were stated as linear functions of the choice attributes with an alternate specific constant (ASC), also included in the utility functions to represent the difference in utility between respondents' choice of the provided choice alternatives (local variety or improved variety) and the status quo option when all attributes are equal. The ASC was included in the model as a dummy variable with the provided choice alternatives being coded as one and the status quo option as zero (Tarfesa and Brouwer, 2012). In addition, following Greene *et al.* (2006), the random price parameter was assumed to follow a constrained triangular distribution to ensure a negative sign on the price parameter. However, a normal distribution was defined for the other random parameters. Although the main model for the study was the G-MNL, both MXL and the S-MNL models were

estimated alongside the standard MNL model to compare the results emanating from the study.

Table 4.5 presents the estimation results of the standard MNL, S-MNL, MXL, and GMNL models. The standard MNL is usually estimated before the S-MNL, MXL, and G-MNL models as it generates the initial start values for the means of the coefficients and sets the starting values for the standard deviations (e.g., Hole, 2007). As shown in the table, the results are basically as expected with coefficient estimates showing the expected signs and acceptable levels of statistical significance. The ASC parameter is positive, which implies that respondents, on average, prefer the cultivation of either of the two sweet potato varieties as opposed to the status quo option of no cultivation at all. Moreover, positive coefficients of the survey attributes (i.e., yield, tolerance, and both sweetness and color of the flesh) imply that farmers derive higher utility from the improvement of such sweet potato varietal traits.

The negative sign of the maturity period and price change attributes indicate that farmers derive lower utility from their sweet potato production when the maturity period is longer and the price change is high. The standard deviations of the random parameters are also significant meaning that there is considerable unobserved preference heterogeneity in the survey sample.

As for the models estimated in the study, there is substantial improvement in the model fit that is seen at the convergence of the models (in terms of log-likelihood, McFadden Pseudo R², and the Akaike information criteria) when moving from the standard MNL model to the G-MNL model.

Table 4.14: Regression results for different DCE Models

Characteristics	MNL		MXL		S-MNL		G-MNL		G-MXL	
The Mean estimate of random attribute parameters	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
ASC (1 = none status quo)	2.806***	0.167	3.338***	0.190	4.358***	0.469	4.263***	0.283	4.706***	0.477
Yield level (1 = high)	0.041***	0.007	0.038***	0.009	0.044***	0.007	0.042*	0.008	0.044***	0.009
Tolerance to pests and diseases (1 = high)	0.079***	0.027	0.076**	0.029	0.073***	0.024	0.084**	0.029	0.068**	0.032
Sweetness of flesh (1 = good)	0.106***	0.029	0.097*	0.030	0.116***	0.025	0.104***	0.029	0.108***	0.032
Colour of flesh (1 = appealing)	0.038	0.028	0.020*	0.030	0.046*	0.023	0.028*	0.029	0.032	0.035
Maturity period (1 longer)	-0.052***	0.014	-0.057**	0.014	-0.035***	0.012	-0.053**	0.014	-0.052***	0.015
Price change (1 = high)	-0.0003	0.0003	-0.0007	0.000	-0.001*	0.0003	-0.0002*	0.0003	-0.0003	0.0003
Standard deviation of random parameters										
ASC			0.139*	0.279			4.632***	0.532	5.015***	0.704
Yield level			0.051**	0.130			0.069**	0.011	0.076***	0.012
Tolerance to pests and diseases			0.115*	0.011			0.162***	0.042	0.055*	0.051
Sweetness of flesh			0.037***	0.038			0.088*	0.047	0.095*	0.052
Colour of flesh			0.126*	0.046			0.010***	0.042	0.003*	0.061
Maturity period			0.138**	0.036			0.011**	0.024	0.051***	0.019
Price change			0.042*	0.016			0.001*	0.001	0.0007*	0.001
Model summary statistics										
Log-likelihood.	-3246.79		-3208.73		-3197.44		-3136.86		-3126.51	
LR chi-square	101.15		2371.44		2394.02		2515.18		2535.88	
Prob > chi square	0.0000		0.0000		0.0000		0.0000		0.0000	

McFadden Pseudo R ²	0.0432	0.2698	0.2724	0.2862	0.2885
Scale (tau) parameter τ	-	-	0.8247***	0.069***	0.381***
Weighting (gamma) parameter γ	-	-	fixed	fixed	0.982***
Akaike Information Criteria (AIC)	6507.60	6445.50	6410.90	6303.70	6285.00
Number of observations	4000	4000	4000	4000	4000

*Explanatory notes: ASC alternative-specific constant, which is a dummy for the respondent choosing to grow sweet potatoes as opposed to not growing; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.*

Source: Author's Compilation (2021)

Notably, the MNL model does not account for both taste and scale factors and when taste factors were accounted for through the MXL model (which by formulation accounts for taste factors only), the model fit improved by 38.06 points in the log-likelihood, 0.27 points in the Pseudo R2 and 62.10 points in the Akaike information criterion.

This means that it was important to account for taste heterogeneity in the study. Again, when the scale factors were accounted for through the S-MNL model (which by formulation accounts for scale factors only), the model fit improved by 49.35 points in the log-likelihood, 0.23 points in the Pseudo R2, and 96.70 points in the Akaike information. Over and above the MXL, the model fit for the S-MNL model improved by 11.29 points in the log-likelihood, 0.003 points in the Pseudo R2, and 34.40 points in the Akaike information. This implies that there was considerable scale heterogeneity in the survey sample. The fact that the model fit for the S-MNL was better when compared to that of the MXL model and also the significant *tau* (τ) parameter means that scale factors were much more important than the taste factors in the study. Accounting for both scale and taste factors in the study using the G-MNL model further improved the model fit by 110.93 points in the log-likelihood, 0.24 points in the Pseudo R2, and 203.90 points in the Akaike information. This means that choice models that account for both taste and scale variation perform better as opposed to those either capturing taste (e.g. MXL model) or scale variation (e.g. S-MNL model) (Fiebig *et al.*, 2010; Ndambiri *et al.*, 2016; Scarpa *et al.*, 2011). As in Ndambiri *et al.* (2016), the G-MNL model was found to capture both taste and scale variation better than the G-MXL model based on both LL information and AIC values. Owing to its better performance, the G-MNL model was thus used to derive the welfare estimates for the study.

Furthermore, the statistically significant scale parameter, τ , in the S-MNL, G-MNL, and G-MXL models means that scale variation was of more significance in the choice data as opposed to taste variation. This means that it was likely that the choice behavior of the farmers in this experimental design may have been characterized by significant choice uncertainties. It also means that this choice study may have also presented a more challenging choice situation to the farmers since according to Fiebig *et al.* (2010) and Christie and Gibbons (2011), a significant scale factor is usually, but not always, a case of more difficult choice contexts presented to respondents, which in turn maximizes chances for choice uncertainty. The weighting parameter was also found closer to zero meaning that the variance of the random taste variation increased with scale.

Estimates of WTP and standard errors were calculated using the Delta procedure, as earlier indicated. As shown in Table 4.6, it is evident that the WTP estimates are positive and statistically significant in all the models, which means that sweet potato farmers in the study area are willing to contribute positive amounts in support of a policy or program that improves the aforementioned varietal attributes. Of much interest is the fact that when no taste and scale factors are accounted for in the choice analysis, as is the case with the MNL model, the welfare value is highest for the yield attribute (KES 64.44) and lowest for the flesh color attribute (KES 12.95). When taste factors have been accounted for in the MXL model, the welfare value is highest for the sweetness of the flesh attribute (KES 234.67) and lowest for the colors of the flesh attribute (KES 100.85). After accounting for the scale factors using the S-MNL model, the welfare value becomes highest in the sweetness of the flesh attribute (KES 313.40) and lowest for the maturity period attribute (KES 100.28). In the case where both taste and scale factors have been

accounted for through the G-MNL model, the welfare value is still highest in the sweetness of the flesh attribute (KES 334.70) but lowest for the color of the flesh attribute (KES 108.29). The results suggest that farmers in the survey sample highly valued the sweetness of the sweet potato flesh more than the other attributes. While this was followed by tolerance to pests and diseases and then yield level, a choice could be made between flesh color and maturity period attributes owing to the indifference observed.

Table 4.15: WTP estimates for the different sweet potato varietal traits in the study area

Characteristics	MNL	MXL	S-MNL	G-MNL
	WTP	WTP	WTP	WTP
Yield level	64.44**	137.58**	128.43**	138.36*
Tolerance	50.86***	187.09**	184.25*	142.17***
Sweetness of flesh	33.08**	234.67***	313.40***	334.70**
Colour of flesh	12.95*	100.85*	116.91**	108.29**
Maturity period	32.92***	128.06*	100.28**	118.20*

Explanatory notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Author's Compilation (2021)

Notably, the MNL model provided the most conservative WTP estimates for the choice attributes as opposed to the MXL, S-MNL, and G-MNL models. Moreover, differences in the welfare values seem to suggest that the welfare estimation process was highly sensitive to model specifications, notwithstanding the significant heterogeneity in taste and scale across the individuals.

4.4 Descriptive and Econometric Results on Preference Certainty and Choice Consistency

The second objective of the study was to analyze farmers' preference certainty and consistency in their choice decisions for sweet potato varietal traits in Western Kenya. As mentioned earlier, respondents were asked to rate their level of certainty regarding the choices they made in the DCE for the different varietal traits on a scale of 0 to 10. The aim was to capture self-reported individual choice certainties that could be used to further inform the choice model results. Descriptive statistics for the findings indicate that respondents were considerably certain about the choices they made, with an average certainty score of 7.0 and a standard deviation of 1.38. Table 4.7 displays the distribution of the certainty scores for the data set.

Table 4.16: Certainty distribution of the respondents in the sample

Certainty	Frequency	Percentage
0	0	0
1	3	0.7
2	8	1.9
3	13	3.3
4	13	3.2
5	19	4.9
6	33	8.2
7	58	14.6
8	91	22.7
9	79	19.8
10	83	20.9
Total	400	100

Explanatory notes: N=400 respondents.

Source: Author's Compilation (2021)

In addition, a least squares regression model, showing econometric results, was estimated as in Chang *et al.* (2007) and Wang and Whittington (2005) to explore possible drivers underlying the observed variation in self-reported choice certainty. The regression results are presented in Table 4.8, where the response variable is the average self-reported choice certainty across all 10 choice tasks.

Table 4.17: Least squares regression results on the determinants of reported preference certainty

Variable description	Coefficient	Standard Error
Age (years)	0.009*	0.001
Gender (1=Male)	0.011	0.030
Education (1=educated)	0.157**	0.049
Access to farm credit (1=access)	0.709**	0.040
Access to farm extension services (1=access)	0.224**	0.039
Membership to farm organizations (1=member)	0.016	0.036
Sweet potato variety grown (1=improved)	0.369**	0.025
Frequency of growing sweet potatoes (1=more than once)	0.233*	0.025
Sweet potato use (1=commercial purposes)	0.521*	0.061
Source of sweet potato vines (1= own farm)	-0.066**	0.016
Sweet potato yields (tonnes)	0.003*	0.001
Income from sale of sweet potatoes (KES)	0.001*	0.000
Distance to a reliable input/output market (Kms)	-0.060**	0.017
Consistency (1=consistent)	0.047*	0.025
Constant	7.695**	0.066
Model summary statistics		
F (14, 385)	11	4.55
Prob > F	0.0	000
Adjusted R ²	0.1	170
Number of observations	40	00

Explanatory notes: Response variable: reported preference certainty; * $p < 0.1$;

**** $p < 0.05$; *** $p < 0.01$.**

Source: Author's Compilation (2021)

As shown in the table, older farmers were more likely to be certain about their preferences than younger farmers and this could be attributed to the cumulative experience in sweet potato farming that older farmers had over the younger ones. In addition, female respondents were found to have a lower reported choice certainty compared to their male counterparts. A possible reason might be that younger female respondents are less involved in decision-making while making farm choices of the sweet potato variety to be grown, and therefore experienced higher choice uncertainty.

The regression results also show that choice certainty among sweet potato farmers also increased with having gone to school, access to farm credit and extension services, membership to farm organizations, sweet potato variety grown, frequency of growing sweet potato crop in a year, sweet potatoes use, sweet potato yields, and the income derived from sweet potato sales. Nonetheless, choice certainty was found to decline with sources of sweet potato vines and distance to a reliable input-output market. The consistency variable was also positive and significant meaning that individuals consistent in their choice decisions for sweet potato varietal traits were more likely certain about their preferences as opposed to individuals with inconsistent choice behavior.

Preference consistency was also explored in the study by asking respondents to answer the same choice card on two occasions. In a given choice set, the first-choice card was repeated either as the 6th, 7th, 8th, 9th, or 10th card. Preference consistency across the two choice occasions was assessed by directly comparing the choices made by each individual on both choice occasions. The study first sought to tabulate descriptive statistics of respondents who chose the same option on the second occasion as they did on the first occasion and found that this happened in 65.9% of the cases. The pattern of

the repeated choices made in the two choice occasions is summarized descriptively in Table 0.98. As shown in the Table 0.9, about 15.3% of the respondents made the same choice when the 1st card was repeated as the 6th choice card in the sequence of 10 choice cards.

This share slightly but gradually decreased when the same first choice card is repeated further down the choice sequence to 11.3% consistent choices when the 1st card is repeated in the 10th and last choice task.

Table 4.18: Sample shares (%) consistently choosing the same varietal alternative

Choice task where the same first choice card is shown again	Frequenc y	Percent
1 – 6	61	15.3
1 – 7	56	14.0
1 – 8	53	13.3
1 – 9	48	12.0
1 – 10	45	11.3
Total	263	65.9%

Source: Author's Compilation (2021)

Moreover, to identify what might drive consistent behavior among respondents, possible explanatory factors influencing the probability of consistent choices were regressed on the binary choice consistency indicator (yes or no) in a logit model to gain econometric insight into the objective. Choice consistency was given the value 1 if the respondent made the same choice in both choice occasions and zero otherwise. The regression results are presented in Table 4.10. The results reveal that older farmers were more likely to be consistent in their choices than younger respondents. Male respondents were also more likely to be consistent in their choices than female respondents. Consistent behavior

among individual farmers was also found in the study to increase with access to farm credit and agricultural extension services, membership to farm organizations, and sweet potato is grown. The frequency with which sweet potato crop was grown in a year, sweet potato use, sweet potato yields, and income from the sale of sweet potatoes. Preference consistency was nevertheless found to decline with sources of sweet potato vines and distance to reliable input-output markets. The choice task of the repeated card variable was negative and significant confirming that the consistent choice behavior of individual respondents declined as the repeated choice card was located further away from the 1st choice card.

Table 4.19: Logit model results explaining consistent choice behavior of individual preferences

Variable description	Coefficient	Standard Error
Age (years)	0.003*	0.002
Gender (1=Male)	0.345*	0.052
Education (1=educated)	0.272**	0.082
Access to farm credit (1=access)	0.174*	0.067
Access to farm extension services (1=access)	0.407*	0.064
Membership to farm organizations (1=member)	0.368**	0.063
Sweet potato variety grown (1=improved)	0.205*	0.043
Frequency of growing sweet potatoes (1=more than once)	0.198*	0.042
Sweet potato use (1=commercial purposes)	0.267*	0.104
Source of sweet potato vines (1= own farm)	-0.118**	0.028
Sweet potato yields (tonnes)	0.076*	0.012
Income from sale of sweet potatoes (KES)	0.000*	0.000
Distance to a reliable input/output market (Kms)	-0.524*	0.031
Choice task of repeated card (6 - 10)	-0.239*	0.015
Constant	3.932**	0.169
Model summary statistics		
Log likelihood	-7237.31	
LR chi-square (14 d.o.f.)	949.70	
Prob > chi square	0.0000	
McFadden Pseudo R ²	0.0616	
Number of observations	4000	

Explanatory notes: Response variable: consistent choice=1, otherwise=0; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Author's Compilation (2021)

4.5 Statistics on Attribute Non-Attendance (ANA)

The fourth and last objective intended to assess the attribute non-attendance of the farmers in their choice decisions for sweet potato variety traits in Western Kenya.

Detailed descriptive results with analysis of the attribute attendance are presented in

Table 4.11. As shown, about 21% of respondents considered all the attributes in their choice decisions. However, the study found that respondents, as per their self-reported attendance, ignored different sweet potato varietal attributes in their choice decisions while nearly all of them showed lexicographic preferences towards only one attribute. The least attended attribute was 'yield' (ignored by 7% of respondents), followed by 'flesh color' (ignored by 12.3% of respondents), and then tolerance to pests and diseases (ignored by 17% of the respondents). The most ignored attribute was flesh color (ignored by 61.8% of the respondents). About 42.3% of the respondents ignored the price change attribute, which means that there were no considerable varietal traits and price trade-offs for these respondents.

Table 4.20: Stated attribute non-attendance of the survey sample

Variable	Number of respondents	% of the total
Attended to all attributes		
Yield, tolerance, flesh taste, flesh colour, maturity period, price change	85	21.3
Ignored one attribute		
Yield level	28	7.0
Tolerance level	68	17.0
Flesh taste	81	20.3
Flesh colour	247	61.8
Maturity period	49	12.3
Price change	169	42.3
Ignored two attributes		
Yield and tolerance level	7	1.8
Yield and flesh taste	9	2.3
Yield and flesh colour	22	5.5
Yield and maturity period	2	0.5
Yield and price change	14	3.5
Tolerance level and flesh taste	11	2.8
Tolerance level and flesh colour	49	12.3
Tolerance level and maturity period	17	4.3
Tolerance level and price change	34	8.5
Flesh taste and flesh colour	67	16.8
Flesh taste and maturity period	13	3.3
Flesh taste and price change	47	11.8
Flesh colour and maturity period	42	10.5
Flesh colour and price change	123	30.8
Maturity period and price change	30	7.5
Ignored three attributes		
Yield, tolerance, flesh taste	1	0.3
Yield, tolerance, flesh colour	5	1.3
Yield, tolerance, maturity period	1	0.3
Yield, tolerance, price change	4	1.0
Tolerance, flesh taste, flesh colour	9	2.3
Tolerance, flesh taste, maturity period	6	1.5
Tolerance, flesh taste, price change	8	2.0
Flesh taste, flesh colour, maturity period	12	3.0
Flesh taste, flesh colour, price change	39	9.8
Flesh colour, maturity period, price change	26	6.5
Ignored four attributes		
Yield, tolerance, flesh taste, flesh colour	1	0.3
Yield, tolerance, flesh taste, maturity period	1	0.3

Yield, tolerance, flesh taste, price change	1	0.3
Tolerance, flesh taste, flesh colour, maturity period	6	1.5
Tolerance, flesh taste, flesh colour, price change	6	1.5
Flesh taste, flesh colour, maturity period, price change	9	2.3
Ignored five attributes		
Yield, tolerance, flesh taste, flesh colour, maturity period	1	0.3
Yield, tolerance, flesh taste, flesh colour, price change	1	0.3
Tolerance, flesh taste, flesh colour, maturity period, price change	4	1.0
Ignored all attributes		
Yield, tolerance, flesh taste, flesh colour, maturity period, price change	0	0.0

Source: Author's Compilation (2021)

Table 4.11 and Table 4.12 display additional econometric findings on the estimated stated non-attendance obtained through the MNL and MXL models, as well as the estimated inferred non-attendance obtained through the ECLC models. Notably, the MNL- ANA and MXL- ANA models take into account non-attendance by requiring that the attribute parameters be set to zero whenever a responder states that they did not evaluate a certain attribute. An alternate specific constant, abbreviated as ASC, is incorporated into the utility function to accommodate both the possible "sweet potato variety" configurations (local and improved). Because analyzing ANA was the focus of this research, only ANA model results that do not take into account socio-demographic factors were considered.

As can be seen in Table 4.11, the outcomes are, for the most part, in line with predictions, with all estimations of coefficients displaying the anticipated signs and achieving satisfactory levels of statistical significance. The fact that the ASC parameter is positive indicates that respondents, on average, favor the cultivation of the two sweet potato types

over the option of maintaining the status quo in the market (no cultivation of either of the sweet potato varieties). When upgrading from an MNL model to an MXL model, there is a significant improvement in model fit (in terms of log-likelihood, McFadden Pseudo R², and the Akaike information criteria).

Because the standard deviations of the random parameters are statistically significant, it can be deduced that there is a substantial amount of unobserved heterogeneity in the respondents' individual preferences. The latent error component in the MXL model is statistically significant, indicating that there are unobserved changes in the error variance associated with the two sweet potato varietal options in comparison to the base alternative.

Table 4.21: MNL and MXL model results on ANA for sweet potato varietal traits in Western Kenya

Descriptions	Not Accounting for ANA				Accounting for ANA			
	MNL - Standard Model		MXL- Standard Model		MNL – ANA Model		MXL– ANA Model	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
ASC (1 = none-status quo)	2.806***	0.167	3.338***	0.190	2.499**	0.147	3.936***	0.276
Yield level (1 = high)	0.041***	0.007	0.038***	0.009	0.056***	0.007	0.049***	0.007
Tolerance to pests and diseases (1 = high)	0.079***	0.027	0.076**	0.029	0.038**	0.029	0.052*	0.030
Sweetness of flesh (1 = good)	0.106***	0.029	0.097*	0.030	0.076***	0.029	0.086***	0.031
Color of flesh (1 = appealing)	0.038	0.028	0.020*	0.030	0.119**	0.041	0.077*	0.044
Maturity period (1 = longer)	-0.052***	0.014	-0.057**	0.014	-0.060***	0.014	-0.059***	0.015
Price change (1 = high)	-0.0003	0.0003	-0.0007	0.000	-0.0003	0.0004	-0.0001	0.0004
<i>Standard deviation of random parameters</i>								
ASC			0.139*	0.279			2.549***	0.247
Yield level			0.051**	0.130			0.026**	0.012
Tolerance to pests and diseases			0.115*	0.011			0.066*	0.039
Sweetness of flesh			0.037***	0.038			0.024**	0.048
Colour of flesh			0.126*	0.046			0.072*	0.052
Maturity period			0.138**	0.036			.0310*	0.018

Price change			0.042*	0.016			0.000*	0.0009
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<i>Model summary statistics</i>				
Log-likelihood	-3246.79	-3208.73	-3235.55	-3170.51
LR chi-square	101.15	2371.44	63.95	2347.88
Prob > chi square	0.0000	0.0000	0.0000	0.0000
McFadden Pseudo R ²	0.0432	0.2698	0.0487	0.2785
Akaike Information Criterion (AIC)	6507.60	6445.50	6485.10	6369.00
Number of observations	4000	4000	4000	4000

Explanatory notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Source: Author's Compilation (2021)

Notably, both the MNL and the MXL models are dependent on the respondents' self-reporting of their attribute attendance. Recent research (such as those published by Hensher *et al.*, 2012 and Scarpa *et al.*, 2011) has provided evidence to support the hypothesis that the answers provided to supplementary questions might not be compatible with the ANA that is inferred from statistical models. In the current study, this paradox is investigated by constructing an ECLC model in which class membership is computed endogenously. The search for the specification began with a comprehensive 64-class ECLC model. Classes with extremely low projected class probabilities were gradually removed from the model, and adjustments to the Akaike information criteria were taken into account (AIC). After finding evidence of unobserved preference heterogeneity in the estimated MXL model, we explored an ECLC model that incorporates preference heterogeneity between classes by estimating class-specific taste parameters. This model allows for preference heterogeneity to exist both within and between classes. A seven class ECLC model was determined to suit the dataset by balancing advances in model fit while limiting classes with a very small probability. This model was found to be the best match for the dataset. The seven classes of the ANA were as follows: (i) full attendance (ii) ignored yield (iii) ignored tolerance (iv) ignored flesh taste (v) ignored flesh color (vi) ignored maturity period (vii) ignored price change. The proportion of respondents who are expected to fall into each class is shown by the ECLC class probabilities, which indicate this proportion. The research indicated that there were significant differences between the self-reported ANA of respondents and the expected class probabilities. This was determined by contrasting the self-reported ANA in Table 0.12, with the predicted probability of the seven-class ECLC model in Table 0.13. For example, 2.1% of

respondents were expected to have attended to all of the traits, whereas 21.3% of respondents self-reported attending to all of the attributes. The model also forecasts that almost twenty percent of respondents based their decision entirely on yield level, which is significantly higher than the seven percent who self-reported their attendance. When it comes to the respondent's choice decisions for the other varietal traits, significant disparities can be detected between the anticipated values and the values the self-report experienced. It is interesting to note, however, that around 59.2% of respondents were expected to have ignored the flesh color feature. This figure compares favorably with 61.8% in self-reported attendance, which shows that the attribute was not given much consideration.

Table 4.22: ECLC model results on ANA for sweet potato varietal traits in Western Kenya

Choice	Parameter	Std error
Latent class 1		
ASC	2.985***	0.222
Yield level	0.095***	0.011
Tolerance	-0.099	0.070
Sweetness of flesh	-0.118	0.076
Colour of flesh	0.034	0.081
Maturity period	-0.122***	0.035
Price change	-0.0005	0.001
Latent Class 2		
ASC	2.985***	0.222
Yield level	Fixed	Fixed
Tolerance	-0.099	0.070
Sweetness of flesh	-0.118	0.076
Colour of flesh	0.034	0.081
Maturity period	-0.122***	0.035
Price change	-0.0005	0.001
Latent class 3		
ASC	2.985***	0.222
Yield level	0.095***	0.011
Tolerance	Fixed	Fixed
Sweetness of flesh	-0.118	0.076
Colour of flesh	0.034	0.081
Latent class 4		
ASC	2.985***	0.222
Yield level	0.095***	0.011
Tolerance	-0.099	0.070
Sweetness of flesh	Fixed	Fixed
Colour of flesh	0.034	0.081
Maturity period	-0.122***	0.035
Price change	-0.0005	0.001
Latent class 5		
ASC	2.985***	0.222
Yield level	0.095***	0.011
Tolerance	-0.099	0.070
Sweetness of flesh	-0.118	0.076
Colour of flesh	Fixed	Fixed
Maturity period	-0.122***	0.035

Price change	-0.0005	0.001
Latent class 6		
ASC	2.985***	0.222
Yield level	0.095***	0.011
Tolerance	-0.099	0.070
Sweetness of flesh	-0.118	0.076
Colour of flesh	0.034	0.081
Maturity period	Fixed	Fixed
Price change	-0.0005	0.001
Latent class 7		
ASC	2.985***	0.222
Yield level	0.095***	0.011
Tolerance	-0.099	0.070
Sweetness of flesh	-0.118	0.076
Colour of flesh	0.034	0.081
Maturity period	-0.122***	0.035
Price change	Fixed	Fixed
<i>Estimated class probabilities</i>		
Probability - class 1	0.021	3.564
Probability - class 2	0.200**	0.091
Probability - class 3	0.062	0.690
Probability - class 4	0.050	0.635
Probability - class 5	0.592	2.358
Probability - class 6	0.015***	0.157
Probability - class 7	0.061	1.447
<i>Model summary statistics</i>		
Log-likelihood	-3212.67	
LR chi-square (12 d.o.f.)	2363.56	
Prob > chi square	0.0000	
McFadden R ²	0.2689	
Akaike Information Criterion (AIC)	6451.30	
Number of observations	4000	
Parameters	13	

Explanatory Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Author's Compilation (2021)

4.6 Hypothesis Testing and Interpretations

The study tested four null-hypotheses as described below:

H₀₁: That farmers are not willing to pay more amount of money for improved sweet potato varietal traits in western Kenya.

The study applied five utility models: MNL, MXL, S-MNL, G-MNL, and G-MXL, which were calculated using the Delta procedure to estimate farmers' WTP for improved sweet potato attributes in Western Kenya. As is the case with the econometric models specified above, the welfare value was highest for the Sweetness of the flesh attribute (KES 334.70, $P < 0.01$), Color of the flesh attribute (KES 100.85, $P < 0.1$), Maturity period attribute (KES 100.28, $P < 0.05$); Tolerance level attribute (KES 187.09, $P < 0.05$) and Yield attribute (KES 137.58, $P < 0.05$). The first null hypothesis was rejected because it was clearly evident that WTP estimates were virtually all statistically significant in the five models, and thus implying that sweet potato farmers in the study area are willing to contribute positive amounts in support of a policy or program that improves the aforementioned varietal attributes.

H₀₂: That farmers are not certain and consistent in their preferences towards sweet potato variety traits in Western Kenya.

A scale of 0-10, in the DCE card was employed to capture certainty choice for Sweet Potato attributes in Western Kenya. The findings indicated that respondents were highly certain about their choices, with an average certainty score of 7.0 and a standard deviation of 1.38. The second null hypothesis was therefore rejected on this count, and conclusions were deduced that sweet potato farmers preferred improved sweet potato variety traits in Western Kenya. Similarly farmers were highly consistent in their preference choices as they chose to prefer choice sets in the second similar scenarios as

they did in the first time in 65.9 percent measures, to signify a definite consistency tendency.

H₀₃: That preference variation (taste and scale factors) play no significant role in the choice decisions of the farmers towards sweet potato variety traits in Western Kenya.

In this study, five behavioral models were estimated (MNL, MXL, S-MNL, G-MNL, and G-MXL) with choice attributes as the random parameters to assess the significance of taste and scale variation in the choices made by sweet potato farmers in western Kenya. As shown in Table 4.5, the S-MNL results indicated vital statistical significance (Yield level = 0.044, $P < 0.01$; Tolerance to pests and diseases = 0.073, $P < 0.01$; Sweetness of flesh = 0.116, $P < 0.01$; Color of flesh = 0.046, $P < 0.1$; Maturity period = - 0.035, $P < 0.01$ and Price change = -0.001, $P < 0.1$). Moreover, the Alternate Specific Constant (ASC) parameter was positive (ASC = 4.358, $P < 0.01$). Because of this, thus, the third null hypothesis was rejected. Farmers in Western Kenya are heterogeneous in their choice decisions towards adopting improved Sweet Potato variety attributes.

H₀₄: That there is no attribute nonattendance among farmers in their choice decisions for sweet potato variety traits Western Kenya.

The researcher estimated nonattendance using both the MNL and the MXL models. The MNL – ANA Model results indicated vital statistical significance of the attributes (Yield level = 0.056, $P < 0.01$; Tolerance to pests and diseases = 0.038, $P < 0.01$; Sweetness of the flesh = 0.076, $P < 0.01$; Color of flesh = 0.119, $P < 0.1$; Maturity period = - 0.060, $P < 0.01$ and Price change = -0.00031, $P > 0.1$). Similar findings were also observed in MXL-ANA deductions. Therefore, we failed to accept the fourth null hypothesis and concluded that there exists attribute nonattendance among farmers in their choice decisions for sweet

potato variety traits in Western Kenya. Similarly, the fact that the ASC parameter was positive (ASC= 2.499, $P < 0.01$) indicated that respondents, on average, favor the cultivation of improved or traditional Sweet Potato varieties as opposed to the status quo of no cultivation.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

This study sought to investigate farmers' preferences towards sweet potato variety traits in western Kenya (i.e., Busia, Bungoma Kakamega, and Vihiga Counties). The specific objectives of the study were to: assess farmers' willingness to pay (WTP) for better-quality sweet potato varietal traits in western Kenya; evaluate farmers' preference certainty and consistency in their choice decisions for sweet potato varietal traits in the region; explore the role of preference variation in the choices made by farmers towards sweet potato variety traits and; ascertain attribute non-attendance of the farmers in their choice decisions for sweet potato variety traits in the study area. This chapter, therefore, gives a summary of conclusions and recommendations.

5.2. Summary of Findings

The study described the socio-demographic and economic characteristics of the sweet potato farmers in Western Kenya. The study findings revealed that the mean age of the respondents was 45 years, and most respondents (78%) were men. Most respondents (93%) had primary and post-primary education, but only 11% and 14% had access to farm credit and agricultural extension services, respectively. The average distance to a reliable input/output market center was approximately 3 kilometers, and 16% of the interviewed farmers were members of farm organizations. 62% of respondents grew improved sweet potato varieties, and 36% of respondents said they grew sweet potatoes more than once per year, according to the study. In addition, the study revealed that 95%

of the farmers interviewed produced sweet potatoes for commercial purposes. According to the study, 35% of the farmers obtained planting vines from their farms. The average sweet potato yield was 1.91 tons per acre (4.775 tons per hectare), yielding a revenue of approximately KES 11,702 per acre.

In addition, 81% of the farmers felt that the need for extension services is a significant problem facing sweet potato farming in the study area. This was followed by the unavailability of farm credit (76%), yield variability (67%), input quality (58%), input availability (54%), and price variability (50%). However, low incidences of flooding (18%) and drought (22%), exploitation by middlemen (22%), and theft of produce were some of the minor challenges faced by farmers in production. Moreover, respondents had a positive attitude towards improved sweet potato variety since the alternative was chosen in 62% of the cases compared to the local variety option, which was chosen in 34% of the cases.

Regarding farmers' willingness to pay (WTP) for better-quality sweet potato varietal traits in western Kenya, the study employed DCE models (S-MNL, G-MNL, and GMXL) to estimate farmers' willingness to pay for quality sweet potato varietal traits. The results indicate that sweet potato farmers in Western Kenya were willing to pay positive amounts of money for improved traits. Farmers were willing to pay the highest amount for sweetness of the flesh attribute (KES 334.70, $P < 0.01$) followed by tolerance attribute (KES 187.09, $P < 0.05$), yield level attribute (KES 137.58, $P < 0.05$), color of the flesh attribute (KES 100.85, $P < 0.1$) and maturity period attribute (KES 100.28, $P < 0.05$) respectively. These results suggest that farmers in the survey sample highly valued sweetness of Sweet Potato more than the other attributes. While this was followed by

tolerance to pests and diseases and yield level, a choice could be made between flesh color and maturity period attributes owing to their observed values.

To ascertain farmers' preference certainty and consistency in their choice decisions for Sweet Potato varietal traits in Western Kenya, choice certainty card scale of 0-10 to assess preference certainty was used. The findings indicate that farmers were considerably certain about their choices, with an average certainty score of 7.0 and a standard deviation of 1.38. Moreover, least squares regression results on the determinants of reported preference certainty showed that most of the determinants had positive and statistically significant relationships. Age = 0.009, $P < 0.1$; Education = 0.157, $P < 0.05$; Access to farm credit = 0.709, $P < 0.05$; Access to farm extension services = 0.224, $P < 0.05$; Sweet potato variety grown = 0.369, $P < 0.05$; Sweet potato yields = 0.003, $P < 0.1$ and Income from sale of sweet potatoes = 0.001, $P < 0.1$. Though, some of the hypothesized determinants had negative relationships, they however exhibited strong statistical significance. For instance, Distance to a reliable input/output market = -0.060, $P < 0.05$, and Source of sweet potato vines = -0.066, $P < 0.05$.

As for attribute non-attendance of the farmers in their choice decisions for sweet potato variety traits, it was revealed that 21% of respondents considered all attributes in their choice decisions. Nevertheless, the study found that respondents, in self-reported attribute non attendance, ignored certain sweet potato varietal attributes in their choice decisions. The most ignored attribute was flesh color 61.8% followed by price change attribute 42.3%, tolerance to pests and diseases 17% and yield attribute 12.3% respectively.

Similar findings were also seen with inferred attribute non attendance. The study employed MNL and MXL models to assess ANA for sweet potato varietal traits. The econometric results showed significant differences between respondents' self-reported ANA and the expected class probabilities and attributes with an ASC positive 2.499 and significant $P < 0.0$. In addition, most of the attributes had positive and significant relationship (Yield level = 0.056, $P < 0.01$; Tolerance to pests and diseases = 0.038, $P < 0.01$; Sweetness of flesh = 0.076, $P < 0.01$; Colour of flesh = 0.119, $P < 0.1$; Maturity period = -0.060, $P < 0.01$ and Price change = -0.00031, $P > 0.1$). Sweet potato farmers in Western Kenya preferred to grow vines of mostly improved varieties with superior traits rather than maintaining the status quo of no production of the crop.

5.3 Conclusions

In relation to the first objective of this study, farmers' WTP for sweet potato varietal traits was examined using discrete choice experiment models, starting with the standard MNL, MXL, S-MNL, G-MNL and even G-MXL model. The discrete choice experiment method used in this study provides a good application of a bottom-up research approach aimed at solving the myriad problems affecting farmers in developing world. While the approach can be used to fine-tune the existing technologies, it was in this case, used to generate information about farmers' WTP for technologies that improve sweet potato crop varietal traits.

The study found that sweet potato farmers in the study area were willing to contribute positive amounts in support of a policy or program that improves varietal attributes. From the different modeling frameworks, the study found that farmers highly valued taste of

sweet potato flesh more than all the other attributes. This was followed by tolerance to pests and diseases and then yield level; with room for choice being left out between flesh color and maturity period attributes. While the MNL model provided the most conservative WTP estimates for the choice attributes, different models yielded different WTP estimates, which means that the computation of the welfare values was highly sensitive to model specifications. This study emphasized G-MNL findings for WTP estimates because of its superiority in comparative model fit analysis. Based on these premise breeders should prioritize sweet potato varietal traits with flesh sweetness, resistance to pests and disease, and yield potentials in that order. In future, however, more studies should be undertaken to understand welfare values that farmers attach to different levels of choice attributes.

With empirical results suggesting that farmers in the study area had a positive attitude towards improved sweet potato varieties compared to the local varieties, it would therefore be critical for the relevant agencies, like KALRO, KEPHIS, and International Potato Centre (C.I.P) to provide new sweet potato variety vines that have been developed in accordance to traits that farmer's value. Indeed, there is a continuing challenge in implementing this noble aim, where some researchers e.g., Nkirote, (2016) have stated that there is no government policy concerning sweet potato production technologies which would guide the incorporation of the stated traits to sweet potato vines. She further notes that scarcity of funds has led to the provision of poor low yielding planting materials to farmers. This needs an important policy change by all relevant governmental bodies so as to enable provision of sweet potato varieties that rhyme with farmers' desires and preferences. From a policy perspective, developing improved crop varieties through

participatory breeding programs that address farmers' desired attributes will increase adoption, Martey *et al.* (2020). While this happens, the corresponding breeding efforts should not lead to pricey varietal products as this may limit the uptake of improved crop varieties.

There is a significant but negative relationship between preference for sweet potato varieties and maturity period. This means that the longer the maturity period the lesser utility enjoyed by sweet potato farmers. This calls for breeders to develop early maturing sweet potato varieties as an enticement for farmers to grow improved varieties of the crop on an enhanced scale. This phenomenon was noted by (e.g. Kapinga *et al.*, 1997) who subsequently recommended the development of such early maturing sweet potato varieties.

The second objective of the study, intended to better our understanding of farmers' preference certainty and consistency for sweet potato varietal traits in Kenya. This was achieved through the discrete choice experiment (DCE) approach where farmers' preference certainty and consistency were evaluated for six selected varietal traits of yield level, tolerance to pests and diseases, the sweetness of the flesh, color of the flesh, maturity period, and price. On preference certainty, respondents were asked to rate their level of certainty regarding the choices they made for the different varietal traits on an ordinal scale of 0 to 10. As for preference consistency, respondents were asked to answer the same choice card on two occasions where the first-choice card was repeated either as the 6th, 7th, 8th, 9th, or 10th card in the choice sequence, or thereafter, preference consistency across the two choice occasions was compared.

The study found that respondents were considerably certain about the choices they made, with an average certainty score of 7.0 and a standard deviation of 1.38. Moreover, respondents were also consistent in their choices because they chose the same option on the second occasion as they did on the first occasion in 65.9% of the cases. While choice certainty and consistency were found to be an increasing function of factors such as age, gender, education, access to farm credit, extension services membership to farm organizations, sweet potato variety is grown, the frequency with which sweet potato crop was grown in a year, sweet potatoes use, sweet potato yields, and income from the sale of sweet potato, it declined with sources of sweet potato vines and distance to reliable input/output markets. The overall policy implication is that sweet potato farmers in the study area are well aware of their preferences for different varietal traits and that breeding programs in the country could well work with sweet potato farmers in advancing varieties with better and desirable traits for improved livelihoods and food security situation in the country. It affirms that policy recommendations and decisions coming out of this are true reflections of farmer and farm dynamics which augurs well with other studies like Oyinbo *et al.* (2019) who notes that majority of farmers exhibit consistent choices, which is not surprising if they are largely familiar with the attribute and attribute levels presented in the choice experiment and therefore can always readily express their preferences. Indeed, both high ratings of preference certainty and consistency remove all doubts from any inferred uncertainties brought about by high and significant measures of scale variation over taste variations in the study, suggesting overriding levels of choice uncertainties, since according to e.g Oyinbo *et al.* (2019), significant scale heterogeneity infer less consistent choices resulting from high error variances.

The third objective of the study, intended to assess farmers' preference variation in their choice decisions for sweet potato varietal traits in western Kenya through evaluation of how five behavioral choice models account for either taste and/or scale variation in the choices made by individuals. To begin with, all five models (MNL, MXL, S-MNL, GMNL, and G-MXL) random parameters were estimated to assess their significance in accounting for either taste and/or scale variation. In this case, farmers were presented with attributes on sweet potato yield level, tolerance to pests and diseases, the sweetness of the flesh, the color of the flesh, maturity period, and price change. Both log-likelihood information and the Akaike information criteria (AIC) were used to evaluate how the five behavioral models account for taste and scale variation. Notably, the survey results indicate that farmers were deriving utility from both local and improved sweet potato varietal alternatives vis a vis the status quo.

Further, the study results showed that positive changes in sweet potato crop traits such as yield level, tolerance to pests and diseases, the sweetness of the sweet potato flesh, and maturity period would lead to the higher utility for the farmers. However, positive changes in maturity period and price were likely to lower the utility of sweet potato production by farmers. The study also found significant preference variation in the choice decisions of the farmers on sweet potato traits such as yield level, sweetness of the flesh, color of the flesh, maturity period and price change.

Significant scale variation meant that it was more likely that the choice behavior of farmers in this experimental design was characterized by high levels of choice uncertainties. In other words, this choice study likely presented very challenging choice tasks to farmers since an insignificant scale factor is usually, but not always, a case of

less difficult choice contexts presented to respondents; which in turn minimizes chances for uncertainties in the choice decisions made by farmers, (e.g. Fiebig *et al.*, 2010; Christie and Gibbons, 2011). Zawedde *et al.* (2014), noted that a key responsibility of the extension service should be to ascertain whether new technologies have net benefits for the farmers under their jurisdiction before they embark on education and promotional activities. Such extension activities should consider inherent heterogeneities among sweet potato farmers expounded by this study. Of all the five-choice models, the G-MNL model performed better in modeling the choice decisions of Sweet Potato farmers as opposed to the rest based on the LL information and AIC criteria. However, further studies are required to ascertain the impact of accounting for preference variation on different choice model formulations. Thus, future choice studies should endeavor to provide more comparative empirical studies about various modeling approaches to preference variation especially with choice data on the valuation of different agricultural technologies especially from developing world, so as to contribute meaningfully towards building more consensus on preferred approaches to modeling preference variation.

As implied above, there was significant unobserved preference heterogeneity amongst the survey respondents which means that breeding efforts should take into account huge latent differences among Sweet Potato farmers. In this, just like results from Danne *et al.* (2017) imply, the significant standard deviations reveal heterogeneity around the mean of the variables "alternative specific constant (**ASC**)," "yield level," "sweetness of the flesh," "tolerance to pests and diseases" and "maturity period" and further indicates that preferences for these variables vary widely between farmers. Indeed, third-party players that are involved in the development of vines that are directly desired by farmers and also

indirectly by relevant consumers who procure sweet potatoes or their products should be cognizant of such information which may be useful for developing effective marketing/extension strategies for reaching consumers in each of these heterogeneous groups, Behe *et al.* (2013). Models estimation in the study showed that the G-MNL model which accounts for taste and scale factors had the best fit for choice data at convergence points in terms of log-likelihood, McFadden Pseudo R², and the Akaike information criteria when compared to S-MNL, MXL, and MNL models. It is therefore recommended that future choice studies analyzing varietal trait improvement should prioritize the use of the G-MNL model. As noted earlier, however, further studies comparing these models should be undertaken on the best outcome for crop varietal improvement data.

The fourth objective aimed at analyzing choice data on sweet potato varietal characteristics to determine whether or not respondents took into account all of the characteristics that were offered while making their selections. Previous researchers have found evidence suggesting that there may be a sizeable fraction of respondents who neglect certain characteristics while making decisions about their preferences. The results of this study make it very clear, both from the perspective of self-reported and inferred attribute non-attendance, that this is the situation. The scrutiny of the data showed that just roughly 21.3% of respondents reported taking into consideration all of the characteristics in the process by which they made their selection. The model fit was significantly improved as a direct result of the incorporation of ANA into the decisionmaking process of the respondents. The mixed logit models that accounted for both ANA and heterogeneity in preferences offered the best model fit for the data.

A comparison was also made between self-reported and inferred ANA. The findings further corroborate earlier hypotheses put forward by members of the scientific community, which suggest that there is a poor mapping between stated and inferred instances of non-attendance. The fact that respondents stated significantly greater levels of non-attendance in follow-up questions, as compared to inferred ANA estimated from the ELCL model, is particularly interesting. Endogeneity problems in the follow-up questions, in which respondents are reminded that they should have considered all qualities, could be the cause of the discrepancy between the stated and inferred ANA values. According to what the ECLC model deduced, approximately 2.1% of respondents paid attention to every attribute. It was also obvious that many of the respondents overlooked the flesh color attribute, which suggests that the trait might not be an accurate indicator of the preferences of farmers in terms of sweet potato varietal upgrades. The fact that a significant number of respondents did not take into account the cost of acquiring improved traits is another worrying trend that emerged from the analysis of self-reported attendance. It is problematic to estimate the WTP values for a large proportion of respondents because these respondents do not consider the trade-offs between changes in price and changes in other sweet potato varietal attributes. Although this was downplayed in the ECLC model through the predicted probability of 6.1%, it means that estimating the WTP values would be problematic for a large proportion of respondents.

There is currently a lack of knowledge regarding the dynamics of attribute nonattendance, although some respondents disregarded particular qualities while making their selections about which option to select. According to Hensher *et al.* (2005),

respondents can choose to disregard attributes for a variety of reasons, including the fact that the feature in question is not relevant to the respondents' behavior. Oyibo *et al.* (2019) suggest that from a methodological point of view, it is worthwhile to assure the robustness of results by addressing concerns of heterogeneity in error variances and ANA in choice experiment studies. They say this is because doing so will lead to more accurate conclusions to be arrived at. As they point out, their findings are similar across all of the models, which shows that any potential bias from scale and ANA concerns are relatively minimal, just as was the case in this study. Similar inferences can be drawn from their research, specifically that the results of other studies that do not take into account these factors could not necessarily point in the same direction. When results are critically analyzed, the attribute that received the least attention, which is the color of the skin, also attracted the lowest WTP of 108.29. Flesh color also elicits weak significance measures, as corroborated in table 4.5, which displays the regression results. Similarly, characteristics that garnered high WTP, such as the sweetness of the flesh, yield level, and resistance to pests and illnesses, tended to receive the least amount of disregard and possessed substantial regression outcomes. This provides further evidence of the robustness of the study, as well as availability of simultaneous and logical findings on measures of varied heterogeneity of sweet potato growers in the study area and throughout Kenya. As a result of this, having a distinct and improved understanding of how respondents process attributes and the reasons why they might overlook attributes may help to enhance the design of choice sets as well as the definition of choice models that account for various processing techniques. The addition of follow-up questions and an investigation into how the features of respondents and the survey influence ANA is one method for eliciting reasons for non-attendance. Experiments carried out in the

laboratory are another method that can be used to investigate the phenomenon of attribute non-attendance in greater depth. This would be especially helpful given that the findings from laboratory studies can be used to confirm findings from discrete choice experiments on how respondents process various features in a variety of choice contexts.

Moreover, the researcher rejected all four null hypotheses of the study given availability of strong statistical evidences. The study concluded that sweet potato farmers in the study area were willing to contribute positive amounts in support of a policy or program that improves the aforementioned varietal attributes. Similarly, concluded that on average, the farmers prefer the cultivation of either of the two sweet potato varieties as opposed to the status quo option of no cultivation at all. In addition, the positive coefficients of the survey attributes (i.e., yield, tolerance, and both sweetness and color of the flesh) implied that farmers derive higher utility from the improvement of such sweet potato varietal traits.

5.4 Recommendations

The Kenya Agriculture and Livestock Research Organization (KALRO) should consider producing improved seed varieties (sweet potato breeding programs in Western Kenya) since sweet potato farmers are willing to pay a premium to purchase sweet potatoes with high-quality attributes.

At the National and County level, the Ministry of Agriculture (MoA) should provide regular agricultural extension services to sweet potato farmers in Western Kenya. The respondents in the survey did not pay enough attention to all attributes when making their selections for the sweet potato varietal qualities, implying a definite presence of attribute

non-attendance. This needs to be carefully considered when policy recommendations and research designs are being formulated. In addition, there needs to be more knowledge regarding the dynamics of attribute non-attendance in order to arrive at workable and realistic conclusions from DCEs.

The sweet potato breeding research institutions such as KALRO should use the findings to support development of high-quality sweet potato varieties in Kenya by employing discrete choice approaches, particularly choice certainty, choice consistency, preference variation, and attribute non-attendance in the choice decisions of individual respondents in discrete choice experiments.

Both at National and County levels, the Ministry of Agriculture in Western Kenya (Busia, Bungoma, Kakamega, and Vihiga) should subsidize improved sweet potato vines. The findings indicated that farmers in Western Kenya preferred high-yielding, faster maturity, and sweet and Sweet flesh of Sweet Potato varieties but had limited access to farm credit for purchase of improved varieties.

Western Kenya County Governments (Busia, Bungoma, Kakamega, and Vihiga) should organize forums to sensitize female and youth farmers to participate actively in sweet potato production. The study revealed that older farmers were more likely to be sure about their preferences than young farmers and as well as female farmers. This can be attributed to the cumulative experience in sweet potato farming that older farmers have over their youthful counterparts. Women in Western Kenya and all over Africa have challenges in accessing factors of production smoothly.

Western Kenya County Governments (Busia, Bungoma, Kakamega, and Vihiga) should support sweet potato farmers in forming cooperative societies at the sub-county and county levels to improve sweet potato production and income. The regression results showed that choice certainty among sweet potato farmers increased with membership in farm organizations and also with income derived from sweet potato sales.

5.3. Further areas of research

The following areas are recommended for further research:

The researcher conducted the study in the Western parts of Kenya. Future scholars should consider conducting similar studies in all sweet potato-growing regions in Kenya to scale up the geographical scope and provide national findings for comparative evaluations.

It is imperative that future scholars and institutions like KALRO should conduct similar studies using randomized controlled trials to elicit evidence-based findings on farmers' preferences for improved Sweet Potato attributes in Kenya and beyond.

It is prudent for future scholars to consider increasing the time-to-wait (one to two months) in respondents' choice decisions in discrete choice experiments. The current study hardly had any time to wait period, since intertemporal aspects were not taken into account; though results were still robust.

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- Research Appendices

APPENDIX I: SURVEY QUESTIONNAIRE



This survey aims to assess farmers' preferences for sweet potato variety traits in western Kenya.

0. Do you currently grow sweet potato?

- 1 No, I don't grow sweet potato (STOP THE INTERVIEW).
- 2 Yes, I grow sweet potato (CONTINUE THE INTERVIEW).

The questionnaire will take no more than 15 minutes. You do not need to know much about growing of sweet potatoes and there are no right or wrong answers. We are simply interested in your opinion.

Your answers will be treated strictly confidential. Your answers will not be shared with anyone else and only used for this independent study of a PhD course at Moi University. Your anonymity will be guaranteed. **Your opinion is highly valued and your time is greatly appreciated!**

- 1. What is the size of land on which you grow sweet potatoes?.....acres**
- 2. For how long have you been growing sweet potato?.....years**

3. What is the main sweet potato variety that you grow in your farm (variety and name)?

1 Local, namely

.....

.....

2 Improved, namely

.....

.....

4. How often do you grow sweet potato?

1 Once a year

2 Twice a year

3 Thrice a year

4 Four times a year

5. How do you use your sweet potato?

1 For subsistence purposes

2 For commercial purposes

3 Both subsistence and commercial purposes

6. Where do you get sweet potato seeds for planting?

1 From own farm

2 From other farmers

3 From government agricultural centres (e.g. KARI)

4 From private agricultural centres (e.g. private farms, Agrovets)

Other.....

...

7. How much sweet potato do you harvest from your land? tones

8. What is the cost of cultivating sweet potato on your land per season?

KES.....

9. What is your income from cultivating sweet potato on your land per season?

KES.....

10. What is your perception about the variety of the sweet potato that you grow?

(where 0 = not sure; 1 = bad; 2 = average; 3 = good).

.....

.....

11. What is your perception about the yield of the sweet potato that you grow?

(where 0 = not sure; 1 = low; 2 = average; 3 = high).

.....

.....

12. What is your perception about the sweetness of the sweet potato that you grow?

(where 0 = not sure; 1 = bad; 2 = medium; 3 = good).

.....

.....

13. What is your perception about the flesh colour of the sweet potato that you

grow? (where

0 = not sure; 1 = not appealing; 2 = appealing; 3 = highly appealing).

.....

.....

14. What is your perception about the pest and disease tolerance level of the sweet potato that you grow? (where 0 = not sure; 1 = low; 2 = average; 3 = high).

.....

What is your perception about the maturity period of the sweet potato that you grow? (where 0 = not sure; 1 = early maturity; 2 = average; 3 = late maturity).

.....

15. What is your perception about average changes in the prices of the sweet potato seeds that you grow? (where 0 = not sure; 1 = minimal changes; 2 = average; 3 = high changes).

.....

16. What is your perception about the availability of sweet potato seeds that you grow? (where

0 = not sure; 1 = not available; 2 = available; 3 = highly available).

.....

18. What is your perception about ease of access of quality sweet potato seeds for your farm? (where 0 = not sure; 1 = not accessible; 2 = accessible; 3 = highly accessible).

.....

19. What is your perception about the labour requirement for your sweet potato

farming? (where 0 = not sure; 1 = low requirement; 2 = average; 3 = high labour requirement).

.....

What is your perception about ease of access of farm credit for your farming

activities? (where 0 = not sure; 1 = not accessible; 2 = accessible; 3 = highly accessible).

.....

.....

20. What is your perception about ease of access of extension services for

your sweet potato farming? (where 0 = not sure; 1 = not accessible; 2 = ccessible; 3 = highly accessible).

.....

.....

21. How severe are the following production challenges in your sweet potato

farming? (indicate severity of each where 0 = don't know; 1 = not severe; 2 = severe; 3 = most severe).

- ✓ Labour scarcity.....
- ✓ Yield variability.....
- ✓ Frequent drought.....
- ✓ Frequent floods.....
- ✓ Poor extension services.....

- ✓ Poor input quality.....
- ✓ Poor input availability.....
- ✓ Poor credit availability.....
- ✓ Lack of markets.....
- ✓ Price variability.....
- ✓ Poor road network.....
- ✓ Theft of produce.....
- ✓ Middlemen problem.....

23. Do you use organic manure in your farm to grow sweet potato?

- 1 No
- 2 Yes

If yes, what is the cost value per season? KES.....

24. Do you use chemical fertilizers in your farm to grow sweet potato?

- 1 No
- 2 Yes

If yes, what is the cost value per season? KES.....

25. Do you apply insecticides/pesticides in your farm to grow sweet potato?

- 1 No
- 2 Yes

If yes, what is the cost value per season? KES.....

26. Do you use mobile money to transact in your sweet potato farming?

- 1 No

2 Yes

27. What is the importance of each of the following sources of information for your sweet potato farming? (*where 0 = don't know; 1 = not important; 2 = important; 3 = most important*).

- ✓ Friends.....
- ✓ Relatives.....
- ✓ Newspaper.....
- ✓ Radio.....
- ✓ Television.....
- ✓ Input dealer.....
- ✓ Farmer association.....
- ✓ Extension agent.....

[THE CHOICE EXPERIMENT]

I will now briefly read out some information, followed by some cards. In Kenya, enhancing sweet potato production and productivity is indispensable for reducing hunger and food insecurity. In order to achieve this, the involvement of smallholder farmers in sweet potato production is essential. Moreover, the development, release, and the availability of sweet potato varieties with farmer-preferred traits is also important in motivating farmers to devote substantial amount of resources in the cultivation of sweet potato. However, despite high investments so far in the development of high-yielding sweet potato varieties in the county, the uptake of these improved varieties by farmers has been very low. While both farm and farmer characteristics have been important in influencing farmers' choice decisions for different varieties, the role of varietal traits has

only received limited attention in the sweet potato breeding programs. Your input is therefore very crucial towards this end.

28. Have you ever heard of improved sweet potato varieties?

- 1 No
- 2 Yes

29. Do you grow improved sweet potato varieties in your farm?

- 1 No
- 2 Yes

30. How much would you willing to pay to get improved sweet potato variety seeds for planting in your farm? KES

.....

31. On a scale from 0 (completely uncertain) to 10 (completely certain), how certain are you that you would actually pay the amount of money you have stated?

Payment certainty 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

I will show you 10 cards which describe the characteristics of 2 varieties, that is, the local sweet potato variety and the improved sweet potato variety. The characteristics of the two types of varieties relate to the yield level (6 metric tons/ha, 10 metric tones/ha, 14 metric tons/ha), tolerance to pests and diseases (low, medium, high), flesh sweetness (low, medium, high), flesh colour (orange, white, yellow), maturity period (upto 3 months, upto 5 months, upto 7 months) and price change (KES 100, 200, 300). You only have to say which of the two variety types you prefer. I will first show you an example card.

INTERVIEWER INSTRUCTION: SHOW THE EXAMPLE CARD

This is the example card. You see the two sweet potato variety types, the local and the improved variety. In this example card, you also see the varying levels of the sweet potato traits under investigation, that is: yield level (6 metric tones/ha, 10 metric tones/ha, 14 metric tones/ha), tolerance to pests and diseases (low, medium, high), flesh sweetness (low, medium, high), flesh colour (orange, white, yellow), maturity period (upto 3 months, upto 5 months, upto 7 months) and price change (KES 100, 200, 300). The question therefore is, in this card and in the cards that will follow after this, how important are the sweet potato traits (yield level, tolerance to pest and diseases, sweetness of the flesh, colour of the flesh, maturity period) to you personally and to what extent are you willing to pay an extra price to get varietal traits that you prefer most? As said, you only have to say which of the two variety types you prefer most. You can also choose none of the two. In that case, you do not pay anything extra for your current variety that you grow and you stay with the characteristics of your current variety type. Is this clear? Can you tell me which variety type you prefer in this example card?

INTERVIEWER INSTRUCTION:

- ✓ AFTER THE RESPONDENT CHOOSES BETWEEN THE TWO ALTERNATIVES, ASK HIM/HER HOW CERTAIN HE/SHE IS ABOUT HIS/HER CHOICE ON A SCALE OF 0 TO 10 (0=NOT CERTAIN AT ALL, 10=COMPLETELY CERTAIN)
- ✓ IF THE RESPONDENT CONSISTENTLY CHOOSES NONE OF THE TWO, ASK HIM/HER WHY (SEE QUESTION 35); IF THE RESPONDENT DOES NOT UNDERSTAND THE ASSIGNMENT OF CHOOSING BETWEEN THE 2 VARIETY TYPES, TRY TO EXPLAIN IT ONCE AGAIN UNTIL HE/SHE UNDERSTANDS

I will now show you 10 new cards, which I want you to evaluate separately and independently from each other. Each card gives you a completely new choice occasion between two types of varieties with different traits/characteristics. After each card you are also asked to state how certain you are about your choice on a scale from 0 – 10, where 0 means completely uncertain and 10 means completely certain.

32. Which sweet potato variety do you prefer?

	Local	Improved	None
CARD 1	☐	☐	☐
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 2			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 3			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 4			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 5			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 6			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 7			33.
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 8			W
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 9			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		
CARD 10			
Choice certainty	0-1-2-3-4-5-6-7-8-9-10		

hen making your choices, can you indicate about which sweet potato trait

you were each time most uncertain? *(please tick only one option that you were most uncertain about)*

- 1 I was most uncertain about the choice between the two sweet potato varieties
- 2 I was most uncertain about the different yield levels of the sweet potato
- 3 I was most uncertain about the different sweetness levels of the sweet potato
- 4 I was most uncertain about the different flesh colours of the sweet potato
- 5 I was most uncertain about the different disease and pest tolerance levels
- 6 I was most uncertain about the different maturity periods of the sweet potato
- 7 I was most uncertain about the price increases of the sweet potato
- 8 I was equally uncertain about all characteristics

34. When making your choices, how important was each of the following?

(where 0 = don't know; 1 = not important; 2 = important; 3 = most important) if you ignored a trait, please give this trait a nine (=9)

- ✓ **Variety** of the sweet potatoes *(whether local or improved)*.....
- ✓ **Yield** level of the sweet potatoes.....
- ✓ **Tolerance** to pests and diseases.....
- ✓ **Sweetness** of the sweet potato.....
- ✓ **Flesh colour** of the sweet potato.....
- ✓ **Maturity period** of the sweet potato.....
- ✓ **Price change** of the sweet potato seed

35. If the respondent consistently chooses none of the two, please explain why.

- 1 I don't care about any of the sweet potato varieties.
- 2 I don't care about any of the sweet potato variety traits.
- 3 I don't believe there is any difference between any of the sweet potato varieties.
- 4 I don't believe there is any difference between any of the sweet potato variety traits.
- 5 I don't believe the sweet potato traits can be changed as displayed in the cards.
- 6 I don't have enough money/income to pay extra for sweet potato varieties.
- 7 Other, namely

.....

...

Finally, some questions about yourself concerning your own personal situation for statistical purposes only, to make sure we have a representative sample of respondents.

Please note that all information provided will be treated strictly confidential!

36. Age of the farmer?.....years.

37. Gender of the farmer?

- 1 Male
- 2 Female

38. What is the family size of the farmer including only children under 18 years old?.....persons.

39. Education of the farmer?

- 1 = Did not go to school
- 2 = Primary school

3 = Secondary school

4 = College

5 = University

40. What is your main professional background experience?

1 Agricultural sector

2 Non-agricultural sector

41. What is the main professional background experience of spouse?

1 Agricultural sector

2 Non-agricultural sector

42. What is your main current preoccupation?

1 Farm activities

2 Off-farm activities

3 Both farm and off-farm activities

43. Have you accessed farm credit in the past one year?

1 No

2 Yes

44. Have you accessed farm extension in the last one year on sweet potato farming?

0 No

2 Yes

45. Do you own any livestock (cattle, sheep, goats, rabbit, etc not chicken) in your farm?

1 No

2 Yes

46. What is the number of livestock in total? units

47. What is your monthly income from livestock rearing? KES.....

48. What is the distance from your homestead to the nearest market centre?

.....Kms

49. Are you a member of any association that helps you in the growing of sweet potato?

1 No

2 Yes

50. Any regular (weekly, monthly etc) financial contribution into the association kitty?

1 None

2 Yes, KES.....

**THIS IS THE END OF THE INTERVIEW THANK YOU VERY MUCH FOR
YOUR TIME**

DO YOU HAVE ANY COMMENTS OR SUGGESTION

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

.....

.....

APPENDIX II: DCE CARDS

1.1

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	6	6	
	TolerancePD	Low	Low	
	Flesh sweetness	Bad	Bad	
	Flesh colour	Orange	Orange	
	Maturity period	3	3	
	Price change	100	100	None of the two
I prefer:		☐	☐	☐

How certain are you about your choice? *Completely Uncertain* 0 1 2 3 4 5 6 7 8 9 10 *Completely Certain*

1.2

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	10	14	
	TolerancePD	High	High	
	Flesh sweetness	Good	Bad	
	Flesh colour	Orange	Orange	
	Maturity period	3	3	
	Price change	200	200	None of the two
I prefer:		☐	☐	☐

How certain are you about your choice? *Completely Uncertain* 0 1 2 3 4 5 6 7 8 9 10 *Completely Certain*

13

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	14	6	
	Tolerance/D	Low	Low	
	Flesh sweetness	Bad	Average	
	Flesh colour	White	White	
	Maturity period	5	5	
	Price change	300	300	None of the two
I prefer:		☐	☐	☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

14

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	10	10	
	Tolerance/D	Medium	Medium	
	Flesh sweetness	Average	Average	
	Flesh colour	White	White	
	Maturity period	5	5	
	Price change	200	200	None of the two
I prefer:		☐	☐	☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

15

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	6	10	
	Tolerance/D	High	High	
	Flesh sweetness	Bad	Average	
	Flesh colour	Yellow	Yellow	
	Maturity period	5	3	
	Price change	100	200	None of the two
I prefer:		☐	☐	☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

1.6

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	6	6	
	Tolerance/D	Low	Low	
	Flesh sweetness	Bad	Bad	
	Flesh colour	Orange	Orange	
	Maturity period	3	3	
	Price change	100	100	None of the two
I prefer:		☐	☐	☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

1.8

1.7

		LOCAL VARIETY	IMPROVED VARIETY
	Yield/Level	54	14
	Tolerance/PD	High	High
	Flesh sweetness	Good	Good
	Flesh colour	Yellow	Yellow
	Maturity period	7	7
	Price change	300	300

None of the two

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

1.9

		LOCAL VARIETY	IMPROVED VARIETY
	Yield/Level	14	14
	Tolerance/PD	Medium	Medium
	Flesh sweetness	Good	Bad
	Flesh colour	White	White
	Maturity period	3	7
	Price change	300	100

None of the two

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

1.10

		LOCAL VARIETY	IMPROVED VARIETY
	Yield/Level	6	10
	Tolerance/PD	Medium	Medium
	Flesh sweetness	Average	Good
	Flesh colour	Yellow	Yellow
	Maturity period	7	7
	Price change	100	100

None of the two

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain

0 1 2 3 4 5 6 7 8 9 10

Completely Certain

2.2

2.1

	LOCAL VARIETY	IMPROVED VARIETY
 Yield Level	15	10
 Tolerance PD	High	Low
 Flesh sweetness	Good	Bad
 Flesh colour	Orange	Yellow
 Maturity period	3	5
 Price change	100	100

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain 0 1 2 3 4 5 6 7 8 9 10 Completely Certain

	LOCAL VARIETY	IMPROVED VARIETY
 Yield Level	6	10
 Tolerance PD	Low	Medium
 Flesh sweetness	Bad	Average
 Flesh colour	Orange	White
 Maturity period	3	7
 Price change	200	300

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain 0 1 2 3 4 5 6 7 8 9 10 Completely Certain

2.3

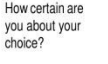
	LOCAL VARIETY	IMPROVED VARIETY
 Yield Level	14	10
 Tolerance PD	Medium	High
 Flesh sweetness	Good	Average
 Flesh colour	White	Orange
 Maturity period	3	5
 Price change	100	100

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain 0 1 2 3 4 5 6 7 8 9 10 Completely Certain

2.4

	LOCAL VARIETY	IMPROVED VARIETY
 Yield Level	14	14
 Tolerance PD	Low	Medium
 Flesh sweetness	Bad	Average
 Flesh colour	White	Orange
 Maturity period	5	7
 Price change	100	100

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain 0 1 2 3 4 5 6 7 8 9 10 Completely Certain

2.6

		LOCAL VARIETY	IMPROVED VARIETY
	Yield Level	11	9
	Tolerance PD	High	Low
	Flesh sweetness	Good	Bal
	Flesh colour	Yellow	Orange
	Maternity period	7	5
	Price change	100	200
			None of the two

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain 0 1 2 3 4 5 6 7 8 9 10 Completely Certain

		LOCAL VARIETY	IMPROVED VARIETY	
	Yield Level	6	14	
	Tolerance PD	High	Low	
	Flesh sweetness	Bal	Good	
	Flesh colour	Yellow	White	
	Maternity period	5	7	
	Price change	100	200	None of the two

I prefer: ☐ ☐ ☐

How certain are you about your choice?

Completely Uncertain 0 1 2 3 4 5 6 7 8 9 10 Completely Certain

APPENDIX III: RESULTS OF THE ESTIMATED BEHAVIOURAL CHOICE MODELS

Characteristics	MNL		MXL		S-MNL		G-MNL		G-MXL	
	Coef.	Std error	Coef.	Std error	Coef.	Std error	Coef.	Std error	Coef.	Std error
<i>Mean estimate random parameters</i>										
ASC_local	- 6.5962***		0.49401 4.411		- 6.623***	0.513	-6.613** 3.135		- 6.612* *	3.114
ASC_improved	- 0.6396***		0.2097 0.649***	0.209	- 0.599***	0.210	-0.628*** 0.210		- 0.629* **	0.210
Yield level	0.0321*** 0.0097		0.035*** 0.009		0.033*** 0.010		0.034*** 0.010		0.034* **	0.010
Tolerance	0.1104*** 0.0387		0.118*** 0.040		0.108*** 0.039		0.113*** 0.040		0.113* **	0.040
Sweetness of 0.0385 flesh	0.1773***		0.170*** 0.041		0.170*** 0.039		0.175*** 0.041		0.174* **	0.041
Colour of flesh	-0.0133		0.00905 0.042		-0.009 0.039		-0.020 0.042		-0.020 0.042	0.042
Maturity 0.0195 period	0.0754***		0.076*** 0.020		0.073*** 0.020		0.073*** 0.020		0.074* **	0.020
Price change	-0.0004		0.0000 0.000	0.000	0.000 0.000		0.000 0.000		0.000 0.000	0.000
<i>Standard deviation random parameters</i>										
ASC_local			0.154 3.470				0.021 7.308		0.023 7.758	
ASC_improved			0.008 0.134				0.046 0.136		0.043 0.137	
Yield level			0.029*** 0.008				0.037*** 0.008		0.037* **	0.008
Tolerance			0.063 0.050				0.040 0.055		0.041 0.055	
Sweetness of flesh			0.111*** 0.036				0.114*** 0.040		0.111* 0.040	
Colour of flesh			0.203** 0.096				0.149 0.100		0.155 0.100	

Maturity period		0.032**	0.015		0.047***	0.014	0.047* **	0.014
Price change		0.002***	0.000		0.001***	0.000	0.001* **	0.000
<i>Model summary statistics</i>								
Log likelihood (LL) Information	-2771.97	-2757.45	-2765.24		-2754.31			2754.38
LR chi-square	59.995	3273.99	3244.42		3280.29			3280.13
Prob > chi square	0.0000	0.0000	0.0000		0.0000			0.0000
McFadden	0.0107	0.3725	0.3691		0.3732			0.3732
Pseudo R²								
Scale parameter τ	-	-	0.0103		0.0906			0.0908
Weighting parameter γ	-	-	fixed		fixed			0.1002
Akaike Information Criterion (AIC)	5559.90	5546.90	5550.50		5542.60			5544.80
Number of observations	4000	4000	4000		4000			4000
Parameters	16	17	18					

*Explanatory notes: ASC_local and ASC_improved refer to alternative-specific constants, which represent dummies for the respondent's choosing the alternative sweet potato varieties, respectively. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; 95% confidence intervals in parentheses.*